NATIONAL CONFERENCE

ON

ADVANCES IN MECHANICAL, INDUSTRIAL & MATERIALS ENGINEERING

Organised By

DEPARTMENT OF MECHANICAL ENGINEERING

BABA BANDA SINGH BAHADUR ENGINEERING COLLEGE

FATEHGARH SAHIB, PUNJAB - 140407

www.bbsbec.edu.in

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ABOUT THE INSTITUTE

Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, was established in the year 1993, under the patronage of Shriomani Gurudwara Prabandhak Committee, Sri Amritsar. The college presently runs seven B.Tech. Programs and eight M.Tech. programs and is reckoned as one of the leading institutes in North India. BBSBEC is a center of erudition and nurturing young talents in different fields of engineering. The major emphasis of imparting technical education is to encourage curiosity and innovativeness among the students and strengthen the foundation from where they can acquire quick learning ability to cope with the fast changing needs of the industry. The campus provides students with the opportunities to gain and use knowledge to build successful lives and careers, and become an integral part of the community. The college is situated in an environment conducive to academics. It is housed in a sprawling pollution-free campus of 90 acres and is located in the sacred surroundings of historic Gurudwara of Fatehgarh Sahib.

ABOUT THE DEPARTMENT

The Department of Mechanical Engineering was established in the year 1993 with the inception of the college. The department was accredited by National Board of Accreditation (NBA) in year 2004 and reaccredited for further five years in year 2008. The department is also accredited by The Institution of Engineers India and IAO. Apart from B. Tech. (Mechanical Engineering) with an annual intake of 180 students, the department is running full time M. Tech. programs in CAD/CAM and Mechatronics & Robotics. The department is known in the region for its highly qualified and experienced faculty, which is actively engaged in research and publishing good number of research papers every year in National and International Journals and conferences. Core research areas are Surface Engineering, Manufacturing System Design, Non-conventional machining etc. The departmental laboratories are fully equipped with latest and sophisticated equipment, thus providing stimulating environment for academia and research.

ABOUT THE CONFERENCE

The objective of this conference is to bring the academicians, practicing engineers, and the researchers in the field of mechanical, materials and industrial engineering on a common platform to exchange ideas relating to the recent advances and their applications. The original and unpublished research papers are invited in the following areas (but not limited to):

- **Mechanical Design:** Design of Machine Elements, CAD, FEM, System Dynamics, Modeling & Simulation.
- **Materials Engg:** Advanced Materials, Composite Materials, Smart Materials, Surface Engineering, Tribology, NDT.
- **Industrial & Production Engg:** Manufacturing Systems & Design, Agile /Lean / Flexible Manufacturing, SCM, TQM, TPM, Technology Management, Quality Systems, Productivity, Innovations, Ergonomics, Accreditations.
- **Advanced Manufacturing Techniques: Rapid Prototyping**, Non Traditional Machining, Nano Technology, Manufacturing Optimization.
- **Thermal Engg:** Combustion, IC Engines, Future Fuels, Heat and Mass Transfer
- **Automation:** Mechatronics, CAM, FMS, CIMS, **Robotics, MEMS.**

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MESSAGE

It is really a matter of pride for me to know that BBSBEC – a premier technical institute of SGPC established in 1993 at Fatehgarh Sahib, **is organizing a National conference on "Advances in Mechanical Industrial & Materials Engineering (AMIME-2015)" on November 6th - 7th 2015.** Needless to say that Surface Engineering, Manufacturing System Design, Industrial Engineering and Non-Conventional Machining are the widely talked about and important fields in view of its immense impact.

A conference of this kind certainly provides a platform for the researchers, practicing engineers, academicians and students to deliberate on the latest developments taking place in the world and come out with the strategies to deal with the challenges.

I extend my heartiest felicitations to the organizers and wish them success in their endeavor.

Jathedar Avtar Singh
President SGPC & BBSB Education trust

MESSEGE

In today's world, Mechanical, Materials and Industrial Engineering are the most demanding fields. Their uses are so beneficial that they have become indispensable for the human beings. I am happy to know that the **Department of Mechanical and Industrial Engineering of Baba Banda Singh Bahadur Engineering College** is organizing **a National conference on "Advances in Mechanical Industrial & Materials Engineering (AMIME-2015)" on November 6th - 7th 2015.**

I am certain that this conference would be a befitting stage for the participants and students to exchange their views and come out with new ideas for further progress and development in these fields.

I wish the organizers and delegates the very best in their efforts.

S. Amarinder Singh)
Member-Secretary, Trust

MESSEGE

I feel pleasure to know that Mechanical Engineering Department of Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib is going to organize a National Conference with an aim to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences, research results regarding all aspects of Mechanical and Industrial Engineering. It would also provide the premier interdisciplinary forum for researchers, practitioners and educators to present and discuss the most recent innovations, trends, concerns, practical challenges encountered and the solutions adopted in the field of Mechanical and Industrial Engineering.

I wish that this conference be a success with interesting technical sessions, meeting of new friends and colleagues for further collaborations and emerging with new ideas in this exciting technical field of Mechanical and Industrial Engineering.

Dr. Gurmohan Singh
Vice Chancellor
Sri Guru Granth Sahib World University

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Rakesh Kumar Verma,
Vice Chancellor (IAS)
I. K. Gujral Punjab Technical University

MESSAGE

I am pleased to share with you that the Department of Mechanical Engineering of Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib has organized **a National conference on "Advances in Mechanical Industrial & Materials Engineering (AMIME-2015)"on November 6th - 7th 2015.**

I hope, the researchers, technocrats, academicians and students would deliberate on latest developments in the field of Mechanical and Industrial Engineering. In the present era of technological advancement, young minds need exposure which is provided by such conferences. It would not only quench the intellectual thrust but also would provide pedagogical, scholastic and practical exposure to the budding talents. The conference would further endeavor to meet the challenges of the turbulent corporate world. The participants would be encouraged to bring about unprecedented transformation in the field of Mechanical and Industrial Engineering by pioneering research avenues in the global environment.

I extend my best wishes for the success of the National Conference.

Dr. Mohan Paul Singh Ishar
Vice Chancellor
Maharaja Ranjit Singh Punjab Technical University

MESSAGE

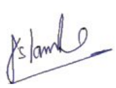
In pursuance of our mission '**To mould the youth into World-class Technocrats' of tomorrow who would endeavor to increase the quality of life for Human kind**', the Mechanical Department of our college is contributing towards facilitating the generation of ideas and thrusting research by holding National conference on "Advances in Mechanical Industrial & Materials Engineering (AMIME-2015)" on November 6th - 7th 2015.

The core purpose of the conference is to promote academia, practitioners and researchers to focus on trendsetting technological initiatives in the world. Engineering is about tackling challenges of the society for the benefit of the society. Beyond catalyzing changes in what we do, technology affects how we think and act. Thus all those involved in the conference will be making a contribution in some way or the other in ushering the era into more effective research studies and ideas generation. I am sure that synergy created by this team will propel us into creating more such platforms to exchange and brain storm.

I welcome all the delegates into the serene environment of BBSBEC, Fatehgarh Sahib, I hope they will return enriched and rejuvenated.

Team BBSBEC believes in excellence, equity and efficiency. So, I congratulate HoDs, faculty, staff members and students of Mechanical and Industrial Engineering Departments for their efforts in successfully organizing and participating in this conference.

"In pursuance of excellence" Wishing great success to all



Maj. General (Dr.) G. S .Lamba
Principal,
BBSB Engg. College, Fatehgarh Sahib

MESSAGE

It gives me immense pleasure that Department of Mechanical Engineering of Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib is holding a National Conference on "Advances in Mechanical Industrial & Materials Engineering (AMIME-2015)" on November 6th - 7th 2015. The conference will serve as a platform for scholars to meet the technical challenges in the field of electrical, electronics and communication engineering.

It is the outcome of endless efforts put by the organizers in a planned manner within a stipulated period. The overwhelming response received to the conference is heartwarming. The deliberations during conference are expected to promote the research work in the area of Surface Engineering, Manufacturing system design, Industrial Engineering and Non-Conventional Machining. On behalf of Mechanical and Industrial Engineering Department I welcome the delegates and wish for a comfortable and enjoyable stay during the conference.

Dr. Lakhvir Singh
Chairman (AMIME-2015)
Professor & Head, Department of Mechanical and Industrial Engineering

Keynot Address
Dr R K Garg
Professor, Department of Industrial and Production Engineering
Dr B R Ambedkar National Institute of Technology Jalandhar
E-mail: gargrk@nitj.ac.in

In my remarks today, I will share with you:

First, the lessons learned from recent development experience.
Second, perspectives on what's new about the emerging research agenda and why
Third, some thought on current state of requirements and how researchers' community should position itself.

The theme of this Conference: '**Advances in Mechanical, Industrial and Materials Engineering**' is timely. With the change in technology, keeping pace with advances in each facet of mechanical engineering is the need of the day. The industry is in strong demand of new materials which are having more strength but less weight, more hardness, capability to perform at high temperatures and does not corrode in aqueous environment. Nanomaterials are being used in a big way thesedays to answer a few requirements out of these. The nanoparticles are being used extensively in the area of biotechnology to come up with advances in material properties thesedays. It is imperative to state that the present era is more demanding than the past. One of the emerging research area being dealt by mechanical engineering is dealing with implant materials. It is seen that that the cost of an implant is very high thesedays in India. The prime reason behind that has been the unavailability of the quality components manufactured indigenously. I am sure that this Conference will result in new horizons in this area. With my own experience, I can say that inspite of fitting the available implants to variable sizes of humanbeings, implants may be made with new materials not necessarily metals and alloys rather nanomaterials may be advented to replace the costly existing implants. Composites may also be advented in this regard. Further, the size of implants should be suitably matched with the person in need which may be possible by rapid prototyping. Since the machining of the new materials is not economical with conventional methods of machining, there is a strong requirement that a few researchers across the globe can work together and come up with a solution to this problem. Indirectly, this shall be a service to the society. I am sure that researchers in various parts of India may excel in this direction to come up with viable solution so as to come up with some new materials for implants so that the cost can be borne by an ordinary Indian and its machining becomes easy and economical.

Expert Talk

POST PROCESSING OPERATIONS ON DIES AND MOULDS MANUFACTURED BY EDM

Dr. Sehijpal Singh
Professor and Head
Mechanical Engineering Department
Guru Nanak Dev Engineering College Ludhiana
(E-mail: mech@gndec.ac.in)

1. Electric Discharge Machining

EDM is a non convectional machining process in which material is removed by electrical discharges between two electrodes (workpiece and tool) in presence a dielectric fluid. Electric discharge machining involves removal of material by spark erosion. Series of electrical discharges emerge between the tool electrode and the workpiece electrode in dielectric fluid and melt the material in the form of small craters. Spark erosion was first observed by Sir Joseph Priestly in 1768. In 1943 it was discovered that precision machining can be achieved by EDM. With the use of harder, tougher and stronger materials in manufacturing industries and requirement of ultra-precision machining, EDM is one of the important methods in machining. EDM process consists of electrode, workpiece material, dielectric fluid, the range of pulse rate, current and voltage. The aim of process is a controlled removal of material from work piece. A suitable tool electrode with controlled feed movement is employed in place of a cutting tool. The cutting energy is obtained from short duration of electrical impulses. Dielectric fluid is pumped through the arc gap to flush away the eroded particles between the work piece and the tool electrode. The functions of the dielectric fluid are to increase the energy density in plasma channel, recondition of the dielectric strength, cooling of the electrode and provide transportation to removed particles

Drilling, milling, grinding and other traditional machining operations can be replaced by EDM. It is a well established machining option for many manufacturing industries throughout the world. EDM is used for machining of hard metals and alloys and plays major role in machining of dies, moulds, tools, etc., made of tungsten carbides or hard steels. Electric Discharge Machining has also made its importance in the new fields such as sports, medical and surgical components, instruments, optical, including automotive R&D areas. Complicated die contours in hard material can be fabricated with high degree of accuracy and surface finish. There is no physical contact between the tool and work, this makes process more versatile. As a result for slender and fragile jobs can be machined conveniently.

Metal moulds and dies are generally polished manually as the post processing operation in order to improve the surface integrity such as surface roughness, micro crack and residual stress after electrical discharge machining (EDM).

Complex shapes of dies and moulds are mainly manufactured by EDM but, the surface after EDM has recast layer with many craters and micro- cracks. These defects can only reduce not eliminated. Polishing is a post processing operation after EDM and essentially required in most cases to get surface without defects and shine like mirror. These post processing operation are mainly done manually so, an expert craftsman is needed to perform these operations. The post processing operations are labour-intensive operations, which are expensive and the outputs are hardly reproducible from part to part.

There is negligible data available about the extent of post processing operations and difficulties encountered by the industry while doing post processing operations. A survey needs to be conducted and number of case studies could be undertaken to access the post processing operations. In a recent study it has been reported that local tool and die industry cost addition by post processing operations varies from 8% to 35% of EDMed cost and time addition varies 25% to 66% time of EDM. Overall survey found that these operations increase cost and time in manufacturing of EDMed dies and moulds. In the present talk various processes which are being used for carry out post processing operation have been introduced.

2. Post Processing Operations

The post processing operations are required to achieve superior surface finish up to mirror-like finishing and very close dimensional precision on already produced components or surfaces. The post processing operations are assigned as the last operations in the single part production cycle usually after the conventional or nonconventional machining operations. These operations are also done after net shape processes such powder metallurgy, cold flashless forging, etc.

Electrical discharge machining (EDM) process has excellent performance on machining of hard material, which is an important machining method for mould and die industry. However, the surface of workpiece after EDM has recast layer with many craters and micro-cracks. That is why components after rarely used after EDM . Polishing is a post-processing operation after EDM and usually essential to obtain mirror-like surface and eliminate other surface defects.

The main post processing operations includes polishing, buffing, etching, honing, lapping, etc.

2.1 Polishing

Polishing process is done for smoothing a workpiece's surface using an abrasive and a work wheel. Technically *polishing* refers to process that use an abrasive which is glued to the work wheel, while *buffing* uses a loose abrasive applied to the work wheel. Polishing is a more aggressive process while buffing is less harsh, which leads to a smoother, brighter finish. Polishing is often used to enhance the appearance of component or surface. It prevents contamination of metal surfaces, remove oxidation, create a reflective surface, or prevent corrosion. In metallography and metallurgy, polishing is used to create a flat, defect-free surface for examination of a metal's microstructure under a microscope. Silicon-based polishing pads or a diamond solution can be used in the polishing process. Polishing of stainless steel can also increase the sanitary benefits of stainless steel.

The condition of the surface determines the type of abrasive will be applied. The first stage, if the material is unfinished, starts with a rough abrasive with 60 – 80 mesh size. After that finer abrasive 120 – 400 mesh size are used. To achieve required surface finish, abrasives more then 400 mesh sizes can be used. The rough passes of polishing with large grit remove imperfections within the metal surface like pits, nicks, lines and scratches. The finer abrasives leave progressively finer lines that are not visible to the naked eye. Super fine finished surface can be achieved by polishing and buffing compounds, polishing wheels and high speed polishing machines. Electric drills can also used for polishing surfaces of components. Lubricating and cooling mediums are also used during polishing such as kerosene and wax. Some polishing materials are specifically fabricated to be used as dry. The polished surface doesn't become wet with their application.

To achieve the required surface finish, the work of mould making should be planned from beginning. Poor machining quality cause coarse tool marks on the components surface will lead to expensive bench work during polishing. Hand work should be done prior to hardness of metal and should be relatively soft and workable. When the mould is made by EDM then, the tool electrode should highly polish in order to minimize the requirement of polishing to the resulting mould. Many hours of labour in polishing can be saved by applying proper hardening procedures.

Polishing equipment should be include polishing stones from 100 grit to 800 grit and in the variety of sizes and shapes to fit any contour, sticks, felt bobs, bristle brushes, hard sewn buffs, polishing cloths, polishing compounds and pastes, flexible shaft grinding machines and hand grinders.

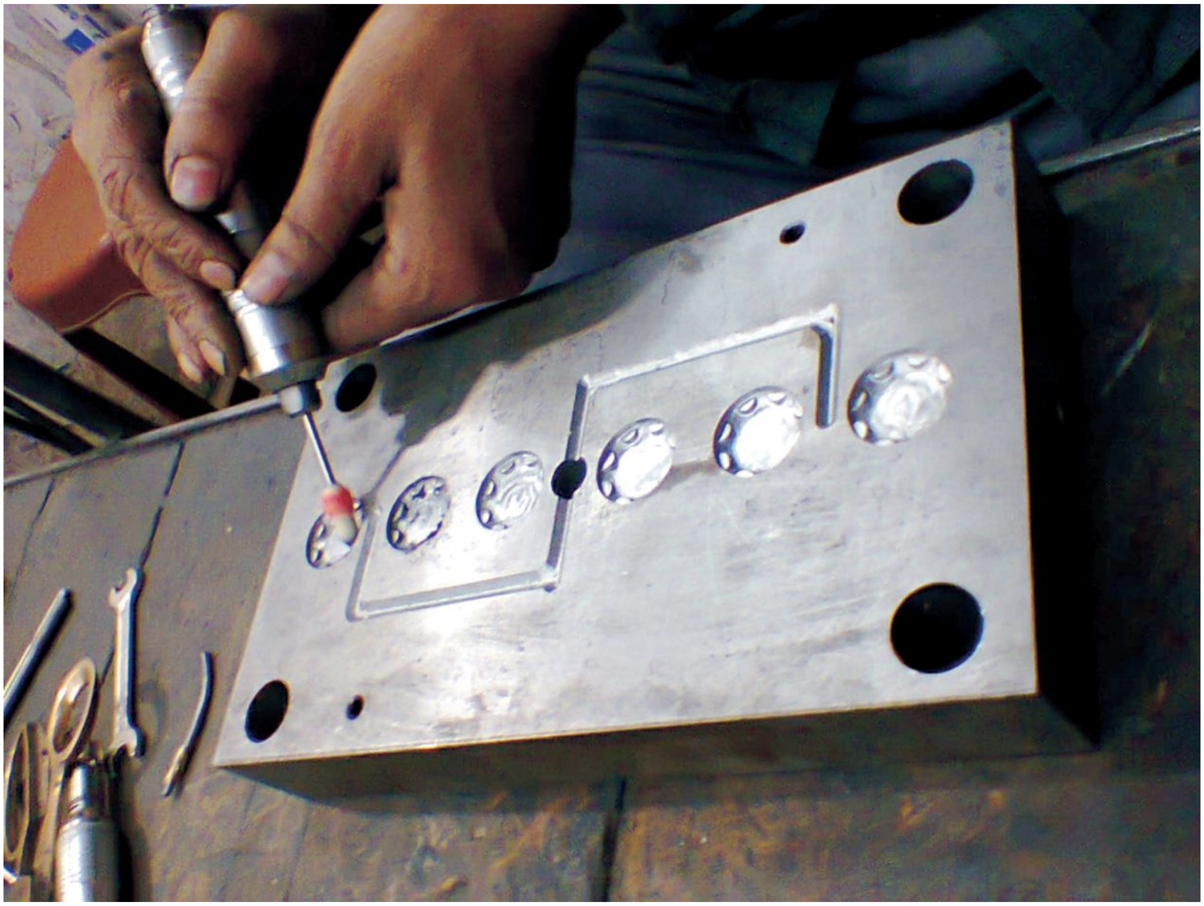


Fig. 1.1 Polishing operation on mould cavity

Two basic mechanisms are involved in the polishing process:-

1 Fine scale abrasive removal and
2 Softening and smearing of surface layers by frictional heating during polishing.

The shiny appearance of polished surface comes from the smearing action. Parts with irregular shapes, sharp corners, deep recesses, and sharp projections are difficult to polish. Only a very small amount of metal is removed in polishing operation. Components to be electroplated are usually polished prior to plating. The value of surface roughness achieved in this operation can be measured by surface roughness testers

There are usually three polishing ways:-

Mechanical Polishing

It is the simplest way of polishing. Various hand tool are used such as die grinders, polishing points, Polishing brushes etc. Mechanical polishing is mainly done manually. There is a direct contact between work piece and tool. The most important advantage is that the workpiece can be in good leveling and high brightness after polishing. While it has the disadvantage that it will take much labor and cause serious pollution, and the luster can't be consistent and durable. The workpiece may rust quickly in this way.

Mechanical polishing is suitable for simple, medium and small size products but not be available on complex parts.

Chemical Mechanical Polishing

CMP process uses a suspension of abrasive particles in a water base solution with a chemistry selected to produce controlled corrosion. This process removes material from the workpiece surfaces through combined actions of abrasion and corrosion. The result is exceptionally fine surface finish and a workpiece that is essentially flat. Less equipment investment is the basic advantage. Rapid, high efficiency and good anticorrosion capability are the few characteristics. But the drawback is brightness inhomogeneous, and difficult to heat. Gas overflow always happen so, ventilation should be added. Chemical polishing is suitable for small batch complex and small parts which the brightness requirement is not very high.

Electro Polishing

Mirror like finishes can be obtained on metal surface by electro polishing, a process that is the reverse of electroplating because there no mechanical contact with the workpiece, this process is particularly suitable for irregular shapes. The electrolyte attack projections and peaks on the work piece surface at a higher rate than for the rest of the surface, thus producing a smooth surface. Advantages are that the luster may keep long, easy to operate, with less pollution.

2.2 Buffing

Buffing is similar to polishing, with the exception that very fine abrasives are used on soft disks typically made of cloth, felt and leather. Buffing gives much higher lustrous, reflective finish and is done after polishing. A common misconception is that a polished surface has a mirror bright finish, however most mirror bright finishes are actually obtained from buffing. The abrasive is supplied externally from a stick of abrasive compound. Buffing may be done by hand with a stationary polisher or die grinder, or it may be automated using specialized equipment. The abrasive include iron oxide, emery, etc. and binder is paste made of wax mixed with grease, paraffin, turpentine, etc. Parts of steel and other hard materials are usually ground, polished and buffed before electroplating.

2.3 Etching

Etching is the process of using strong acid to cut into the unprotected parts of a metal surface to create a design in the metal. Simply etching is the process that removes material from surface.

Fig. 1.2 Steel die polished and etched with design

The etching process is done after polishing process. Etching process is ideal for many alloys. It is fast, flexible and relatively inexpensive. Complex designs are simple to produce while material properties unaltered. Etching is done only when requirement is raised by costumer according to design. This process increases manufacturing time and cost of dies and moulds.

Etching process are mainly of following types:-

1. Wet etching process
2. Dry or Plasma etching process

2.4 Honing

Honing is an abrasive machining process that produces a precision surface on a metal workpiece. An abrasive stone scrubs on workpiece surface along a controlled path. It is used for polishing bores and reamed holes and also external cylindrical surfaces using bonded abrasives stones. Honing is a cutting operation which can be used to remove material less than 0.25 mm (S. Kalpakjian, 2011). This process is mainly used to correct the roundness, taper and tool marks left by previous operation. It also improves surface texture of workpiece. Honing is done by means of bonded abrasive grit sticks, applied to the surface to be honed under controlled pressure and with a combination of rotary and reciprocating motions of abrasives. Generally honing allowance is 0.1 to 0.25mm (S. Kalpakjian, 2011).The surface finish can be controlled by the type and size of abrasive used, the pressure applied and the speed of rotation. Coolant or fluid is used to remove chips and keep temperature low.

Honing can be done manually in which tool is rotated and work is passed back and forth over the tool. Special honing machines are available in market for production work. Typical applications are the finishing of cylinders for internal combustion engines, air bearing spindles and gears.

2.5 Lapping

Lapping is a process in which two surfaces are rubbed together with an abrasive between them. Rubbing can be done by hands or machine. Lapping produces geometrically true surfaces, corrects minor surface imperfections, improves dimensional accuracy and provides a very close fit between two contact surfaces. Very thin layers of metal 0.005 to 0.01mm (S. Kalpakjian, 2011) are removed in lapping therefore, unable to correct the manufacturing and surface errors. It is used when specified accuracy and surface finish are not obtained by other methods.

Lapping is done by the lap which is made from cast iron, copper, leather, or cloth and which rubbed against the work with abrasive slurry. The slurry contains abrasive powder mixed with special pastes with some carrier. The laps may be operated by hand or machine, the motion being reciprocating or rotary. Depending on the hardness of workpiece, lapping pressure range is adjusted and surface finish can obtained.

EXPERT LECTURE

SURFACE MODIFICATION OF CA6NM HYDROTURBINE STEEL FOR PROTECTION AGAINST EROSION

Harpreet Singh Grewal and Harpreet Singh
School of Mechanical, Materials and Energy Engineering
Indian Institute of Technology Ropar, RUPNAGAR-14001 (India)

The world is facing energy crisis due to depletion of fossil fuels at a very fast rate. In current scenario, renewable energy sources are given considerable attention world-wide to meet the ever-increasing energy demands. One such energy source, widely utilized all around the globe, is hydropower. In Southeast Asia, the rivers originating from Himalayas are the main source of hydropower. However, since Himalayas are relatively young, their morphology is rather fragile in nature, which eventually leads to higher concentration of sand particles in river water. When this sand-laden water passes through turbines, the degradation of submerged components takes place. The phenomenon of loss of material from the surface of the components due to interaction with sand particles entrained in river water is known as slurry erosion (SE). Another form of erosion, known as cavitation erosion (CE) is also a predominant form of degradation, existing in hydroturbines. Both SE and CE significantly affect the performance of hydroturbines by directly lowering their efficiency and damaging the submerged turbine components. Several-a-time, a sudden rise in sand concentration due to natural causes such as heavy rains and floods in the mountains leads to the shutdown of the plants, which results in enormous economic losses. In the present work, two different surface modification techniques namely; thermal spraying and FSP were utilized for enhancing the mechanical, as well as, tribological (SE and CE) properties of CA6NM hydroturbine steel. Ni-Al2O3 based powders with proportion of Al2O3 varied from 20 wt. % to 60 wt. % were deposited on CA6NM steel by high velocity flame spraying. In addition, FSP was also employed to modify the surface of CA6NM steel. The processed surface layer was immediately cooled using methanol kept, at -20° C, to help further refinement of the material.

In-depth analysis of the thermal sprayed and friction stir processed (FSPed) samples was undertaken using optical microscope (OM), scanning electron microscope (SEM) equipped with (EDS) and X-ray diffraction (XRD). In addition to this, electron back-scatter diffraction (EBSD) technique was also used for the analysis of the FSPed sample. Micro and nano-indentation testing was also performed along with scratch resistance evaluation. Moreover, the tribological performance of both the sprayed, as well as, FSPed samples under slurry and cavitation erosion conditions was also evaluated. The design and development of slurry erosion test rig was done in-house for this performance evaluation. All the coatings were effective in controlling the SE of the CA6NM steel. Among the coatings, one containing 40 wt. % Al2O3 showed the highest resistance against SE. This could be attributed to the presence of optimum combination of the hardness and fracture toughness. In comparison to the coatings, FSP was able to reduce the SE of the CA6NM steel by only 60 %. In other words, FSP was found to be less effective in comparison with thermal spraying. However, cavitation erosion (CE) studies showed that none of the developed coatings was effective in controlling the damage. On the other hand, the CE resistance of CA6NM steel got enhanced by around 2.4 times after FSP. This improvement could be attributed to its higher hardness and yield strength in comparison to the unprocessed steel.

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A Review On Parametric Analysis Of Surface Roughness During Turning Of Different Types Of Steel

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ABSTRACT

Steel is one of the most widely used metals in the modern world and it is regarded as the most important, multi-functional and most adaptable of materials. In manufacturing industry it is used to manufacture parts of almost all size. Metal cutting is one of the most widely used manufacturing processes for steel. The most common types of cutting process are turning, milling and drilling. Many researchers had investigated the process of turning of steel. This paper reviews the work carried out in area of investigation of the effects of different cutting parameters on the surface roughness while turning different types of steel. The majority of researchers used three primary cutting parameters namely cutting/spindle speed, depth of cut and feed rate for their study. Most of the studies concluded that cutting speed is the most significant factor which effects surface roughness and lower values of feed rate and depth of cut were proposed for lower value of surface roughness.

Keywords: Turning, Steel, Surface roughness, cutting parameters, spindle speed.

INTRODUTION

Surface finish of the machined parts is one of the important criteria by which the success of a machining operation is judged. It is also an important quality characteristic that may dominate the functional requirements of many components *[*Droozda*]*, such as prevention of premature fatigue failure, improving corrosion resistance, reducing friction, wear, and noises thus finally improves the product life [M.M.A. Khan]. Surface inspection is carried out manually by inspecting the machined surfaces. As it is a post-process operation, it becomes time-consuming as well as laborious. In addition, a number of defective parts can be found during the period of surface inspection, which leads to additional production cost [M.A. Xavier]. Aspects such as tool life, wear, surface finish, cutting forces, material removal rate, power consumption and cutting temperature on tool and workpiece's interface decide the productivity, product quality and overall economy in manufacturing by machining and quality of machining [R. Kumar]. Taking into consideration the above given response of surface roughness many researchers have tried to optimize the turning process by using different statistical methods and varying the parameters and cutting environment such as cutting speed, feed rate, depth of cut, nose radius of tool, dry cutting environment, wet cutting environment, types of cutting fluids etc. for different types of steel as workpiece material. A wealth of literature exists in the above mentioned area; some important works are discussed in this paper.

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LITERATURE REVIEW

Mittal & Mehta(1988) developed surface prediction models developed and factors influencing the surface roughness. In their study they considered aluminium alloy 390, ductile cast iron, medium carbon leaded steel, medium carbon alloy steel 4130, and inconel 718 as workpiece materials for investigation under a wide range of machining conditions defined by cutting speed, feed and tool nose radius. Statistical analysis of experimental data proved that the surface finish is strongly influenced by the type of the metal, speed and feed and tool nose radius. While the effects of feed and the tool nose radius on surface roughness were generally steady for all materials, the effect of cutting speed was not.

Ozel et al. (2005) investigated the effects of cutting edge preparation geometry, workpiece surface hardness and cutting conditions on the surface roughness and cutting forces in the finish hard turning of AISI H13 steel. It was found that that the effect of cutting edge geometry on the surface roughness is really significant. The cutting forces were effected not only by cutting conditions but also the cutting edge geometry and workpiece surface hardness. Their study proved that effects of workpiece hardness, cutting edge geometry, feed rate and cutting speed on surface roughness are statistically significant. The effects of two-factor interactions of the edge geometry and the workpiece hardness, the edge geometry and the feed rate, and the cutting speed and feed rate were also found to be important. Especially, honed edge geometry and lower workpiece surface hardness produced better surface roughness.

Sahin & Motorcu (2005) developed a surface roughness model for turning of mild steel with coated carbide tools. The model was developed in terms of cutting speed, feed rate and depth of cut, using response surface methodology. Machining tests were carried out with TiN-coated carbide tools under various cutting conditions. First-order and second-order model predicting equations for surface roughness were formed by using the experimental data. The established equation proved that the feed rate was main influencing factor on the surface roughness. The value of surface roughness increased as feed rate increased and cutting speed decreased. Analysis of variance for the second-order model proved that the interaction terms and the square terms were statistically insignificant. Moreover, it was observed that the first-order effect of feed rate and cutting speed was significant while depth of cut was insignificant.

***Lima et al.(2005)* had** evaluated the machinability of hardened steels at different levels of hardness and using a range of cutting tool materials. They had proved in their result that turning of AISI 4340 steel using low feed rates and depths of cut, the forces were elevated when machining the softer steel and that surface finish of the machined part was enhanced as cutting speed was increased and deteriorated with increasing feed rate.

Ciftci (2006) **had evaluated** the results of experimental work in dry turning of austenitic stainless steels (AISI 304 and AISI 316) using CVD multilayer coated cemented carbide tools. The cutting tools used were TiC/TiCN/TiN and TiCN/TiC/Al_2O_3 coated cementide carbides. It was found that the cutting speed considerably affected the machined surface roughness values. With increasing cutting speed, the surface roughness values decreased until a minimum value was reached beyond which it increased.

***Thamizhmanii et al.* (2007) a**nalyzed surface roughness of SCM440 alloy steel turned with ceramic tool using Taguchi Method. It was stated that depth of cut played a very significant role in producing better surface finish followed by feed and cutting speed had lower effect on surface roughness. Purpose of this research was to determine the optimum cutting conditions to obtain higher surface finish in turning process.

Nalbant et al. (2007) optimized the cutting parameters for better surface finish in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance were used to study the performance characteristics in turning of AISI 1030 steel with TiN coated tools. The experimental results proved that the insert radius and feed rate were the main parameters among the three controllable factors (insert radius, feed rate and depth of cut) that effected the surface roughness. In turning, use of greater insert radius (1.2 mm), low feed rate (0.15 mm/rev) and low depth of cut (0.5 mm) were advocated to obtain better surface finish.

Ozel et al. (2007) investigated surface finish and tool flank wear in finish turning of AISI D2 steels using ceramic wiper (multi-radii) design inserts. The value of surface roughness and tool flank wear was determined with the help of multiple linear regression models and neural network models. It was found that multi-radii wiper tools can be used to higher feed rates while maintaining good surfaces finish. Experimental results indicated that surface roughness values as low as 0.18–0.20 μm were attainable with wiper tools. Low feed rates resulted in lower flank wear and better surface finish was produced at the lowest feed rate and highest cutting speed combination. This study proved that neural network models are appropriate to determine tool wear and surface roughness patterns for a range of cutting conditions.

Singh & Rao (2007) conducted an experimental investigation to determine the effects of cutting conditions and tool geometry on the surface finish in hard turning of the bearing steel (AISI 52100) using mixed ceramic inserts made up of aluminium oxide and titanium carbonitride (SNGA), having different nose radius and different effective rake angles. Mathematical models for the surface roughness were developed by using the response surface methodology. Their study proved that feed rate was the most significant factor effecting surface finish followed by nose radius and cutting velocity. Though, the effect of the effective rake angle on the surface roughness was less, the interaction effects of nose radius and effective rake angle were very significant.

Kumar et al. (2008) studied the relative performance of TiCN and TiAlN coated tools in machining of AISI 4340 hardened steel under dry, wet and minimum fluid application conditions. Both the tools performed better with minimum fluid application than wet and dry machining. The performance of the TiAlN tool was observed to be better; in terms of wear resistance of the tool and better surface finish on the components.

Lalwani et al. (***2008)*** investigated the outcome of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface finish in hard turning of MDN 250 steel using coated ceramic tool. Response surface methodology (RSM) and sequential approach was used with face centered central composite design. It was revealed that the cutting forces and surface roughness did not vary much with cutting speed in the range of 55–93 m/min.

Dhiman et al. (2008) analyzed machining behaviour of mild steel AISI 1018 during dry turning. It was predicted among cutting parameters affecting machining variables (tool tip temperature, surface roughness and cutting force) for AISI 1018 steel, speed was the most influencing and depth of cut had minimum effect. Tool tip temperature increased with increasing cutting speeds but surface finish was least affected. Surface finish deteriorated at high feed rates, so it was suggested that feed should be kept low (0.08 - 0.12). From 0.5 mm to 1 mm depth of cut, lower tool tip temperature, good surface finish and lower cutting force was observed. At lower speeds, surface roughness increased with increasing feed but at higher speeds it was less dependent on feed.

Isik(2010) **investigated effect of cutting fluids in turning of mild steel AISI 1050 with coated carbides tool. It was observed that t**he coolant helped breaking up chips and removing them from the cutting area more efficiently, which means the cutting tool spent less time for breaking metal chips. The cutting fluid had considerably reduced the amount of heat and friction at tool-work piece interface. For most tests, cutting speed did not show a significant effect on surface finish for both dry and wet machining conditions. The effect of the cutting speed was insignificant. Cutting fluid did not show a noteworthy improvement on surface roughness particularly when turning with 0.8 mm nose radius. In fact, the roughness deteriorated under wet machining in some of tests.

Selvaraj & Chandarmohan (2010) investigated the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel (AISI 304) during dry turning. Taguchi's approach, Orthogonal array, S/N ratio and analysis of variance was used to investigate the cutting characteristics of AISI 304 austenitic stainless steel turned with TiC and TiCN coated tungsten carbide cutting tool. ANOVA results proved that feed rate, cutting speed and depth of cut effected the surface roughness by 51.84%, 41.99% and 1.66% respectively. The lowest levels of all three factors were predicted to be optimal for lower surface roughness value.

Basavarajappa et al. (2012) analyzed the effects of process parameters on machinability aspects by using multilayer hard coatings on cemented carbide substrate for machining of hardened AISI 4340 and revealed that the optimal combination of low feed rate and low depth of cut with high cutting speed was favorable for reducing machining force. The machining power and cutting tool wear increased almost linearly with increment of cutting speed and feed rate. The combination of low feed rate and high cutting speed was found necessary for better surface finish.

Rodrigues et al. (2012) analyzed effect of cutting parameters on surface roughness and cutting force in the turning of mild steel. The feed rate had considerable effect on both the cutting force and surface roughness. Cutting Speed had negligible effect on the cutting force as well as the surface roughness workpiece. Depth of cut had a significant effect on cutting force, but an insignificant influence on surface roughness. This study concluded that in the turning process, optimum surface roughness can be achieved with relatively higher values of speed (>450 rpm), higher values of depth of cut (>0.75mm) and relatively lower values of feed rate (<0.11 mm/rev).

Saraswat et al. (2013) investigated the effect of cutting parameters on the surface roughness of EN9 steel when turned with HSS tool. Cutting parameters were optimized using Taguchi method by minimizing S/N ratio. It was also found that feed rate (60.85 %) was the most significant factor on which surface roughness depended, followed by spindle speed (20.46 %), and depth of cut (18.26 %).

Lavanya et al. ***(2013)*** optimized the process parameters in turning of AISI 1016 steel using Taguchi method and ANOVA. The optimal settings of process parameters for optimal surafce roughness found were: speed: 740 RPM, feed rate : 0.05 mm/rev and depth of cut : 1.0 mm. From the results obtained, a regression model was developed for surface roughness; From which the value of surface roughness could be predicted if the values of cutting speed, feed and depth of cut were known. From ANOVA table and response table for signal to noise ratios, based on the ranking it can be concluded that speed had a greater influence on the surface roughness followed by feed and depth of cut had least influence on Surface Roughness.

Gautam et al. (2014) investigated effect on surface roughness in dry turning of mild steel using two HSS tools with different nose radius. Feed was the most important cutting parameter on the surface roughness followed by cutting speed and depth of cut. It was concluded that tool with 1 mm nose radius produced better surface finish than that of 0.65 mm.

Patel & Panchal (2014) did parametric analysis of dry and wet turning using full factorial method. Feed rate was the most significant parameter which contributed 62.52% in dry turning and 53.56% in wet turning operation, The percentage contribution of side rake angle was15.20% and depth of cut of 18.8% on surface roughness for dry turning operation and the percentage contribution of side rake angle is 14.49% and depth of cut of 30.21% on surface roughness for wet turning operation. Optimal parameters for surface roughness are side rake angle (-5º), feed 0.20 mm/rev and depth of cut 0.8 mm for dry and wet turning operation.

CONCLUSION

The objective of this study was to summarize the work done in the area of turning of different types of steel. Cutting speed was also found to be the most significant factor which effected surface roughness followed by feed rate and depth of cut. Higher values of cutting speed and nose radius along with lower values of feed rate and depth of cut were proposed by most of the researchers for better surface finish. It was observed that most of the studies concluded that with increase of cutting speed the value of surface roughness, tool wear and cutting temperature also increased. The use of cutting fluid resulted in lower values of surface roughness and cutting temperature while minimum quantity lubrication produced better results in terms of surface roughness and cutting temperature.

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Ahp And Topsis For Justification Of Jit Implementations (prerequisites And Benefits) In Indian Manufacturing Industries

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Abstract

Study on JIT had always been a major problem in the research on business management. The class of product always depends upon the infrastructural capability of the enterprise, its abilities to handle their human resources, equipment and facilities. The literature has been deeply analyzed and examines the JIT implementation in the organizations, various strategies, and important issues of JIT for accruing strategic benefits for meeting the challenges posed by global competition with the use of AHP-TOPSIS method. This pragmatic research gauges the JIT critical factors to determine the strategic success factors in uncertain environment using analytical hierarchy process and Technique for Order of Preference by Similarity to Ideal Solution. The research out also reveals that the holistic Just in Time manufacturing methods outscore the traditional manufacturing method towards enhancing the manufacturing performance. The research highlights that detailed JIT implementation (Prerequisite and benefits) over a reasonable period can reasonably contribute towards achievement in performance of organization.

Keywords: Just in time (JIT), Analytical hierarchy process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), performance, manufacturing methods.

Introduction

Just in time (JIT) is a production strategy that strives to improve a business' return on investment by reducing in-process inventory and associated carrying costs. Just in time is a type of operations management approach which originated in Japan in the 1950s. It was adopted by Toyota and other Japanese manufacturing firms, with excellent results: Toyota and other companies that adopted the approach ended up raising productivity (through the elimination of waste) significantly. To meet JIT objectives, the process relies on signals or Kanban between different points, which are involved in the process, which tell production when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. Implemented correctly, JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality, and efficiency. To achieve continuous improvement key areas of focus could be flow, employee involvement and quality. In Indian manufacturing industries, the endeavor of Indian manufacturing organizations to achieve manufacturing performance enhancement and growth by reducing cost of products, effectively managing and controlling inventories (Singh and Ahuja, 2015).The significant performance measures of JIT for Indian manufacturing industries were obtained by fuzzy model using fuzzy logic toolbox of MATLAB for enhancing business performance to check the normality of the independent and dependent variables data have been applied an organization can reap benefits of all the selected PMs(Singh and Ahuja, 2015).

To significantly examine the factors affecting the implementation, it reveals that implementing JIT is by no ways an easy task, it is heavily burdened by organisational, financial, cultural, behavioral, operational, technological and departmental barriers , but JIT can be realistically achieved in an Indian manufacturing enterprise by bringing out successful cultural changes, commitment of management (Singh and Ahuja, 2013).The impact of JIT manufacturing method on performance of organisation and highlights the need for aligning organisational efforts in establishing manufacturing methods for attaining improvements in performance of manufacturing organizations, it affirms the fact that implementation of JIT programme does not bring about immediate results, but it requires systematic planning and a focused plan of JIT implementation, assisted adequately by top management through adequate enhancement in culture of organisation over adequate time to attain the true results from the holistic JIT implementation programme (Singh and Ahuja, 2014). The manufacturing industries in the world have undergone a tremendous change in the last three decades. Due to this there are drastic changes in management approach, techniques used in production and process, expectations of customer, attitudes of supplier, as well as competitive behaviour (Ahuja et al., 2006).

In the highly dynamic and rapidly changing modern era, the global competition among organisations has lead to higher expectations from the manufacturing organisations (Miyake and Enkawa., 1999). The global marketplace has witnessed an increased pressure from customers and competitors in manufacturing as well as service sector.

A survey conducted in various manufacturing industries to find out success or failure of JIT implementation in Indian industries by using AHP and TOPSIS. This paper includes few, facile and potential JIT (Prerequisite and benefits) for the overall blend of JIT manufacturing using analytical hierarchy process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), in Indian manufacturing Industry. The goal of this paper is to present the AHP and TOPSIS technique for justification of JIT for various organizations in India. AHP and TOPSIS sums up the information from different, concurrently interacting factors, to assess relative standings of JIT Prerequisites and Benefits for the adequate implementation of JIT for Indian industries.

Literature review

There is reasonable consensus among researchers that Just in Time (JIT) is a philosophy of continuous improvement in which non-value adding activities are identified and removed in order to reduce costs, improve product quality, improve performance, improve delivery, add manufacturing flexibility and stimulate innovation in the workplace. The literature has been deeply analyzed and examines the evolution of JIT and its implementation in the organizations, Various strategies, elements and important issues of JIT for accruing strategic benefits for meeting the challenges posed by global competition (Singh and Ahuja, 2012). The quality requirements and competitive price all over the world had forced organizations to use various manufacturing methods, But AHP method, this study is facile to analyze and affirm the important criteria and attributes, for attaining the overall objective for JIT implementations in

Indian manufacturing organizations (Singh and Ahuja, 2014). Fuzzy logic tool is best suited for dynamic environment where decisions are required to be taken on the basis of multi variable parameters to determining the significant performance measures gained by organization with implementation of JIT manufacturing by using a formalized decision analysis approach based on multiple criteria and rule-based system is the contribution of the presented model and main advantages of proposed model is that it enhances the decision making capacity of organizations which are at different stages of implementation of JIT or planning to implement JIT(Singh and Ahuja, 2014).

In Prerequisites, There are four major areas to be looked after for the implementation of JIT successfully and these are inventory, production, quality and customer's relation. Schermerhorn (1996) has put forth the theory that the effectiveness of JIT implementation hinges on a wide range of special support that includes: high quality supplies, strong management commitment, a manageable supplier network, geographic concentration, efficient transportation, and materials handling.

Before a manufacturing or service organization can enjoy the fruits of JIT, the firm must accept JIT as an organisational philosophy. This may require the organization to change or modify its operating procedures, its production or service systems and in most cases its organisational culture (Yasin et al., 2004a). Figure 1 explains the modifications in an organization prior to JIT implementation.

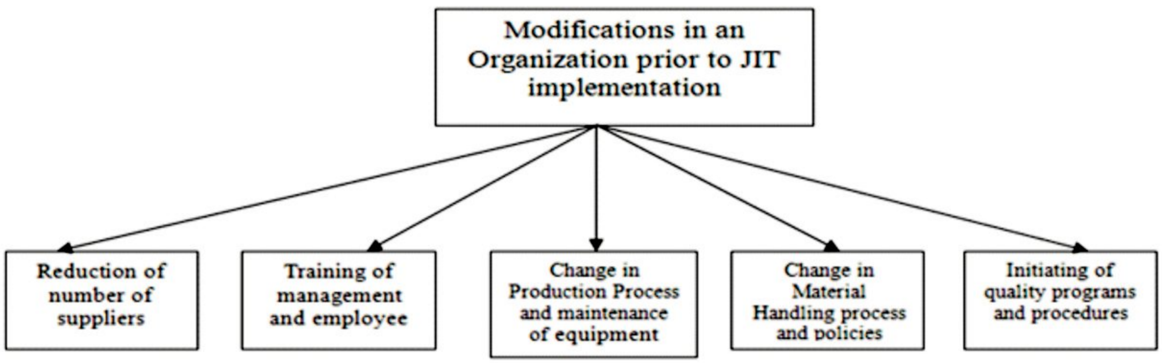

Figure 1 Organizational modifications prior to JIT implementation

Main aim of JIT manufacturing is to reduce inventories. Maskell (1987) mentioned four types of inventory procurement problems and their solution in table 1.

Table 1 Inventory procurement problems and their solutions

Problem	Solution
Supplier lead times	Closer supplier relationships
Inflexible production planning	Closed-loop MRP-II system
Large batch sizes	reduced set-up time
Long queue times	Plant layout and MRP-II

- Reduced setup time. Cutting setup time allows the company to reduce or eliminate inventory for "changeover" time. The tool used here is SMED (single-minute exchange of dies).
- The flow of goods from warehouse to shelves improves. Small or individual piece lot sizes reduce lot delay inventories, which simplifies inventory flow and its management.
- Employees with multiple skills are used more efficiently. Having employees trained to work on different parts of the process allows companies to move workers where they are needed.
- Production scheduling and work hour consistency synchronized with demand. If there is no demand for a product at the time, it is not made. This saves the company money, either by not having to pay workers overtime or by having them focus on other work or participate in training.
- Supplies come in at regular intervals throughout the production day. Supply is synchronized with production demand and the optimal amount of inventory is on hand at any time. When parts move directly from the truck to the point of assembly, the need for storage facilities is reduced.

Yasutaka et al. (2013) had a large scale empirical study on just in time quality assurance and they validate change level prediction through an extensive study on six open source and five commercial projects. They concluded that different factors are effective for open source and for commercial projects in RQ1 and RQ2. They also concluded that a change level prediction model can predict changes as being defect prone or not with 68% accuracy, 34% precision, and 64%

recall and they said that Just In Time quality assurance reduces the costs of building high quality software. Igor et al. (2013) proposed parameter based value specialization as a way to improve the quality of the code produced by JIT engines in which they implemented the technique on Ion Monkey Java script compiler which was developed in Mozilla foundation. The researchers concluded that by using such optimization technique the execution time of an industrial strength JIT compiler was improved and found that this approach was most profitable when applied on functions that are called always with the same parameters. Kun and Yi. (2013) proposed Just In Time Learning method using adaptive relevant sample strategy for online prediction of product quality in chemical processes which was applied to crude oil endpoint in an industrial fluidized catalytic cracking unit and they concluded that JITL method can achieve a better prediction **performance and found various limitations like how to determine the number of relevant samples in an adaptive manner.**

Results And Methodology

The AHP and TOPSIS is a set of principles that suspiciously delimit the scope of the problem environment. It is mainly used for dealing with multi-criteria decision making (MCDM) problems (Saaty, 1980). It is based on the precise mathematical arrangement of persistent matrices and their associated right-eigenvector's ability to generate true weights (Merkin, 1979; Saaty, 1980). It can be authoritative model used for decision-making. The validity of AHP is based on the thousands of actual applications in which the AHP results were useful and used by the acquainted DMs (Saaty, 1994). It is widely used for decision-making in the whole world today. The study has been carried out in the medium and large scale manufacturing organizations in India that have implemented or in the process of implementing JIT. To study the Prerequisites and benefits of JIT AHP and TOPSIS are used. In the present study the questionnaire survey technique has been used for gathering information on the status of JIT implementation issues and the recognition of various manufacturing performances in the Indian manufacturing industry. The suggestions received from the consultants, managers, senior executives from the industries and academicians have been added to make the questionnaire more accordant to the purpose and bring out major outcomes as a result of strategic JIT implementation.

The JIT questionnaire deliver the purpose of divulge the exploits of Indian organization with JIT practices and highlights the major contributions of JIT in recognizing the overall organization's goals and objectives. Figure 2 shows the steps undertaken in finalization of the JIT questionnaire-

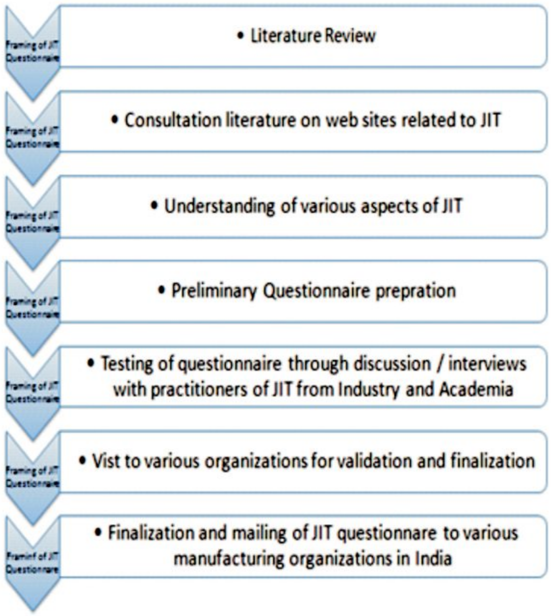

Figure -2 Questionnaire finalization procedure

EVALUATING WEIGHT OF CRITERIA BY AHP APPROACH

Step-1. Represent decision matrix

The first step of TOPSIS method involves the construction of a decision matrix(DM) where i is the criterion index (i=1……..m); m is the number of potential sites and j is the alternative index (j=1………n). The elements of the matrix are related to the values of criteria i with respect to alternative j.

DECISION MATRIX

$$\begin{bmatrix} 5 & 7 & 9 \\ 3 & 5 & 7 \\ 9 & 9 & 7 \\ 7 & 7 & 5 \\ 5 & 3 & 9 \\ 9 & 5 & 3 \\ 7 & 7 & 5 \end{bmatrix}$$

Step-2. Normalized Matrix

Having made all the pair wise comparisons and entered the data, the consistency is determined using the eigenvalue. So next step is to calculate priority vector that is the normalised eigenvector of the matrix. For this, each entry in column is divided by the sum of all entries in that column to get value of normalised matrix. The normalised value rij is calculated as:

NORMALIZED MATRIX

$$\begin{bmatrix} 0.2799 & 0.4316 & 0.5039 \\ 0.1680 & 0.3083 & 0.3919 \\ 0.5039 & 0.5550 & 0.3919 \\ 0.3919 & 0.3083 & 0.2799 \\ 0.2799 & 0.1850 & 0.5039 \\ 0.5039 & 0.0383 & 0.1680 \\ 0.3919 & 0.4316 & 0.2799 \end{bmatrix}$$

Step-3. **Relative Importance Matrix By AHP**

In the first stage data was collected from various organizations implementing JIT by distributing questionnaires and then the selected attributes were compare to each other. In this comparison, the importance of ith sub-objective is compared with jth sub objective where ith sub-object is represented in row and jth sub- object represents column. A 3 × 7matrix was formed and to fill this matrix following procedure was adopted.

The diagonal elements of the matrix always remain 1.

Upper triangular matrixes were filled as per the data obtained through companies and this represents how much one attribute is important than the other. According to importance of attribute value of each attribute has been given from 1-8 in table.

To fill the lower triangular matrix, reciprocal values of the upper diagonal was used, i.e. if aij is the element of row ith and column jth of the matrix, then the lower diagonal is filled using this formula aji = 1/aij. Thus, the pair-wise comparison of matrix for different attributes is shown in Table.

RELATIVE IMPORTANCE MATRIX BY AHP

$$\begin{bmatrix} 1.000 & 1.000 & 0.333 \\ 1.000 & 1.000 & 1.000 \\ 3.000 & 1.000 & 1.000 \end{bmatrix}$$

The results of pair wise comparisons are filled in positive reciprocal matrices to calculate the Eigenvector and Eigen value. The consistency of the judgments is determined by a measure called consistency ratio (C.R.). The consistency ratio is obtained to filter out the inconsistent judgments, when the value of the consistency index (C.I.) is greater than 0.1 then all the judgments are found to be consistent and accepted for analysis. Saaty (1980) has proved that for any reciprocal matrix, the maximum eigen value is equal to the size of comparison matrix, and then a measure of consistency which is called consistency index (CI) as deviation or degree of consistency was given by him. Considering above relative weight, that would also represent the eigen values of criteria, should verify as below:-

$A \times W_j = \lambda_{max} \times W_j$

By Calculate the λ_{max} by MatLab, $\lambda_{max} = 3.1356$

CONSISTENCY RATIO= CI (Consistency Index) =

Therefore, CR= (3.1356-3)/(3-1) =**0.006 (less than 0.10)**. Hence, it indicates that the data is consistent and accurate.

Step-4. **Weighted normalized matrix**

Not all of the selection criteria may be of equal importance and hence weighting were introduced previously to quantify the relative importance of the different selection criteria (see Section 2). The weighting decision matrix is simply constructed by multiply each element of each column of the normalized decision matrix by the predefined weights

$$\sqrt{\sum_{j=1}^{n} (V_j^{-} - V_{ij} \quad)2}$$

WEIGHTED NORMALIZED MATRIX

$$\begin{bmatrix} 0.0619 & 0.1416 & 0.2272 \\ 0.0371 & 0.1011 & 0.1767 \\ 0.1114 & 0.1820 & 0.1767 \\ 0.0867 & 0.1011 & 0.1262 \\ 0.0619 & 0.0607 & 0.2272 \\ 0.1114 & 0.1011 & 0.0757 \\ 0.0867 & 0.1416 & 0.1262 \end{bmatrix}$$

Step-5. Calculate positive and negative ideal solution

PIS = $A^+ = \{ v_1^+, v_2^+ \ldots, v_n^+ \}$, where: $V_j^+ = \{ (max_i (v_{ij})$ if j ? J) ,(min_i v_{ij} if j€J) }	(j ? J')
NIS = $A^- = \{ v_1^-, v_2^-, \ldots, v_n^- \}$, where: $V_j^- = \{$(min vij if j ? J); (max vij if j€J) }	(j ? J)'

$V^+ = [0.1114, 0.1820, 0.2272]$
$V^- = [0.0371, 0.0607, 0.0757]$

Step-6. Calculate the separation distance of each competitive alternative from the ideal and non- ideal solution

$S^+ = \sqrt{\sum_{j=1}^{n} (V_j^+ - V_{ij})2}$

$S^- =$

$S_1=2.2300$ $S^-_1=1.0342$
$S_2=1.5620$ $S_2^-=3.3200$
$S_3=3.1342$ $S_3^-= 1.4570$
$S_4=2.3450$ $S_4^-=1.0015$
$S_5=1.3560$ $S_5^-=2.5234$
$S_6=2.3750$ $S_6^-=0.1334$
$S_7=1.3420$ $S_7^-=1.0034$

Step-7. Measure the relative closeness of each location to the ideal solution. For each competitive alternative the relative closeness of the potential location with respect to the ideal solution is computed

$C_i= \ C_i= S_i^- / (S_i^+ + S^-_i),\ 0 \le C_i \le 1$
$C_1=0.3168$
$C_2=0.6800$
$C_3=0.3173$
$C_4=0.2992$
$C_5=0.6504$
$C_6=0.0531$
$C_7=0.4278$

Step-8. **Rank the preference order**

After assigning weight to each criterion using the AHP approach the places that were considered potentially suitable for a study the JIT prerequisities were ranked using the TOPSIS method:

Construction of a decision matrix (DM) using Step3 of the proposed site selection process.
Calculation of the normalized decision matrix (Equation 1).
Construction of a weighted normalized decision matrix (Equation 2).
Identification of the ideal (V^+) and negative ideal (V^-) solutions (Equations 6 and 7).

According to the value of C_i the higher the value of the relative closeness, the higher the ranking order and hence the better the performance of the alternative. Ranking of the preference in descending order thus allows relatively better performances to be compared

$\mathbf{C_2 > C_5 > C_7 > C_3 > C_1 > C_4 > C_6}$

C1= Employ and management committee
C2 = Relation with supplier
C3= Work place organisation
C4= Manufacturing flexibility
C5= Quality and Quantity
C6= Maintenance Management
C7= Delivery Complaint

Conclusion

The AHP and TOPSIS method has been used in the selection of the best competitive advantage for manufacturing organization under uncertainty to develop its most critical competitive advantage in JIT implementation. Also by using the AHP AND TOPSIS method, this study is facile to analyse and affirm the important criteria and attributes, for attaining the overall objective for JIT implementations in Indian manufacturing organisations. The results obtained by this study are quite significant and promising and shows that success rate of JIT implementation

There are many performance measures that from which an organization can reap its goals. Most critical performance measures which effects the performance of the organization are setup time (ST), delivery compliance (DC), inventory level (IL), firm's culture and values (FCV), productivity (P) and quality (Q). These performance measures are divided according to weight age gained from the feedback response from various organizations.

From **TOPSIS-AHP Method, it is clear that** Relation with supplier higher in ranking order and Quality and Quantity at second position .So prerequisites relation with supplier and quality and quantity are important factor in JIT implantation. Delivery Complaint, Work place organisation, Employ and management committee are also important factor in JIT implementation. Manufacturing flexibility, Maintenance Management are less effective than other prerequisites in JIT implementation

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Theoretical Analysis Of Free Vibration Characteristics Of Cantilever Beams Made From Different Materials

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Abstract

This paper focuses on the theoretical analysis of free vibration characteristics of cantilever beams. Now a day vibration is one of the most important areas of the research, because so many failures are occur due to excess vibrations in machines or any other field like construction etc, so that we measured the vibration and reduce it or control it. It is both useful and harmful for engineering systems. To control the vibration dampers are used but they posses internal damping due to that energy dissipate in to heat. Estimating Damping is a biggest challenge in materials. The objective of the study is to find out the Free Vibrations and natural frequency of cantilever beams which are made up from different materials (Aluminium, Stainless Steel, Mild Steel and Wood).All the theoretical values are calculated.

Keywords- Cantilever Beam, Damping ratio, Free vibration.

INTRODUCTION

Any motion which repeats itself after an interval of time i.e Vibration. Vibration analysis is one of the important tasks in designing of structural and mechanical system. The effect of vibration absorber on the rotating machineries, vehicle suspension system and the dynamic behaviour of machine tool structures due to excitation are the important information that design engineer wants to obtain. This information helps to design system to control the excessive amplitude of the vibration. But in case of cantilever beams, a straight, horizontal cantilever beam under a vertical load will deform into a curve. When this force is removed, the beam will return to its original shape; however, its inertia will keep the beam in motion. Thus, the beam will vibrate at its characteristic frequencies.

Chopade, J.P., Barjibhe, R.B. (2013) this paper focuses on the theoretical analysis of transverse vibration of fixed free beam and investigates the mode shape frequency. All the theoretical values are analyzed with the numerical approach method by using ANSYS program package and correlate the theoretical values with the numerical values to find out percentage error between them. It has been found that the relative error between theoretical approach and the numerical approach are very minute. The numerical study using the ANSYS program allows investigates the free vibration of fixed free beam to find out mode shape and their frequencies with high accuracy. From there it concluded that theoretical data is in good agreement with numerical results with negligible error.

Singh, R., Sharma, M., Singh, V.P. (2012) In this paper eddy current damper is used to control the vibration of the cantilever beams. Eddy Current Damper works on the principle of Electromagnetic Induction. According to the theory of electromagnetic induction, a current flows in a conductor whenever a change in magnetic flux is linked with it. One of the major causes of failure of structures is vibration or dynamic loads which produces the dynamic stresses in the structural elements. From the analysis it can be seen which structural parameters most affect the dynamic response so that if an improvement or change in the response is required, the structure can be modified in the most economic and appropriate way. Very often the dynamic response can only be effectively controlled by changing the damping in the structure. Eddy currents provides an efficient way of adding damping to the structure without coming in contact with the structure.

Cekus, D (2012) In this paper the Lagrange multiplier formalism has been used to find a solution of free vibration problem of a cantilever tapered beam. The sample numerical calculations for the cantilever tapered beam have been carried out and compared with experimental results to illustrate the correctness of the present method. In this the free vibration problem of the cantilever tapered Timoshenko beam has been formulated and solved on the basis of Lagrange multiplier formalism. On the basis of a comparison between numerical calculations and experimental results, the percentage of error is to be find out.

I. BEAMS

A beam is a structural element that is capable of with standing load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a moment. Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

Cantilever beams

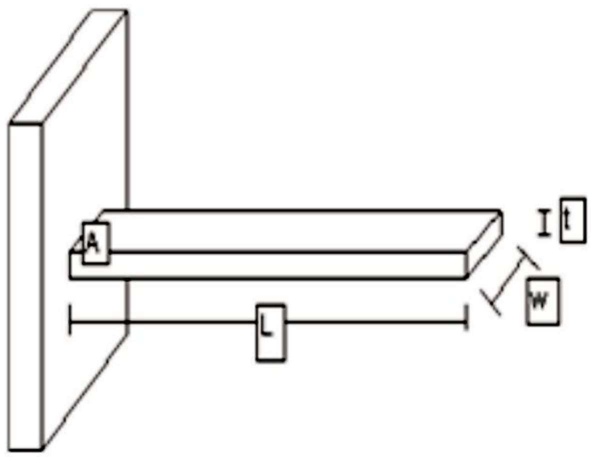

Fig-1 Cantilever Beam

A cantilever beam is one whose one end is fixed and the other end carries a point or concentrated load.

L-length

W-width

T-thickness

III. THEORY OF VIBRATION

Theory of Free Vibration of Cantilever Beams

For a cantilever beam subjected to free vibration, and the system is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of the shaft, the equation of motion can be written as:-

$$\frac{d^2}{dx^2}\{EI(x)\frac{d^2Y(x)}{dx^2}\} = \omega_n{}^2 m(x)Y(x)$$

Where, E is the modulus of rigidity of beam material I is the moment of inertia of the beam cross- section, $Y(X)$ is displacement in y direction at distance X from fixed end n is the circular natural frequency m is the mass per unit length $m=pa(x),p$ is the material density x is the distance measured from the fixed end.

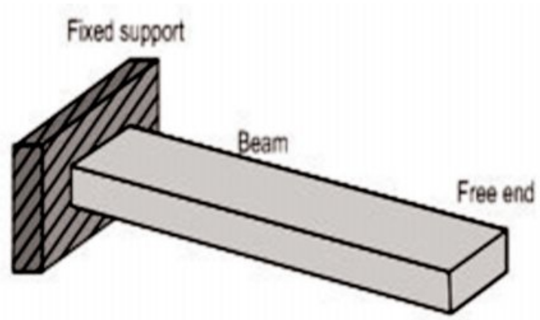

Fig -2 A cantilever beam

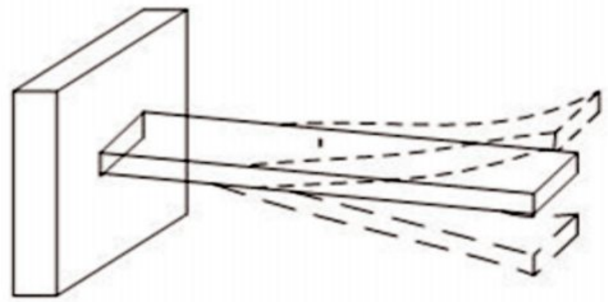

Fig -3 The beam under free vibration

Fig.-2 shows of a cantilever beam with rectangular cross section, which can be subjected to bending vibration by giving a small initial displacement at the free end; and Fig.-3 depicts of cantilever beam under the free vibration.

The natural frequency is related with the circular natural frequency as

$$f_{nf} = \frac{\omega_{nf}}{2\pi} Hz$$

where I, the moment of inertia of the beam cross-section, for a circular cross-section it is given as

$$I = \frac{\pi}{64} d^4$$

Where, d is the diameter of cross section and for a rectangular cross section

$$I = \frac{bd^3}{12}$$

Where b and d are the breadth and width of the beam cross-section as shown in the Fig.

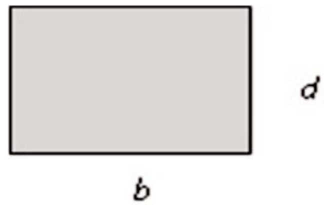

Fig-4 Cross-section of the cantilever beam

Euler Bernoulli Beam Theory

Euler Bernoulli's Beam Theory also known as engineer's beam theory or classical beam theory is a simplification of the linear theory of elasticity which provides a means of calculating the load carrying and deflection characteristics of beams . It covers the case for small deflections of a beam which is subjected to lateral loads only. It is thus a special case of Timoshenko beam theory. For a cantilever beam subjected to free vibration, and the system is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of the shaft, the equation of motion can be written as:-

$$\frac{d^2}{dx^2}\{EI(x)\frac{d^2Y(x)}{dx^2}\} = \omega_n^{\,2} m(x)Y(x)$$

Following are the boundary conditions for a cantilever beam:-

$$x = 0, Y(x) = 0, \frac{dY(x)}{dx} = 0$$

$$x = l, \frac{d^2Y(x)}{dx^2} = 0, \frac{d^3Y(x)}{dx^3} = 0$$

$$\frac{d^4Y(x)}{dx^4} - \beta^4 Y(x) = 0$$

$$\beta^4 = \frac{\omega_n^{\,2} m}{EI} \quad \beta_n L = \alpha_n$$

$$\omega_{nf} = \alpha_n^{\,2}\sqrt{\frac{EI}{mL^4}}$$

IV. OBJECTIVE

- **The main objective of the study is to find the free vibration and natural frequency of a cantilever beams made of Aluminium, Stainless Steel, Mild Steel and Wood.** The natural frequencies is measured by theoretical techniques by varying the parameters like thickness and length but keeping the width same.

Cantilever Beam's Specifications

Table-1 (Beam's Specifications)

Material	Mild Steel	Aluminum	Stain less Steel.	Wood
Flexural Member Length (mm)	Beam 1200, 800	Beam 1200,800	Beam 1200,800	Beam 1200, 800
Width(mm)	32,32	32,32	32,32	32,32
Thickness (mm)	6.5, 3.5	6.5, 3.5	6.5, 3.5	6.5, 3.5
Young's modulus (Gpa) Density (kg/m^3)	200 7850	70 2700	180 7750	12.28 650

Notation Used

1-1200mm×32mm×6.5mm

2-1200mm×32mm×3.5mm

3-800mm×32mm×6.5mm

4-800mm×32mm×3.5mm

V. THEORETICAL CALCULATIONS

Calculate natural frequency of cantilever beams of different materials by theoretical formulation.

E- Young's modulus

I-Moment of inertia

L- Length of beam

ω_n- Natural frequency

K- Stiffness m- Mass

Table 2 Theoretical Calculations

S No.	Specimen	Mass (Kg)	Stiffness (N/m)	Natural freq.
1	AL1	0.6732	88.998	1.828
2	AL2	0.3628	13.894	0.983
3	AL3	0.4492	300.37	4.111
4	AL4	0.2419	46.89	2.213
5	SS1	1.9968	228.85	1.702
6	SS2	1.0752	35.72	0.916
7	SS3	1.3312	772.38	3.830
8	SS4	0.7168	120.58	2.062
9	MS1	1.9596	254.28	1.811
10	MS2	1.0550	39.699	0.975
11	MS3	1.3062	858.20	4.075
12	MS4	0.7033	133.98	2.194
13	WD1	0.1622	15.61	1.559
14	WD2	0.0873	2.437	0.839
15	WD3	0.1081	52.69	3.509
16	WD4	0.0582	1.755	0.872

CONCLUSION

The main purpose of the present work is to study the vibration damping characteristics of four materials The vibration analysis has been done using theoretical analysis. In this analysis natural frequency plays an important role to find the free vibrations of a cantilever beams which are made up from different materials.

On the basis of present study following conclusions are drawn:

It concluded that when the thickness decreases but length same then the natural frequency decreases.

When the length decreases but thickness same then the natural frequency goes to increase

The natural frequency decreases with decreases in thickness. But it is increases in SS1SS2, MS1, MS2 WD1, WD2 these cases.

All the theoretical natural frequency value decreases when thickness decreases but same length and it increases when length decreases but same thickness.

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Impact Of Global Talent Management On Firm Performance – A Review

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ABSTRACT

Global talent management is the standard human resource practices and functions; and in the international context the term global talent management is used interchangeably with international human resource management. Talent management scheme has impact on the performance of the multinational and the national firm but the small and medium scale firms have not been gaining from this technique.This technique is similar to the process involved with human resource management systems impact organizational performance. This processes as described in the strategic human resource management literature, suggests that human resource management systems, in general, do not lead directly to firm performance. Rather they influence intermediate employee outcomes such as human capital (e.g., knowledge, skills and abilities), and employee behaviours that in turn lead to improved performance. This is referred to as the black-box of strategic human resource management. Global talent management scholars can borrow from the strategic human resource management literature to describe how and why global talent management systems impact performance both at the individual and organizational levels. Through this review paper, the authors have tried to compile some of the available literature in concerned area so that further research may get some direction.

Keywords: Global talent management, strategic human resource management, firm performance, organization performance.

INTRODUCTION

The importance of global talent management is evidenced by academics and HR practitioners alike. Similar to the results from the Manpower Talent Shortage Survey (2011), the general consensus is that organizations face intense competition for talent worldwide and confront major challenges in attracting, retaining, and developing people they need in many positions.Some organization regards some few strategic staff as the talent of the firm while others believe that all their staff is talent of the firm. Thus talent management is an off -short of the human resources management scheme of the firm. According to the Manpower Talent Shortage Survey, the top three most difficult positions to fill in the Americas (e.g., Argentina, Brazil, Canada, Colombia, Costa Rica, Guatemala, Mexico, Panama and Peru, and United States) include technicians, sales representatives, and skilled trades workers, in Asia-Pacific (e.g., Australia, China, Hong Kong, India, Japan, New Zealand, Singapore and Taiwan) include sales representatives, technicians and labourers, in Europe, Middle East and Africa (e.g., Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Romania, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey and the United Kingdom) include skilled trades workers, technicians, and engineers.

One of the most significant developments in people management over the past fifteen years has been the focus on effectively managing the individuals who are most important to the strategic success of companies, both domestic and international. This focus has taken the general labels of "talent management" or more popularly, "global talent management."

REVIEW OF LITERATURE

Talent management is the implementation of integrated strategies or systems designed to increase workplace productivity by developing improved processes for attracting, developing, retaining and utilizing people with the required skills and aptitude to meet current and future business needs. Talent management is the additional management processes and opportunities that are made available to people in the organization who are considered to be 'talent' (Ashridge consulting,2007; Likierman, 2007).

One of the major topics of research in global talent management has been around the notion of talent shortages(Manpower Group Talent Shortage Survey 2011), and the implications of talent shortages on the practice of human resource management in multinational organizations(Collings &Mellahi, 2009; Farndale, Scullion, & Sparrow, 2010; Scullion, et al., 2010; Stahl, et al., 2012; Vaiman, et al., 2012). Ironically the topic of global talent management is prevalent in times of economic prosperity as well as in times of economic uncertainty and economic and financial recession (Tarique& Schuler, 2010). There is considerable evidence that shows even in recent poor economic conditions organizations worldwide are having difficulty managing talent across a wide range of positions (McCauley & Wakefield, 2006).

Talent management can be a planning tool for human resource management, as a planning tool talent management looks very similar to workforce planning, but where HR will experience a real opportunity for contribution to the organization is in the quality of implementation supporting the plan. Talent management is the systematic attraction, identification, development, engagement/ retention and deployment of those individuals who are of particular value to an organization, either in view of their 'high potential' for the future or because they are fulfilling business/operation-critical roles. (McCartney, 2006).

Although the origins of talent management can be traced back to 1865 (Simonton, 2011) and to the fields of arts/entertainment management, sports management literatures, and early education, interest in talent management in the business context came in the 1990s with the ground breaking study entitled "The War for Talent," by McKinsey (Michaels, Handfield-Jones, & Axelrod, 2001). This study, reflecting the high tech boom times of the late 1990s, suggested that demand for talented employees exceeded the available supply, thus leading to the problem of talent shortage. Several HR practitioners and consultants recognized the importance of this trend, and as a result, several excellent studies were done in subsequent years by human resource practitioners and consultants to examine talent shortages (Tarique& Schuler, 2010). As a consequence of this, the phrases "talent acquisition, retention and management" and "attracting, retaining, and developing talent" become popular among human resource management community.

There is a growing effort by most firms in subjecting incentives to individual performance, particularly in developed markets, such as USA, Taiwan, Japan with increasing effort on performance related pay (Booth & Frank, 1999). Providing incentive on employee contribution play a significant role by increases their job satisfaction which in turn lead to firm greater performance (Ahiabor 2013; Ann & Nathan 2012; Atteya, 2012). Singh (2004), strengthened further that, incentive compensation does not only guarantee firm performance, the pay structure also plays a significant role in enhancing performance.

Research shows that organizations increasingly focus on talent management. Moving fromreactive to proactive, companies is working hard to harness talent. According to SHRM's (2006) Talent Management Survey Report, 53% of organizations have specific talent management initiatives in place. Of these companies, 76% consider talent management a top priority. In addition, 85% of HR professionals in these companies work directly with management to implement talent management strategies. Yet different companies may not define talent the same way. The belief in talent and its impact on the bottom line are at the heart of talent management. To be effective, the talent mindset must be embedded throughout the organization, starting with the CEO. Going beyond succession planning for top leadership positions, companies that value talent have a deep appreciation for the contribution of individuals at all levels, now and for the future. In essence, talent is the vehicle to move the organization where it wants to be.

Organizational strategies and talent management strategies will continue to be driven by workforce trends such as an increasingly global and virtual workforce, different generations working together, longer life expectancies and an empowered and autonomous workforce that have forever changed the workplace (Tucker, Kao, & Verna, 2005). Demographic changes have also caused the workforce to continue to diversify--from age, gender and ethnicity to lifestyles, migration patterns and cultural norms (Ward-Johnson, 2007).

To sustain outstanding business results in a global economy, organizations will rethink and reinvent their approaches to talent management (Ashton & Morton, 2005). Effective talentmanagement calls for strong participatory leadership, organizational buy-in, employee engagement and workplace scorecards with talent management metrics (De Long & Davenport, 2003). Companies that master talent management will be well-positioned for long-term growth in workforce performance for years to come.

One of the primary concerns of many organizations today is employee retention. Retention is viewed as a strategic opportunity for many organizations to maintain a competitive workforce (De Long & Davenport, 2003; Schramm, 2006). Attracting and retaining a talented workforce keeps many vice presidents of HR thinking of possibilities and opportunities (Kaliprasad, 2006). Retention is improved when employees are offered compensation and benefits, have a supportive work culture, can develop and advance and balance work and life activities (Messmer, 2006).The best practice organizations treat employee retention as a strategic problem (Farley, 2005). These organizations have well-defined plans that prioritize the skills they wish to retain, and the employment proposition best suited to the purpose (Farley). The resources of the firm, ranging from the executive team, HR, employee communications, PR and line management are teamed together to tackle the issue cooperatively (Patel, 2002).

A recent study shows that 85% of HR executives state that the "single greatest challenge in workforce management is creating or maintaining their companies' ability to compete for talent." Without question, effective talent management provides one of the most critical points of strategic leverage today. Offering enormous business value, talent management is complex and continually evolving. Influenced by external factors such as the economy, global expansion and mergers and acquisitions, critical success factors for effective talentmanagement include alignment with strategic goals, active CEO participation and HR management. Over time, common themes around talent management are emerging, such as the role of line leaders in the development of talent. Overall, the main recurring themes areCEO involvement, culture, management, processes and accountability. There is the competitive perspective that proposes talent management is about accelerated development paths for the highest potential employees, applying the same personal development process to everyone in the organization, but accelerating the process for high potentials. Hence the focus is on developing high potentials or talents more quickly than others.

GENERAL RECOMMENDATIONS

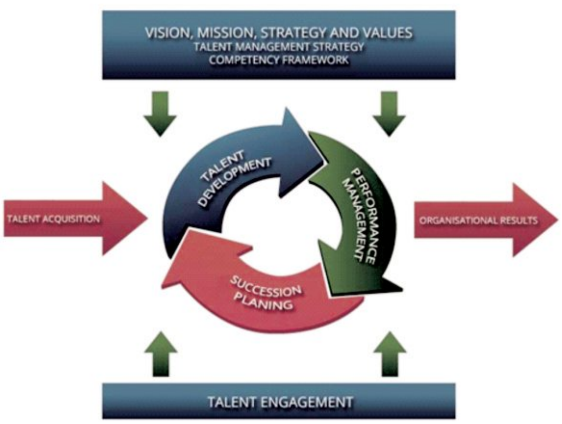
1. Talent management scheme should be used for all categories of staff within the firm that have special talent.
2. Firms should separate between their talent management scheme and the total human recourses management style of the firm
3. Talent management should be result oriented and not another human resources management style without result in focus.
4. The government in the developing nations especially should take the issue of talent management very important in their economics policy from time to time; a pure capitalist economy must be practiced with caution.

FUTURE RESEARCH

It would be useful to examine the difference between the HR personnel's agreement in the usefulness of talent management programs versus their self-perceived inability to correctly measure talent performance. Further research is recommended to examine the usefulness of talent management programs on other important aspects within the programs themselves. Another idea that might be explored would be to compare and contrast the experiences of different organizations that utilize talent management systems against those that do not.Finally, investigating the reasons why management does not have the same conviction with regards to the usefulness of talent management programs that the HR department has would be beneficial. HR personnel are in near unanimity regarding the usefulness of talent management programs, yet a large percentage of companies fail to implement these programs. Understanding the underlying reasons for management's resistance to these concepts might open the door for more widespread adoption of talent management programs.

CONCLUSION

The paper described the concept of global talent management& related issues and presented some reviewed literature.It is suggested that firms should take to cognizance the issue of talent management, the fact that mobility of labour is very high today cross national and international border made talent management issue of import to modern management and government especially in developing nations. It is equally of value that firms should train and retrain their work force to develop needed talent in the staff. The correlation between profitability and talent management cannot be overemphasized.



Schematic of Issues involved in talent management

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Role Of Manufacturing Informatics For changeability In advanced Manufacturing – A Review

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ABSTRACT

Manufacturing informatics is one of the engineering scientific foundations, which mainly concerns effective description, rational disposal and operation of manufacturing information. Advanced manufacturing processes will likely be more energy and resource efficient in the future, as companies strive to integrate sustainable manufacturing techniques into their business practices to reduce costs, to decrease supply-chain risks, and to enhance product appeal to some customers. Advanced manufacturing will increasingly rely on new processes that enable flexibility and faster additive manufacturing techniques capable of assembling products by area or by volume rather than by layering materials as is done today.Manufacturing informatics will contribute to major improvements in product and process design and to more efficient and flexible shop floor operations. The objective of this paper is to understand and explicate the interaction between manufacturing informatics and advanced manufacturing. Through this review paper, the authors have tried to compile some of the available literature in concerned area so that further research may get some direction.

Keywords: Manufacturing Informatics, ICT, smart manufacturing, advanced manufacturing, changeability.

INTRODUCTION

Advanced manufacturing is highly knowledge intensive and ICT has a huge role to play in improving manufacturing intelligence, supporting collaboration, increasing efficiency, and enabling new business models and technologies. Drawing on capability in ICT, mathematical sciences, digital economy and engineering, manufacturing the future supports research relating to the use of new and emerging ICT tools and information methodologies in next-generation manufacturing technologies, processes and systems. Flexibility in manufacturing is associated with rapid responses at the appropriate level to new information and constraints, which may range from changes in consumer preferences or international trade regulations or union requirements to a temporary fault in a crucial piece of machinery on the factory floor. A deeper basic understanding of relations between tolerances and function may be key to developing new assembly and shaping processes to be controlled by ICT.

Advanced manufacturing improves existing or creates entirely new materials, products, and processes via the use of science, engineering, and information technologies; high-precision tools and methods; a high-performance workforce; and innovative business or organizational models.

An advanced manufacturing production system is capable of furnishing a mix of products in small or large volumes, with both the efficiency of mass production and the flexibility of custom manufacturing, to respond rapidly to customer demand and desired quality. Advanced manufacturing results from substantive advancements over the current state of art in the production of materials and products; these advancements include improvements in manufacturing processes and systems, which are often spurred by breakthroughs in basic science and engineering disciplines. These new systems, which are often referred to as "intelligent" or "smart" manufacturing systems, integrate computational predictability and operational efficiency. Advanced manufacturing produces goods that minimize use of resources while maintaining or improving cost and performance.

REVIEW OF LITERATURE

Advanced manufacturing and advanced networked information and computation technology will become synonymous (SMLC 2009; SMLC 2011, Warren, 2011). Many countries have enacted government level plans to invest and accelerate changes in manufacturing (Science and Technology Policy Institute, 2009; European Commission, 2009, EPSRC, 2011). The auto ancillary industry in India has witnessed huge capacity expansion and modernization due to entry of foreign automobile manufacturers in the post liberalization era. In spite of potential benefits, the adoption of advanced IT among SMEs is low in India. There are several technological, economical and organizational factors that enable or inhibit the adoption of advanced IT (Kannabiran G. and Dharmalingam P., 2012).

In recent years, the tasks that can be monitored and controlled with information technology are increasing in number as well as complexity; these increases are enabling high-speed production with increasing accuracy (Isermann 2011; Mekid, Pruschek and Hernandez 2009). The use of computer-enabled technologies improves communications that enable both "smart manufacturing" in the factory and "smart supply-chain design"— sending the right products to the right suppliers (Sanders, 2011). The greater use of information technology in manufacturing links the design stage of an individual component to the larger assembly manufacturing system to the use of manufactured products (Iorio, 2011).

The first major trend in advanced manufacturing is the increased use of information technology. Numerous examples of information technology exist in the domain of manufacturing, including its support of digital-control systems, asset-management software, computer-aided design (CAD), energy information systems, and integrated sensing(SMLC 2011).

Sophisticated automation and robotics have the power to democratize manufacturing industries, starting at the lower end of the value chain, but increasingly moving toward complex decision-making roles. Contract manufacturing firms that specialize in mass production of technology products and product components are using robots to push back against rising wages and to increase competitiveness (Yee and Jim 2011).

There is a growing requirement in recent times for stronger cost control and a demand for higher returns in businesses. Lal(2005) identified and analyzed the factors that Information and communication technologies (ICTs) have been used as a proxy of new technologies. The findings of the study suggested that industry-specific characteristics such as skill- and export-intensiveness have bearings on the type of ICT adoption. The size of operation measured in terms of sales turnover influenced the adoption of new technologies. The results also suggested that there are marginal differences in the labour productivity and profitability of firms that adopted varying degree of ICTs. The use of information and communication technology (ICT) to gain competitive advantage has become a key strategic issue amongst organizations in the fast globalizing environment as ICT plays a strategic role in the management of organization(Apulu, I., Latham, A., 2011).

The use of information technology not only speeds up overall productivity in the factory by increasing communication speed and efficiency, it also maintains quality by better controlling processes (Iorio 2011; Industrial College of the Armed Forces 2010). In recent years, the tasks that can be monitored and controlled with information technology are increasing in number as well as complexity; these increases are enabling high-speed production with increasing accuracy (Isermann 2011; Mekid, Pruschek, and Hernandez 2009).

Key framework conditions that set the stage for advances in manufacturing include government investments, availability of a high-performance workforce, intellectual property (IP) regimes (national patent systems), cultural factors, and regulations (Zhou et al. 2009; Kessler, Mittlestadt, and Russell 2007).

In many industrial scenarios, conventional centralized and hierarchical approaches can be inadequate-especially under conditions of disruption and long-term change – to cope with the high degree of complexity and practical requirements for robustness, generality and reconfigurability in manufacturing plant control as well as in production management, planning and scheduling (Mařík& McFarlane, 2005).

Advanced processes and production technologies are often needed to produce advanced products and vice versa (Wang 2007). For example, "growing" an integrated circuit or a biomedical sensor requires advanced functionality and complexity, which requires new approaches to manufacturing at the micro scale and the nano scale (Parviz 2007). Similarly, simulation tools can be used not only for making production processes more efficient, but also for addressing model life-cycle issues for green manufacturing.

The manufacturing enterprise is intensively deploying a host of hardware/software automation/information technologies in order to face the changing societal environment pulled by the increasing customization of both goods and services as desired by customers. "Only a form of technical intelligence that goes beyond simple data through information to knowledge and is embedded into manufacturing systems components and within the products themselves will play a prominent role as the pivotal technology that makes it possible to meet agility/reconfigurability in manufacturing over flexibility and reactivity" (Morel et al., 2005).

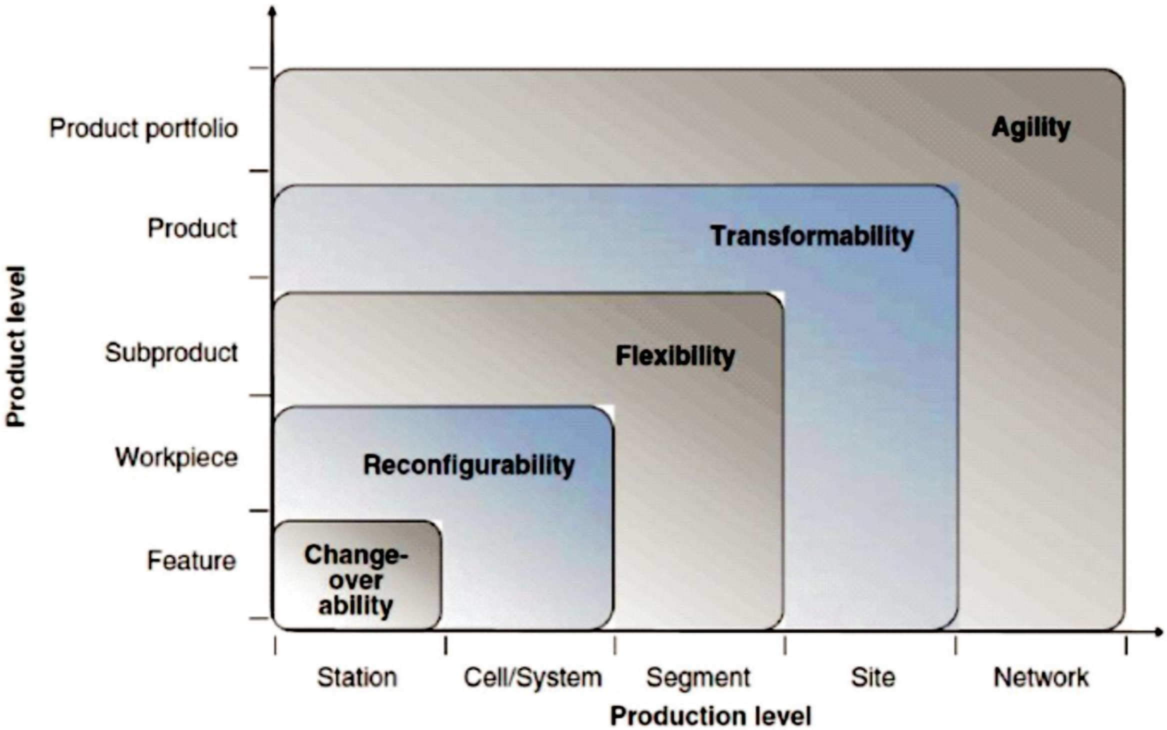
Industrial applications of agent-based technologies can be found mainly at three different levels (Mařík& McFarlane, 2005):

i. Real-time manufacturing control
ii. Production management level (encompassing problems such as planning, scheduling, orders pre-processing, etc.)
iii. Virtual enterprises (VE) that will integrate manufacturing, sales networks, suppliers, distribution channels.

Rapid changes in process technology demand production systems that are themselves easily upgradeable, and into which new technologies and new functions can be readily integrated (Mehrabi, Ulsoy&Koren, 2000). This situation has created the need for novel manufacturing control systems that are able to manage production change and disturbances, both effectively and efficiently (Van Brussel, Wyns, et al., 1998), and has lead to the creation of concepts such as "flexible manufacturing" (Draper, 1984), "holonic manufacturing" (Van Brussel, 1994), "agile manufacturing" (Goldman, Nagel, & Preiss, 1995), and reconfigurable manufacturing" (Koren&Ulsoy, 1997; Mehrabi et al., 2000). All these approaches aim to incorporate increased levels of flexibility, reconfigurability, and intelligence into manufacturing systems in order to meet highly dynamically marked demands. There is a recognized interest and a base of literature on flexible and adaptive enterprise wide optimization and decision making (Stephanopoulos and Reklaitis, 2011; Wassick, 2009; Engell, 2007, Christofides, et. al. 2007; Grossmann, 2005; Ydstie, 2004).

Manufacturing informatics is one of the engineering scientific foundations, which mainly concerns effective description, rational disposal and operation of manufacturing information. In digital manufacturing, information is not only the dominant factor but also the most active actuation factor. Enhancing the information processing ability of the manufacturing system has become one of the key technologies of digital manufacturing (Tapscott, 1996; Balakrishnan, et al. 1999; Seino T, Yoshio I, Kinoshita M， et al, 2001; Zhang B P., 2003).

The move toward rapid changeability of manufacturing to meet customer needs and respond to external *impediments*(Wiendahl et al. 2007). Here, “changeability” is used as an overarching term that encompasses the terms that typically describe existing paradigms of changing production capacity. Among these terms are “flexibility” (Buzacott and Yao 1986; Sethi and Sethi 1990), “reconfigurability” (Mehrabi, Ulsoy, and Koren 2000), “transformability” (Jovane, Koren, and Boer 2003; Nyhuis, Heinen, and Brieke 2007), and “agility” (Gould 1997). The hierarchy of these terms, shown in Figure 3 and defined in the sidebar “Definition: Changeability of Manufacturing,” was proposed by Wiendahl et al. (2007) to distinguish among the changes that take place at different factory levels.



Schematic of changeability at various product and factory production levels.

Changeability of Manufacturing

Changeover ability designates the operative ability of a single machine or workstation to perform particular operations on a known work piece or subassembly at any desired moment with minimal effort and delay.

Reconfigurability describes the operative ability of a manufacturing or assembly system to switch with minimal effort and delay to a particular family of work pieces or subassemblies through the addition or removal of functional elements.

Flexibility refers to the tactical ability of an entire production and logistics area to switch with reasonably little time and effort to new – although similar – families of components by changing manufacturing processes, material flows and logistical functions.

Transformability indicates the tactical ability of an entire factory structure to switch to another product family. This calls for structural interventions in the production and logistics systems, in the structure and facilities of the buildings, in the organization structure and process, and in the area of personnel.

Agility means the strategic ability of an entire company to open up new markets, to develop the requisite products and services, and to build up necessary manufacturing capacity.

FUTURE RESEARCH

The future research of manufacturing informatics includes the reliable acquisition, representation, transfer, storage and use of manufacturing information, such as geometry quantities, physical quantities, and manufacturing skill. It also includes digital representation of non-signifying manufacturing knowledge, such as fuzzy knowledge, sense knowledge etc. Advanced manufacturing is driven by advances in science and technology that occur in university or industrial laboratories, on factory and shop floors, or at business schools. Both incremental advances and breakthrough advances in traditional and emerging sectors are important for the future of manufacturing.

CONCLUSION

Advanced manufacturing is the manufacturing that builds on and encompasses the use of science, engineering, and information technologies, along with high-precision tools and methods integrated with a high-performance workforce and innovative business or organizational models, to improve existing or create entirely new materials, products, and processes. The advanced manufacturing systems are challenged to incorporate increasing capabilities of reconfigurability and intelligence in order to be able to succeed in a very competitive and global market, on which product variety and complexity increase, product lifecycle shrinks, quality requirements increase, and profit margins decrease. We can identify that considerable advances have been made in the last years in communication and information technologies. Manufacturing Informatics influences all manufacturing processes; manufacturing informatics is the enabler for the factories of the future. These advances are allowing the deployment of distributed and real-time embedded computing architectures that can become key enablers to the development of future factories.

The paper described the concept of manufacturing informatics and presented some reviewed literature that take benefit of some of these new technological conditions for advanced manufacturing. As technology evolves, the immediate challenge is how to allow designers to deploy this technology in the field. The research must continue to cover new aspects that are being leveraged by software and hardware technology advances.

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Analysis of Failuresdue To Corrosion Fatigue In Stainless Steel

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ABSTRACT

Corrosion fatigue is an important but complex mode of failure for high-performance structural metals operating in deleterious environments. This view is based on the likelihood of cyclically varying loads and chemical environments in service, the need for predictable long-life component performance and life extension, the universal susceptibility of pure metals and alloys to Corrosion fatigue damage, and the time-dependent multivariable character of corrosion fatigue. For example, stress corrosion cracking immune alloys are susceptible to corrosion fatigue. Corrosion fatigue has affected nuclear power systems, steam and gas turbines, aircraft, marine structures, pipelines, and bridges; corrosion fatigue issues are central to the behavior of many aging systems.

Keywords: corrosion fatigue, stress corrosion cracking, steam turbine, gas turbine&pipeline.

INTRODUCTION

Corrosion fatigue is defined as the sequential stages ofmetal damage that evolve with accumulated load cycling, ina aggressive environment compared to inert or benign surroundings, and resulting from the interaction of irreversible cyclic plastic deformation with localized chemical or electrochemical reactions. Environment-enhanced fatigue is a modern term; however, corrosion fatigue is traditionally used when emphasizing electrochemical environments. Corrosion fatigue is the mechanical degradation of a material under the joint action of corrosion and cyclic loading.

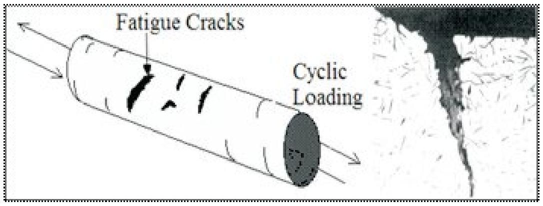

Fig. 1 Corrosion fatigue.

Nearly all engineering structures experience some form of alternating stress, and are exposed to harmful environments during their service life.The environment plays a significant role in the fatigue of high-strength structural materials like steel, aluminum alloys and titanium alloys.

1.1Stages of Corrosion Fatigue

Corrosion Fatiguedamage accumulates with increasing load cycle count (N) and in four stages:stages:

(a) cyclic plastic deformation,

(b) Micro crack Initiation

(c) Small crack growth to linkup andCoalescence, and

(d) Macro crack propagation.

1.2 Mechanisms

It is important to understand damage mechanisms in order to correctly interpret and extrapolate laboratory corrosion fatigue data. The mechanism for corrosion fatigue may involve hydrogen embrittlement; film ruptures dissolution and repassivation; enhanced localized plasticity; interactions of dislocations with surface dissolution, films or adsorbed atoms; and complex combinations of these processes. The contribution of each mechanism is controversial and depends on metallurgical and environment (thermal and chemical) variables. While providing significant insight, existing mechanism-based models are generally not capable of accurately predicting corrosion fatigue behavior beyond the range of laboratory data. Hydrogen environment embrittlement (HEE) is an important mechanism for corrosion fatigue cracks propagation in ferritic and martensitic steels, as well as aluminum, titanium, and nickel-based alloys exposed to gases and electrolytes within order of 100ºC of ambient temperature. This hypothesis is supported by extensive but circumstantial evidence, and is most readily accepted for high-strength alloysin strong hydrogen-producing environments. In HEE atomic hydrogen chemically adsorbs on strained-clean initiation sitesor crack surfaces as the result of electrochemical reduction ofhydrogen ions or water. (Adsorbed hydrogen is also producedby the reactions of H_2, H_2O, C_2H_2, or H_2S molecules withmetal surfaces.) Hydrogen production follows mass transport within the occluded crack (pit or crevice) solution, crack tip dissolution, and hydrolysis of cations for local acidification; and precedes hydrogen diffusion by lattice, interface, or dislocationprocesses in the initiation-volume or crack tip plastic zone. Fatigue damage is promoted by hydrogen-affected latticebond decohesion, grain or dislocation cell boundarydecohesion, enhanced localized plasticity, or metal hydride formation (in materials such as HCP titanium-based alloys).Hydrogen-enhanced corrosion fatigue cracking is eitherintergranular ortrans granular, with the latter involving dislocation substructure, low index crystallographic planes, or interfaces.

A second mechanism for corrosion fatigue is based on damage by passive film rupture and transient anodic dissolution at a surface initiation site or crack tip. This model was developed with several necessary empirical elements to predict corrosion fatigue propagation in carbon and stainless steels in high-temperature pure water, and is sometimes applied to titaniumand aluminum alloys in aqueous chloride solutions. Localizedplastic straining, described by continuum mechanics or dislocation plasticity, ruptures the protective film. Crack advance occurs by transient anodic dissolution of metal at the breached film, and at a decreasing rate while the surface repassivates pending repetition of this sequence. The increment of corrosion fatigue growth depends faradaically on the anodic charge (transient current-time integral) passed per load cycle. Charge is governed by clean-repassivating surface reaction kinetics for the corrosion fatigue sensitive alloy microstructure in occluded crack solution, and by the time between ruptures given by local strain rate and film ductility. As with the hydrogen mechanism, film rupture modeling is complex and controversial; confirming data exist, but other research shows the model to be untenable for specific alloy/ environment systems.

Several corrosion fatigue mechanisms were proposed based on interactions between dislocations and environment-based processesat initiation sites or crack tip surfaces. For example, in-sit transmission electron microscopy and dislocation modelingshow that adsorbed hydrogen localizes plastic deformation in several pure metals and alloys. Second, reaction productfilms are not capable of extensive plastic deformationrelative to the underlying metal, and may cause corrosion fatiguedamage by one or more processes, viz: (1) interference withthe reversibility of slip, (2) localization of persistent slipbands, (3) reduction of near-surface plasticity leading to reduced or enhanced corrosion fatigue depending on the cracking mechanism,(4) localization of near-surface dislocation structure and voids, or (5) film-induced cleavage. Adsorbedcations could similarly affect fatigue. Finally, anodic dissolution may eliminate near-surface work hardening and hence stimulate fatigue damage. These mechanisms have not been developed and tested quantitatively.

LITERATURE REVIEW

Ryuichiro Ebara et.a; (2010),investigated that in the most of the corrosion fatigue failures of components for machines and structures that corrosion fatigue crack initiate from corrosion pit. Corrosion pits are most frequently observed at crack initiation area, if the crack initiation area kept soundly after failure. Several micro-cracks in association with corrosion pits are observed at the surface near corrosion fatigue crack initiation area. Intergranular fracture surfaces are most frequently observed in the corrosion fatigue crack propagation area. These phenomena are the key characteristics to judge corrosion fatigue failure of steam turbine blades in failure analysis.

From his experimental works it can be concludedthat the role of corrosion pit at corrosion fatigue crack initiation is very important for most of the stainlesssteels. Further studies are expected for mechanism of corrosion pit initiation and quantitative evaluation of corrosion fatigue crack initiation life.

S. Beretta et.a; (2011), investigated that during the railway axles' service life, fatigue is a major process resulting in structural degradation and failure. Moreover, experience with existing axles has indicated that also the corrosion is a key problem that must be addressed if maintenance costs are to be managed within acceptable limits, and if thestructural reliability of the axles is to be maintained. Even when the axles are operated to the operating loads, failure can happen due to the synergetic effect of both corrosion and cyclic loads.The authors clearly indicated that the presence of a mild aggressive environment, as the artificial rainwater, both intermittently or continuously, enhanced fatigue crack growth significantly and decrease a railway axles' lifetime drastically. The authors also analyze the pit-to-crack transition and the crack propagation mechanism in order to describe the corrosion-fatigue crack.

From his works it can be concluded that Crack growth rate measurements, enables us to set a modified version of a model proposed by Murtaza and Akid for the fatigue corrosion life prediction of railway axles. The corrosion–fatigue crack growth model enables us, also, to obtain a fairly precise prediction of the S–N diagram of A1T steel under corrosion–fatigue sustained by the free corrosion of the material.

E. Rezig et.a; (2010),investigated that Passive metals such as stainless steels suffer from localized corrosion when in contact with corrosive environments like chloride solutions. When coupled with fatigue, localized corrosion damage acts as a stress raiser and moves the endurance of the metal from crack initiation domination to a life consumed by crack propagation. The difference between endurance in fatigue crack initiation and in fatigue crack propagation becomes more extreme as material strength increases. Fatigue cracks in stainless steels have been shown to initiate at corrosion pits and in 12% Cr high strength martensitic alloys the initiation time represents most of the fatigue life. but it is most widely thought to occur where there is insufficient access of oxygen to the metal surface to maintain the protective passive film. This may arise within ajoint or beneath a seal or surface deposit and metal loss occurs preferentially in the occluded region.

From his works it can be concluded as follows

1. 15-5 PH stainless steel is susceptible to crevice corrosion attack, readily creating surface corrosion defectswhich reduced the fatigue strength markedly from that of pristine samples.

2. The calculated Kt values of the defects ranged from 1.3- 1.78 depending on their depth and aspect ratio. This is significantly less than the experimentally derived Kt value of a factor of 3, obtained by comparison with pristine sample fatigue strengths. Fatigue lives could be approximately related to the value of calculated defect Kt for lives to crack lengths of 0.2 and 0.8 mm.

3. Measurements of the crack development from the corrosion defects showed significant variation in the early crack growth behavior. Comparison with calculated fatigue crack growth crack length cycles curves showed that some defects had significant initiation stages whereas others did not, and this was the source of the variability.

M. Knop et.a;(2010)investigated that Corrosion fatigue of steels in aqueous environments is of particular interest in regard to predicting the lives of submarines and offshore structures, where the main sources of cyclic stress are the diving cycles and wave action, respectively. Important variables affecting corrosion-fatigue crack growth rates are the stress-intensity-factor range (K), R-ratio, electrochemical potential, environment, and cycle frequency (or more specifically the rise-time of the loading cycle, since crack growth generally only occurs during loading. At intermediate K levels, the

strength and microstructure of steels (with strengths in the range of 350–800 MPa) appears to have little influence on fatigue crack growth rates (da/dN) in air and aqueous environments.

And from his works we can conclude that corrosion-fatigue crack growth and the effects of cycle frequency are based on experimental observations for cathodically protected E12018-M2 weld metal and comparisons with literature data.

There was little effect of the yield strength (720–900 MPa) on fatigue crack growth rates (in air and aqueous sodium chloride) as found for other steels for yield strengths between 350 MPa and 900 MPa.

The effects of cycle frequency (rise-time) on corrosion-fatigue crack growth rates at intermediate ΔK for the weldmetal were similar to those observed for other steels with strengths less than 900 MPa.

Corrosion-fatigue crack growth rates at low cycle frequencies (long rise-times) were about an order of magnitudehigher than those at high cycle frequencies (where crack growth rates trended towards those for steels in a laboratory air environment).

Sigmoidal curves could be fitted to the da/dN–rise-time data, with the curves shifted upwards (to higher da/devalues) and to the right (longer rise-times) with increasing ΔK, such that (i) the gradient at the inflection points of the sigmoidal curves is the same,

and (ii) the inflection points all fall on a common transition line.

A new model for predicting the effects of rise-time on corrosion-fatigue crack growth rates has been formulated. This model is based on purely synergistic interactions between the environment and deformation during loading, with the degree of synergism depending on the crack velocity (da/dt) (and surface-reaction kinetics involving the generation of hydrogen).

The purely synergistic model is consistent with fractographic observations showing that predominatelytrans granular cleavage-like cracking was produced for all the rise-times and □K values used.

Previously proposed models, such as the 'superposition' model, did not properly account for the data.

Experimental Analysis and comparison (Extent of loss)

S.No	Material	Component	Medium/ Cause	Observation	Findings
1	Stainless steel	Steam turbine blades	For 12%Cr stainless steel tested at60Hz in 3-3x10-4 % NaCl aqueous solution. The decrease of fatigue strength due to 3% NaCl at $2x10^7$ cyclesand $3x10^{-2}$ %NaCl aqueous solution at 10^9 cycles is approximately 75%.	Corrosion fatigue strength of the turbine bladedecrease even in a mild steam environment if very small quantity of Cl- concentrate at the irregular area of thesteam turbine blade.Corrosion fatigue crack initiated from corrosion pit and propagated with intergranular fracture surfaces. The initiation and growth of corrosion pit, crack initiation from corrosion pit and the crack propagation appearance can be vividly identified	In this stainless steel frequency effect was not almost observed in 3%NaCl aqueous solution. The reduction of corrosion fatigue strength for welded jointwithout reinforcement tested at 20Hz was 33% at 10^7 cycles. For both welded joint without reinforcement and weldedwith reinforcement frequency effect was very small. Corrosion fatigue crack initiated at corrosion pit for base metal and welded joint.
2	A1T mild steel	Railway axles	Synergetic effect of both corrosion and cyclic loads&presence of a mild aggressive environment, as the artificial rainwater both continuously enhanced fatigue crack growth significantly and decrease a railway axles' lifetime.	for prediction of the corrosion fatigue life of railway axles, crack growth rate measurements were performed during crack propagations tests under correlate fatigue and corrosion onA1T small scale specimens.	composition of the artificial rainwater is Ammonium sulfate 46.2 mg/l;Sodium sulfate 31.95 mg/l; Sodium nitrate 21.25 mg/l; Sodium chloride 84.85 mg/l.To predict the corrosion fatigue lifetime of the A1T railway axles the Hobson-Brown model, modified in the work of Murtaza and Akid is proposed.
3	High strength stainless steel			Fatigue cracks in stainless steels have been shown to initiate at corrosion pits and in 12% Cr high strength	• 15-5 PH stainless steel is susceptible to crevice corrosion attack. • The calculated Kt values of the defects ranged from 1.3- 1.78 depending

				were shown to be attacked preferentially within the pits, forming stress raising notches that then became	crack development from the corrosion defects showed significant variation in theearly crack growth behavior.	
				crack initiation sites. As the crack propagated, it transformed from		
				crack initiation sites. As the crack propagated, it transformed from the initial intergranular form to a transgranular mode.		
4	High-strength steels	Submarine hulls & offshore structure	Stress intensity factor range, electrochemical potential, environment and cyclic frequency.	At low Stress intensity factor range values (approaching threshold values), crack growth rates in aqueous environments can be higher, lower, or about the same as those in air, depending on the extent of crack-closure (which is dependent on variables such as R ratio, environment, and potential, including enhanced crack closure due to	There was little effect of the yield strength on fatigue crack growth rates. Corrosion-fatigue crack growth rates at low cycle frequencies were about an order of magnitudehigher than those at high cycle frequencies.	4

CONCLUSION

From all the above discussion it is observed that main reasons for corrosion fatigue are follows:

Stress concentrations.
Stress fluctuations.
Electrochemical potential.
Stress intensity factor range.
Aqueous medium (mainly presence of chlorine).
Cyclic frequency.
Aggressive environment.

The solo or combined effects of above mentioned factor cause corrosion fatigue. This starts as corrosion pits, micro cracks propagate with intergranular surface fracture which is accelerated due to mainly cyclic frequency and stress intensity factor range.

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Analysis of ISO 9000 and Business Performance Relationship through Structural Equation Modeling in Indian Manufacturing Industry

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ABSTRACT

ISO 9000 is a management system that outlines the minimum requirements for organizations to follow to ensure that a company provides a consistent quality product or service. *Exploratory Factor Analysis (EFA) and* ***Confirmatory Factor Analysis (CFA) approach using Structural Equation Modeling (SEM) in AMOS 20.0 is used to analyze the significant ISO 9000 variables in Indian manufacturing industries for business performance improvements. The required data have been collected from 96 Indian Manufacturing industries through ISO 9000 Questionnaire. It has been found****that ISO 9000 significant issues like Customer Orientation, Process Control and Continuous Improvement can be helpful for having overall business performances* in terms of Employee Satisfaction, Technological and Operational Benefits, Business Benefits, Production related Benefits and Customer related benefits *in Indian Manufacturing Industries*.

INTRODUCTION

ISO 9000 has been around for nearly 30 years in one or other of its revisions and for almost all the organizations on the path of quality improvement, implementation of ISO 9000 Quality Management System (QMS) has become the first step (Coleman and Douglas, 2003). The approach of ISO 9000 QMS is based on the belief that desired result is achieved more efficiently when activities occurring are treated as a process (Bhuiyan and Alam, 2004). ISO 9000 standards help to ensure that organizations follow specific documented procedures in the manufacturing of products. These procedures are generated in accordance with customer requirements. The developing nations have been striving to implement ISO 9000 in increasing numbers to access international markets (Magd, 2006). Castka and Balzarova(2008)have stated that ISO 9000 provide a structural and infrastructural platform for organizations to develop and adopt corporate social responsibility. Jain and Ahuja

(2012c) have found that despite government support pace of Indian companies moving for ISO 9000 certification is slow and there is an immense need to clarify the motivators, barriers, benefits and implementation procedures in the Indian perspective so as to enable them competitive in global market. The top management's contributions for successful ISO 9000 implementation have been found to be highly critical and know-how to use ISO 9000 initiatives in the different situations to develop employee involvement in every step of the manufacturing process (Jain and Ahuja, 2013b).To be successful in the highly competitive environment and to achieve world-class manufacturing, organizations must possess effective manufacturing strategies. ISO 9000 is one step in building better quality system to achieve business excellence(Devos et al., 1996). There is a positive relationship between ISO 9000 quality certification and quality and operative results (Marın and Ruiz-Olalla, 2011). The ISO 9000 issues like Customer Orientation and Continuous Improvement are more influencing in manufacturing performance enhancement (Jain and Ahuja, 2012a).Adoption of ISO 9000 is must for Indian manufacturing industries.Organizations depend on their customers and therefore meet customer requirements and strive to exceed customer expectations. According to Ferreira et al., (2010) Customer satisfaction and retention are key issues for organizations in today's competitive market place and making its proper evaluation a main concern for companies.ISO 9000 quality systems have been developed to provide necessary conceptual and structural input for satisfying customer needs by ensuring consistent and desired product quality (Sarkar, 1998). Effectiveness of a system can be judged by higher customer satisfaction through increased employee involvement and product quality improvement. Pan (2003)and Mo and Chan (1997) have found that the major driving forces for ISO implementation are customer needs and expectations.Identifying, understanding and managing interconnected processes as a system contribute to the organization's effectiveness and competence in achieving its objectives. ISO 9000 facilitate organizations to develop stable internal processes (Singh et al., 2011). Jain and Ahuja (2013a) have also found with fuzzy methodology that if the critical issues of ISO 9000 like Continuous Improvement, Customer Orientation and Process Control are implemented in Indian Manufacturing Industry then they can improve the business performance.Yahya and Goh (2001) and Withers and Ebrahimpour (2001) have found that process control is one of most difficult element to implement. Everyone in the organization should be continually seeking ways to reduce variation, continually inquiring methods and looking for better ways of doing things, persistently questioning targets and looking for new targets that enhance the organization's capability and performance. Lee et al. (1999) and Karapetrovic (1999)have agreed that the focus of ISO 9000 standards is changed from simple compliance to continuous quality improvement. Continual improvement of the organization's overall performance should be a permanent objective of the organization. To survive and develop activities in an increasingly competitive environment enterprises have to continuously improve their performance (Fassoula and Rogerson, 2003). Using the AHP approach, Jain and Ahuja, (2012b) has been able to identify and pursue important functions for achieving the overall objectives of business performance in the manufacturing organizations. Management commitment and Continuous improvement in manufacturing system has proved to be critical for bringing cultural change and for successful ISO 9000 implementation into manufacturing system.

STRUCTURAL EQUATION MODELING

SEM is a technique used widely for applied statistical analyses by researchers and scientists Pugesek et al., (2003). There is a journal available solely for SEM, titled "Structure Equation Modeling: A Multidisciplinary Journal". A number of authors have used SEM in their research. Punniyamoorty et al. (2012) have applied SEM in supplier selection. They developed a model forsupplier selection including tangibleand intangible attributes. Their model proposed that management and organization, quality, technical capability, production facilities and capacities, financial position,delivery, service, relationship, safety and environment concern and cost have aninfluencing power on the supplier selection.With the help of SEM,Lam et al. (2012) have confirmed that Total Quality Management (TQM) has positive and significant relationship with market orientation and service quality. Koo et al., (1998) applied path diagram methodology to present the employee attitude importance towards ISO certification. Psomaset al., (2011) used SEM technique to build a model on quality improvement of ISO 9001 certified organizations. Chileshe and Haupt(2005) applied SEM technique in construction project management and proposed a model to enhance competitive success. Gera (2011) presented amodel with SEM on e-service quality in India. Chinda and Mohamed (2008) used SEM technique to describe the safety culture enablers in construction industry. Amzat and Idris (2012) discussed the effect of management and decision making style on job satisfaction with the help of SEM. Goode et al., (1996) performed structural equation modelling for customer satisfaction in theuse of services. Prajogo et al.,

(2012) presented a Structural Equation Model of different aspects of ISO 9000 implementation and examined the relationship between supply chain activities and operational performance. Wu and Liu (2010) established a structural model for ISO certified manufacturing industry and performance measurement indicators. Fotopoulos and Psomas (2010) described a structural equation model to establish relationship between TQM and business performance improvement. Sagheer et al., (2009) applied SEM technique to analyze the standards compliance in a developing country's food industry. Iriondoaet al., (2003) stated that SEM is a powerful tool to analyze casual relation between variables.

SEM covers diverse statistical techniques such as path analysis, confirmatory factor analysis, causal modeling with latent variables, and even analysis of variance and multiple linear regressions.Shah and Goldstein (2006) have stated that SEM is a technique that is able to specify, estimate and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables. SEM is a general term that has been used to describe a large number of statistical models used to evaluate the validity of substantive theories with empirical data. It examines the structure of interrelationships through a number of equations and these equations depict the relationships among the dependent and independent variables, called the constructs, which are the unobserved or latent variables represented by multiple indicators. Observed variables are also called measuredindicators, and researchers usually use a square or rectangle to assign them graphically.

The structural equation model consists of two components: the inner model, which shows the linear relationships among the exogenous and endogenous latent variables, and the outer model, which relates each latent variable to its corresponding manifest indicators (Hair 2005).SEM has been described as a combination of EFA and multiple regressions (Ullman, 2001). EFA is designed for the situation where links between the observed and latent variables are unknown or uncertain. In contrast to EFA, CFA is appropriately used when the researcher has some knowledge of the underlying latent variable structure. Based on theoretical knowledge, empirical research, or both, the relations are hypothesized between the observed measures and the underlying factors and then this hypothesized structure is tested statistically. It takes a confirmatory rather than an exploratory approach for the data analysis. The present study has been done using the EFA, CFA approach using SEM.

The core of the SEM analysis should be an examination of the coefficients of hypothesized relationships and should indicate whether the hypothesized model is a good fit to the observed data. In general, fit means consistency of two or more factors and it is believed that a good fit among relevant factors will lead to better performance Schumackerand Lomax, (2004);Barrett, (2007). In reference to model fit, researchers use numerous goodness-of-fit indicators to assess a model. Some common fit indexes like Normed Fit Index (NFI), Non-Normed Fit Index (NNFI, also known as TLI), and Incremental Fit Index (IFI), Comparative Fit Index (CFI), and root mean square error of approximation have compiled by Schreiber et al., (2006).

RESEARCH METHODOLOGY

The present study uses the EFA and the CFA approach using SEMin AMOS 20.0 software to employ the inter-relationship among the variables in the study. The required data has been collected through "ISO 9000 Questionnaire" from various Indian Manufacturing industries.

The study has been carried out in the medium and large scale manufacturing organizations in the country that have successfully implemented ISO 9000 or are in the process of implementing ISO 9000, to study the ISO 9000 implementation issues and achievements realized as a result of strategic ISO 9000 implementation programs. In this study, a sample population of 400 manufacturing organizations have been randomly selected and posted as well as emailed the 'ISO 9000 Questionnaire'. A reasonably large number of manufacturing organizations (96 organizations) have responded, after repeated follow-up and requests giving 24% of response rate, which is fairly good (Yahya and Goh, 2001;Amar and Zain, 2002;Coleman and Douglas, 2003;Magd and Curry, 2003; Quazi and Jacobs 2004; Bhuiyan and Alam, 2005; Lee, 2005; Park et al., 2007; Feng et al., 2008; Khanna et al., 2010). The questionnaires which were incomplete has not been considered among respondents. The approach has been directed towards evaluation of contribution made by strategic ISO 9000 initiatives in Indian Industry for enhanced manufacturing performance. In order to ascertain the contributions of ISO 9000 initiatives towards realization of manufacturing performance improvements, a detailed 'ISO 9000 Questionnaire' has been designed for accessing the capabilities of the Indian manufacturing industry. The questionnaire survey technique has been deployed in the present study for seeking information on the status of ISO 9000 implementation issues and the realization of various manufacturing performance enhancements. For effectively conducting the survey, the ISO 9000 Questionnaire has been designed through extensive literature review and validated through peer review from academicians,consultants, ISO 9000 practitioners and MR from the industry. To ensure the significance and the effectiveness of the questions to the manufacturing industry, the questionnaire has been pre-tested on a representative sample of industry. The suggestions from the peers, consultants, ISO 9000 councilors, senior executives from the industries and academicians have been incorporated to make the questionnaire relevant to the purpose and bring out key outcomes as a result of strategic ISO 9000 implementation. The ISO 9000 questionnaire serves the purpose of enlightening the exploits of Indian entrepreneurs with ISO 9000 practices and highlights the contributions of ISO 9000 in realizing the overall organization's goals and objectives.Further segregation of these questionnaires has also been done, which has been discussed below in Table 1.

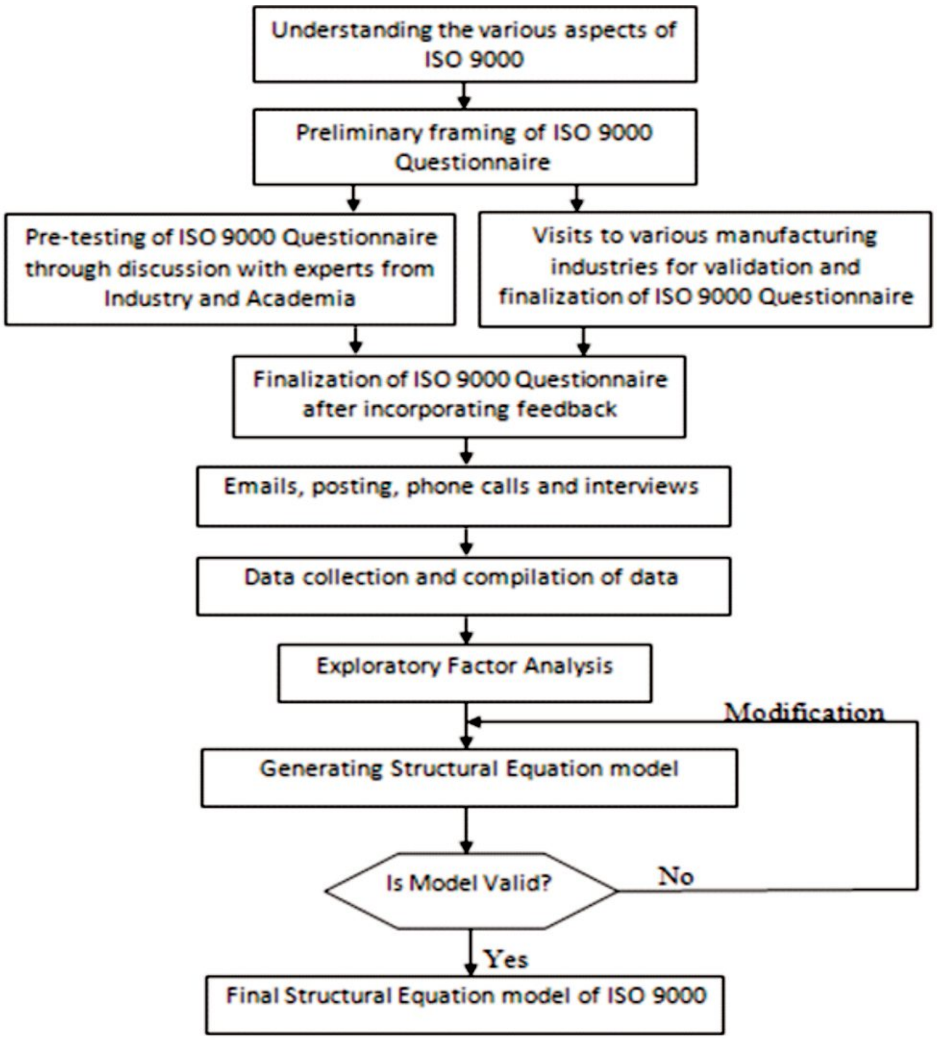

Figure 1 Methodology of study

Table 1Profile of organizations responded

Category	Number of respondents	Percentage of respondents
Industry type		
Small scale	45	46.9
Large scale	51	53.1
Turnover in rupees		
Less than 25 crore	14	14.6
25 - 75 crore	15	15.6
75 - 200 crore	20	20.8
More than 200 crore	47	49.0
Number of employees		
less than 250	29	30.2
251 - 750	22	22.9
751 - 1500	18	18.8
More than 1500	27	28.1
Experience with ISO 9000		
implementation		
0 - 5 years	28	29.2
6 - 10 years	31	32.3
More than 10 years	37	38.5

STRUCTURAL EQUATION MODELING OF ISO 9000 MODEL.

An extensive literature review was carried out to identify and select variables for ISO 9000 model. There are a number of variables that can represent these models, but the variables which were critical according to peers and ISO9000 practitioners were carefully selected so as they should bear on the effectivenessof ISO 9000. In the present study, effort has been made to validate the results put forth by Jain and Ahuja (2013a) with the tool of SEM. So the input variables selected are take from Jain and Ahuja (2013a).

Continuous Improvement
Process Control
Customer Orientation

Further, in the present study, the performance parameters or the dependent variables i.e. 'Business performance' (BP)has been used, which ismainly used for describing variousbusiness output performances of the manufacturing organization like business benefits, technological and operational benefits, production benefits, customer related benefits and employee related benefits.

The theoretical framework of the ISO 9000 model is shown in Figure 2. The key data required for themodel has been obtained using self-administered questionnaires. The questionnaire used, was divided into2parts. The first part was dedicated for gathering general information about the respondents and their respective organizations such as position, name of the organization, years of ISO 9000 implementation, job title etc. It is also very useful in identifying discrepancies or errors in responses obtained. Further, the 2nd part of the questionnaire was dedicated for measuring the effectiveness of ISO QMS in the respective organizations. Each statement in the questionnaire was designed to extract the respondents opinion on the above parts in the context of business performance measurement using a 4-point likert scale.

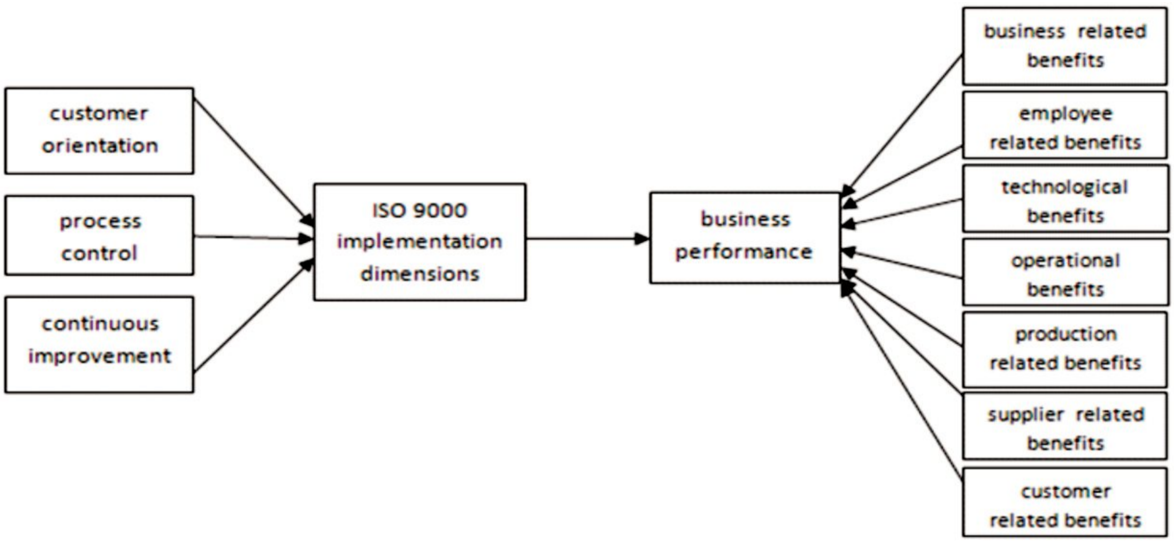

Figure2 Theoretical SEM-ISO 9000 model

Preliminary Analyses

- On the data collectedvarious data examination techniques have been applied like factor analysis, test for the reliability of the data.Exploratory factor analysis has been performed using the SPSS software for independent variables. Principle Component Extraction has been performed with varimax rotation with Kaiser Normalization and coefficients values less than 0.4 have been suppressed (Table 2). The variables which show factor loadings in other component have not been considered for CFA. To measure the determination of the data i.e. whether it is suitable for confirmatory factor analysis, the strength of the inter-correlations among the items was checked by Bartlett's test of sphericity and using Exploratory factor analysis (EFA) the adequacy of the sample size has been checked by Kaiser Meyer Olkin (KMO) test (Pallant, 2005). Barletts test of spericity should be significant at $p < 0.05$ for CFA to be considered appropriate, and KMO index should range from 0 to1, with 0.5 as minimum value for CFA (Tabachnick and Fidell, 2007). The KMO and Bartlett's Test for the independent and dependent variable are shown in the Table 3 and the values of the test recommended that the data is suitable to continue with a confirmatory factor analysis procedure. test for reliability of the data is done using Cronbach's Alpha which is a reliability measure of the data for testing internal consistency. Table 3 shows value of Cronbach'sAlpha for all variables which are ranging from 0.852 to 0.946.

Table 2 Rotated Component Matrix for independent variables.

		Component	
	1	2	3
E2	.831		
E4	.772		
E1	.772		
E3	.772		
E10	.746		
E5	.711		
E6	.686		
E12	.668		
E11	.580		
E14	.552	.401	
E13	.539		
E7	.436		
K3		.819	
K1		.801	
K4		.771	
K6		.737	
K5		.735	
K7		.702	
K8		.694	.412
K12		.685	
K11		.678	
K9		.616	
D2			.791
D4			.766
D3			.762
D1			.693
D7			.561
D8			.488
D5			.470

Table 3 KMO and Bartlett's Test for the independent and dependent variables

Variable	Kaiser-Meyer-Olkin Measure	Bartlett's Test of Sphericity		Cronbach's Alpha (α)
		Chi-Square value	P-value	
Customer orientation (CO)	0.827	263.753	0.000	0.852
Process Control (PC)	0.886	652.568	0.000	0.919
Continuous improvement (CI)	0.913	654.639	0.000	0.930
ISO 9000Business performance (BP)	0.889	957.430	0.000	0.946

SEM- ISO 9000 Model and Result Analysis

Figure3 illustrates the SEM- ISO 9000 model which is constructed *using AMOS 20.0* to build up the relationship between each variable in the study. The un-standardized SEM- ISO 9000 model presents the regression coefficients linking the independent construct in the study. AMOS output for un-standardized model provides the covariance between independent variables, the ordinary regression coefficient, the error measurement of each independent variables and the significance level (p-value) for each relationship.

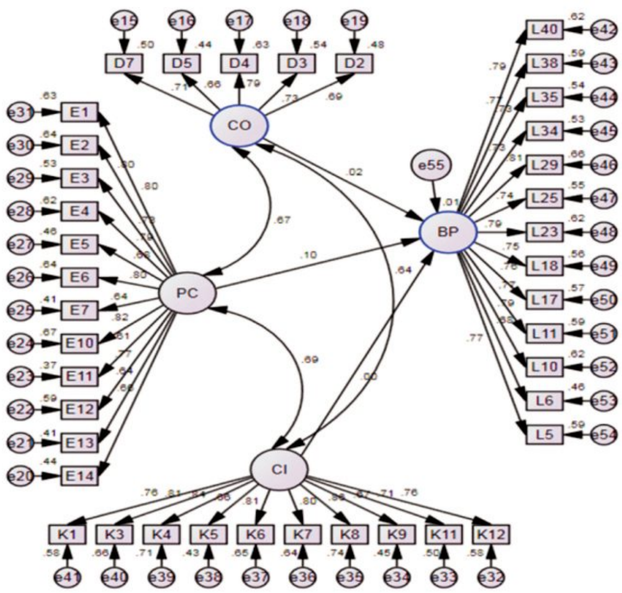

Figure3 Model 1: illustrating the full SEM- ISO 9000 model

Path Diagram with the regression coefficients among the construct of SEM - ISO 9000 model is shown in Figure3. The output of model 1 has been compared with the ***cutoff criteria presented by Schreiber et al. (2006) for Several Fit Indexes.T***he value of RMR is 0.044which is the square root of the average squared amount by which the sample variances and covariance's differ from their estimates. Preferred RMR is as smaller the better it is. The value of GFI (Goodness of Fit Index) suggested byJeong and Phillips, (2001) is found to be0.620. Although GFI is an alternative to the chi-square test and calculates the proportion of variances that is accounted by estimating population covariance (Tabachnick and Fidell, 2007). GFI ranges from 0 to 0.95.

The value of AGFIis0.575which is based upon degrees of freedom with more saturated models reducing fit (Tabachnick and Fidell, 2007).The values of GFI and AGFI closer to 0.95 is considered as a perfect fit of the Model.

Table 4 Modification Indices for SEM- ISO 9000model

Covariance's of items			M.I.	Par Change
e53	<-->	e54	30.918	.160
e51	<-->	e52	19.958	.103
e44	<-->	e45	19.054	.130
e22	<-->	e29	16.352	-.106
Regression Weights of the items			**M.I.**	**Par Change**
L11	<---	CO	4.696	-.260
K8	<---	CO	5.142	.250

Modification Indices of SEM- ISO 9000 model

The SEM-ISO 9000 is modified using the modification indices of AMOS 20.0 as shown in Table4. Modification indices indicate the improvement in fit that will result in the inclusion of a particular relationship in the model. Instead of showing all possible modifications, setting a threshold for modification indices reduces the display of modification indices to a smaller set. Or we can say that the modification index for a parameter is an estimate of the amount by which the discrepancy function would decrease if the analysis were repeated with the removed constraints on that parameter. The actual decrease that would occur may be much more. Each time Amos displays a modification index for a parameter, it also displays an estimate of the amount by which the parameter would change from its currentconstrained value, if the constraints on it are removed. The modified SEM-ISO 9000 model and its output is shown in Figure4.

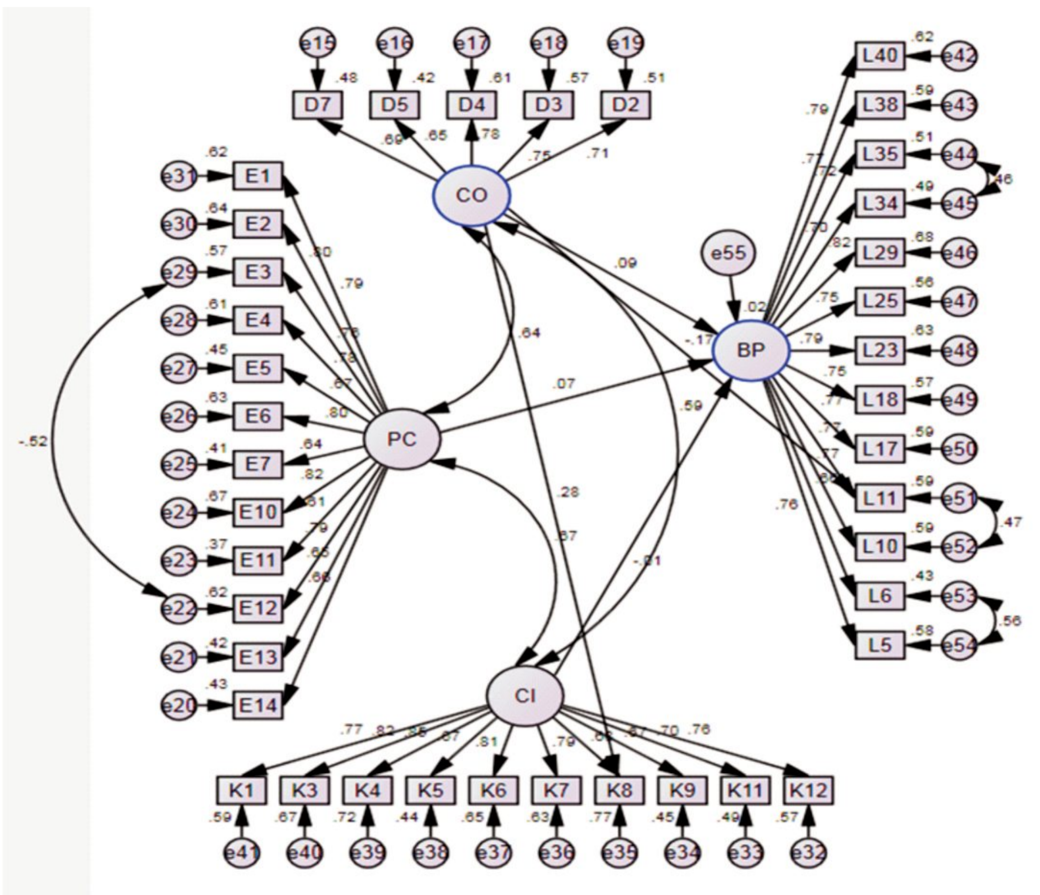

Figure4 : Model 2: Path diagram of SEM- ISO 9000 model after modification

Model Fit summary has been made in Table 5 showing the indices before and after modification. It was seen that after modifying the model 1, there has been slight improvement in the model 2 as the value of RMR decreased to 0.042. Similarly, the value of GFI increased to 0.644. The RMSEA value is coming closer to .08 showing a near model fit. The other values as shown in Table 5 are also coming closer to model fitvalues like CFI, NFI, RFI etc.

Table 5 SEM-ISO 9000 model Statistics

Model Fit Summary	Before Modification Indices	After Modification Indices	Recommendedvalue for Model Fit*
CMIN/Df Degrees of Freedom	1.799 734	1.658 728	x2/ df< 3.0 Smaller is better
Probability level	0.000	0.000	
Root-Mean-Square Residual Index (RMR)	0.044	0.042	Smaller is better; 0 indicates perfect fit
Root-Mean-Square Error of Approximation (RMSEA) **Baseline Comparisons**	0.09	0.08	< 0.08
Goodness-of-Fit Index(GFI)	0.620	0.644	>0.95
Adjusted Goodness-of-Fit Index(AGFI)	0.575	0.599	> 0.95
Comparative Fit Index (CFI)	0.795	0.832	> 0.95
Incremental Fit Index (IFI)	0.798	0.835	> 0.95
Normed Fit Index (NFI)	0.637	0.668	> 0.95
Relative Fit Index (RFI)	0.614	0.644	> 0.95
Tucker-Lewis index (TLI)	0.782	0.820	> 0.95

CONCLUSIONS

ISO 9000 certification is a admired initiatives employed by various manufacturing organizations to obtainrejuvenated effect on organizational performance enhancement. These systems are employed world over for attaining customer satisfaction, productivity, increased market share, profitability and even survival, but these initiatives are directly affected by the Quality of product, Cost of product and Quality Management System followed by industry.

To validate this study empirically, SEM-ISO 9000 model is formed with SEM. Varioussignificantfactors used for SEM model are customer orientation, process control, continuous improvement and business performance. Further various data examination techniques like test for feasibility of independent and dependent variables data have been applied. Through EFA and CFA, various items affecting the model to unfit have been removed from independent and dependent variables. Then using AMOS 20.0 software Structural Equation Modelinghas been performed and statistics data before and after modification indices were compared. After comparing SEM-ISO 9000 model is coming to near fit values. Which implies that companies implementing the significantissues like customer orientation, process control and continuous improvement are getting better business performances in terms of business benefits, technological and operational benefits, production benefits, employee benefits and customer related benefits. Hence this study has validated the previous study by Jain and Ahuja (2013a) that continuousimprovement, customer orientation and process control issues of ISO 9000 can improve the business performance in Indian industry.

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Analysis of Suspension Arm: Comparing Different Materials

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Abstract

The function of suspension system is to absorb vibrations due to rough terrains or road disturbances and to provide stability under circumstances like accelerating, cornering, uneven road, braking, loading and unloading etc. Control arm is one of the most important part of the suspension system, as it joins the steering knuckle to the vehicle frame. Also suspension arm is responsible for up and down movement of wheels when hitting bumps. It is also designed to maximize the friction between tire contacts, patch the road surface to provide vehicle stability under any circumstances. It can be seen in many types of the suspensions like wishbone or double wishbone suspensions. Many times it is also called as A-type control arm. In this study control arm was reverse engineered.CAD model was prepared using CATIA v5 software and finite element analysis was done using ANSYS 14.5 software by importing the parasolid file to ANSYS. The model is subjected to loading and boundary conditions and then analyzed using the FEA techniques. The static structural analysis and fatigue analysis were done to find out the stress, safety factor and life of component. The model was meshed using 8-noded solid 185 elements.Result obtained from the analysis were studied to check whether the design is safe or not and to find the best suitable material for suspension arm.

Key Words–*Suspension System, Control Arm, FEA analysis, ANSYS*

INTRODUCTION

The lower suspension arm are connected to the vehicle frame with bushing and permits the wheel to go up and down in response to the road surface. Control arm is the most crucial part of the suspensions system. It is made from materials like steel, iron or aluminum. Suspension arm is very important for the all vehicles on the road, if there is no suspension arm in suspension system, then it is expected that it can result in annoying vibrations and unwanted driving irregularities that could sometimes lead to road accidents like collisions with another car or obstruction on the road.

Suspension arm is one of the most important component in the suspension system. It is fitted in various types of the suspensions like Macpherson, wishbone or double wishbone suspensions. During actual working conditions the maximum load is transferred from tire to the ball joint in Macpherson strut system and in double wishbone maximum load is transferred from upper arm to the lower arm which is responsible for the failure and twisting of lower suspension arm at the ball joint locations as well as control arm because of more impact load. Hence it essential to focus on the stress and deformation study of lower suspension arm to develop and the changes in existing design. The FEA approach is used for analysis of a suspension link for static and Von-Mises stress analysis of lower suspension arm. Analysis is to be done considering the Gross vehicle weight to find the best suitable material for suspension arm.

LOADING AND BOUNDARY CONDITIONS

Figure shows solid model of lower suspension arm prepared using CATIA V5 software.

Figure-2.1) Solid Model

Figure 2.2 shows the meshed model of lower suspension arm with 5 mm of mesh size and 8 node Solid 185 element were considered for the analysis. Figure 2.3 shows boundary condition and Figure 2.4 shows loading conditions applied to the Lower suspension arm.

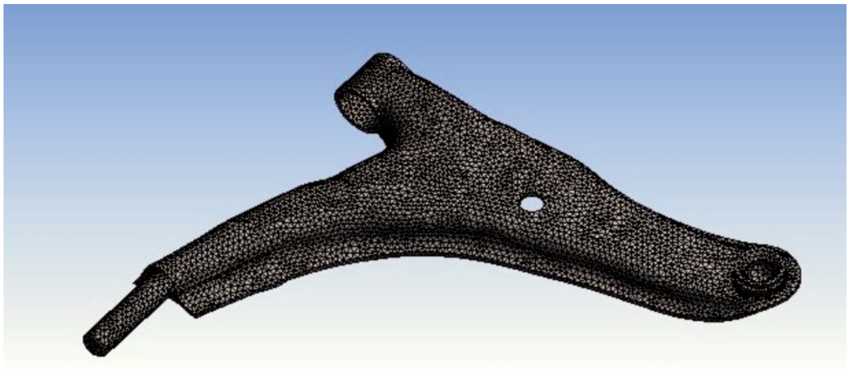

Figure 2.2) Mesh Model

- No of Nodes – 9634
- No of Elements- 34175
- Element Type – Solid 185 (8 node)

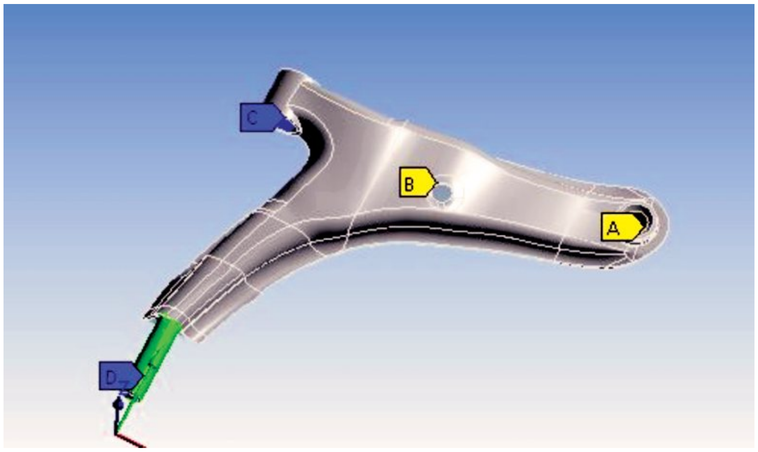

Figure 2.3) Boundary Condition

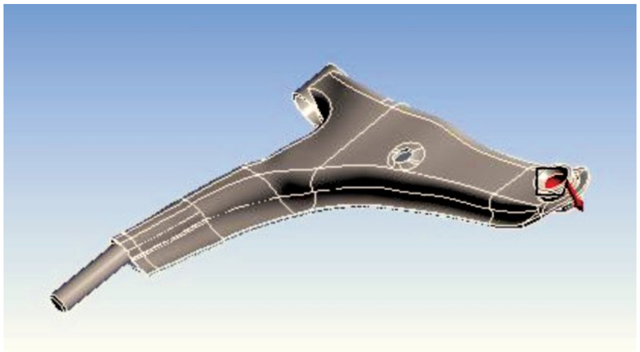

Figure 2.4) Loading Condition

In following table particular conditions are shown in Table2 for the typical component.

Table2: Vehicle Specification

Wheel Base	2365mm
Overall Length Overall Width	4095mm 1575mm
Overall Height	1395mm
Ground Clearance	170mm
Turning Radius Unladed Weight	4.8mm 870Kg
Laden Weight	1315Kg

MATERIAL PROPERTIES

Strength and fatigue behavior of any material depend upon its tensile strength. The mechanical properties of structural steel and aluminum alloy are shown in Table3

Table3: Material Properties

Properties	Unit	Aluminum Alloy	Structural Steel
Density	Kgm^{-3}	2770	7850
Poisson's Ratio		0.33	0.3
Young's modulus	MPa	71000	200000
Tensile Yield Strength	MPa	280	250

RESULTS

Many features were analyzed like stress, safety factor and life from FEM analysis and results that were found are given below,

Stress Analysis

In stress analysis of lower suspension arm subjected to high stress shown in figure 10. According to the methodology to safer the design stress induced in arm should be less than the yield strength of the material. The stress found from the analysis is 166.46MPain structural steel and 165.44 MPa in aluminum alloy.

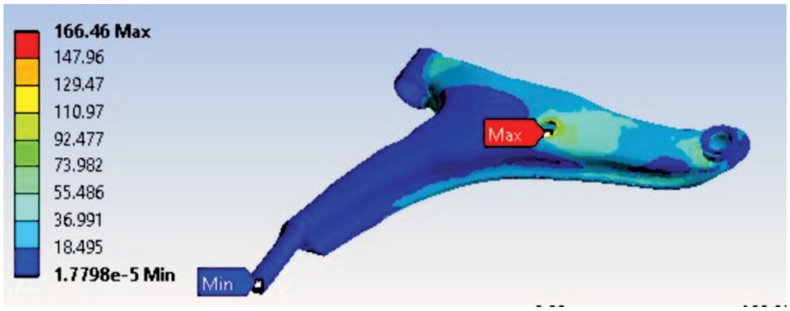

Figure4.1) Equivalent Stress (Structural steel)

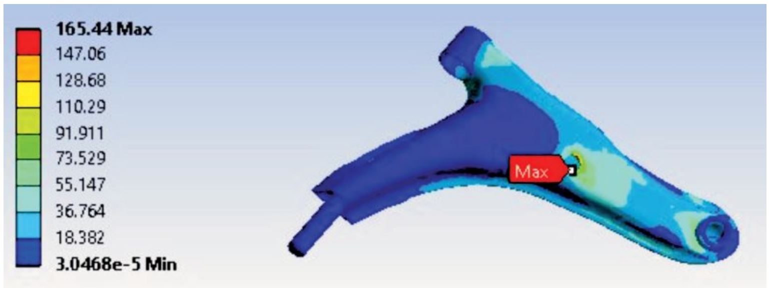

Figure4.2) Equivalent Stress (Aluminum Alloy)

Safety Factor

Safety factor shows that the component is safe or not. If safety factor is below 1 then it means component is not safe.Safety factor of structural steel is 1.5019 and safety factor of aluminum alloy is 1.69.

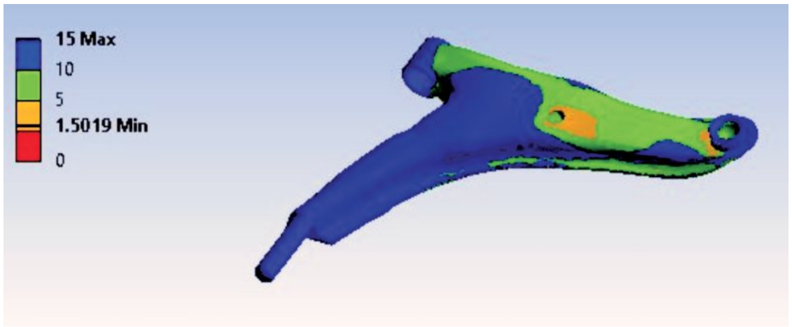

Figure4.3) Factor of Safety (Structural Steel)

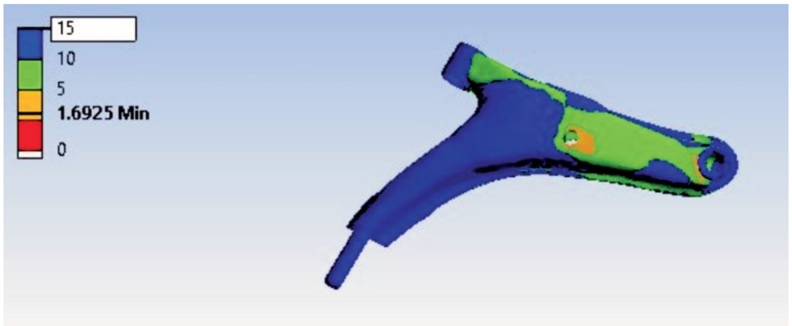

Figure4.4) Factor of Safety (Aluminum Alloy)

Fatigue Life

Fatigueanalysis assists designers to calculate the life of a material or structure by viewing the effects of cyclic loading on the component. Life cycles of suspension arm were calculated in the fatigue analysis.

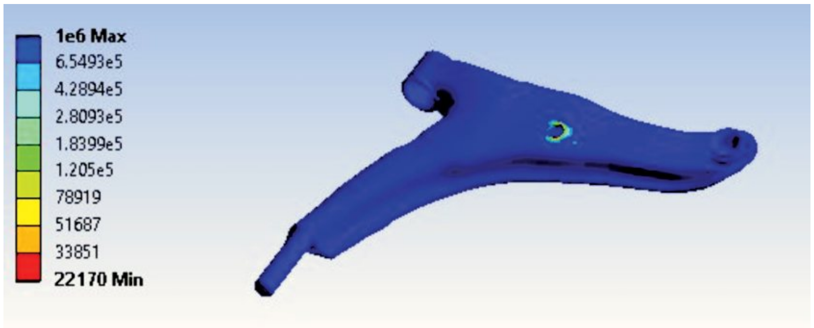

Figure4.5) FatigueLife cycles (Structural Steel)

Figure4.6) Fatigue Life Cycles (Aluminum Alloy)

Table6: Final Results

Parameter	Units	Structural Steel	Aluminum Alloy
Equivalent stress	MPa	166	165
Safety Factor		1.5019	1.6925
Fatigue Life	Cycles	27170	34000
Mass	Kg	2.71	0.95

CONCLUSION

From the analysis of lower suspension arm it is concluded that if Aluminium alloy will give comparative higher structural strength and fatigue life than structural steel. Hence, weight of the component made up from Aluminium Alloy is subsequently reduced.

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Experimental Investigation Of Slurry Erosion Behaviour Of Hardfaced Ca6nm Turbine Steel Balkaran Singh Dhaliwal[1]*, Deepak Kumar Goyal[2] And Khushdeep Goyal[3]

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Abstract

In the present investigation, erosion wear behaviour of hydraulic material CA6NM is investigated. Two electrodes ZEDALLOY 350 and ZEDALLOY 550 were used for hard facing with the help of Shielded Metal Arc Welding (SMAW). The erosion experiments were carried out using erosion test rig having factors like particle size, slurry concentration, and impact angle. L9 Taguchi technique is used to acquire the erosion test data in a controlled way. The study reveals those particle size and impact angles are most significant among various factors influencing wear rate of hardfacing. In comparison, the coated sample shows better results in erosion than uncoated. Scanning electron microscopy (SEM) is technique is used to analyze the microstructure of eroded specimen.

Keywords Erosion, Turbine Steel, SMAW.

Introduction

Slurry erosion is a major problem in Hydropower plants and its parts as a result it reduces the efficiency and increases the operational costs (Romo et al, 2012). It depends on various parameters like silt size, hardness, concentration, velocity of water etc. so, it is very difficult to find common cause and remedy for slurry erosion. Selection of materials of turbines is also a considerable area of interest to resist erosion (Grewal et al, 2013). In recent past, many researches had tried to improve the erosion resistance of hydro components such as impellers. Manisekaran et al (2007) addressed the effect of angle of impingement and particle size on erosion resistance and found a dominant ductile behaviour of the samples even at high angle test conditions. Goyal et al (2012) investigated the erosion performance of WC–10Co–4Cr and Al_2O_3 -13TiO_2 coatings on CF8M turbine steel. It was found that WC–10Co–4Cr coatings are more useful to increase slurry erosion than other coatings. Xie et al (1999) found that for very dilute slurries, the effect of the concentration of solids can be neglected because the particles did not interfere with each other where the solids concentration is less than 1% by volume, or when the particle to particle distance is greater than 20 times. Bhandari et al (2011) studied the slurry erosion behavior of D-Gun spray Al_2O_3 -13TiO_2 coated CF8M steel. It was found that slurry erosion performance of Al_2O_3 -13TiO_2 coated steel was superior to that of Al_2O_3 steel.

Different welding techniques are versatile means of developing wide variety coatings or hardfacing to enhance the surface performance and durability of engineering components exposed to different forms of wear such as abrasion, erosion, and corrosion. SMAW is a hardfacing technique, which gives an extremely good adhesive strength and coating surface with compressive residual stresses. SMAW involves the entrainment of electrodes with more hardness than base material.

Objective of this study is to Study the Erosion Behaviour of Turbine Steel Before and After Hardfacing by SMAW steel under the hydro accelerated conditions by using a high speed erosion test rig. It has been learnt that there is very less information available on the slurry erosion behavior of these hardfacing systems in the open literature, therefore the outcome of the study shall be useful to explore the possibility of use of these hardfacing systems in actual hydraulic turbines.

EXPERIMENTATION

Test Material

The substrate material CA6NM was procured from M/S Mithila Malleables Pvt. Ltd. Mandi Gobindgarh, The substrate material was selected on the basis of its cost and the availability. The detailed composition of material used i.e. CA6NM is shown in table 1. The dimension of the samples was taken as 30x30x4 mm.

The SMAW technique has been used for hardfacing. The electrodes used in this study were commercially available ZEDALLOY 350 and ZEDALLOY 550 electrodes. To improve the surface finish of hardfacing to the substrate, cup grinding is used. Samples were then hardfaced by SMAW available at Subhash Mechanical Works, sirhind, punjab, India. The hardfacing were deposited using the standard process parameters.

Test Apparatus

The jet type erosion tester was made at Punjabi University, Patiala. The erosion tester shown in figure 1 consists of a centrifugal pump, conical tank, nozzle, specimen holder, valves, and flow meter. Centrifugal pump driven by 5 HP, 1440 rpm electric motor has a capacity of max pressure 13.5 bar at a discharge of 240 l/min. Slurry available is sucked through a 100mm GI pipe with help of pump and delivered to the nozzle through 25 mm pipe having control valves. Slurry is re-circulated during test. During test the temperature of slurry increase to a certain level and thereafter remains constant, which is due to mechanical action of pump. The flow rate of the slurry is controlled with help of main valve and bypass regulator valve between delivery side and nozzle. The rectangular tapered tank having 600x450 mm at top which converges to 100x100 mm at the bottom through a length of 1200 mm was used to store the slurry.

Table 1 Chemical composition of CA6NM

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
Min.		0.5				11.5	3.5	3.50	
Max	0.05	1.00	0.60	0.04	0.03	14	5.5	5.50	bal

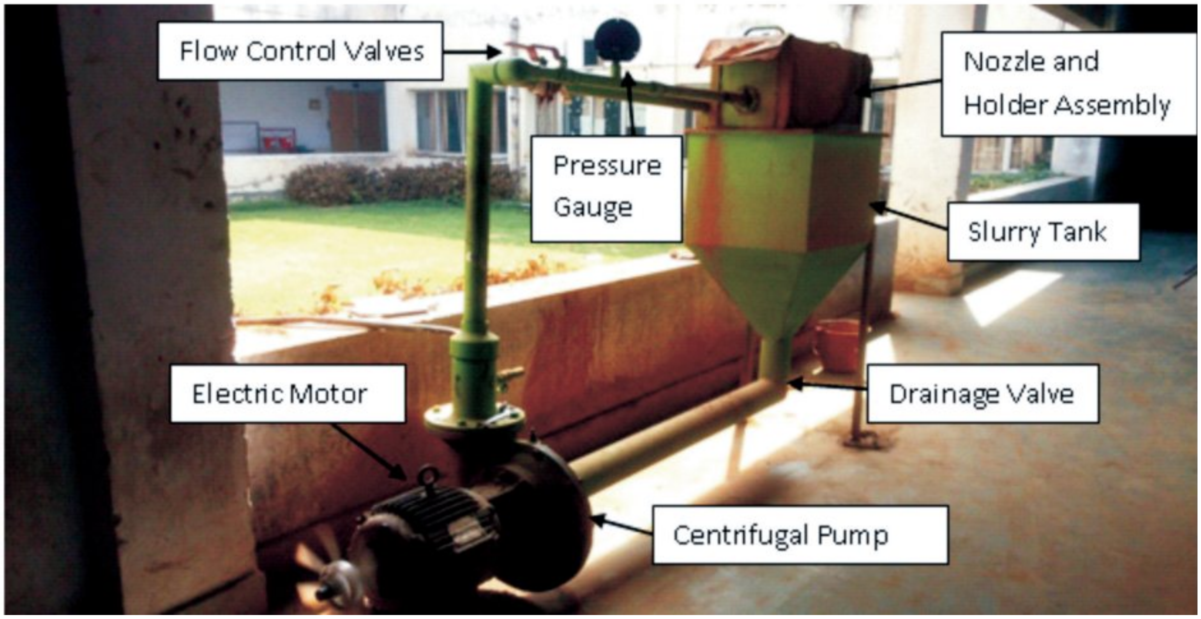

Figure 1- Jet Erosion Tester

Experimental Design

Table 2 shows the chosen L_9 experimental plan and Table 3 shows the parameters and their values corresponding to their levels

Table 2 Chosen L_9 experimental plan

Run	Particle size	Concentration	Impact angle
1	A1	B1	C1
2	A1	B2	C2
3	A1	B3	C3
4	A2	B1	C2
5	A2	B2	C3
6	A2	B3	C1
7	A3	B1	C3
8	A3	B2	C1
9	A3	B3	C2

Table 3 Description of particle size

Particle size (μm)	
A1	150
A2	300
A3	450

Table 4 Description of concentration

Concentration (ppm)	
B1	15000
B2	20000
B3	30000

Table 5 Description of impact angle

Impact angle	
C1	30°
C2	60°
C3	90°

Results and Discussions

Erosion Performance

Erosion Performance of uncoated CA6NM steel at different experimental runs

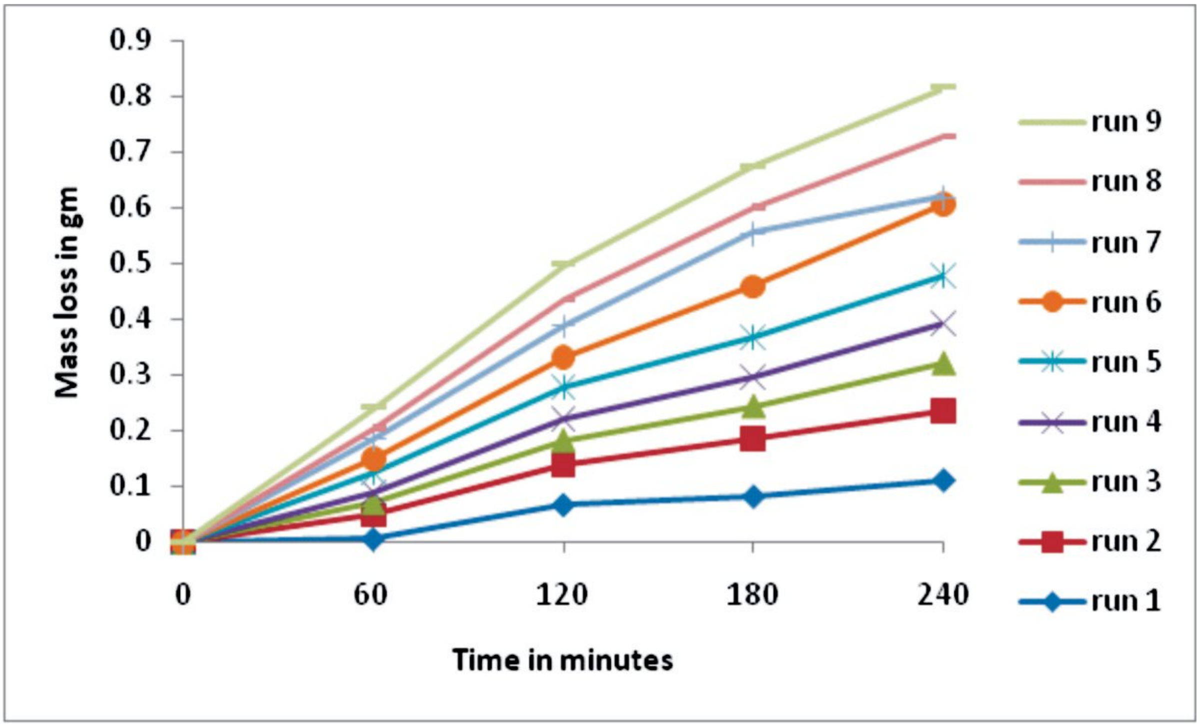

Figure 2. Variations in mass loss w.r.t time for uncoated specimen at different runs

Figure 2 shows that the erosion of uncoated specimens, which corresponds to erosion rate for all nine runs, performed over a range of parameters at all uncoated specimens of CA6NM. As it can be observed in results maximum erosion took place in run 7 at impact angle 90°, concentration of 15000 ppm and particle size 450μm and minimum erosion took place in run 4 where impact angle is 60°, concentration is 15000ppm and particle size 300μm.

Erosion Performance of hardfaced ZEDALLOY 350 at different experimental runs

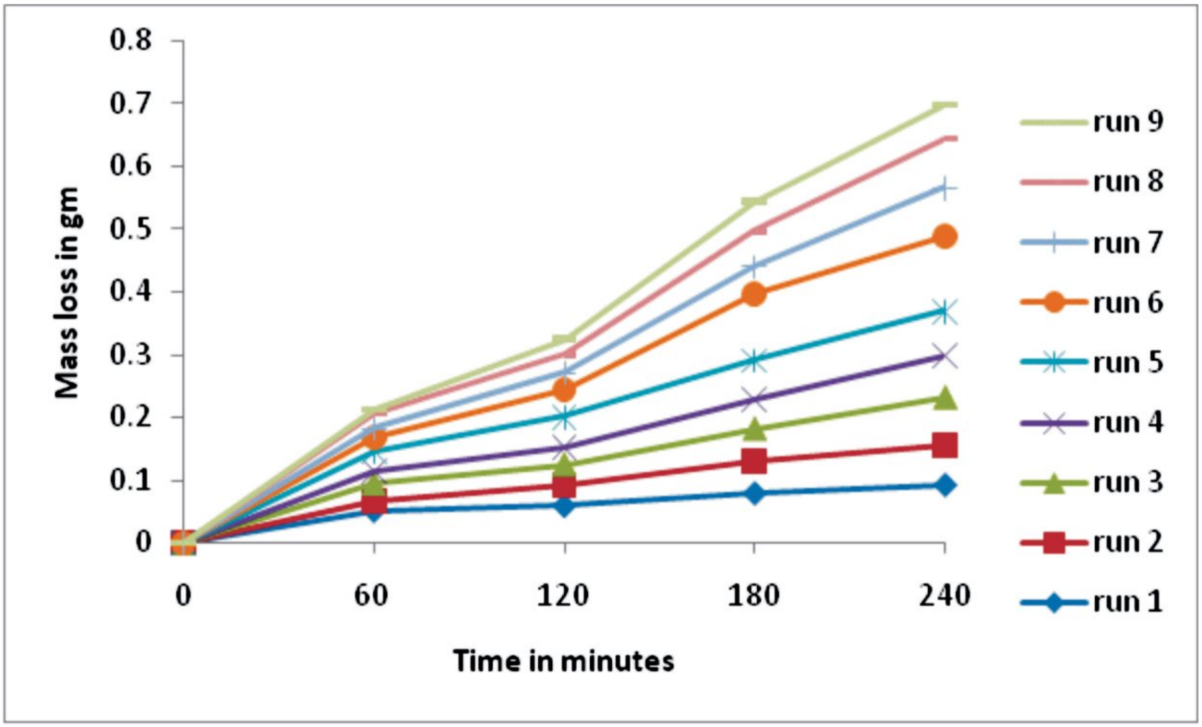

Figure 3. Variations in Mass Loss w.r.t Time for Hardfaced ZEDALLOY 350 Specimen at Different Runs

Like uncoated specimen, similar results are found for specimens hardfaced with ZEDALLOY 550 by SMAW technique as shown in figure 3. As it can be observed in results maximum erosion rate is occurs in run 6, where the various parameters were particle size-300μm, concentration-30000ppm, and impact angle 30° and minimum erosion rate occurs in run 9, where parameters are particle size-450, concentration-30000ppm, and impact angle-60°.

Erosion Performance of hardfaced ZEDALLOY 550 at different experimental runs

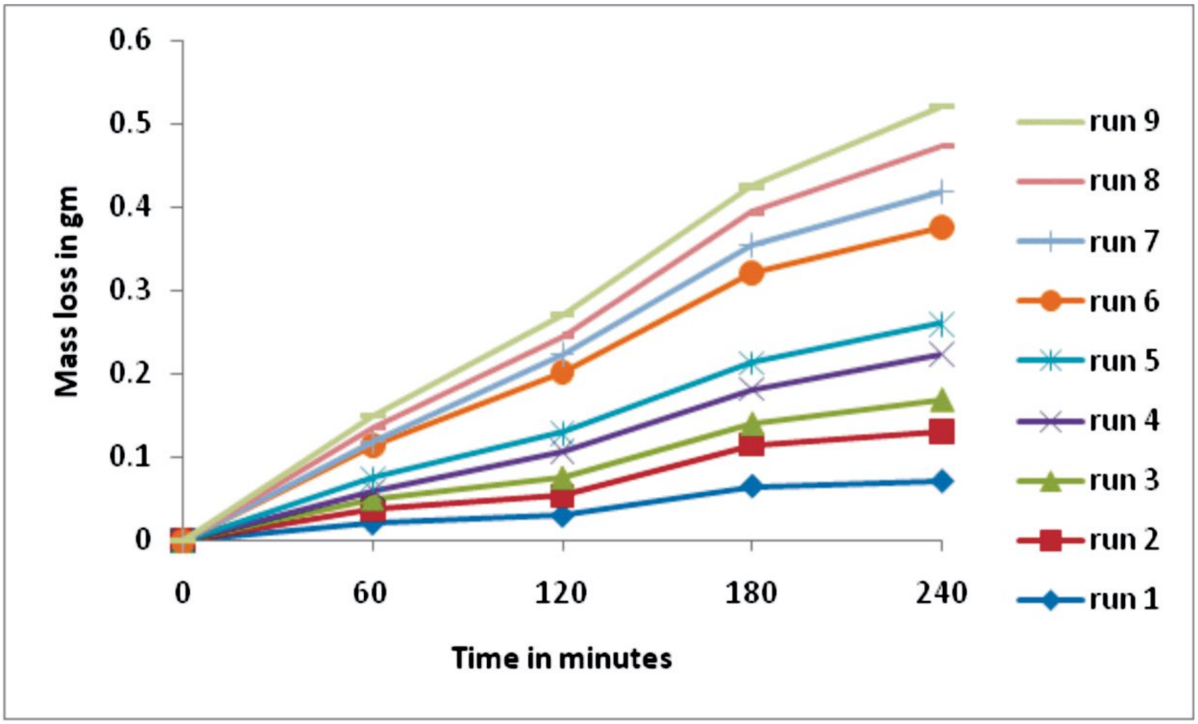

Figure 4. Variations in mass loss w.r.t time for **hardfaced ZEDALLOY 550** specimen at different runs

From figure 4, it is clear that maximum erosion rate occurs in run 6, where the various parameters were particle size-300µm, concentration-30000ppm, and impact angle-30^{o} and minimum erosion rate occurs in run 5, where various parameters were particle size-300µm, concentration-20000ppm, and impact angle-90^{o}.

Effect of Various Parameters

Mass loss comparison due to slurry erosion on uncoated CA6NM specimen and after hardfacing with ZEDALLOY 350 and ZEDALLOY 550 at different runs

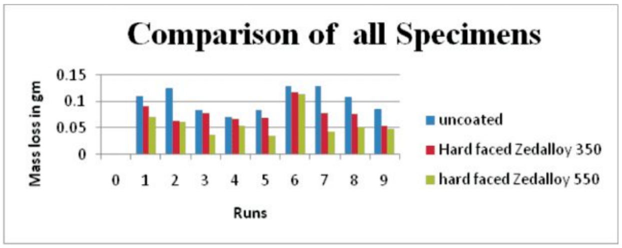

Figure 5. Comparison of mass loss due to slurry erosion on uncoated CA6NM specimen and after hardfacing with ZEDALLOY 350 and ZEDALLOY 550

Figure 5 shows the comparison of mass loss for CA6NM steel and hardfacing for different runs. The mass loss for uncoated material is more at every run as compared to hardfacing materials. The more effect of erosion can be seen and run 7, where impingement angle is 90°. This is because of the large force exerted due to direct impingement of slurry on the surface of specimen. In run 4, the difference between erosion rate of two hardfacing (ZEDALLOY 350 and ZEDALLOY 550) is less.

SEM Analysis

SEM Analysis of unperformed uncoated CA6NM steel and hardfaced ZEDALLOY 350 and ZEDALLOY 550 specimen

The figure 9 shows the SEM micrograph of uncoated CA6NM and hardfaced ZEDALLOY 350 and ZEDALLOY 550. The micrograph 9 shows that in uncoated material, there is fine pores present in the material. The irregular surface and fine pores on the surface may be due to the casting defects. The hardfaced ZEDALLOY 350 in figure 10 shows that in hard faced specimen of CA6NM with electrode ZEDALLOY 350 before performation of experiment laminar layers on coating are seen due to grinding process done on coating to increase surface finish and outlook. The SEM micrograph in figure 11 observed that after finishing with grinding some layers are formed due to non-reachable manual surface finish. As a result some portion of the material comes smooth and at some places uplift of the hard faced surfaces.

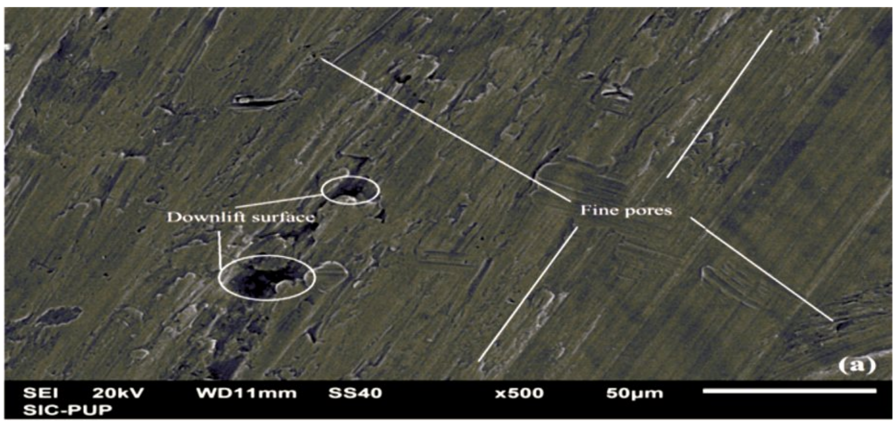

Figure 9 SEM of unperformed uncoated specimen

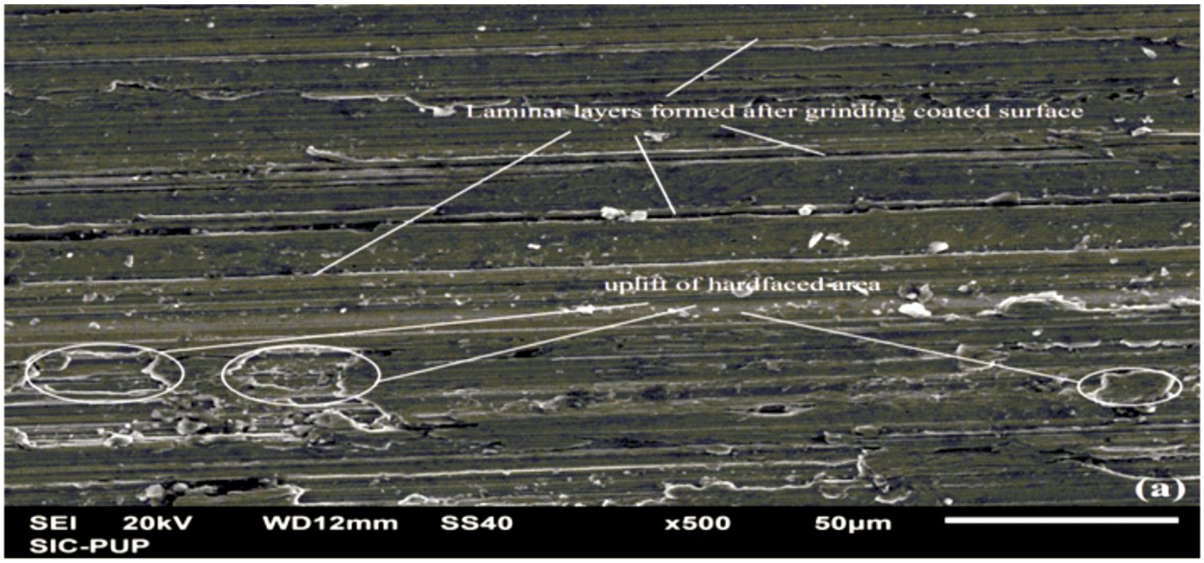

Figure 10 SEM of Unperformed hardfaced ZEDALLOY 350 Specime

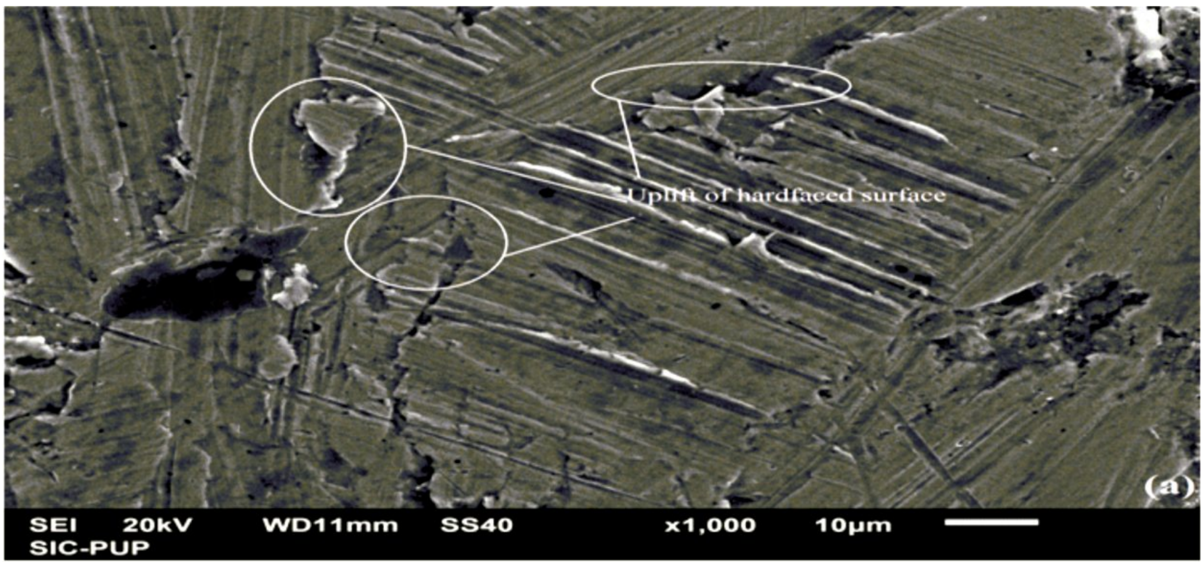

Figure 11 SEM of Unperformed Hardfaced ZEDALLOY 550 Specimen

SEM Analysis of performed uncoated CF8M steel and Ni-20Cr and WC-12Co coated specimen

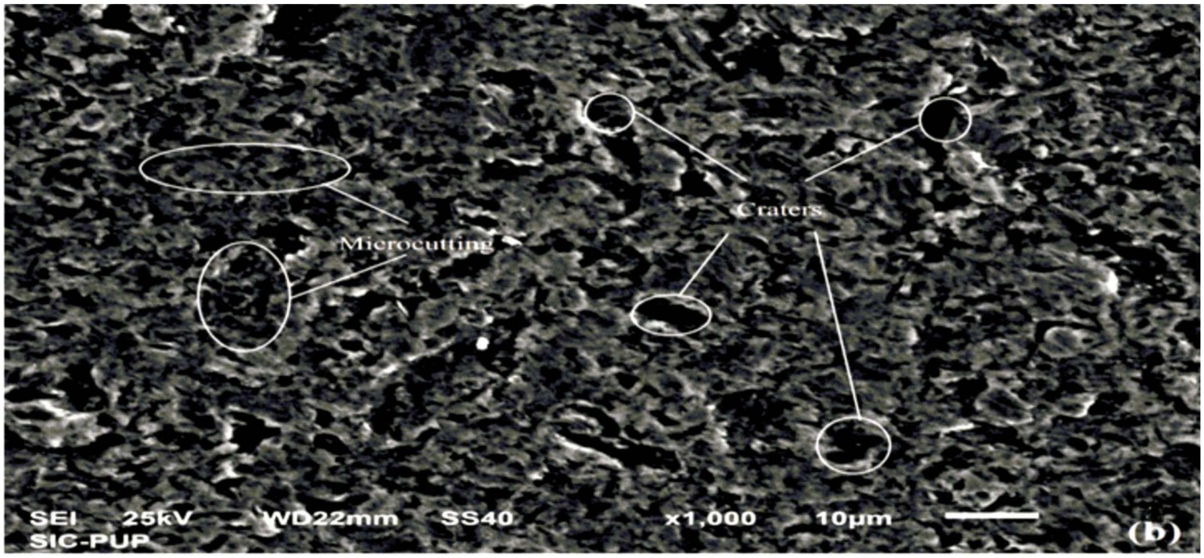

Figure 12 SEM of Performed Uncoated CA6NM Specimen

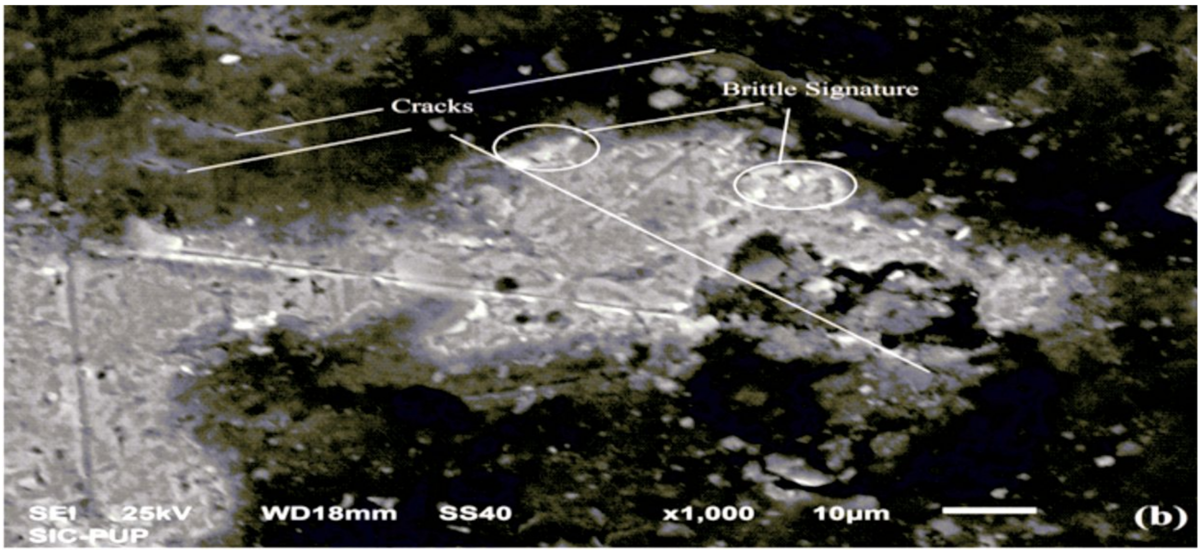

Figure 13 SEM of Performed Hardfaced ZEDALLOY 350 Specimen

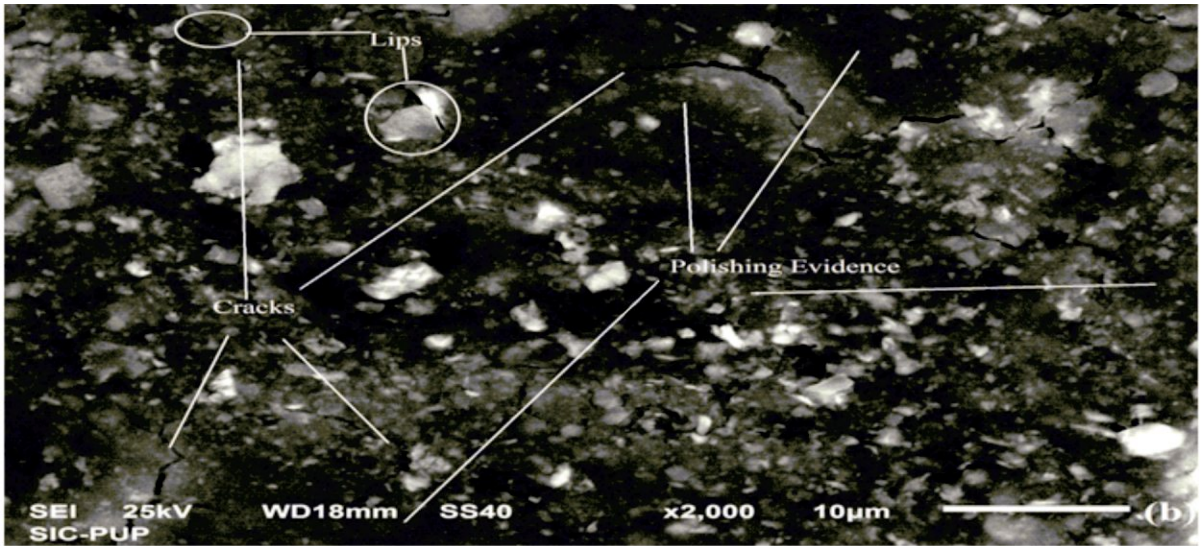

Figure 14 SEM of Performed Hardfaced ZEDALLOY 550 Specimen

Figure 12 shows micro cutting, craters which are created by irregular-sharp edged slurry particles. Formations of craters on the surface on the surface may be due to indentation of the surface by abrasive particles with impingement angle close to 90°. In figure 13, shows Brittle signature on few areas of the hard faced surface due to fatigue process caused by the repeated interaction of the coating surface with the slurry. The black portions shown in figure are the chips of silica sand broken off from the impacting particles and became embedded in the surface. The chip was broken off because of the high forces in this area. Eroded surfaces revealed broken phase and fragments as well as craters in the material zone. In figure 14, when specimen undergoes slurry erosion test, where slurry with water strikes on surface material results in disappear of the wrinkled surface and formation of plowing along with lip due to the large size particles. These lip sheared because of abrasive particles impinging at shallow angle on testing. Some cracks are also formed.

CONCLUSIONS

The effect of various parameters on slurry erosion mechanism of uncoated and coated CF8M steel was investigated. The important conclusions drawn from the investigation are:

The mass loss comparisons shows that erosion rate of uncoated CA6NM is more than the hard faced CA6NM alloy means hard facing shows better performance than uncoated steel in all conditions in which test was performed.

For uncoated CA6NM the maximum erosion is at 90° impact angle and minimum at impact angle 60°, for ZEDALLOY 350 maximum at 30° and minimum at 60° and for ZEDALLOY 550 maximum erosion at 30° and minimum at 90°.

From erosion wear rate of hardfacing it is observed that erosion rate seems to be in equilibrium from at entire time in which experiment is performed.

The hardness of CA6NM hardfaced with ZEDALLOY 550 is highest.

The mass loss increase for both uncoated and hard faced specimens when concentration is too high means (30000ppm).

For hardfaced specimens of CA6NM higher erosion is found at the impact angle 30°, concentration 30000ppm, and particle size 300µm as a result of particle size does not play a major role in erosion.

The order reducing erosion rate was observed from the comparison between the hard faced and uncoated CA6NM is: Uncoated CA6NM > hardfaced CA6NM with ZADALLOY 350 > hardfaced CA6NM with ZEDALLOY 550

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Comparative Study Of Aluminium And Magnesium Alloy Of Car Wheel

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ABSTRACT

*Alloy wheels are vehicle wheels which are made from an alloy of aluminium and magnesium metals or at times a mixture of both. Alloy wheels contrast from normal steel wheels because of their lighter weight, which improves the steering and the speed of the car. The 3-dimensional model was designed in the modelling software CATIA v5.and further it was imported to the ANSYS 15.0 by using .igs format. In this project, Aluminium alloy is comparing with other alloy.**By using ANSYS software reduces the time compared with the method of mathematical calculations by a human. ANSYS static analysis work is carried out by considered two different materials namely aluminium and magnesium alloy and their relative performances have been observed respectively. In This paper by observing the results (von-misses, total deformation. Stress intensity, safety factor) of static analysis obtained aluminium alloy is suggested as best material.***

KEYWORDS Alloy Wheel, CATIA, Stress Analysis, Aluminium alloy, Magnesium alloy, ANSYS15.0 etc.

INTRODUCTION

Archaeologies and historians of today see the introduction of the wheel as the real genesis of any old civilization. The wheel is the most significant discovery of old times. The wheel has developed from an oversized bearing to a fully integral part of any modern transportation vehicle. The modern motor vehicles are produced according to very strict rules to ensure the safety of passengers. Materials to produce these wheels have become has sophisticated as a design and material can range from steel to non-ferrous alloys like magnesium and aluminium. Automotive wheels have evolved over the decades from early spoke design of wood and steel. Today's modern vehicles are uses the stamped metal configuration and modern cast and forged aluminium alloys rims. Since the 1970's several innovative methods of testing well aided with experimental stress measurement have been initiated in recent years, the procedures have been improved by a variety of experimental and analytical methods for structural analysis (finite element method).

Types of wheels

There are only a few types of wheels still in use in the automotive industry today. They vary significantly in size, shape, and materials used, but all follow the same basic principles. The first type of wheel worth mentioning, and by far the most-used wheel, is the steel wheel. This kind of wheel consists of several sheets of steel, stamped into shape and typically welded together. This type of wheel is strong, but heavy. They are found on every kind of vehicle from sports cars to the larger pickup trucks; the wheels look different but are essentially the same device. The second type of wheel to be mentioned is the rally wheel. These are essentially steel wheels but they are made somewhat differently, and tend to consist of a heavier gauge of steel. While the inner portion of a steel wheel is generally welded to the rim along its entire circumference, a steel wheel's inner portion is cut to resemble the spokes of a mag wheel, and is welded accordingly. Mag wheels are cast and/or milled wheels typically made from aluminium or an alloy thereof. They used to be made of magnesium for their light weight and strength, but magnesium catches fire somewhat easily and is very difficult to put out. This is unfortunate, because it is superior to aluminium in every other way. This tendency also makes it a dangerous metal to work with, because piles of shavings tend to burst into flame and burn through concrete surfaces when they get too hot.

As previously mentioned, spoke wheels (sometimes with more than 100 spokes) are still in use today and are popular on roadsters and low-riders. They tend to be fairly low in weight, and are reasonably strong. They have an “old school” appearance and style which is often highly sought after. Various combinations of these technologies can be used to produce other, more unusual wheels. Large earth-moving vehicles such as the more gargantuan dump trucks often have some degree of the vehicle's suspension actually built into the wheel itself, lying between the hub and rim in place of spokes. Also, various companies make wheels which are designed like steel wheels but are made of aluminium. The most famous of these are made by centreline, and the style is actually called the centreline wheel.

WHEEL SPECIFICATIONS AND MATERIAL PROPERTIES

Alloy Wheel Specifications

The alloy wheel was designed by using the wheel specifications which are described below with figure(2) and table(2) specifications:-

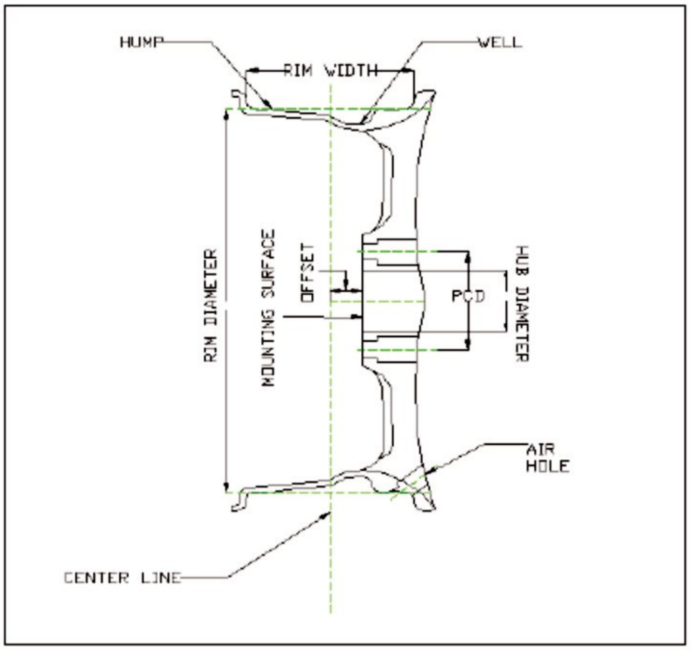


Fig-2 Specification of wheel

Table -2 Specifications of wheel

Specifications	Measurements(mm)
Rim diameter Rim width	355.6 152
Offset	40
PCD	100
Hub diameter	72

Material Properties

Table -2.2 Material Properties

Properties	units	Al Alloy	Mg Alloy
Poissons Ratio		0.33	0.35
Density	Kg m^{-3}	2770	1800
Young's Modulous	MPa	71000	45000
YieldStrenghth	MPa	280	193

MODELLNG IN CATIA AND ANALYSIS

Modelling

CATIA is modeling software which is used for creation and modification of the objects. In CATIA design and modelling features are available. Design means the process of creating a new object or modifying the existing object. Drafting means the representation or idea of the object. Modeling means create and converting 2D to 3D. By using CATIA software create the model of wheel rim.

Final view of wheel

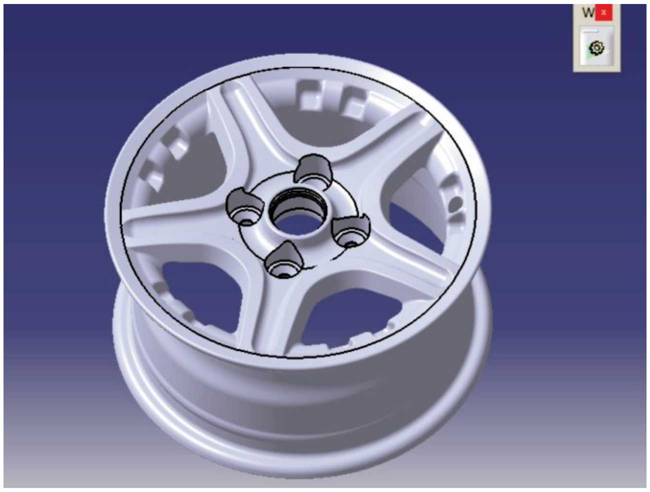


Fig-3.1.1 Final View Of Wheel

Meshing

The model was meshed with 10 node tetrahedron mesh and the elements were 208273 and nodes were 347677

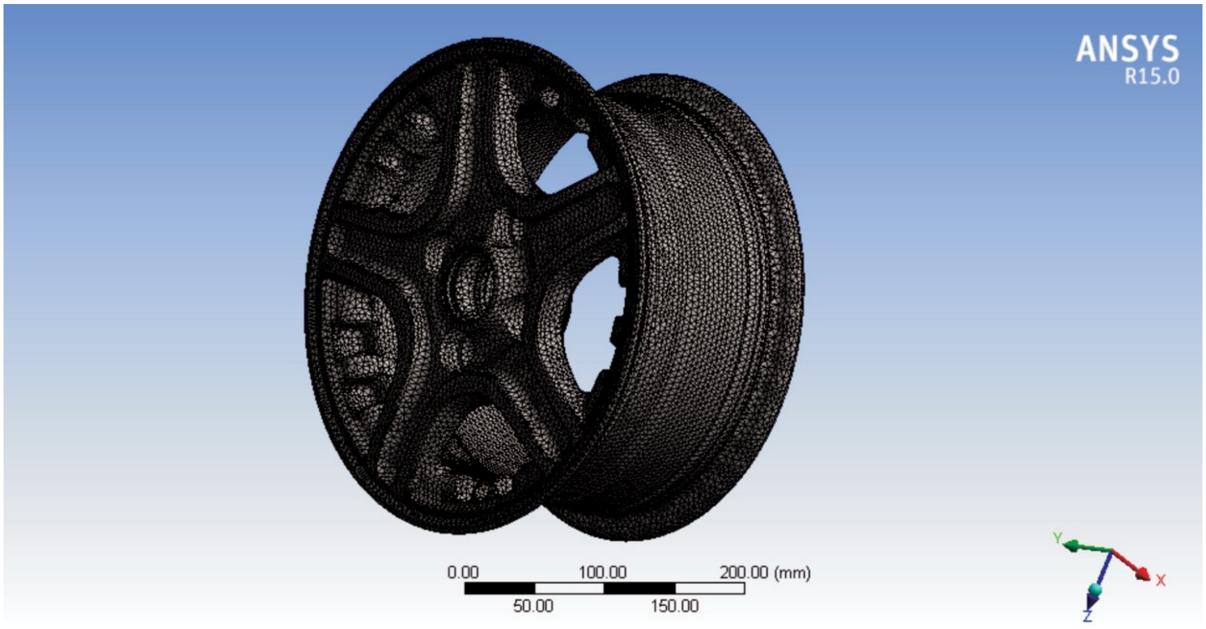


Fig-3.2 Meshing of wheel

Boundry conditions

In this project the alloy wheel is constrained in all degree of freedom using cylindrical support at bolt.

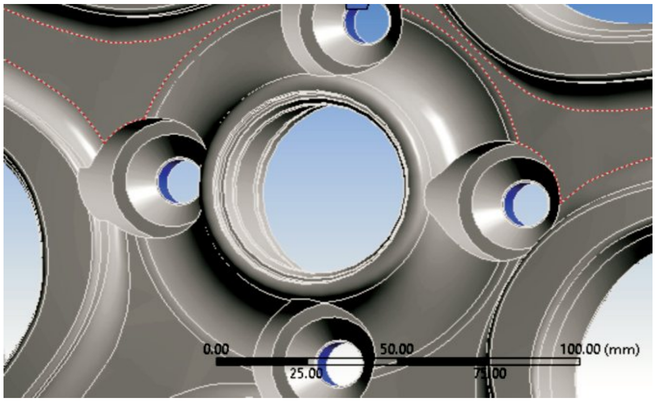


Fig-3.3 Boundry conditions

Loading conditions

According to the boundary conditions a load of 2.8653 MPa [1] was applied on the circumferential area of the rim.

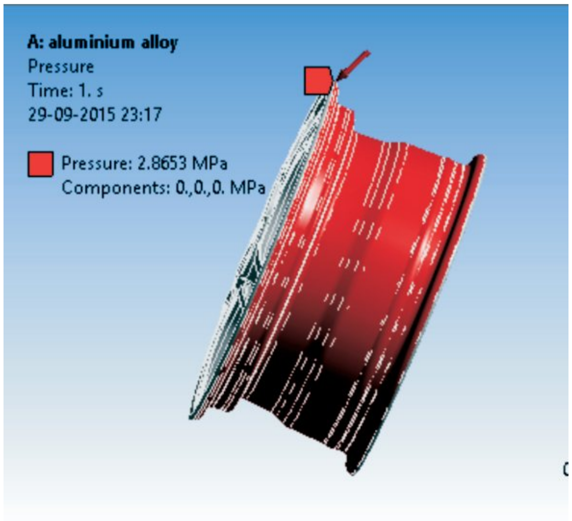


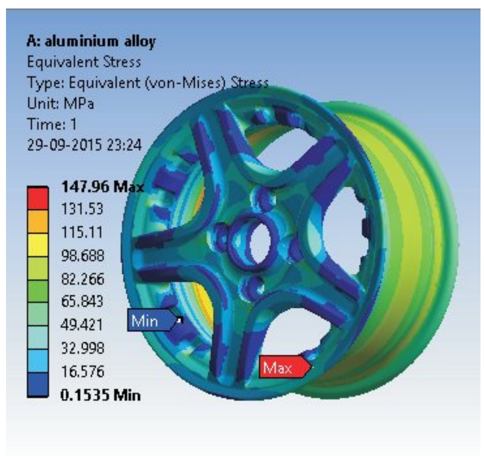
Fig-3.4 (a) Loading conditions (Pressure)

RESULTS

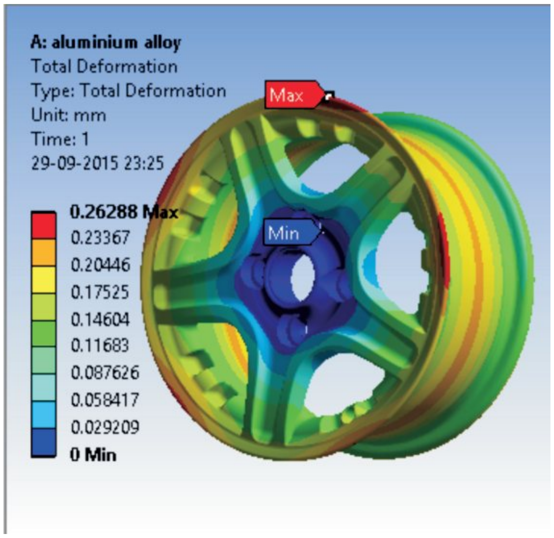
The CATIA file was imported into the ANSYS15.0 as iges for the analysis.Boundry and loading condtions were applied as dicussed above 3.3 and 3.4. and the results are in table 4.2 .

Results for Aluminium Alloy

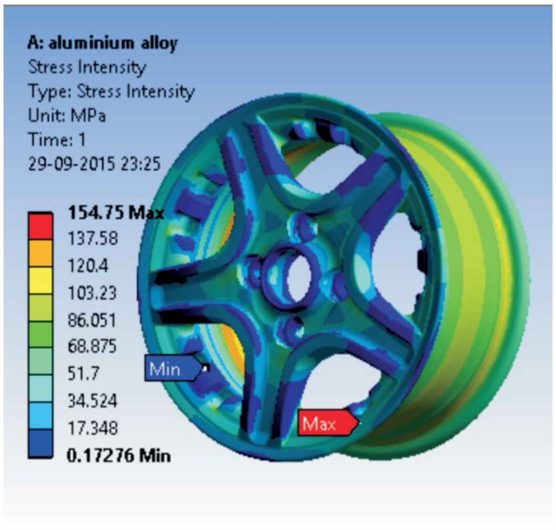
a) Equivalent Stress



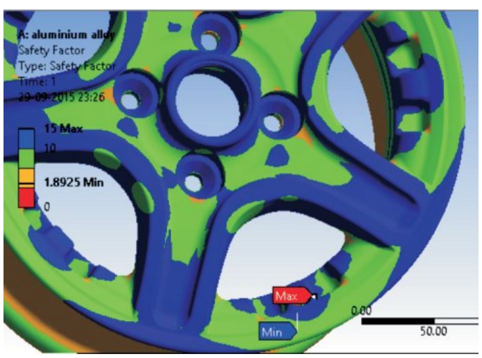
b) Total Deformation



c) Stress Intensity

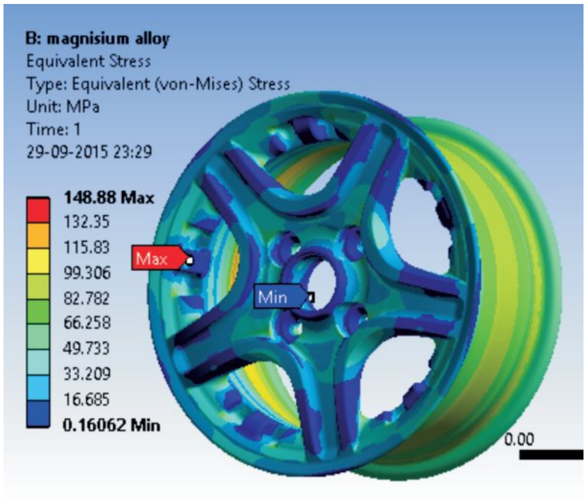


d) Safety Factor

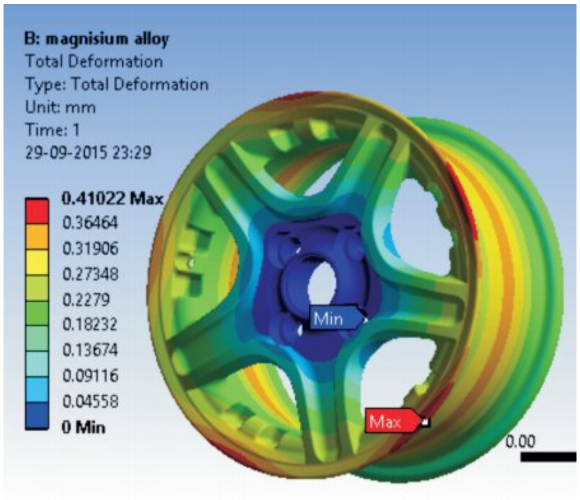


Results for Magnesium Alloy

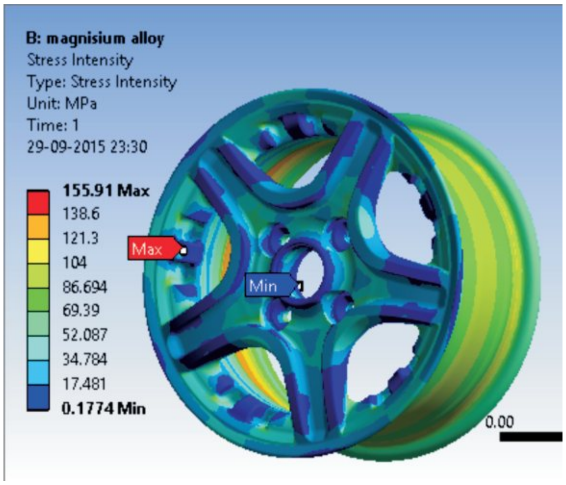
a) Equivalent Stress



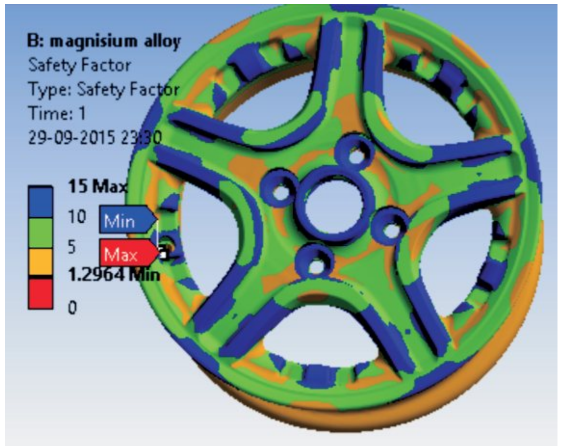
b) Total Deformation



c) Stress Intensity



d) Safety Factor



COMPARISON OF RESULTS IN TABULAR FORM

Table -4.2 Results

		Al. Alloy	Mg Alloy
Von-misses (MPa)	Min	0.1535	0.16062
	Max	147.96	148.88
Total Deformation (mm)	Max	0.26288	0.41
Stress Intensity (MPa)		154.75	155.91
Safety factor		1.8	1.2

CONCLUSION

CAD model of the wheel rim is generated in CATIA and this is imported to ANSYS for processing work. An amount of 2.8653MPa is applied along the circumference of the wheel rims made of both ALUMINIUM ALLOY & MAGNESIUM ALLOY. Following are the conclusions from the results obtained:

1. In both cases von-misses stresses are less than stress intensity. Magnesium alloy wheel rim subjected to more stresses compared to aluminium alloy.
2. Aluminium alloy wheel rim is subjected to less deformation compared to magnesium alloy.
3. The safety factor of aluminium alloy is more than that of magnesium alloy.
4. Since in both the cases von-misses stresses less than the yield strength i.e. stresses intensity, hence deformations taking into account, Aluminium Alloy is preferred as best material for designing of wheel rim.

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Role Of Technology-push And Demand-pull Scenariosin Manufacturing Industry - A Literature Review

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ABSTRACT

Technological-push and demand-pull are fundamentally different models of development and diffusion of technological innovations. Technological-pushrequires the adopter to fit the technology to the organization, whereas demand-pull requires the technology fit the adopter. Recent writers have advocated the importance of both, rather thanas alternatives to each other. The purpose of this paper is to focus on market-pull and technology-push scenarios in manufacturing ventures, specifically examining how and why this approach shifts.The study reveals that TP and DP are inter-related to each other and has a significant impact on the development of an organization and achieving its core competences.

Keywords: Technology-push, demand-pull, manufacturing industry.

INTRODUCTION

The contribution of technology and its management is vital to increase the competitive advantage in manufacturing industry. There are certain changes in the international economy that have gradually shifted the basis of industrial competitiveness from static price competition towards dynamic improvement.The manufacturing sector plays a crucial part in stimulating a more robust economy. Therefore, an open economy is vital to securing economic growth in the manufacturing sector. However, there has been little progress for increasing the competitiveness of the manufacturing sector within the last several years. Furthermore, a lack of policy co-ordination among various government agencies is a barrier to increasing innovation and competitiveness in the manufacturing sector in the US and India (Agarwal and Thiel, 2012).

Manufacturing, defined as the transformation of materials and information into goods for the satisfaction of human needs, is one of the primary wealth-generating activities of any nation. Promoting excellence in manufacturing emerges as a strategic goal of both industry and society in the years to come (Chryssolouris et al., 2013).

Industries advances to a great extent through the transfer of technology from one company to another, from one country to other. Their progress is based on the accomplishments of otherindustries. Technology is not neutral, it incorporates, reflects and perpetuates value systems and its transfer thus implies the transfer of structures. Technology is both an agent of change and destroyer of values. It can promote equality of income and opportunity or systematically deny it.

The concepts of technology-push (TP) and need-pull (NP) were initially introduced by Schon (1967) as the underlying motivations and driving forces behind the innovation of a new technology. Two schools of thought, namely the TP and the NP, propose and support twodifferent arguments. The TP school suggests that innovation is driven by science, and thus drives technology and application.According to NP school the user needs are the key drivers of adoption. More than 70% of the innovations could be classified as need-pull and organizations should pay more attention to the needs for innovationthan in maintaining technical competence (Chau and Tam, 2000).

TP andDP are fundamentally different models of development and diffusion of technological innovations. Whereas technological-push requires the adopter to fit the technology to the organization, demand-pull requires the technology fit the adopter (Drury and Farhoomand, 1999).

The manufacturing industry seeks an open and inclusive set of indicators to measure sustainability of manufactured products and manufacturing processes. In these efforts, they find a large number of stand-alone indicator sets. This has caused complications in terms of understanding interrelated terminology and selecting specific indicators for different aspects of sustainability (Joung et al., 2013).

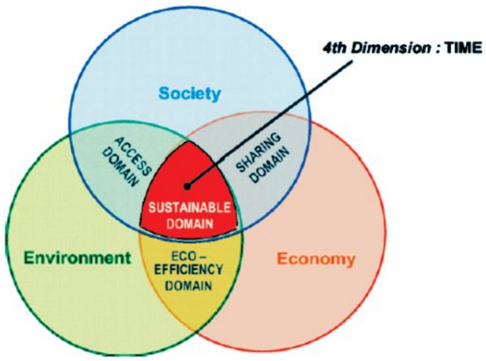

Figure 1: Fundamentals of sustainable development

TECHNOLOGY-PUSH

A technological-push has led to a product orientation of 'if we build it, they will adopt it' philosophy in a wide variety of areas. In contrast, demand-pull places different requirements.

The term 'technology-push' contains the crude implication that technology has autonomous intention, which should surely and deservedly attract the opprobrium of the label 'technologically-determinist'. In contrast the thrust of the social-shaping literature is that all technologies are 'socially-shaped', they result from social action - a statement which is a near truism (Howells, 1997).

The following table summarizes some of the work carried out on technology-push by various authors. The important strategic issues, objective and results have been discussed in Table 1:

Table 1: Technology-Push

Author(s) (Year)	Issues	Aspects	Implications
Chidamber and Kon (1993)	• Contention between demand-pull and technology-push • Organizational policy issue • National policy issue	• To study the interaction between strategy, R&D and marketing groups of a given firm as determinants	• The technology-push and demand-pull research seem to depend strongly on the research methodology factors that determine the innovation success and the level of analysis

Howells (1997)	• Technologically determinist	• To attract the opprobrium of the label 'technologically determinist'	• The location of intention in the firm and a definition of 'needs' and 'use' enable a more precise discussion of the relationship between technology and market in the process of innovation.
Drury and Farhoomand (1999)	• Impetuses for information technology adoption	• To study the effect of introduction of a new technology	• The advent of new technologies prompts firms to upgrade their information systems for competitive reasons
Chau and Tam (2000)	• Benefits obtained from adopting the technology • The costs associated with its adoption	• The gains should be greater than the costs	Numerous benefits mooted are: • providing a flexible environment unconstrained by proprietary systems • offering more choice for hardware • promoting flexibility and integration • utilizing IT resources more effectively and allowing transparent data access
Schmoch (2007)	• Empirical analysis of cycles of technology	• To analyze a broader set of science-based technologies	• The detection of new basic concepts triggers substantial technological activities with considerable market prospects
Nemet (2009)	• The rate and direction of innovation • Role of technology in economic growth • Characterizing the process of innovation	• To study whether the rate and direction of innovation is more heavily influenced by market demand or by advances intechnology	• The concept of technology-push acknowledged some of the nuances of the innovation process that the strictly 'linear' model ignored
Varadarajan etal. (2010)	• Interactive technology	• To develop a process model • To delineate the mechanisms • To necessitate the changes in retailers' strategies	Interactive technologies: • can have both direct and indirect effects on retailers' strategies • can have a profound effect on its competitiveness • can alter industry dynamics • allow smaller firms to successfully compete with larger incumbent players.
Horbach et al.	• Determinants of eco-innovation	• To find different environmental field	• Present regulations are only significant for air, water, soil,

Stefano et al. (2012)	• Strategy • Innovation • Entrepreneurship studies	• To confirm the importance of technology as a source of innovation and clarifying the role of demand	• Resources, competences, and knowledge were identified as a crucial dimension in providing a synthesis • Many technological innovations have their origin in science and technology but still need a market and the related complementary assets to be successfully commercialized
Peters et al. (2012)	• Domestic technology-push policy • Foreign technology-push policy	• To study the influence of technology-push policies on innovative output	• The higher the domestic technology-push policy and the foreign technology-push policy funding in a technological field, the higher a country's innovative output. • The growth in domestic technology-push policy funding triggers more innovative output in a country than the growth in foreign technology-pus policy funding
Lubik et al. (2013)	• Technology-pushstart-ups	• To study the importance of technology-push to industry transformation	• Technology-push start-ups often changed to a market-pull orientation because of new partners, new market information or shift in management priorities

DEMAND-PULL

Demand-pull is composed of two types, internal and external. The different forces are expected to affect the levels of (1) external, (2) internal, and (3) cost benefits achieved by the system. These benefits should be more easily assessed with demand-pull than technological-push (Drury and Farhoomand, 1999).

The following table summarizes some of the work carried out on demand-pull by various authors. The important strategic issues, objective and results have been discussed in Table 2:

Table 2: Demand-Pull

Author(s) (Year)	Issues	Aspects	Implications
Chidamber and Kon (1993)	• Driver of organizational innovation	• To examine underpinnings of market demand as drivers of innovation	• Much of the contention between demand-pull and technology-push findings is due to different research objectives, definitions and models.
Howells (1997)	• Cause of Innovation	• To investigate the factors behind successful industrial innovation	• The presumed importance of market demand over technology-push was not justified
Drury and Farhoomand (1999)	• Demand-pull as a source of impetus	• To assess the external, internal and cost benefits with demand-pull	• Systems, information and management issues are all found to affect the benefits attained.
Chau and Tam (2000)	• Organization size and Migration costs	• To examine influence on the adoption decision for open systems	• Migration costs of open systems had a relatively smaller contribution to the model • An organization would not consider adopting a new technology unless a need is recognized
Schmoch (2007)	• Cyclical developments	• To have a closer look at the underlying mechanisms	A long-term analysis leads to the discovery of typical double-boom cycles of technology: • science/technology-push • market-pull
Nemet (2009)	• Rate and direction of innovation • Changes in market conditions	• To explain negative response of inventions tothe strong market pull policies	• Rapid convergence on a single dominant design • Uncertainty in the longevity of policy signals • Declining R&D funding
Varadarajanet al. (2010)	• Retailing strategy	• To study that how a retailer chooses to compete in the marketplace	The constituent dimensions of the retailing strategy includes: • business model • customer mix • retailing mix • customer-focused retailing programs
Horbach et al. (2012)	Determinants of eco-innovations: • firm specific factors • technology • market • regulation	• To introduce the concept of customer benefits	• There is no strong stimulus for eco-innovation from the demand side since eco-friendly products are still too expensive

Peters et al. (2012)	• Domestic market policy • Foreign market policy	• To study how the locus of policies influences the effect of demand-pull policies on innovative output	• The bigger the domestic market and foreign market created by demand-pull policies in a technological field, the higher a country's innovative output. • Domestic market growth created by demand-pull policies triggers more innovative output in a country than foreign market growth created by demand-pull policies
Lubik et al. (2013)	• Strategic orientation in manufacturing start-ups • Shift in their early development	• To focus on how the market-pull is applicable to start-ups in emerging industries	• Many of the start-ups beginning with a market-pull approach shifted to a technology-push approach

CONCLUSIONS

The available literature reveal that the strategic approach of manufacturing companies changes overtime and companies should balance technology-push and market-pull within their strategy. The technology-push companies often change to a market-pull approach and those having a market-pull approach shift to a technology-push approach. Further research in this area may be aimed at deploying the philosophy of integration of technology-push and demand-pull decisions to cater to the diverse requirements of a problem situation and a management process, in a flexible manner.Further, some new insights may be gained like how firms can successfully shift between or balance these approaches; how each approach works with partners and suppliers; how they manage manufacturing and outsourcing decisions; how they go about scaling-upand how to minimize success bias in future market-pull/technology-push approaches for ensuring sustainable development of manufacturing industry.

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Evaluating The Exploits Of Total Productive Maintenance Implementation In A Food Processing Industry

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ABSTRACT:-

The manufacturing industries have gone through significant transformation in last three decades and the competition has increased severely. Recent enhancement in the need of accessibility, security and quality along with cost of processing and maintaining, plays an important role in setting up a business. As a result, today industries are trying to increase their manufacturing efficiency by focusing on new inventions for realizing consistent improvement in manufacturing performance.The detailed case study on TPM implementation in food processing industry indicates that TPM is a strong contributor to an organization competitiveness and manufacturing performance. In fact TPM is a world class maintenance strategy used for achieving higher productivity through proper waste management. The main aim of this research is to study the TPM application idea followed by 'Food processing industry' and recognizing the different merits derived through various stages. The case study can give perception and help the other companies in the successful implementation of TPM in an effective way.

Introduction

The manufacturing industries have gone through significant change in last two three decades and the competition has increased dramatically (Ahuja and Khamba, 2008a). Since the industrial revolution in the 1700, companies have been striving to improve productivity. Later on the issue of quality became a focal point (Crosby, 1979).Consumers concentrate on the price, delivery and level of excellence of the item. Equipment, materials, money, physical environments and programs, which can be patterned in various ways (Triandis et al., 1994).Recent enhancements in the need of accessibility, security and quality along with cost of processing and maintaining, plays an important role in setting up a business.

The five performance objectives used by companies to stay competitive and to maintain their market share are speed, pricing, dependability, flexibility and quality (Pycraft et al., 2001).

Being the sub-parts of all these benchmark efforts, total productive maintenance (TPM), has emerged as a prominent competitive strategy in the field of manufacturing and maintenance. Globally, all industries are making efforts to gain large acquisition without changing the cost of their goods. This can be only achieved by controlling the cost of processing and productivity of the items and also by minimizing the flaws during manufacturing. The enhancement in the productivity can be gained by automation only if the machinery is well maintained. An industry, in order to sustain and succeed in the market should give importance to quality. Product quality is the product's ability to fulfill the expectations and needs set by the user. Manufacturing sector is not an exception to it. In fact the awareness towards quality is high in the manufacturing sector all over the world. Pertaining to quality and producing products with zero defects is one of the greatest challenges, the manufactures have been facing worldwide. However, by incorporating efficient quality control processes, their dreams have been turned into a possible reality in the recent days.

Total Productive Maintenance(TPM) Overview

TPM was basically originated in Japan, which includes workers at all stages of the organization for optimizing the efficiency of production machine through systematic machine sustenance. Under this management structure, every worker has to participate in eliminating manufacturing defects through machine restoration, aid, settings and by maintaining the machine in favorable working conditions. General improvements in quality and productivity and the creation of a more positive atmosphere in the workplace are also central to TPM philosophy (Shimbun, 1995; Ahuja and Khamba, 2008b).

TPM is planned to enhance machine efficiency by extending all machine related work force and all operators from the high officials to the machine operators, involving in this and thence organizing a inclusive Productive Maintenance structure along with promoting Productive Maintenance through voluntary small team actions wherein, all workers demonstrated commitment to keep the machine running and manufacture. (Tsuchiya, 1992; Leflar, 1999; Venkatesh et al., 2007).

Under TPM, workers responsibility is just not limited to equipment operation only, since they can analysis, clean, grease, adjust and even carry out simple calibrations without banking upon the technicians (Choubey, 2012). This helps technicians to utilize more time at higher level sustenance activities which requires more technical expertise. This provides the management with sufficient inputs regarding machine uptime, utilization and effectiveness. Thus TPM motivates everyone to realize the achievable goals of zero breakdowns enhance efficiency and zero losses.

1. **TPM House**

There are eight pillars of TPM and these pillars are set to acquire to nil defects. These include:

a) **JishuHozen (Autonomous Maintenance):** It means 'sustaining one's machine by oneself. This activity contains seven stages. It is a program which machine operators admit and share commitment for efficiency and condition of their machines in consultation with maintenance crew (Robinson and Ginder, 1995).

b) **Focused Improvement (Kobetsu Kaizen):** This pillar continuously improves the system even with employing small steps of improvement. It involves various techniques for ensuring improvement in the overall efficiency of the machines, operations and in industry through reduction in defects/flaws and performance enhancement (Suzuki, 1994).

c) **Planned Maintenance:** It focuses on enhancing machine availability and eliminating equipment breakdown. The aim of planned maintenance is to implement and sustain machine performance and its operations **(**Suzuki, 1994).

d) **Quality Maintenance (HinshitsuHozen):** It is the foundation of maintaining equipment conditions that eliminate the defects/flaws in production processes and endeavor to eliminate defects.

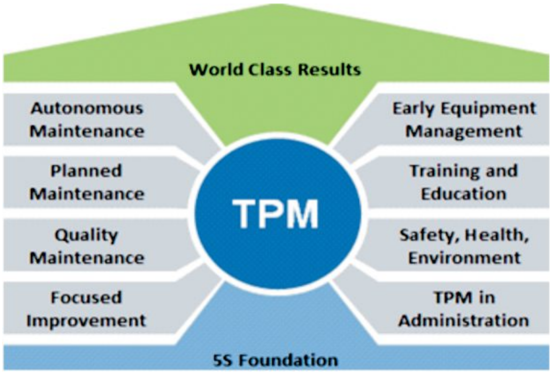
e) **Equipment Process Improvement (OEE):** The objective of TPM is to enhance overall machine efficiency (Waeyenbergh and Pintelon, 2002). An OEE calculation criterion is a significant way of inspecting the effectiveness of the plant equipment and production structure. (Nakajima, 1988)

f) **Education & Training:** Education & Training initiatives are aimed at developing independent operators who have capabilities and skills for autonomous maintenance.

g) **Safety, Health & Environment Pillar:** It involves formation of healthy and secure shop floor environment to eliminate hazardous conditions at workplace to make it motivating for employees.

h) **Office TPM:** It addresses flaws associated with production system by establishing appropriate and efficient work office procedures.

Some organizations add more pillars with respect to their shop floor: like information network and quality management. Figure depicts eight pillar methodologies for adopting TPM.



Literature Review

TPM is aimed at enhancing the equipment effectiveness over its entire life span by adopting a strategic productive maintenance system with the cooperation of all employees from top officials to machine operators (Bamber et al., 1999). The literature reveals two different schools of thought to explain TPM, the Japanese TPM approach and the Westward approach, with significant commonality between two approaches. The Japanese TPM approach is represented by Nakajima (1988),Tajiri and Gotoh (1992) and Shirose (1996); while the westward strategy has been defined by Wireman (1991);Hartmann (1992); and Willmott (1994). The TPM endeavors to actualize flawless production. The Japanese TPM strategy has been envisaged by Japanese Institute of Plant Maintenance (JIPM).

The literature review reveals that TPM is a missing link in successfully achieving not only world class equipment performance to support TQM/TQC and JIT, but is powerful new management tool for improving overall company performance. TPM is used very successfully widely in Japan and Europe but now is implemented in industries of America and India in a successful manner. Thus to study the success factors of implementation of TPM in Indian industry is the need to motivate more industries to deploy TPM practices. Total implementation of TPM means to use all the eight pillars, but most of the industries are either deploying only some pillars or are implementing eight pillars in phases. The impact of TPM program on manufacturing performance depends on the way of implementation of the TPM pillars and has to study exclusively.

Case study

TPM implementation in food processing industry with vision to continue to be the fastest growing convenient food company in India by delighting the hearts and minds of all stakeholders with commitment to deliver sustained growth through empowered people and further with this the company gained extraordinary results.

The following situations necessitated the adoption of TPM initiatives at the manufacturing unit: Poor Team Work among operators, only routine jobs; No systematic approach to attach the Losses; Higher breakdowns, poor basic conditions of the machines-123 Occurrences; Low morale among operators and Higher safety incidences at work centers

After analyzing the existing conditions of the plant various goals had been setup. TPM organizational team was formulated for the implementation of TPM for promoting and sustaining TPM activities. This organizational team involves all company officials and workers. To achieve the overall organizational goals, the company established TPM policies, objectives, targets, organizational structures, as well as all necessary procedure, so that everything should be clear to everyone involved in TPM implementation.

The management envisaged the following TPM implementation policy to achieve overall organizational goals:

- To provide products of consistent quality and defect free in every bag.
- To achieve world class service levels and appropriate partners economics.
- Laser focus on costs, efficiencies and productivity gains.
- Building a culture of total employee involvement where every single employee can make difference.
- Driving the safety, health and environment agenda with passion and impact.

TPM kick-off was held in 'Benchmark Year1' and very good benefits were achieved by the company fro 'Target Year 4' onwards. The implementation of all the eight pillars brought very encouraging and improved results.

TPM DEVELOPMENT AND IMPLEMENTATION

After analyzing the existing conditions of the plant various goals had been setup. TPM organizational team was formulated for the implementation of TPM for promoting and sustaining TPM activities. This organizational team involves all company officials and workers. To achieve the overall organizational goals, the company established TPM policies, objectives, targets, organizational structures, as well as all necessary procedure, so that everything should be clear to everyone involved in TPM implementation.

TPM INVESTMENT VS SAVING

TPM was implemented in the plant and a fair amount of Investment done or TPM promotion and modification activities. The major heads o expanses are kickoff, are kickoff, Training Center, Machine Modification, TPM promotion etc.

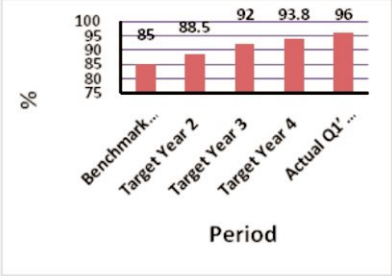
modification activities. The major heads o expanses are kickoff, are kickoff, Training Center, Machine Modification, TPM promotion etc.

All the savings are calculated in the form of savings in major losses. Savings has been generated through Increase in Productivity, Reduction in Breakdown, Wastage Reduction, and Utility Cost Reduction. The organizations achieved the improvements through task Force Approach, applied various TPM tools.

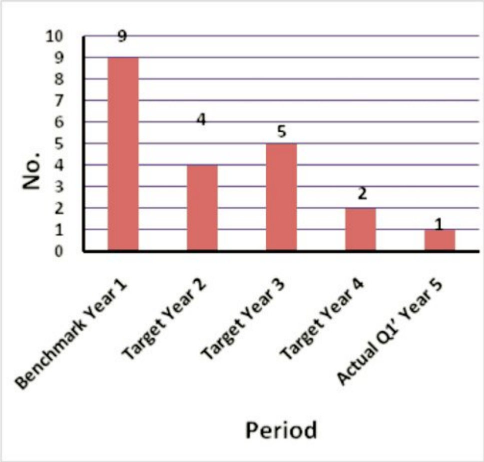
Total Investment: Rs 5.0 Million
Total Savings: Rs 35 Million
Savings =7xInvestments

OVERALL ORGANIZATIONAL ACHIEVEMENTS

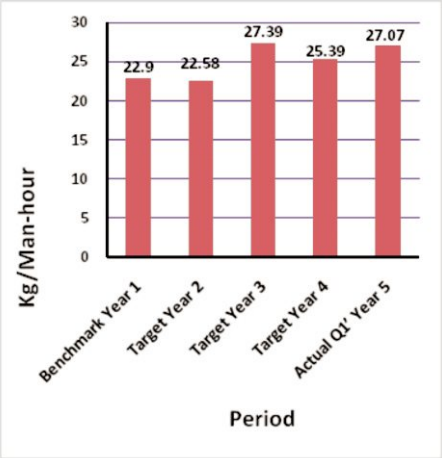
1. 13% improvement in process OEE



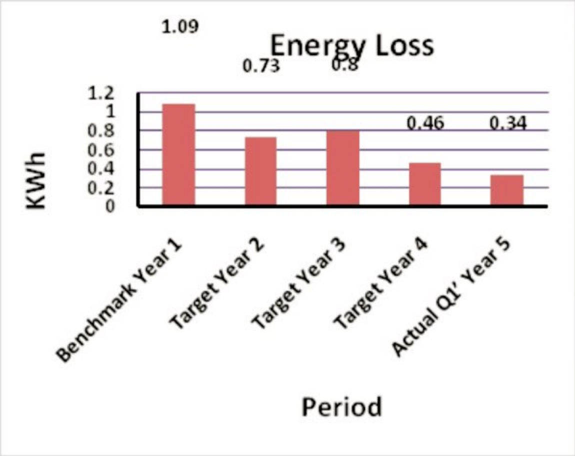
2. 89% Reduction in Regulatory Complaints



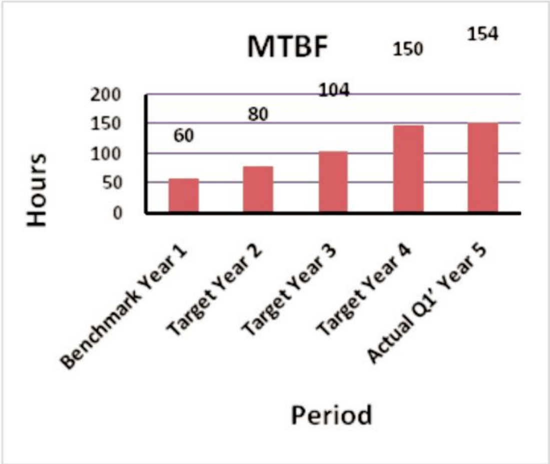
3. 18% Improvement in Manpower Productivity



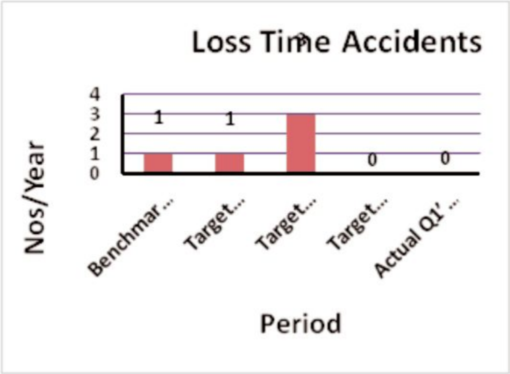
1. 69% Reduction in Energy Loss over benchmark Year



5. 157 % Improvement in MTBF Over benchmark Year



6. No Loss Time Accidents (LTA) since Target Year 3



Results Achieved

Increase in the ownership of equipment and workplace by the operators.

Increase in confidence by operators and staff.

Development of clean, dry and visual workplaces.

Appreciation from customers and other visitors during plant visits.

Increase in team spirit.

Increase in skill ability of operators.

Conclusions

The case study on TPM implementation food processing industry indicates that TPM is a strong contributor to an organization competitiveness and manufacturing performance. In fact TPM is a world class maintenance strategy used for achieving higher productivity through proper waste management.

Effects of TPM implementation in Frito-lays:

1. Self maintenance of the machines by the operators.
2. Confidence of the workers increased with the attainment of zero defects and breakdowns.
3. Workplaces that used to be covered with oil are now so clean and pleasant as to be almost unrecognizable
4. Improvement in the company status, resulting in the increase of orders

The company afterwards getting TPM excellence award on Target Year 5, became the fastest growing convenient food company of India.It is clear from the case study that implementation of TPM can bring in commendable reforms and important improvement in respect of productivity and quality, further a good decrease in labor costs are the prime benefits which the company achieved in the target period.Optimization of Preventive maintenance cost is also to be looked in for improving effectiveness. Once effectiveness of TPM implementation is reached at Benchmark and remains constant for an observable period of time than the next level of Benchmark could be set for further improvement in operations. It must be always kept in mind that there proper way of doing work, when applied for measuring effectiveness of TPM implementation in manufacturing operation

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Design And Optimization Of Rod Bending Machine

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ABSTRACT

This paper presents the real time study of mechanism of rod bending machine. The rod bending machine used to bend an 11mm diameter and 450 mm long EN 8 material rod. The machine used rack and pinion mechanism connected to a hydraulic jack powered by a hydraulic pump to bend the rod. 5HP pump is used in existing machine in a local industry in Mohali. In this research this machine is analyzed and optimized in SolidWorks software. The real time study is carried out by applying a liner motion motor to piston cylinder. Motion analysis is performed by running the mechanism at 10 revolutions per minute for four seconds. Theoretical calculations are made to obtain allowable stress by making use of design data values. The new design has reduced the power requirement to 3HP from 5HP. As a result, response of hydraulic jack, rack and pinion is investigated to find the permissible speed of mechanism. Further simulation is performed to verify the motion analysis results.

Keywords: simulation, Machine Design Theory and solidworks.

INTODUCTION

An essential requirement of the present world is to achieve the objectives with maximum efficiency at minimum cost. This requires least manufacturing cost of replacement when any instrument fails. And also that it performs the intended function at a higher efficiency. As the hydraulic fluid is very powerful way of motion transfer than pneumatic and electrical actuators. In this project work we use hydraulic power to bend the EN8 material rod having 11mm diameter and 18 inches long. The main components used in rod bending machine are hydraulic pump, fluid reservoir, pipes, DC valves, pressure gauges, hydraulic jack, rack and pinion arrangement fitted in a table. Hydraulic pump operates hydraulic jack which is further connected to rack and then rack transfer motion to gears, gears move the handle in which the rod is inserted in this way the machine bends the rod. In single stroke of piston cylinder the machine bends two rod simultaneously.

The design and motion study of various mechanical parts has been studied for several years. Eltantawie carried out the Design, manufacture and Simulate a Hydraulic bending Pressa small hydraulic press for V-bending operation is designed. Bardiya et al performed Analysis and Simulation of Gearless Transmission Mechanism. Gonzalez et alstudied A Multipurpose Control System for Hydraulic Applications.Situm Studied Force and Position Control of a Hydraulic Press [4]. Barbieri et al studied Optimization Method for Spur Gear Dynamics. Kumar et al studied Optimization of design based on Filletradius and tooth width to minimize the stresses on the Spur Gear with FE Analysis.DataDesign Book by Mahandavan.

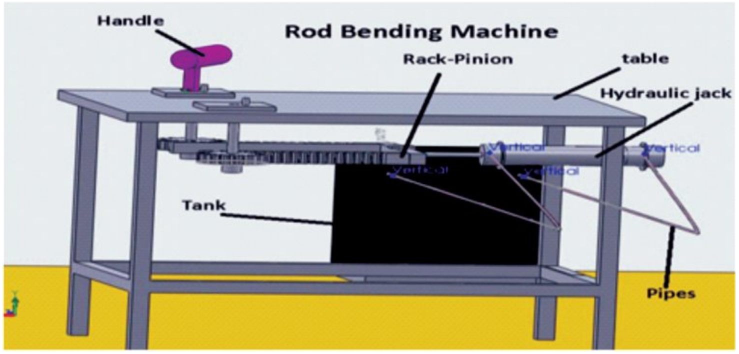


Figure no. 1

Specification of the problem

The objective of the present work is to eliminate operation difficulty, power consumption of old model of rod bending machine and to design the more efficient and compact rod bending machine. Design simulation flow chart is shown in figure 2.

Methodology

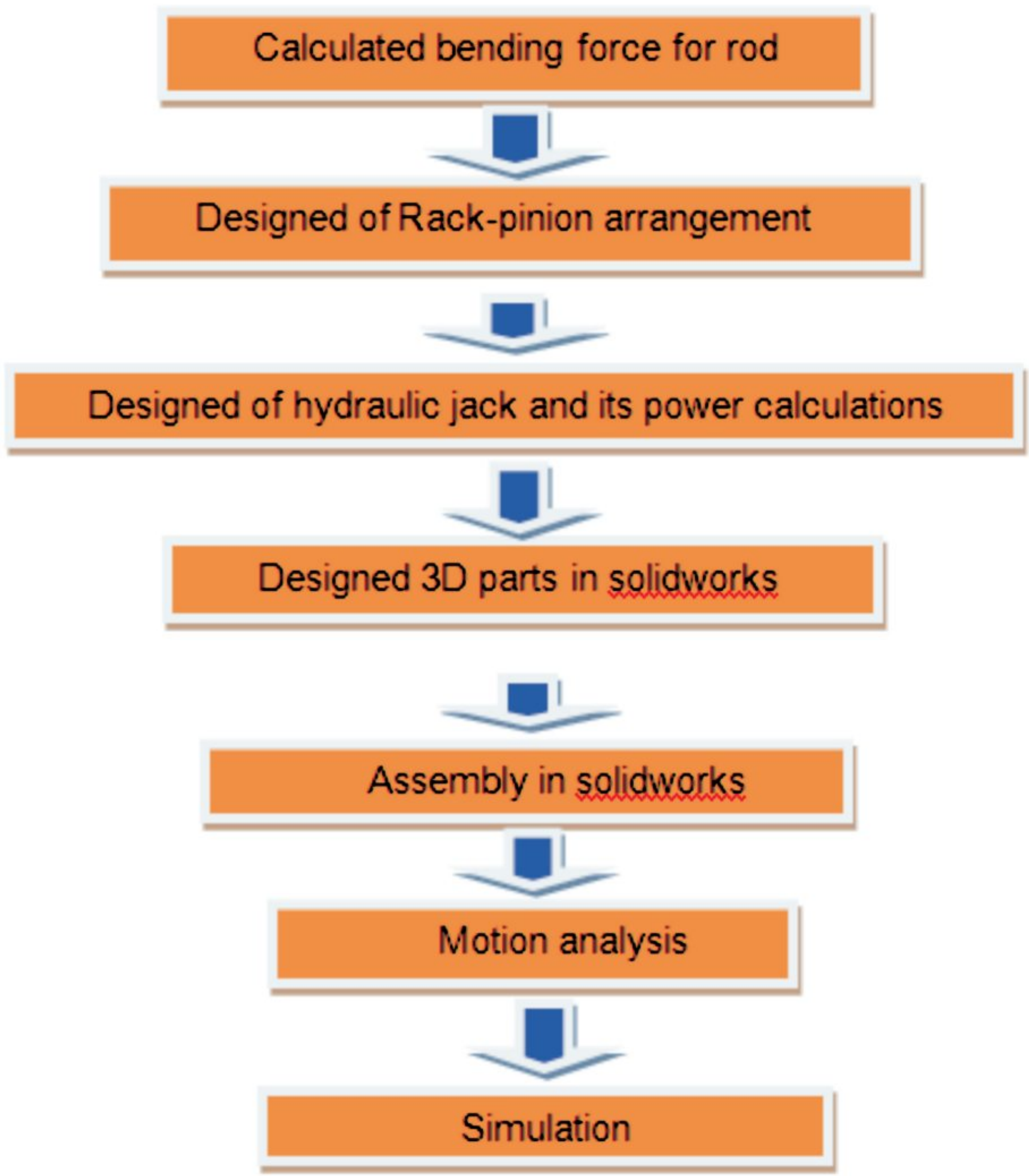


Figure 2: Flow chart for design simulation

Rod Parameters and Bending Force

Table no. 1

Particular	Values
Material of Rod	EN8
Length of Rod	450mm
Diameter of Rod	11mm
Tensile Stress	245×10^{6}N/m^{2}
Bending Force	111702.36N

Calculation of Bending Force

The EN8 material rod is 11 mm thick and 450 mm long. It is a soft grade EN8 material with yield stress 245 MPa =245×10^{6} N/m^{2}.

The bending force for the same material =$\Pi d^{2}\times\sigma_{y}$…… [1]

Where σ_{y} is yield stress

From [1] Bending force = 93085.3 N

Consider 1.2 times losses =93085.3×1.2 =111702.36 N is the force needed to bend the specimen

Now bending torque T = Bending force ×radius of rod

T = 614.36 Nm

Now Power required

Here rpm is 10

$$P = \frac{T(Nm)\times n(rpm)}{4549}$$

From [2] P =1.35Kw or 1350.53 W or 1350.53 N-m/sec

Hence 1.35Kw is the power required to bend 1 rod to bend two rod power becomes double i.e 1.35×2 =2.70 Kw

Design of gear dimensions at Pitch circle 150mm andStandard pressure angle 20^{0}

No. of teeth can be calculated [7].

$$Z = \frac{2k1}{\sin\alpha^{2}}$$

Form [3] Z is 18 teeth

$$P = \frac{z}{d}$$

$$m = \frac{d}{z}$$

Module

D_b=dcosα here D_b is base circle diameter.

The dedendum circle diameter $D_r = d-2(t_f+t_c-k')m$.......[4]

Here t_f is tooth factor=1 (standard)

t_c=tooth clearance factor

k' is correction factor

From [4] D_r=mz-2.5m =124mm

Diameter of addendum circle d_0=d+2m=166mm

Power transmitting capacity of spur gear $P = \frac{Ftv}{100}$

Here F_t is driving force and v is pitch line velocity.

$F_t = \sigma byp = \sigma_d c_v byp$ here σ_d is allowable stress.

c_v- velocity factor , b is face width , y is Lewis form factor and p is circular pitch of gear

Now from [4] F_t = 5883.57N

Radial Force $F_r = F_t \tan\alpha$......[5]

From [5] F_r = 2141.4N

Design of Rack and Pinion

Figure no.3 Rack and pinion mechanism

Table no. 2

Design of Rack	Length 400mm, Breath 50mm, Height50mm, Circular Pitch 25.12mm Addendum a 8mm, Dedendum 10mm, Tooth Thickness 12.56, working depth 16mm, Face width 48mm and Clearance 2mm
Gear Design	Pitch Circle Dia. 150mm, No. of teeth 18, module 8.33mm/teeth, Base circle Dia. 140mm, Tooth factor is 1,deddendum circle dia. 124 mm, Addendum circle dia. 166mm , working depth 16mm, fillet radius 3.2mm, tooth thickness 12.56mm and good grade cast iron is used

Design of Hydraulic Jack

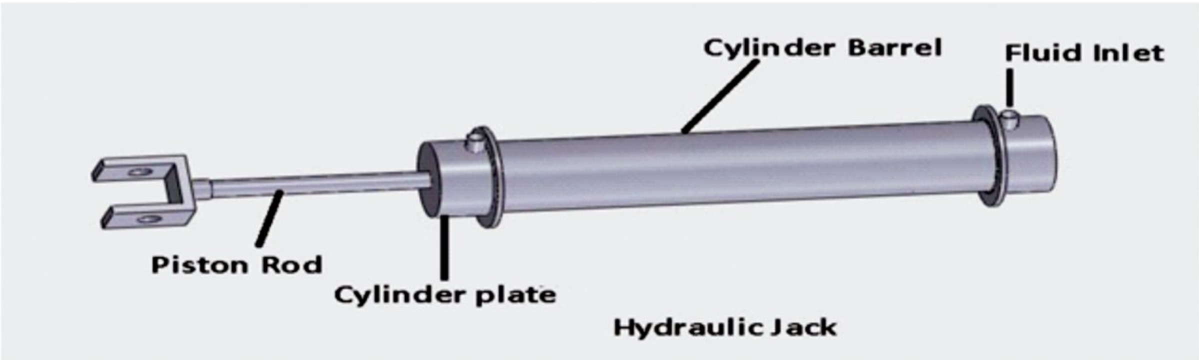


Figure no. 4 Hydraulic jack

[8] The relationship between force on stroke, pressure and radius as follows

$$F_r = P(\pi r^2)$$

Here F_r is resultant force , P is pressure distributed load on surface and r is radius of piston .

The power developed by a hydraulic cylinder equal to the product of its force and velocity.

Power = PxQin

$$\text{Power} \quad \frac{Q(gpm) \times P(psi)}{1714} \quad (HP)$$

Operating pressure is calculated from [7]

474723.16 Pa

Power Calculations and Specification of Hydraulic Cylinder

Table no. 3

Measurement of Cylinder	Dia. 80mm, Length 470mm,
Measurement of piston Rod	Dia. 20mm, Length 490mm
Operating Pressure	474723.16 Pa

Designed 3D parts in Solidworks

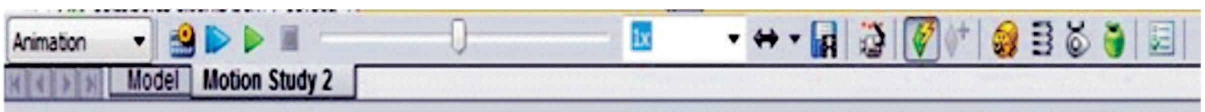
All the components are modeled on SolidWorks software under 3D part workbench. It is assumed that every single component is a rigid body.

Assembly

Parts already modeled are assembled together in sequence to achieve a constraint mechanism. Concentric mate is used between parts having relative motion forming a turning pair. Lock mate is also used between gear and shaft.

Motion Analysis

The basic requirement of motion analysis is to setup a motor (driving element). **Motion analysis is performed by running the mechanism at 10 revolutions per minute for four seconds.**



Simulation

A SolidWorks simulation feature is used to find out the minimum bending stress for rod and **to verify the motion analysis results.**

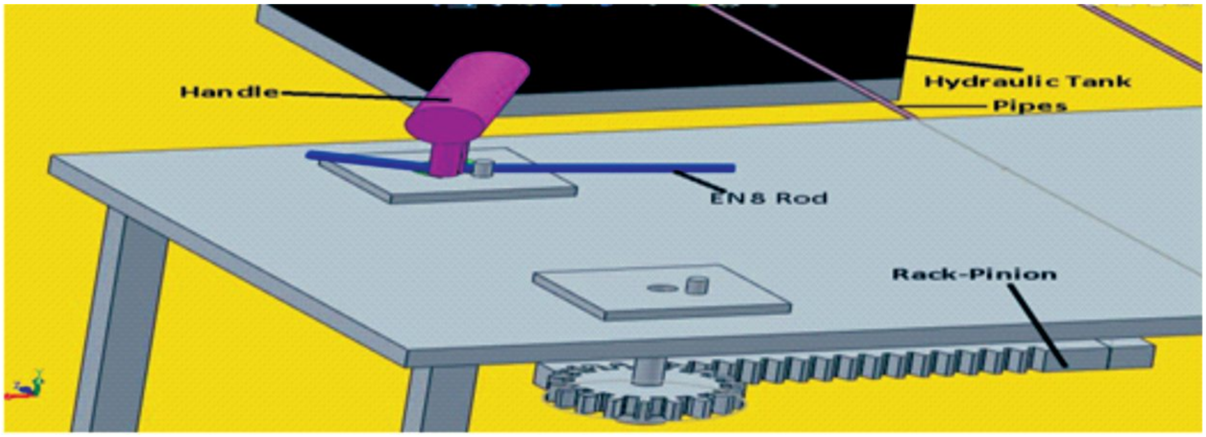


Figure no.6 Bending analysis

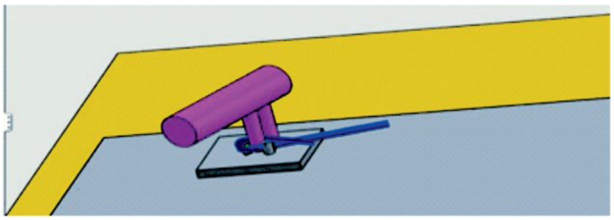


Figure no.7Bending analysis

Simulation is performed by importing motion loads to the component. Motion loads acts on component as dynamic loads. Hence simulation performs dynamic analysis of mechanism. Post processing generates results as shown in the snapshots, fig. no. 6 and 7.

Results and Discussion

It becomes quite clear from the analysis that 2 HP pump is sufficient to bend the EN8 material rod very efficiently at 10 revolutions per minute of motor. SolidWorks simulation helps in getting a clear picture of dynamic analysis of rod, stresses valueand bending force .Thus simulation results satisfy motion analysis results.

Conclusions

Rod bending machine mechanism has been analyzed on SolidWorks software using SolidWorks post processor with the application of motor torque with defined rpm 10 for 4 seconds. Thus system designed is very precise and very easy in handling.

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Development Of Plasma Nitriding On Aisi H13 Steel And Its Characterization

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ABSTRACT:

In this research work plasma nitriding was developed on AISI H13 hot forming tool steel. The specimens were heat treated prior to plasma nitriding. The main plasma nitriding parameters in the process were: substrate temperature-500°C; nitriding time-24 hours; pressure-5mbar; voltage-500 V, gas composition-N2/H2 20:80; duty cycle of 80%, and the frequency used was 30-KHZ. The cross-sectional microstructures of the plasma nitrided specimens were examined by optical microscopy (OM).A diffusion layer was formed on the material by controlling the nitriding parameters but no white layer was observed during the optical microscopy. Microhardness measurements were performed on the surface and through the diffusion layer for each nitrided material. The as-nitrided specimens were characterized by X-ray diffraction (XRD) analysis and Scanning Electron Microscopy/Electron Dispersive Spectroscopy (SEM/EDS) analysis. The results showed the increased hardness of tool steel with nitrided layer. Further, the cross-sectional SEM micrographs showed the intact and pores free outer nitrided layer in the specimens.

Keywords*:* Plasma nitriding, hot working tool steel, SEM/EDS and XRD analysis.

INTRODUCTION

AISI H13 hot working tool steel combines good red hardness and abrasion resistance with the ability to resist heat checking. It is an AISI H13 hot work tool steel, the most widely used steel for aluminum and zinc die casting dies. It is also popular for extrusion press tooling because of its ability to withstand drastic cooling from high operating temperatures. H13 is produced from vacuum degassed tool steel ingots [Tayeb].This manufacturing practice plus carefully controlled hot working provides optimum uniformity, consistent response to heat treatment, and long service life [Wang]. H13 is an outstanding die steel for die casting aluminum and manganese.It is used for zinc in long production runs, and also employed successfully for slides and cores in tool assemblies [Rad]. H13 in the hardness ranges from 45/52 RC is excellent steel for plastic molds. Consider using this grade of hot work tool steel for applications where drastic cooling is required during the operation, and where high red hardness and resistance to heat checking are important. This grade has found wide acceptance for die casting dies for zinc, white metal, aluminum and magnesium. It is also widely used for extrusion dies, trimmer dies, gripper dies, hot shear blades, casings, and other similar hot work applications [Walkowicz].Apart from all these advantageous applications when H13 tool steel is to be processed under savere loading conditions it does not retain its surface hardness and results into wear at the contact surface of steel [Walkowicz]. Therefore to overcome this limitation surface treatment and coating are developed at the surface of steel so as to increase its hardness and wear resistance properties. Plasma nitriding is one of the surface treatment process in which nitrogen ions are introduced on the surface of material. But before starting with the plasma nitriding process the surface of the material needs to be heat treated so as to avoid the problem of decarburizing [Ochoa].

Experimental Details

Substrate Material

In this experiment commercially available steel AISI H13 which is mostly used for hot working applications was considered as a substrate material. **The chemical composition (weight%) of the steel is** 0.38 C, 0.30 Mn, 0.03 P, 0.02 max S, 1.0 Si, 5.3 Cr, 0.2 Ni, 1.3 Mo, 0.4 V and 0.22 Cu. The tool steel specimens in the dimensions of 8mm diameter and 50mm length were machined from the base material with the help of linear precision saw at a blade speed of 900rpm (BUEHLER Isomet) Fig. 1.

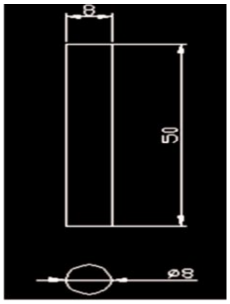

Figure 1- Macrograph of AISI H13 tool steel

Heat Treatment Details and Procedure

It was found from various studies that heat treatment is required before Plasma Nitriding. The same was ensured after discussions with actual industries in Ludhiana. Therefore to increase the hardness to some extent, heat treatment was performed. This was done at Central Tool Room, Ludhiana. The specimens were austenized at 1020℃ for 30 min, quenched in air and then tempered at 520℃ for 1hour in air. The hardness of the substrate was 22HRC before heat treatment and it increased to 48/49 HRC. Afterwards, the surface of the pins were ground by using SiC emery papers to 240, 320, 400, 600, and 1000 grit size. The final mirror polishing of the specimens was done by using 6 μm and 1μm diamond paste in the presence of water on double disc polishing machine prior to Plasma Nitriding.

Plasma Nitriding

Plasma nitriding is the nitrogen diffusion process on the subsurface on the steel components. Typical applications include gears, crankshafts, camshafts, cam followers, valve parts, extruder screws, pressure-die-casting tools, forging dies, cold forming tools, injectors and plastic-mould tools, long shafts, axis, clutch and engine parts [Leite]. It was developed at Facilitation Centre for Industrial Plasma Technologies, Institute for Plasma Research (IPR) Gujarat, India. The samples were nitrided in a hot well plasma nitriding apparatus with 80% duty cycle nitriding time-24 hours; pressure-5mbar; voltage-500 V, gas composition-N2/H2 20:80; and the frequency used is 30-KHZ and the nitriding temperatures is taken as 500℃. The Plasma nitriding hot wall system specifications are given in Table 1. The schematic diagramof Plasma Nitriding set up is shown in Figure 2.

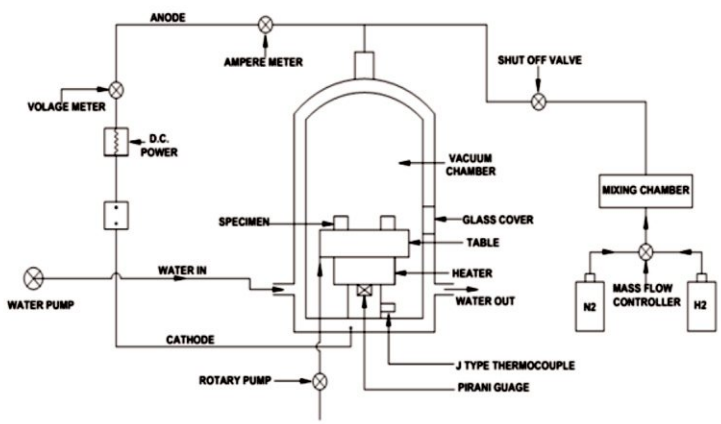

Figure 2- Schematic Diagram of Plasma Nitriding Set Up

Procedure:

Step 1- Loading of the samples was dome inside the chamber. The samples were cleaned in acetone, placed in proper sequence and at exact distance. The chamber was closed properly.

Step2- The vacuum chamber was evacuated. The pressure inside the chamber should be below 0.09 mbar.

Step 3- Sputter cleaning was done to remove the surface contaminates from the surface of the specimens for 30 minutes by introducing H_2 gas inside the chamber at temperature 250°C and pressure 0.9mbar.

Step 4- Introduce N2 and H2 inside the chamber at 20:80 till pressure 5 mbar is attained.

Step 5- Reaching to the required temperature-500℃ by slowly increasing the voltage and duty cycle up to 80%.

Step 6- After reaching the required temperature, hold for Plasma nitriding for required time. The time is this study was planned for 24 hours. Maintain the temperature by regulating the voltage of the D.C. source.

Step7- After completion, the D.C. power source is off and the chamber left for cooling.

Step8- H_2 gas flow was stopped for hazards and continued the N_2 gas flow for fast cooling at the time of cooling. The chamber was not opened before 180°C temperature for avoiding oxidation at atmospheric gasses. The Figure 3 shows the Plasma Nitriding inside chamber.

Nitriding temperature	500°C
Diameter	500mm
Height	500mm
Working diameter	400mm
Working height	300mm
Working capacity	50kg
DC pulse power supply	20KW
Heater power capacity	5KW
Cooling	only for O ring

Table 1- Plasma Nitriding System Specifications

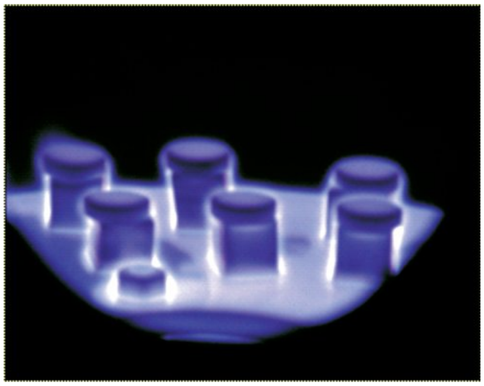

Figure 3- Plasma Nitriding inside chamber

Results and Discussion

Optical Microstructure

The optical microstructure of plasma nitrided layer showed the presence of nitrided layer which is approximately 125 μm thick. This is called case depth of the nitrided layer [Grill]. It showed formation of diffusion layer on the surface. There was no formation of whitelayer or compound layer on the cross section of the sample. In the plasma nitrided sample the presence of diffusion layer is due to the formation of various phases like $F_{e4}N$ and C_rN etc during plasma nitriding process [Priest]. Surface and cross-sectional microstructures of the nitrided specimens were examined by optical microscopy (OM). The nitrided specimens were sectioned with a diamond cutter (BAINCUT-LSS, Metallography Low Speed Saw, Chennai Metco Pvt. Ltd., Chennai, India). Thereafter, the cut sections were hot mounted in BAINMOUNT-H (Hydraulic Mounting Press, Chennai Metco Pvt. Ltd., Chennai, India) with transoptic powder so as to show their cross-sectional details. This was followed by polishing of the mounted specimens by a belt sanding machine having emery belt (180 grit). The specimens were then polished manually down to 1000 grit using SiC emery papers. Final polishing was carried out using cloth wheel polishing machine with 1 μm lavigated alumina powder suspension. Specimens were then washed and dried before being examined under Inverted Optical Microscope interfaced with imaging software Envision 3.0. The same microscope was used to obtain surface microstructures of the coatings. The metallographic studies were conducted at Mechanical Engineering Department (MED), Baba Banda Singh Bahadur Engineering College (BBSBEC), Fatehgarh Sahib, India.

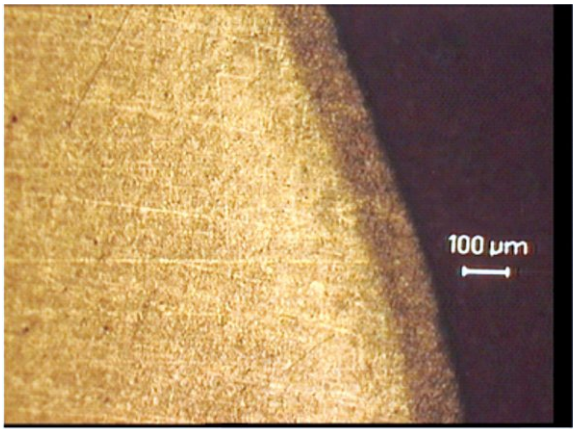

Figure 4: Optical microstructure of H13 steel

3.2 SEM/EDS Analysis of Plasma Nitrided H13 Steels

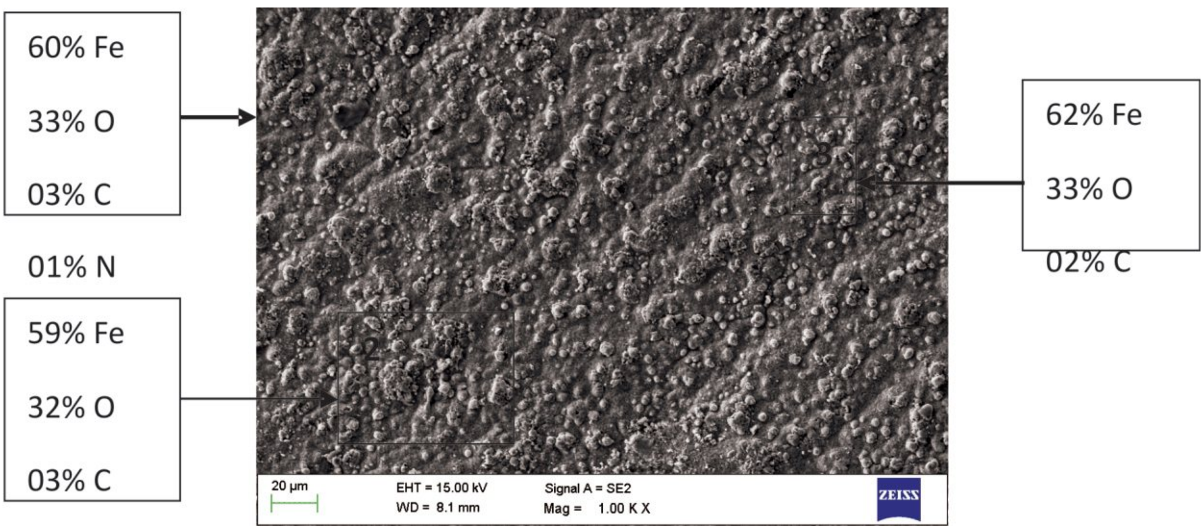

Figure 5- The SEM morphology and EDS analysis of top plasma nitride surface layer.

The FE-SEM-EDS micrographs are shown in Fig. 4. The nitride layer depicts the morphology consisting mainly spongy nodules homogeneously dispersed in the gray matrix. The EDS analysis indicates that the nodules are rich in O. N, Cr and C are found in minor percentages.

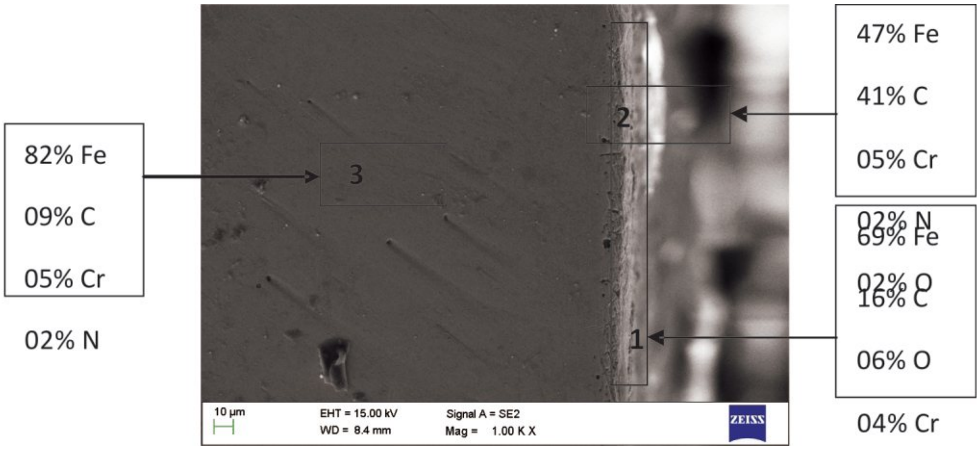

Figure 6- The SEM morphology and EDS analysis of cross section

Microhardness Measurement

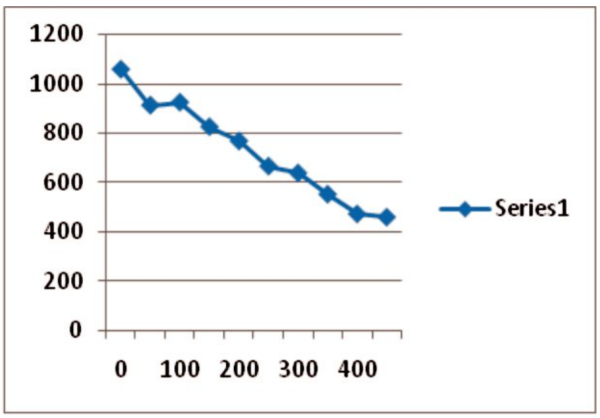

Figure 7- Microhardness profile of Plasma Nitrided layer along the cross-section on AISI H13 steel at 500°C with 80:20-H2:N2.

Figure 7 shows the microhardness profile of Plasma nitride layer along the depth. The microhardness of the nitrided H13 sample was measured along the depth of the nitrided layer along the cross-section. Microhardness value1045 HV was achieved in the outermost layer. Thereafter, the value goes on decreasing towards the inner core of the sample. Therefore, from this case-depth analysis, it is clear that the nitride layer is developed with increased properties.Microhardness of the plasma nitrided sample was measured by SHV-1000, Digital Micro Vikers hardness Tester, Made by **Chennai Metco Pvt. Ltd.**, Chennai, India. 2.942N load was applied on the square pyramidal diamond indenter for penetration and the hardness values were based on the relation $Hv = 0.1891 \times \frac{F}{d^2}$ (Where F is load in N and d is the mean of the indentation diagonal length in mm). Each reported value of the microhardness is a mean of three observations. These microhardness values are plotted as a function of distance from the nitrided/substrate interface. This analysis was carried out at MED, BBSBEC, Fatehgarh Sahib, Punjab (India).

X-Ray Diffraction (XRD) Analysis

The Plasma nitrided specimens were subjected to XRD analysis to identify various phases formed on their surfaces. Diffraction patterns were obtained by Bruker AXS D-8 Advance Diffractometer (Germany) with CuK_α radiation and nickel filter at 20 mA under a voltage of 35 kV. The analysis was carried out at Institute Instrumentation Centre (IIC), Indian Institute of Technology Roorkee (IITR), Roorkee (India). The specimens were scanned with a scanning speed of 1 kcps in 2θ range of 35 to 90°and the intensities were recorded at a chart speed of 1 cm/min with 2°/min as Goniometer speed. Assuming height of the most prominent peak as 100%, the relative intensities were calculated for all the peaks. The diffractometer interfaced with Bruker DIFFRAC^{plus} X-Ray diffraction software provides'd' values directly on the diffraction pattern. These'd' values were then used for identification of various phases with the help of inorganic ASTM X-Ray diffraction data cards.Figure 6 shows XRD profiles of the nitriding samples with 24h and 500˚C. It can be seen from Figure 5that the nitrided layer consist of Fe3N (ε), Fe4N (γ'), phases in all samples which were plasma nitrided at 24h.

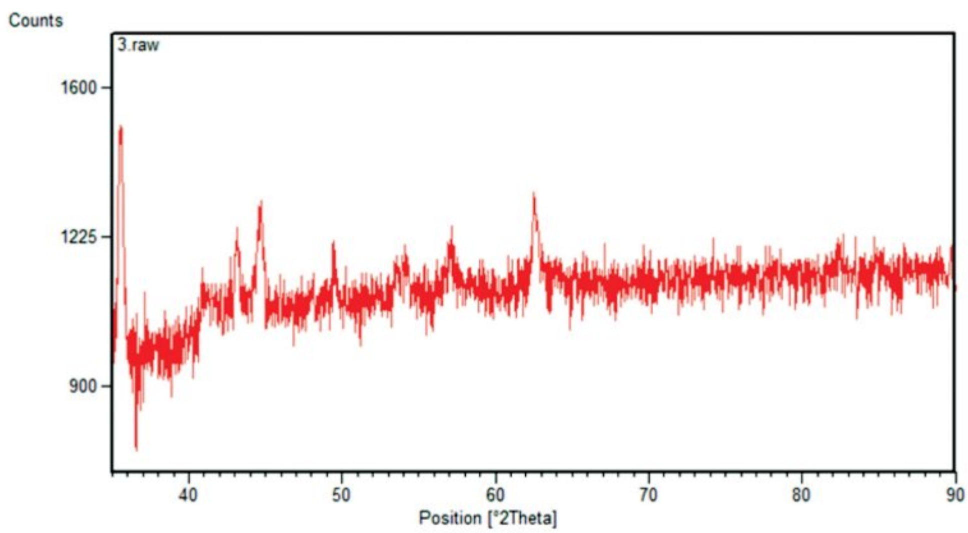

Figure 8. X-ray diffraction pattern for plasma nitrided H13 tool steel at 500°C for 24h.

Surface Roughness Measurement

The surface roughness of the substrate material when measured with standard surface roughness tester was having average surface roughness value as 0.96µm.The aim of this work was to improve the wear properties of the AISI-H13 hot-work tool steel, so that the life enhancement of hot working tool steels could be achieved [Staines]. For 24 hours of plasma-nitriding treatment hardness versus nitriding time data given in Figure 6. This suggests that the life of hot working tool steel is controlled by their surface hardness. This is not surprising, since under repeated high impact loads and varying temperatures, which lead to mechanical and thermal fatigue, wear is controlled by the surface hardness of the materials [Edenhofer]. Figure 4 shows the SEM image of the material ion-nitrided for 24 hours). The surface roughness of the plasma nitrided material was improved after the plasma nitrided process; therefore it is very much clear that nitriding helps to improve the surface properties of the material [ochoa].

Conclusions

From the results it can be concluded that plasma nitriding of AISI H11 steel improved the surface properties of material.

The hardness of the as received material was about 260 HV and after the heat treatment process it was about 540 HV.

Surface hardness of material reached to a maximum value of about 1089 HV0.1 after a time period of 24 hrs and at a temperature of 500°C.

Plasma nitriding results into formation of diffusion layer only without the formation of white (compound) layer.

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Effect Of Process Parameters On Surface Finish During Magnetic Abrasive Finishing Of Brass Pipe By Using Sic Abrasive

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Abstract

Magnetic abrasive finishing (MAF) is relatively a new finishing technique in which magnetic abrasives particles are used for finishing &deburring operations. In the present research, it is aimed to examine the potency of using SiC abrasive with ferromagnetic particles, as a multipoint cutting tool in Magnetic abrasive finishing (MAF), for optimizing surface finishing of brass alloy pipe CuZn35. The various process parameters used in MAF were: Input current, the percentage composition of SiC powder with ferromagnetic particles (Fe & Steel), grit size of SiC abrasive. Taguchi L9 orthogonal array technique was adopted for evaluating the effect of the process parameters on the improvement of the surface finish. The critical analysis of the study was performed by using MINTAB17 software. In the current study, percentage composition of SiC abrasive with ferromagnetic particles is found to be the most significant factor for the improvement of surface finish of brass pipe. Optimum parameters for best surface finish are: 150 grit size of SiC abrasive, 4 amperes input current, 25% of SiCabrasive with ferromagnetic particles.

Keywords: Magnetic abrasive finishing, Surface finish, FMAB, Taguchiapproach.

INTRODUCTION

The surface quality of a part or a component has become a key property in mechanical manufacture with the improvement of manufacturing precision. Surface quality is a remarkable factor for vital properties, such as power losses due to friction and wear resistances, in many of the engineering components and is required at higher demand in wide range of industrial applications. Several techniques of surface finishing are used for final production of advanced materials with complicated shapes [*Djavanroodi 2013*].

Smoothly finished inner pipe surfaces are necessary to prevent the contamination of gas and liquid in high purity piping systems for critical applications like medical instruments, aerospace systems, nuclear energy parts, and semi-conductor plants. Polishing of these precise surfaces need very high costs and a controlled atmosphere during polishing [*Jain 2010*].Amongst them sanitary tubes, vacuum tubes and wave guides are difficult to finish by conventional finishing methods such as lapping, because of their geometry. The performance of entire system is affected by surface roughness of these tubes, but the finishing technology for these tubes is very scant in manufacturing fields [*Wang et al 2005*].

The other problems with traditional machining process is the development of new materials and alloys with ever increasing hardness, high strength, remarkable toughness, high heat resistance and high wear resistance [*Cheung et al 2008*].

With the increasing demand of high surface finish and machining of complex geometry shapes, non-conventional machining processes have overcome conventional machining process [*Jayakumar 2004*].The reason for the huge success of NTM is that there is no direct contact between tool and work piece which results in the reduced tool forces on the work piece. The application of this unorthodox machining is mainly in airplane industry, atomic power plants, automobile industry, turbine piping, die and tool making industries [*Tae-Wan Kim et al 2010*].

The other problems with traditional machining process is the development of new materials and alloys with ever increasing hardness, high strength, remarkable toughness, high heat resistance and high wear resistance [*Liu et al 2013*].

LITERATUREREVIEW

Magnetic abrasive machining for internal finishing of SUS 304 stainless steel tube using mixed type magnetic abrasives was performed. In mixed type magnetic abrasives large iron particles (80μm), generating high pressure is mixed with small magnetic abrasives (10μm) .It is concluded that by the use of mixed type abrasives, surface roughness is decreased from 0.7μm to 0.2μm [v et al 1995].

[*Jain et al 2001*]designed a setup for finishing cylindrical work pieces and it was mounted on lathe machine. The loosely bounded magnetic abrasives were a mechanical mixture of Alumina (25.7μm) and ferromagnetic particles (51.4μm) with servospin-12 lubricant oil. The magnetic field strength generated was 0-0.35 tesla and varied by changing input current. They investigate the effects of working gap and circumferential speed on material removal, change in surface finish and percent improvement in surface finish. The results showed that material removal decreases by increasing working gap or by decreasing circumferential speed of the work piece.

[*Singh et al 2004*] applied Taguchi design of experiments to find out important parameters influencing the surface quality generated. It is concluded that, voltage is found to be the most significant parameter followed by working gap. However, the effects of grain mesh number, and rotational speed seems to be very small. From the main effects of the process parameters, it is observed that within the range of parameters evaluated, a high level of voltage (11.5 V), a low level of working gap (1.25 mm), a high level of rotational speed (180 rpm), and a high level of grain mesh number are desirable for improving ΔRa. To analyze the finishing process, a force transducer was designed and fabricated to measure forces acting during MAF.

[*Jayswal et al 2005*]studied the theoretical investigations of the MAF process. A finite element model of the process was developed to evaluate to distribution of magnetic forces on the work piece surface. The MAF process removes very small amount of material indentation and the rotation of magnetic abrasive particles in circular tracks. A theoretical model for material removing and surface roughness was also proposed accounting for micro cutting by considering a uniform surface profile without statistical distribution.

Numerical experiments were carried out by providing different routs of intermittent motion to the tool. The simulation results were verified by comparing them experimental results.

EXPERIMENTAL SETUP

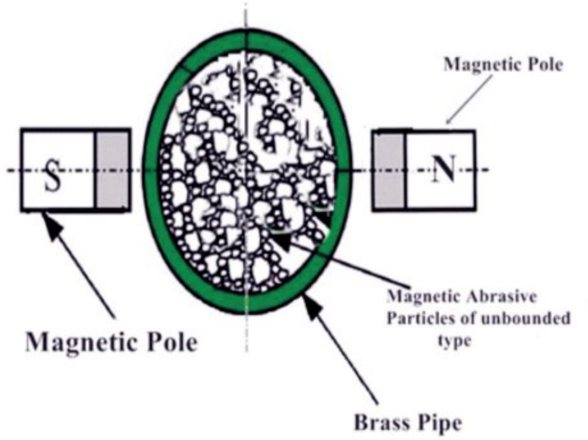

Fig.1 Internal finishing by using magnetic abrasives

As shown in Figs. 1 & 2, the internal magnetic abrasive finishing includes a magnetic pole system. In this process magnetic abrasive particles are introduced inside the cylindrical work piece and are conglomerated at finishing zone under the effect of magnetic field. These combined abrasive particles force against the work surface which results in machining.

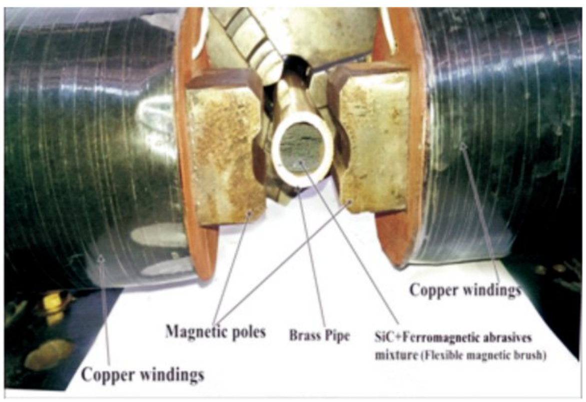

Fig. 2 MAF setup used in the experiment

EXPERIMENTAL PARAMETERS

The parameters used during the experiments are shown in the Tables 1 & 2

Table1:Variableparameters

Current	3 , 3.50 and 4 amperes
Composition SiC: Fe, SiC: Steel powder	55:45, 65:35, and 75:25
Gritsizes of SiC abrasive	90grit,120gritand150girt

Table2: Fixedparameters

Circumferential Speed	180 rpm
Work material Workinggap	CuZn35, Brass pipe 8mm
Machining time	20 min

RESULTS

Effect of input Current

Three values of input currents were used in this experiment. When results of Fe and Steel were compared, it was found that there were similar trends in both cases but better surface finish was obtained by using steel abrasive with SiC abrasive [*Chang et al 2005*].Fig. 3 shows that as the current increases, FMAB becomes stronger due to increase in MFD which results into better surface finishing.

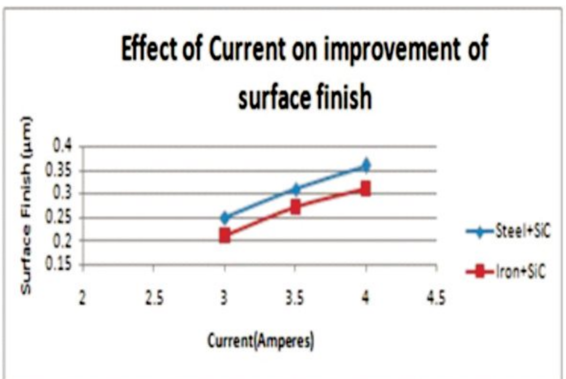

Fig. 3 Effect of input current on improvement of surface finish

Effect of percentage composition of SiC abrasive

Three different % compositions of Fe & Steel were used with SiC abrasive in current experiment. It was found that 75:25 was best composition in both cases. SiC-Steel provided higher surface finish than SiC-Fe. Fig.4. shows that surface finish is highest at 25% composition of SiC i.e. 75% are ferromagnetic particles and 25% is SiC abrasive. As the content of ferromagnetic particles decreases, strength of FMAB decreases. So least surface finish is obtained at 55% composition of ferromagnetic particles i.e. at 45% composition of SiC abrasive. Comparison between Fe & Steel is shown in Fig. 4

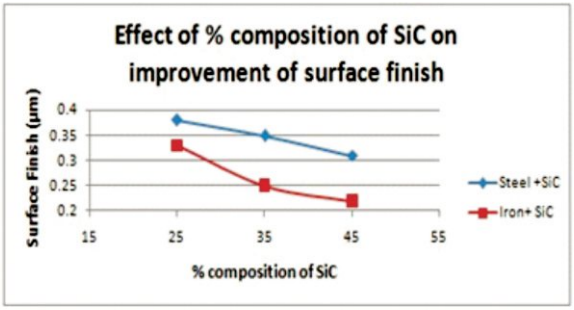

Fig.4 Effect of % composition of SiC abrasive on improvement of surface finish

Effect of grit sizes of SiC abrasive

It is evident from Fig. 5 that the lowest surface finish of brass pipe is obtained when SiC of 90 grit size is used. Then in case of 120 grit size surface finish increases as compared to 90 grit size and surface finish is maximum in case of 150 grit size of SiC abrasive. The reason behind it is the finer size of abrasive. As grit size of abrasive increases, surface finish also increases.

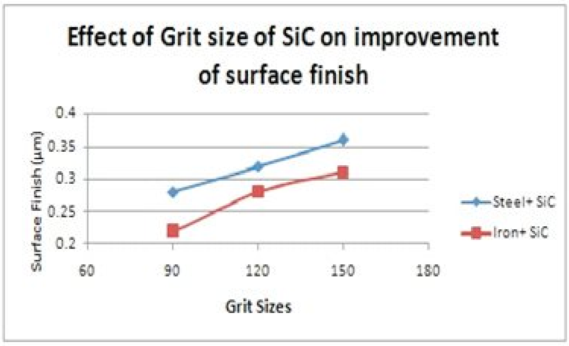

Fig. 5 Effect of grit size of SiC abrasive on improvent of surface finish of brass pipe

MINITAB ANALYSIS

The results of the experimental runs weresubjected to analysis using MINITAB 17 software.Figure 6& 7 show the results of Minitab analysis. It wasfound that the most optimal parameter was 150 grit size of SiC abrasive, 4 amperes input current and 25% composition of SiC abrasive in abrasive mixture of SiC and ferromagnetic particles.

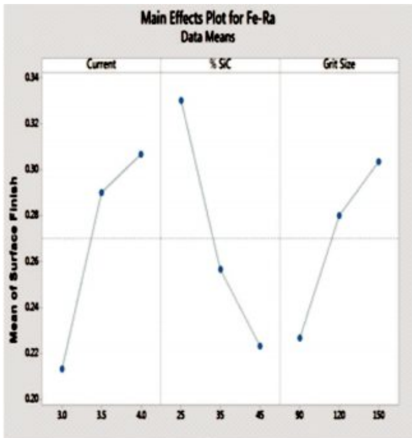

Fig. 6 Mintab analysis of improvement of surface finish of brass pipe by SiC-Fe abrasive mixture

Fig. 7 shows surface finish obtained by using SiC-Steel abrasives.

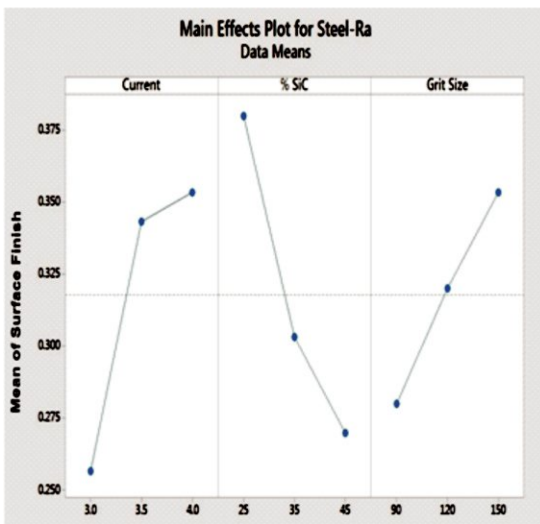

Fig. 7 Mintab analysis of improvement of surface finish of brass pipe by SiC-Steel abrasive mixture

CONCLUSION

All the three individual parameters current, grit size ofSiCabrasive and percentage composition of SiC abrasive have significant effect on the surface finish of CuZn35 brass pipe. However the most significant parameter of the study was percentage composition of SiC abrasive followed by current (4 amperes), 150 grit size of SiC abrasive. Also it was found that the better surface finish can be obtained by using Steel powder with SiC abrasive as compared to Fe powder.

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Emg Signal Based Muscle Fatigue Assessment – A Review

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Abstract:

The Surface electromyography (sEMG) signal processing has become quite common to evaluate local muscle fatigue. A large number of research have been carried out to access muscle fatigue in primarily static but also in dynamic tasks. This paper gives an overview of the various non-invasive electromyography signal analysis techniques available for use in fatigue detection. This paper will be of interest to researchers who wish to select the most appropriate methodology for research on muscle fatigue detection or prediction, or for the development of devices that can be used to reduce various work related musculoskeletal disorders.

Keywords: muscle fatigue; sEMG; power spectral density.

Introduction

Musculoskeletal disorders are an important workrelated problem [Malińska et al 2010; Kamińska et al 2010]. The reason for the occurrence of musculoskeletal disorders may be muscle fatigue, associated with prolonged muscle load even at low load levels [De Looze et al 2009; Farina et al 2006; Visser et al 2006; Roman-Liu et al 2009]. This means that the reduction of the load and fatigue in the working conditions may be an important step in reducing the occurrence of musculoskeletal disorders. A valuable tool for assessment of muscle load and fatigue is non-invasive surface electromyography (EMG) [Solnik et al 2010; Solnik et al 2008; Piscione et al 2006, Bartuzi et al 2010].

Normally, EMG signals are acquired by noninvasive surface electrodes that are placed on the skin superimposed on the targeted muscle for fatigue analysis. EMG signal feature is often extracted before performing analysis [Phinyomark et al 2012a] because a lot of information, both useful information and noise [Phinyomark et al 2012b], is contained in the raw EMG data. An EMG feature is a distinct characteristic of the signal that can be described or observed quantitatively. Generally, EMG features can be computed in numerical form from a finite length time interval and can change as a function of time, i.e. a voltage or a frequency. They can be computed in several domains, such as time domain, frequency domain, timefrequency and time-scale representations [Boostani et al 2003]. However, frequencydomain features show the better performance than other-domain features in case of the assessing muscle fatigue [Al-Mulla et al 2012]. Mean frequency (MNF) and median frequency (MDF) are the most useful and popular frequency-domain features [Phinyomark et al 2009] and frequently used for the assessment of muscle fatigue in surface EMG signals [Cifrek et al 2009].

Frequency Domain Features

Frequency domain analysis is mostly used to study muscle fatigue, and infer changes in motor unit (MU) recruitment. A signal spectrum is influenced by two factors: the firing rate of a recruited MU in the low-frequency range (below 40 Hz), and the morphology of the action potential travelling along a muscle fiber in a high-frequency range (above 40 Hz) [Karlsson et al 1999]. It is time variant, and directly depends on the contraction force, muscle fatigue, and inter-electrode distance. During a constant voluntary contraction, even when there is no voluntary change of muscle state, a myoelectric signal should be considered a non-stationary signal; due to the inherent physiology of an organ. However, it was shown in Refs. [Karlsson et al 2000; Merletti et al 1992], that during relatively low-level (20–30% MVC), and short-time contractions (20–40 s), it can be assumed to be wide-sense stationary. Moreover, at higher levels, 50–80% of MVC, it can only be assumed locally stationary for a period of 500–1500 ms. Therefore, a myoelectric signal can be assumed stationary in real-time applications, even if it has variant spectral characteristics.

2.1 Power spectral density (PSD) plays a major role in spectral analysis. In wide-sense stationary stochastic signals, PSD is defined as a Furrier transform of the autocorrelation function of a signal. PSD function shows the strength of the variations (energy) as a function of frequency and it is most suitable for pulse like signals having a finite total energy. The PSD of a signal x(t) is defined as:

$$S_{xx}(f) = |\hat{x}(f)|^2; \text{ Where } \hat{x}(f) = \int_{-\infty}^{\infty} e^{-2\pi i f t}\, x(t)\, dt$$

Two characteristic variables of PSD are the mean and median frequency (MNF, MDF) which provide information about signal spectrum and its change over time.

1.2 Mean Frequency (MNF) is an average frequency which is calculated as the sum of product of the EMG power spectrum and the frequency divided by the total sum of the power spectrum [Oskoei et al 2008]. MNF is also called as mean power frequency and mean spectral frequency in several works. The definition of MNF is given by

$$MNF = \int_{f1}^{f2} f.P(f)\, df / \int_{f1}^{f2} P(f) df$$

Where *P(f)* is the EMG signal power spectrum calculated using Fourier Transform for the frequency *f*, *f1* = 8 Hz and *f2* = 500 Hz.

Median Frequency (MDF): is a frequency at which the EMG power spectrum is divided into two regions with equal amplitude [Oskoei et al 2008]. MDF is also defined as a half of the total power, or TTP (dividing the total power area into two equal parts). The median frequency is calculated numerically from the following equation:

$$\int_{f1}^{F_{MDF}} P(f).df = \int_{F_{MDF}}^{f2} P(f).df$$

Where *P(f)* is the EMG signal power spectrum calculated using Fouriere Transform, *f1* = 8 Hz and *f2* = 500 Hz.Thebehavior of MNF and MDF is always similar. However, the performance of MNF ineach of the applications is quite different compared to the performance of MDF, although both features are two kinds of averages in statistics.

It should be noted that MNF is always slightly higher than MDF because of the skewed shape of EMG power spectrum [Knaflitz et al 1990], whereas the variance of MNF is typically lower than that of MDF. In theory, the standard deviation of MDF is higher than that of MNF by a factor

1.253 [Balestra et al 1988]. However, the estimation of MDF is less affected by random noise, particularly in the case of noise located in the high frequency band of EMG power spectrum, and more affected by muscle fatigue [v et al 1981]in static contractions.

MNF and MDFfor assessment of muscle fatigue in static contractions have been hailed as good standard due to the fact that muscle fatigueresults in a downward shift of frequency spectrum of the EMG signal. Moreover, during the fatigue of muscle, several changes have been found, i.e. a relative decrease in signal power at high-frequency, a small increase in signal power at low-frequency, an increase in spectrum slope at high-frequency, and a decrease in spectrum slope at low-frequency [Petrofsky et al 1982; Sato et al 1982; Viitasalo et al 1977].

Time Frequency Domain Features: In dynamic contractions, the EMG signal information has been changed as a function of time that cannot be analyzed by simply applying FFT and most recently EMG studies have been applied to the study of dynamic contraction. The instantaneous mean and median frequency (IMNF and IMDF) are introduced to fulfill the requirement [Roy et al 1998] by using time-frequency or time-scale approaches.

Bonato et al. [Bonato et al 2001] studied different Cohen class time–frequency distributionsand concluded that the Choi–Williams distribution was themost suitable for the analysis of the surface EMG recorded fromdynamic isokinetic tasks.

Choi–Williams distribution (CWD): Choi and Williams [Choi et al 1989] proposed a new time–frequency distribution that does not generate spurious values and preserves desirable properties such as marginal densities. The main characteristic of this Cohen class distribution is the exponential kernel, which determines the cross-term reduction and the elimination of undesirable terms.
From the Choi–Williams time–frequency distribution certainparameters were calculated, as follows: Instantaneous mean frequency (MF) calculated as:

$$MF\,(t) = \int_{f1}^{f2} f.P_{CW}(f,t)\,df \Big/ \int_{f1}^{f2} P_{CW}(f,t)\,df$$

whereP_{CW} *(f,t)* is the time-dependent power spectrum obtainedfrom the Choi–Williams distribution and again, f1 = 8 Hz andf2 = 500 Hz. Instantaneous frequency variance as indicator parameter of the total changes can be defined as:

$$F_{var}(t) = \int_{f1}^{f2} (f - MF)^2 . P_{CW}(f,t)\, dt \Big/ \int_{f1}^{f2} P_{CW}(f,t)\, dt$$

where MF is the instantaneous mean frequency calculated as in (4), where $P_{CW}(f,t)$ is the time-dependent power spectrum obtainedfrom the Choi–Williams distribution and again, f1 = 8 Hz andf2 = 500 Hz.

The interpretation of thesEMG during dynamic tasks is complicated and requires caution.Thus, during dynamic contraction, several factors like change inthe number of active motor units, changes in force/power thoughthe range of motion, changes in fiber and muscle length, togetherwith the change in muscle fiber conduction velocity due to muscle fatigue [Farina et al 2006; Karlsson et al 2000], may increase the non-stationarityof the myolectrical signal. Hence, to extract valid physiologically relevant information future types of EMG-signal based analyses should thus require analysis of the possible confounding movement factors. In this context, the use of high-density, multichannel EMG, as well as direct estimation of conduction velocity could improve the interpretation of fatigue during dynamic tasks.

Conclusion

This paper has described various methods in the study of localized muscle fatigue for both isometric and non-isometric contractions. It is quite evident that the presented bioengineering approaches are quite successful in providing quantitative sEMG based information about the muscle fatigue state. Frequency domain features are found to be reliable for isometric or static contractions and time frequency domain features are found useful for non – isometric or dynamic contractions. Future work may be directed towards the development of automated muscle fatigue detection system to reduce work place injury and musculoskeletal disorders.

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Fabrication Of Solid Ankle Foot Orthosis By Additive Manufacturing Techniques

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ABSTRACT

Ankle-foot orthosisare that encompass the ankle joint and the whole or part of the foot.Developments in non-invasive three-dimensional scanning have made it possible to acquire digital models of freeform surfaces typical of the human body. Combined with additive manufacturing techniques, these technologies have the potential to transform personal medical devices by streamlining fabrication and providing a quantitative means to monitor patient physiology. The design of foot and ankle orthoses is currently limited by the methods used to fabricate the Devices, particularly in terms of to overcome the sweating problem faced by patients.The medical orthotics field contains opportunities for streamlining and improving the process for fitting a patient-specific ankle-foot orthosis (AFO) fabricated by additive manufacturing. The present study is aimed to open new approaches for the development of ankle orthosis.

Keywords : Ankle foot orthosis, solid foot, additive manufacturing, Cad/Cam

INTRODUCTION

An Ankle Foot Orthosis (AFO) is an orthopaedic device that can be prescribed to support the ankle function during walking. In general, an orthosis is defined as “an externally applied device used to modify the structural or functional characteristics of the neuro- muscular system”. [1]An AFO is an orthosis that is specifically designed to modify the functioning of the ankle and/or the foot. AFOs are produced in various forms, composed of different materials, and prescribed with a wide variety of aims.

Different types of AFO sare normally prescribed for various impairments depending on the intensity, range of movement sand patient complexion. Some typical designs include:leaf spring AFOs, hinged, with dorsal cover, etc. [2] Traditionally, patient-specific AFO sare made by one of two methods: 1) thermo forming copolymer sheets of a prescribed thickness(normally 3-4mm) around a plaster-cast impression or 2) Prepeg carbon fiber sheet layup using a plaster cast base as a reference surface.

This cover is then hardened chemically, or by cooling in ambient air, after which it is extracted from the plaster cast and finalized by the orthotist. In this process of finalization, the orthotist decides which parts of the AFO need to be trimmed off, referred to as the trimline. Cerebrovascular accident (stroke) is one of the main causes of disability and mortality in the developed world. Stroke victims experience a number of neurological deficits and disabilities, such as hemiparesis, communication disorder, cognitive impairment and visual-spatial perception disorder. Moreover, approximately 50 to 60% of stroke victims experience some degree of motor impairment even after completing the standard rehabilitation protocol, and approximately 50% are at least partially dependent on others with regard to activities of daily living Recovering the ability to walk is an important goal of the rehabilitation process for stroke patients. According to Gok et al., gait velocity, cadence and step length are diminished in hemiparetic gait and devices, such as an AFO, can improve these aspects. An AFO is generally prescribed to provide mediolateral stability of the ankle in the stance phase, facilitate gait in the swing phase and support the ankle.

ADDITIVE MANUFACTURING OR RAPID PROTOTYPING

Prototyping is the process of building pre-production models of a product to test various aspects of its design. There are limitations to traditional prototyping methods. Such as the time required to fabricate the prototype.The overall complexity of the object and the extreme labour intensity of traditional prototyping method [3-7].

Rapid prototyping is the process of generating an object directly from its digital representation in CAD/CAM system. The main benefit of this process is reduced the time to produce a prototype, which in turn speeds up the entire development process.

Rapid prototyping has also been referred to as solid free-form manufacturing; computer automated manufacturing, and layered manufacturing. Rapid Prototyping has obvious use as a vehicle for visualization. In addition, RP models can be used for testing, such as when an airfoil shape is put into a wind tunnel. PR models can be used to create male models for tooling, such as silicone rubber models and investment casting. In some cases, the RP part can be the final part, but typically the RP material is not strong or strong enough. When RP material is suitable highly convoluted shapes (including parts nested within parts) can be produced because of the nature of RP[8-9].

WHY IS RAPID PROTOTYPING?

Rapid prototyping is the name given to a host of related technologies that are used to fabricate physical objects directly from CAD data sources. These methods are unique in that they add and bond materials in layers to form objects. Such systems are also known by the names additive fabrication, three dimensional printing, and solid freeform fabrication and layered manufacturing. They offer advantages in many applications compared to classical subtractive fabrication methods such as milling or turning:

Objects can be formed with any geometric complexity or intricacy without the need for elaborate machine setup or final assembly;

Objects can be made from multiple materials, or as composites, or materials can even be varied in a controlled fashion at any location in an object;

Additive fabrication systems reduce the construction of complex objects to a manageable, straightforward, and relatively fast process.

METHODOLOGY

Manufacturing techniques of AFO

The process will be used to create orthotic devices is additive manufacturing. Computer assisted design (CAD) systems have also being used to assist in creating the positive improving consistency and repeatability of this process, but the process remains slow and complex and it requires considerable input from experienced craftsmen[10-15]. Furthermore, in these traditional processes the possibilities for innovation or product development are limited. With CAD systems it will be observe that orthoses rejection ratio has been reduced combined with time reduction up to 50% and cost saving up to 25% to 50% (Munguia and Pallari, 2009) as shown in Figure 1.

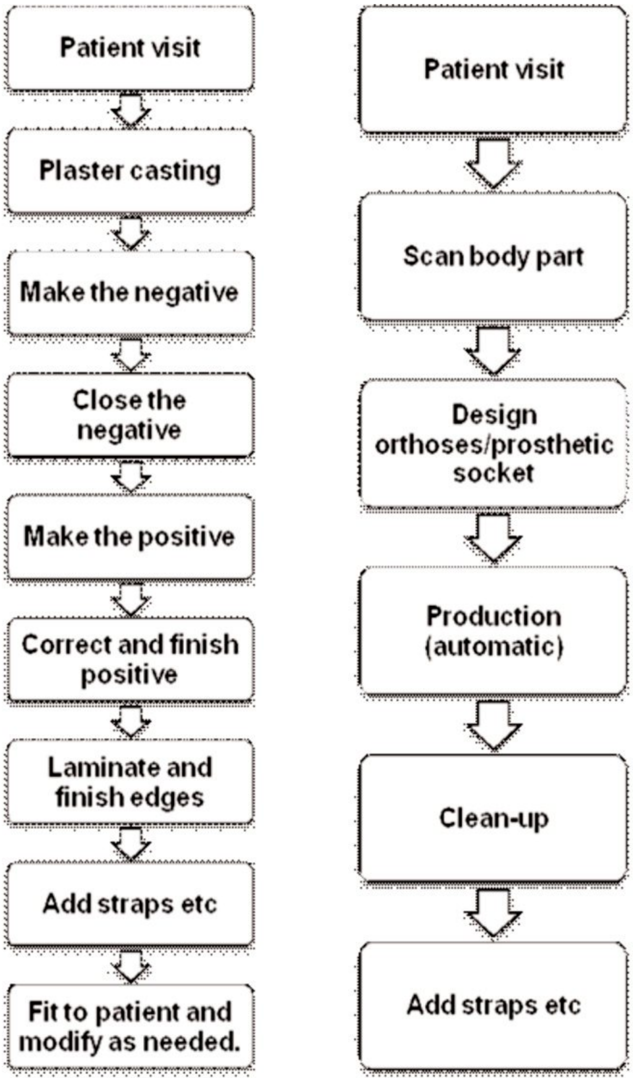

Figure 1 (a) **Traditional process** **(b) Possible AM process**

THE RIGHT AFO FOR EVERY PATIENT

The effect of AFOs on gait has been widely studied, however, there is no conclusive evidence with regard to their effectiveness. Various studies have assessed the effects of wearing an AFO on the kinematics and kinetics of gait, walking speed, balance, and the energy cost of walking. Many of the above-mentioned studies have reported on the beneficial effects of wearing an AFO, whereas others reported no advantages of the AFO. Expert meetings of the ISPO, and the results of recent reviews confirm the absence of unambiguous evidence with regard to the effectiveness and working mechanisms of AFOs[16-20].

These properties have resulted in their wide use as a way to reduce time to market in manufacturing. Today's systems are heavily used by engineers to better understand and communicate their product designs as well as to make rapid tooling to manufacture those products. Surgeons, architects, artists and ininviduals from many other disciplines also routinely use the technology.

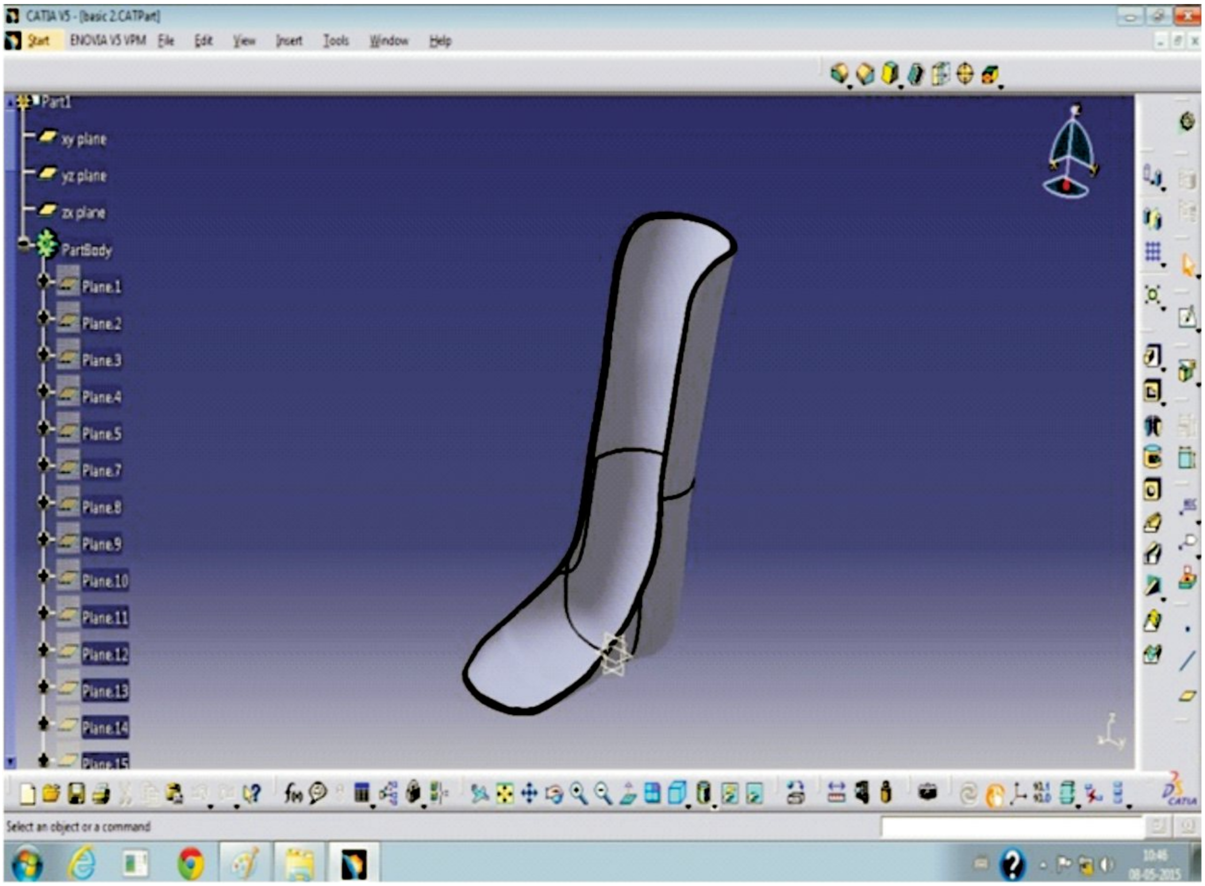

Figure 2 : Catia Model of Ankle Foot Orthosis

Given the artisanal manufacturing style of personalised AFOs, additive manufacturing as been identified as a natural method to produce automated highly personalized devices that fit every patient's specific requirements .Work on additive manufacture of AFOs has focused on highlighting the freedom of design associatedwithadditivetechnologies.demonstratedthedesign,manufacturingandoptimizationpossibilitie sofanFDM made AFO scanned from a pre existing Polypropylene device as shown in Figure 2 [20-25].
Analyzed the dimensional accuracy of passive dynamic ankle-foot orthotics made by FDM by manufacturings caled-down versions of the device, presented an AFO customization process by

manufacturing two samples with the stereolithography process which showed similar presented propertiestoaconventionalPPAFO.Adifferentapproachbymodelingthenecessarymechanicalpropertiesfo rafinite element material definition of laser sintered AFO devices[26-30]. Other related research is based in newdesign-freedomandcustomizationcapabilitiesofadditivemanufacturingfromapure- design perspective . However none of the previous research has addressed the feasibility of AM as a dedicated method for AFO manufacturing particularly concerning two factors: economics and performance optimization.

RESULT & DISCUSSION

Although ankle foot orthotics have been studied by previous research they remain a challenge for AM-based production due to the overall build-size and the time implications of building each device in one piece[31]. The productivity of conventional methods still surpases that of AM for both, SLS and FDM however the advantages of digital fabrication lay on the design opportunities when designing the final devices, as no plaster casts are required to mouldthe plastic

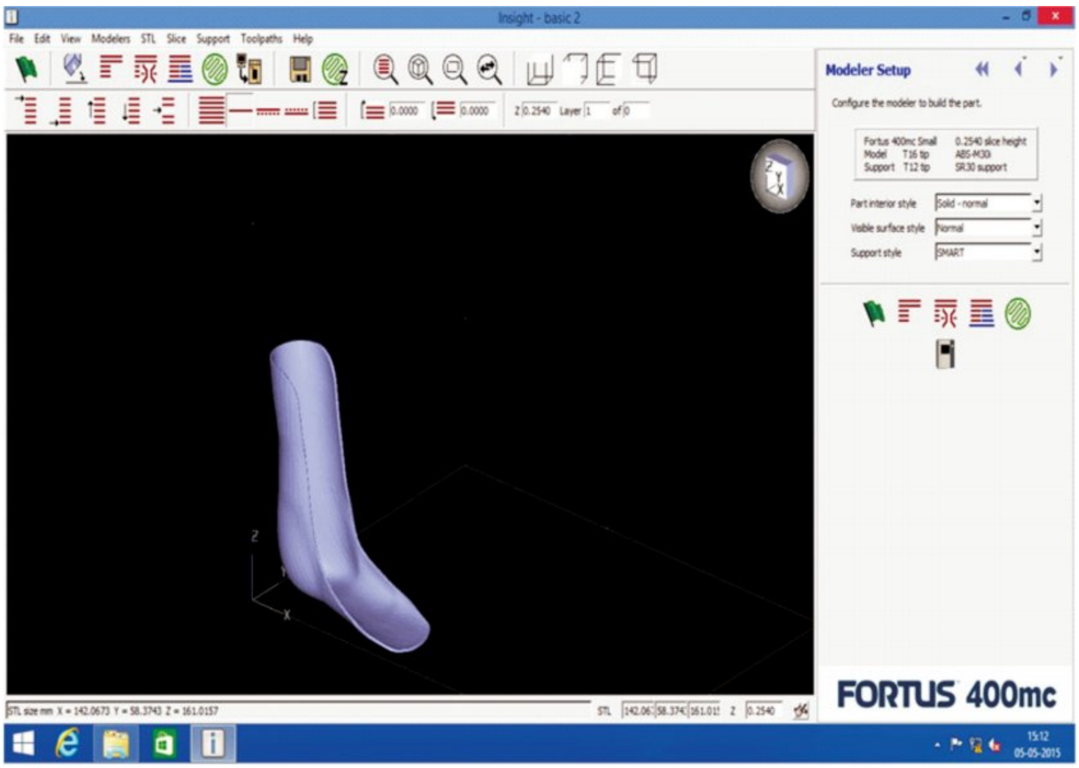

Figure 3 : Prototype Model in FDM Softawre

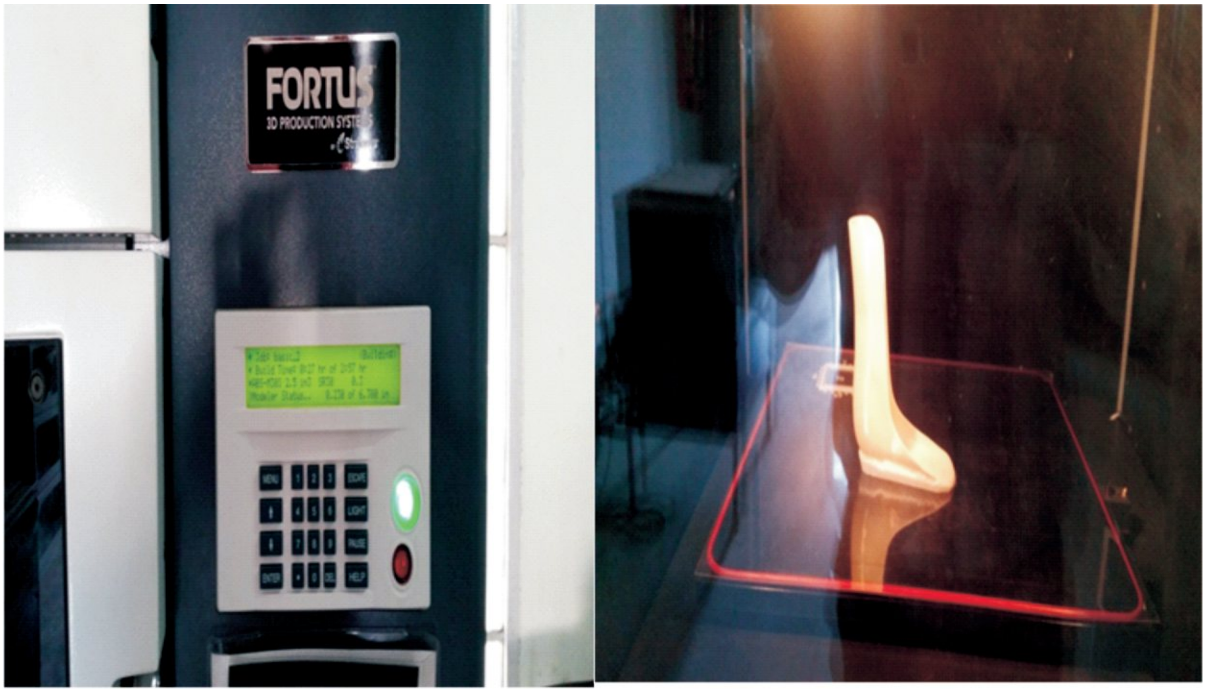

Figure 4 : FDM Machine & Prototype Model of AFO

A modular design approach has been introduced where the three main elements of an AFO: Calf, footplate and strut are split and arranged within the build envelope so the full set of components is produced in one single build and assembledafterwards as shown in Figure 3 & 4 using FORTUS 400mc printinter[32-40].

CONCLUSIONS

The use of low cost AM components in conjunction with composite materials can open new avenues for the design of high complexity products without the need for expensive tooling components or secondary operations such as plaster cast, wood mould machining orthermoforming substrates. However, plastic components being used as a guide-surface or sacrificial skeleton must provide sufficient rigidity for the composite deposition stages, particularly when pressures will be applied by means of vacuum baggin, resin transfer moulding, or simply by applying uniform pressuresmanually[41]. This work introduces the low-cost 3D printing plus reinforcement approach as an alternative route for the design and manufacture of orthotic devices with complex shapes and localized reinforcement needs. It is expected that new applications add-up to increase the body of knowledge about the behavior of such products which will mix both areas, design theory and additivemanufacturing.

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Finishing Of Aluminium Pipes Using Sand Based Magnetic Abrasives.

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Abstract

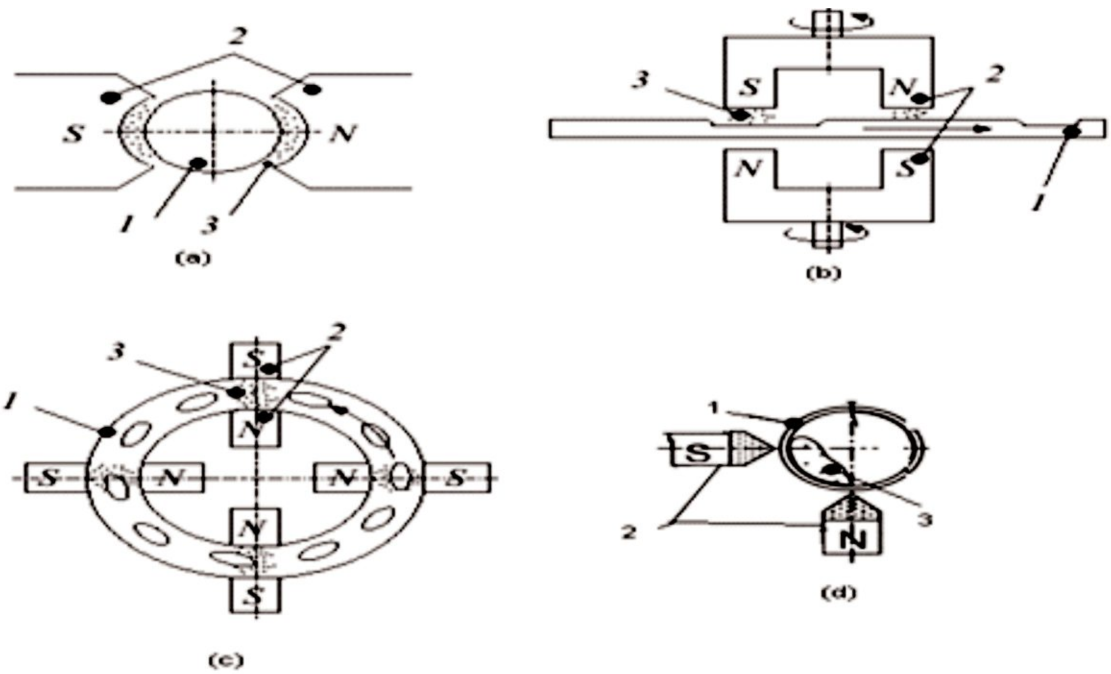
With the advancements in various fields like medical research, space research, robotics, CNC machines etc. there is dire need of machining processes which are capable of providing good surface finish in tight tolerances. Besides this, new materials are being developed to realize the need of present industry. The properties of some of the materials are such that they cannot be machined by conventional or traditional methods. A family of new machining techniques called non conventional machining processes has been developed. These newly developed processes are helping the industry to attain the required degree of accuracy and surface finish. In contrast to these processes the conventional machining processes have limited performance and productivity. Non conventional processes are also capable of machining the hard to machine materials and intricate shapes.

INTRODUCTION

Abrasive Machining is a manufacturing process where material is removed from a workpiece using a multitude of small abrasive particles. Common examples include grinding, honing, and polishing. Abrasive processes are usually expensive, but capable of tighter tolerances and better surface finish than other manufacturing processes.

Present study is based on one of the non conventional machining processes called 'Magnetic Abrasive Machining' which came to the surface in 1938 in a patent by Harry P. Coats. The countries which are involved in the study and development of this process are USA, CIS, England, France, Bulgaria, Germany and Japan. There are certain advantages of this process over the conventional ones which make it useful in improving the surface finish of the part. The magnetic field assisted finishing processes are based on the electro-magnetic behavior of the magnetic abrasive particles in the magnetic field. In magnetic abrasive finishing (MAF) process, magnetic force plays a dominant role for the formation of flexible magnetic abrasive brush (FMAB) and developing abrasion pressure.One of the merits is that the force of machining can be controlled by controlling the magnetic field strength and %age of iron in the abrasive. MAF possesses many attractive advantages and some of them are listed below.

Self-adaptability.
Controllability.
Finishing tool requires neither compensation nor dressing
Material surface is free of burns and thermal defects.
Low energy consumption.
Simple in implementation.
Non-ferrous materials like aluminum and its alloys, brass and its alloys can also be finished with ease.
Most efficient from economical point of view.
Magnetic abrasives have the self-sharpening ability.



An abrasive is a material, often a mineral, that is used to shape or finish a workpiece through rubbing which leads to part of the workpiece being worn away. Abrasives generally rely upon a difference in hardness between the abrasive and the material being worked upon, the abrasive being the harder of the two substances. Abrasives are extremely commonplace and are used very extensively in a wide variety of industrial, domestic, and technological applications. This gives rise to a large variation in the physical and chemical composition of abrasives as well as the shape of the abrasive. Common uses for abrasives include grinding, polishing, buffing, honing, cutting, drilling, sharpening, and abrasive machining. In the present work sand combined with iron powder was used as magnetic abrasive.

Due to interaction of the magnetic force, the mechanical action of the abrasive, the effect of individual input parameters controlling the material removal rate and surface finish in MAF are different from that of other allied processes. The input parameters that significantly affect the material removal rate and surface finish are:

I. Work material
II. Work piece pole gap distance
III. Size of abrasive
IV. Rotational speed of work piece
V. Quantity of Mixture
VI. Percentage of Abrasives
VII. Number of Magnetic poles
VIII. Magnetic flux density
IX. Machining time
X. Shape of pole
XI. Frequency of supply voltage
XII. Axial movement

Control of the Abrasion

In MAF, the main factors which control abrasion are:-

1. **Magnetic Field Strength:** The abrasion of the surface of the tube was greatly affected by

magnetic flux density i.e. magnetic field strength. At low magnetic flux density, the abrasion pressure caused by magnetic abrasive particles was less than the required for machining, sometimes abrasives were dragged by tube along with. There were some values of magnetic flux density at which results were the best. At high magnetic flux density, abrasion pressure is so high that it results in less surface finish improvement.

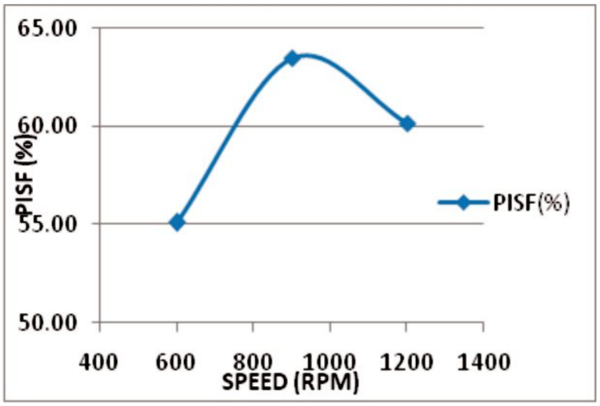
2. Rotational Speed of Work piece: Rotational speed of work piece also affects the surface finish. At very slow and very high speed, the improvement in surface finish was very less. Especially at high speeds improvement in surface roughness was impossible, as magnetic abrasive particles are dragged by tube. At slow speed, time taken was more. At moderate speeds results were good.
3. Quantity of the Magnetic Abrasives: The quantity of the abrasives affects the surface finish. Very low and high quantity leads to less surface finish in comparison to the moderate quantity of the abrasives.It happens due to jumbling of the particles.
4. Composition of the Magnetic Abrasives: Low composition of the abrasives lead to lesser cutting edges and hence less surface finish. High concentration leads to jumbling of the particles and again decreases the surface finish.High surface finish is obtained at moderate compositions.

Experimentation

Commercially available Iron Powder of 200 grit size and silica sand of grit size 100 were selected. Samples of different compositions and quantity were prepared after weighing.The constituents were thoroughly mixed and SAE 40 was used as a lubricating oil to make the samples just wet.

The following observations and calculations were made Table 1

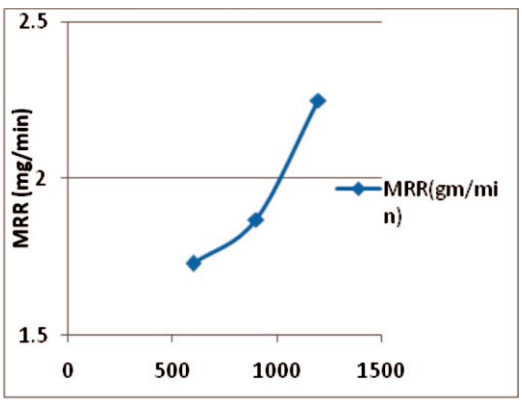
S No	Speed (rpm)	Current (A)	Percentage of Sand(%)	Weight of Abrasives (gm)	PISF(%)
1	600	4	15	10	55.08
2	900	4	15	10	63.49
3	1200	4	15	10	60.17



The effect of speed(rpm) on PISF with Current 4A,Percentage of sand 15%,Weight of abrasives 10gm is shown in graph 1.It has been observed that the PISF increases with the increase in speed upto the speed of 900rpm and then starts decreasing with the the further increase in speed. The maximum PISF of 63.49% is observed at a speed of 900 rpm.

Table 2

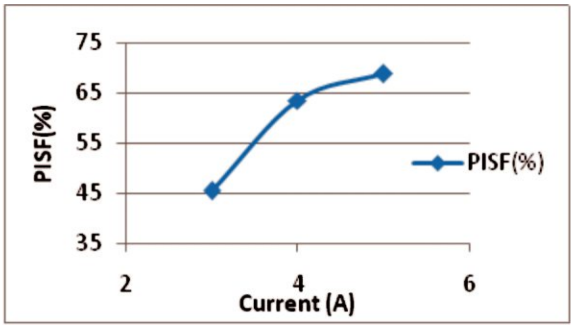
S No	Speed (rpm)	Current (A)	Percentage of Sand(%)	Weight of Abrasives (gm)	MRR (mg/min)
1	600	4	15	10	1.73
2	900	4	15	10	1.87
3	1200	4	15	10	2.25



The effect of speed(rpm) on MRR with Current 4A,Percentage of sand 15%,Weight of abrasives 10gm is shown in graph 2.It has been observed that the MRR increases with the increase in speed upto the speed of 1200 rpm. The maximum MRR= 2.25 mg/min has been observed at 1200 rpm.

Table 3

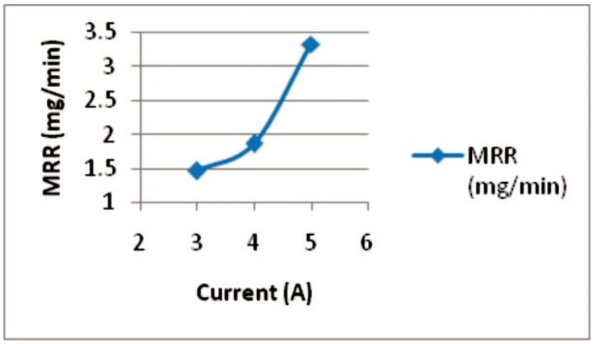
S No	Speed (rpm)	Current (A)	Percentage of Sand(%)	Weight of Abrasives (gm)	PISF(%)
1	900	3	15	10	45.56
2	900	4	15	10	63.49
3	900	5	15	10	68.75



The effect of Current(A) on PISF with speed 900 rpm, Percentage of sand 15%,Weight of abrasives 10gm being constant is shown in graph 3. It has been observed that the PISF increase with the increase in the current .The maximum value of PISF obtained is 68.75 at 5 A current.

Table 4

S No	Speed (rpm)	Current (A)	Percentage of Sand(%)	Weight of Abrasives (gm)	MRR (mg/min)
1	900	3	15	10	1.46
2	900	4	15	10	1.87
3	900	5	15	10	3.33



The effect of Current(A) on MRR with speed 900 rpm, Percentage of sand 15%,Weight of abrasives =10gm being constant is shown in graph 4. It has been observed that the MRR increases with the increase in the current .The maximum value of MRR=3.33 mg/min has been observed at 5A current

Conclusion

1) Current and Rotational Speed of work piece are affecting the metal removal and %age surface finish improvement.
2) The process yields best result of PISF =68.75% and MRR=3.33 mg/min at rotational speed= 900rpm, current= 5A, Percentage of sand =15% and 10 gm weight of the abrasives.

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Development Of Master Production Schedule

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ABSTRACT

Master Production Schedule is an iterative outcome of number of trials made with the aim of optimization of factors of production. Change in environment will invite modification in Master Production Schedule. Thus there is a need to have a firm yet a flexible Master Production Schedule which is real time and accept changes with minimum transient time. This paper discusses in detail, the importance and functions of Master Production Schedule. The data is collected from an industry for Master Production Schedule. A Computer programme has been made for the above data and further this programme is extended to make Master Production Schedule. In developing Master Production Schedule following factors are considered material availability, capacity availability, customer order date, customer delivery date, production start date and production end date. These factors will tell the material and labour availability on schedule dates of manufacturing of the product. Master production schedule will also suggest the production start and production end dates of the products.

Keyword: Master production schedule, material availability, capacity availability, customer order date, customer delivery date.

INTRODUCTION

In the present world of competition, receiving an order is a function of cost, quality, lead time and reliability in delivery dates. The real time information and capability to coordinate between sales and production at the quoting stage is receiving attention at the highest level. A manufacturing industry consists of a number of different sections which work together in a complex manner to attain industrial objectives. It combines a number of separate elements in the form of inputs, such as Energy, Information, Materials, Tooling, Manpower, Technology parameters, capital etc. and their interaction. Manufacturers have to keep customer interest by manufacturing and offering them a variety of products. The manufacturing plan is always subject to changes. The firm cannot stick to a fixed plan. Master Production Schedule is the basic tool employed to stream line the production. The number of forces acting in shaping the Master Production Schedule and the options available to the planner makes the task more complex.

Master Production Schedule is the result of desegregation of an aggregate plan. Master Production Schedule specifies the amount and timing of production for each item. Master Production Schedule is a detailed plan and any kind of system can lead to system nervousness and can cause instability. Various techniques like Freeze fences, safety stocks, capacity changes, product structure analysis are used to facilitate the Master Production Schedule to incorporate changes and make production as smooth as possible.

A number of factors are to be considered for the formulation of Master Production Schedule. These are customer delivery date, customer order date, customer importance, Material availability, capacity availability, product movement, product range and lead times. Even after considering all these factors Master Production Schedule has to be revised a number of times. Master Production Schedule plays a vital role in production control. It forms the basis for Loading, Scheduling, Dispatching, and other control activities. Master production schedule is created to show the specific volume of end products that are scheduled according to the time periods in which they are completed. Operations must first create a Prospective Master Production Schedule to test whether its meet the schedule with the resources e.g. machine capacities, labor, overtime provided in aggregate production plan operations. Operation revises the MPS until it obtains a schedule that satisfies all resource limitations.

Review of Literature

Andrew Sieveking et al. (1995) designed a simulation model called Flexible Object Oriented Production planning simulation to test production strategies, which would reduce inventory costs while achieving the manufacturer's goal of shipping nearly all its customers' orders within 48 hours of arrival. The manufacturer provided product line data including, Bill of material and manufacturing process employed. The developed model evaluated finished good inventory, machine utilizations and order fulfillment statistics under several production strategies. The model also has integrated capacity and materials requirements planning with comprehensive inventory management policies. **William L. Berry**

et al (1992) have dealt with the problem of higher product mix by proposing an approach using product structure analysis for master scheduling of assemble to order products. Product structure analysis has traditionally been concerned with the analysis of product option features and the identification of common material for Master production schedule purposes. The Author argues that the information for the common material in the product structure can be very useful in improving the master production scheduling function and in stream lining the overall design of the manufacturing planning and control system for assemble to order products. Chu et al. **(1995)** consider further an aggregate optimization model for the usual Master Production Schedule. Author gives linear programming formulations for various levels of model complexity, ranging from a basic product mix problem to a global aggregate production planning problem. Author examines stage-wise decomposition from the point of view of practical computational feasibility and study the robustness of this composition. **R. Greg Arbon** et al. **(1994)** developed an Automated Master Production Scheduling System (AUTO-MPS) for long scheduling processes or large volume manufacturing**.** An AUTO-MPS is a hybrid expert scheduling system, which perform production scheduling of thousands of assemblies in a high volume-manufacturing environment. It generates schedules based on a set of rules and constraint satisfaction algorithms which reflect the scheduling strategies created by management to meet their customer demand while still controlling inventory and shipping cost. Use of Hybrid Expert system has enabled this system to reduce the process of generating a good schedule from several days to a few hours. The system has allowed the personnel involved in scheduling process to spend more time performing analysis to support the creation and execution of the production schedule and less time generating the schedule itself. **Shu-Hsing Chung** et al. (2006) carried out the research and developed master production scheduling system for wafer bumping process which aims for having high due date achievements as well as doing customer order promising. A mixed integer programming (MIP) model is applied to optimize the setup schedule and the master production scheduling system can plan master production schedules which are capable to meet the due date requirements and can handle the task of customer order promising. **R. Venkatraman** et al. (1996) **carried out a research work which** is concerned with the disaggregation of aggregate plans to a rolling horizon master production schedule when production lot sizes require minimum batch size production. Actual data from a process industry firm is used to test and validate the proposed rolling horizon master production scheduling model. The work also examines the impact of forecast windows on the performance of a rolling schedule when production quantities on individual product items are based on minimum batch size production. Results indicate that the model's performance is superior to actual company performance in terms of total cost and increasing the length of forecast window can increase cost. **Emin gundogar (1996)** presented a rule-based system for an electromechanical manufacturing company, which is able to rearrange the master production schedule. This system will provide considerable easiness of use in the master production scheduling activities. It is a hard process to modify master production schedule in a firm having various types of products and final assembly groups. Therefore, the system should automatically make the needed and proper modifications when they are input. Besides, it is of great importance to the firm to remove the errors of demand forecasting so as not to reject customer. **Edmund W. Schuster et al.** propose a new way to improve master production schedule stability under conditions of finite capacity. The purpose is to optimize product availability and customer service for typical situations encountered in the consumer goods industry. Using a comprehensive Master production schedule model, author conducts a simulation study with experimental design to identify factors having a significant influence on Master production schedule stability. A. Segerstedt (2006) discusses available-to-promise, planning bills and other help systems for practical applications of Master Production Scheduling. The Author presents how and why, in practice, a Master Production Scheduling system with an available-to-promise function should be used and how this system should be designed. It is also argued that a fully Enterprise Resource Planning system cannot only be created by Material requirement planning, but also by Cover time planning. **Shigeru Shiina et al. (1995)** developed a PC master production scheduling system on this framework; moreover its usefulness has been evaluated by two actual PC production factory groups. It is shown that the tame required to make a schedule can be reduced to 1/3-1/20, compared to conventional methods using spreadsheet tools. **Tang et al. (2002)** has done their research work on establishing a method for planning the Master production schedule under stochastic demand. They aim to evaluate the cost of the re-planning actions on Master production schedule, as generally these values are not considered while covering the demand uncertainty. **Wayne J. Davis et al. (1997)** describe a new object-oriented simulation methodology that is being developed to support master production scheduling. Their goal was to develop a simulation approach that could employ the detailed processing plan using system-wide control strategies. **Yeung et al. (1999)** presented his work on using multiple freeze fences in multi product multilevel MRP system. The Author introduces a new approach to improve Master production schedule flexibility by imposing a freeze fence on each item in the BOM that is having multiple freeze fences in Master production schedule, out the period and order based methods, as the order based method may generate different lengths of the frozen interval when multiple end items are encountered in an uncertain demand environment. The Author suggests that by using multiple freeze fences, much lower end item inventory can be obtained in all environments. The Author proves that in terms of customer service level, end item inventory, and work in process at each component level have shown Master production schedule with multiple freeze fences can perform equally and even better in certain environments. The Author suggest that he future work can be done by including forecasts error standard deviations functions, lot sizing rules and other manufacturing environments.

METHODOLOGY

Master production schedule **is generated by using C language.** In developing Master production schedule the factors considered are material availability, capacity availability, customer order date, customer delivery date, production start date and production end date. These factors are briefly discussed below.

Material Availability: This factor tells us whether we have availability of material on the schedule dates or not. It includes raw material etc. Materials can be 'not available', 'Partially available', or 'available'.

Capacity Availability: This factor tells us about capacity availability on the schedules dates. It includes tooling, machines, labor etc. Capacity can be 'not available', 'partially available' or available.

Customer order date: This factor tells us the product order date i.e. on which date the product is ordered.

Customer delivery date: This factor tells us the product delivery date i.e. on which date the product is to be delivered to the customer.

Production start date: This factor tells us the date on which the production is to be started for the particular product.

Production end date: This factor tells us the date on which the production is to be completed for the particular product.

Probabilities based on the data

For all the above mentioned factors probabilities have been calculated as follows.

<u>Material Availability</u> : Material Availability has been categorized as 'not available', 'partially available'

and 'available'. Based on the data collected 20% of the material falls in 'not available' category, 45% in 'partially available' category and 35% in 'available' category. These percentages have been used to work out probabilities that the next material availability would be 'not available', 'partially available' and 'available'. Using these probabilities as depicted in table 1 simulation model has been developed.

Table 1 Material Availability

Material Availability	Probability
Not available	0.2
Partially available	0.45
Available	0.35

Capacity Availability **:** Capacity Availability has been categorized as 'not available', 'partially available' and 'Available'. Based on the data collected 20% of the capacity falls in 'not available' category, 45% in 'partially available' and 35% in 'available' category. These percentages have been used to work out probabilities that the next capacity availability would be 'not available', 'partially available' and 'available'. Using these probabilities as depicted in table 2 simulation model has been developed.

Table 2 Capacity Availability

Capacity Availability	Probability
Not available	0.2
Partially available	0.45
Available	0.35

Customer order date The Customer order date is going to input by the user.

Customer delivery date Customer delivery date has been categorized in the form of customer order date. Based on the data, 10% of the delivery dates will be 5 days in addition to customer order date, 10% of the delivery dates will be 12 days in addition to the customer order date, 5% of the delivery dates will be 18 days in addition to the customer order date, 10% of the delivery dates will be 20 days, 15% of the delivery dates will be 22 days in addition to customer order date, 15% of the delivery dates will be 25 days in addition to customer order date, 20% of the delivery dates will be 28 days in addition to customer order date, and 15% of the delivery dates will be 30 days in addition to customer order date. These percentages have been used to work out probabilities that tell the Customer delivery date for a particular product. Using these probabilities as depicted in table 3 simulation model has been developed.

Table 3 Customer delivery date

Delivery date	Probability
Order date + 5 days	0.1
Order date + 12 days	0.1
Order date + 18 days	0.05
Order date + 20 days	0.1
Order date + 22 days	0.15
Order date + 25 days	0.15
Order date + 28 days	0.2
Order date + 30 days	0.15

Production start date Production start date is calculated by the following formula

Production start date = production end date - manufacturing time required for the product

Production end date Production end date is same as the customer delivery date.

RESULTS AND DISCUSSIONS

Master production schedule plays a vital role in production control. It forms the basis for loading, scheduling, dispatching, and other control activities. Operations must first create a prospective master production schedule to test whether its meet the schedule with the resources e.g. machine capacity, labor capacity provided in aggregate production plan operations. Operation revises the Master production schedule until it obtains a schedule that satisfies all resource limitations. A number of factors are to be considered for the formulation of Master Production Schedule. These are material availability, capacity availability, customer order date, customer delivery date, production start date and production end date. A Computer programme using C language has been developed for the above data and further this program is extended to make master production schedule. For all the above mentioned factors various types of customers and their probabilities have been calculated. **Then the percentage ranges of these data are developed so that the computer programme generate the corresponding data.** These factors will tell whether we have material and labour available or not on the schedule dates of production of the product. Master production schedule will also tell when to start production and production end dates of the products. Figure 1 shows the Master production schedule developed through Computer language.

PRODUCT	ORDATE	CSTDD	MATAVI	CAPAVI	PRDSD	PRDED
A	1-4-07	21-4-07	PAVI	PAVI	17-4-07	21-4-07
B	5-4-07	27-4-07	PAVI	PAVI	22-4-07	27-4-07
E	13-4-07	1-5-07	PAVI	PAVI	28-4-07	1-5-07
C	8-4-07	3-5-07	PAVI	PAVI	27-4-07	3-5-07
F	16-4-07	6-5-07	PAVI	PAVI	2-5-07	6-5-07
D	10-4-07	10-5-07	AVI	AVI	30-4-07	10-5-07
G	18-4-07	10-5-07	PAVI	PAVI	5-5-07	10-5-07
H	21-4-07	16-5-07	PAVI	PAVI	10-5-07	16-5-07
I	25-4-07	23-5-07	AVI	AVI	15-5-07	23-5-07
J	28-4-07	26-5-07	AVI	AVI	18-5-07	26-5-07
K	30-4-07	30-5-07	AVI	AVI	20-5-07	30-5-07

Figure 1 Master production schedule

CONCLUSION

Master production schedule formalizes the production plan in any organization. It converts the forecast and the firm orders received from time to time to a form in which these items are to be produced. In the process of formulation of Master production schedule many factors are considered such as customer order date, customer delivery date, material availability, capacity availability, production start date and production end date. In this the prospective Master production schedule is developed which is tested on the above mention factors. The use of computer simulation has resulted in the development of a realistic Master production schedule without any assumption. The process also makes the exercise very flexible as the market changes can be easily incorporated new schedule evolved when needed.

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Identification And Reduction Of Defects For Improving Quality At A Small Manufacturing Unit: A Case Study

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ABSTRACT

A case study has been *conducted to analyze the defects due to which rejection occurs. Later on, by applying Pareto principle defects contributing towards 80% of the total defect rate are identified. Through Cause-and-effect matrix it has been noticed that by controlling some parameters effecting common defects, total defect rate can be reduced to satisfactory levels by which rejection can be reduced. Alternatives have been proposed for controlling the detected parameters effecting major defects. From the proposed alternatives, implemented alternatives have shown decrease in major defects which ultimately helps in improving sigma level from 3.83 in January 2014 to 4.16 in August 2014 is recorded. Remarkable difference and improvement is observed in one of the major defect which earlier contributes to more than 42% of total defects, have now decreased to 20.5% of the defects detected.*

KEY WORDS: QUALITY CONTROL, SIX-SIGMA, FORGING INDUSTRY

INTRODUCTION TO QUALITY CONTROL IN FORGING

Quality is a serious issue in forging units, due to variety of defects occurred during different phases of forging operation which results in rejection and rework. Nowadays forging units around the world are trying new improvement measure and techniques. These improvement techniques helps in utilizing the available resources efficiently which helps in increasing market share, productivity, product quality and reduced production cost (Pandey, 2007). Six-Sigma is one of the popular approaches nowadays, as it is adopted by many industries whether Large, medium or small because of its proven benefits in increased profitability and reduction in cost especially for Small and Medium scale industries (SME). In forging and casting industries Six-Sigma becomes globally popular due to variety of hidden defects (Kumar et al., 2011).

First approach under Six-Sigma, popularly known as DMAIC (Define-Measure-Analyze-Improve-Control) is process improvement approach uses **continuous improvement strategies which are bounded by the existing processes in use.**Second approach is aimed at Design Improvement is known as DFSS (Design for Six-Sigma) approach focuses **on current market needs and meet new levels of specification through design and redesign, considering numerous alternatives (Graves, 2014)** (Sharma et al., 2011).

LITERATURE REVIEW

Kaushik et al. (2008) attempted to mark the role of quality management techniques like Six-Sigma with focus on SMEs which were usually supposed to be the part of large industries through the supply chain network. Authors applied Six-Sigma methodology in a small unit manufacturing bicycles chains. Through Six-Sigma project, authors achieved sigma level of 1.40, by reducing bush diameter which was initially at higher levels of 5.46.

Chandna and Chandra (2009) discussed the forging analysis of six cylinder crankshaft manufactured by TATA motors, Jamshedpur India, produced by hot forging. Forging analysis has been being made to explain that how the defects appear and how to prevent them. Analysis has been done by using quality improvement tools such as Pareto analysis, Brainstorming session of workers and Cause and Effect diagrams. . Based on the analysis Corrective measures were suggested to overcome the forging defects. in existing crankshaft production line in the forging shop and controlling vital few forging defects will reduce the present rejection rate from 2.43% to 0.21% and rework from 6.63% to 2.15%.

Kumar et al. (2011) presented a case study from a foundry unit to discuss some facts and benefits of using Six-Sigma DAMIC approach. DMAIC has been found as one of the efficient techniques for solving problems in foundry units at the lowest possible cost. Using DMAIC approach, authors calculated optimum parameters for minimizing defects.

Thottungal and Sijo (2013), used Fish bone diagram and Pareto analysis for identification and intensity of defects in a forging unit. Results indicated that the rejection rate is more than 5% and major defects include lapping, mismatch, scales, quench cracks, under filling. Authors accordingly proposed remedial actions to reduce the rejection rate.

Gupta and Bharti (2013) implemented Six-Sigma based quality improvement model at a yarn manufacturing company. DMAIC (Define, Measure, Analyze, Improve, and Control) methodology was used to understand the problems and deriving solutions to them. From the study it was observed that the final operational department (winding department/packaging department) was most critical department, which resulted in the highest defect rate percentage during final production moments of yarn. After which DMAIC methodology was implemented in winding department.

Patil et al. (2013) reviewed and described various methodologies for Design for Six-Sigma (DFSS) and various obstacles in implementing those methodologies. The research article suggested that if these methodologies were implemented successfully, it would result in product and process improvement in manufacturing and services. It further described some quality ingredients for implementing DFSS methodology and described DMADV methodology as most successful business improvement strategy which could derive better results in manufacturing and non-manufacturing area, if implemented properly.

ABOUT THE CASE STUDY

Present case study has been conducted at a small forging unit in Ludhiana which is an ISO 9001-2000 certified company. Where quality issues are very critical and there is higher defect rate which results in rejection and rework.

Table 1 Shows defect rate in month of January 2014 is 9.8% and in February 2014 is 6.3%. Sigma levels have been calculated as 3.83 in month of January and 3.99 in month of February.

A brainstorming session has been conducted in order to prioritize the defects in order of their severity as shown in Table 2. After prioritizing the defects Critical to Quality(CTQ) tree for the major three defects have been prepared. Table 3 shows the prepared CTQ tree parameters effecting quality drivers/ defects are identified.

Table 1:Final Dispatch Inspection Results for January 2014

S. No.	Month	Quantity inspected	Defect type				Total defects	Defect %
			Scaling	Crack	Cut mark	Unfilled		
1	JAN.	2885	72	141	24	47	284	9.8%
2	FEB.	1620	42	42	8	11	103	6.3%

Table 2: Quality Drivers as Per Priority Order

DEFECT NAME	PRIORITY	DEFECT NAME	PRIORITY
Scaling	01	Unfilled	06
Cracks	02	Underweight	07
Hardness	03	Cutmark	08
Overlap	04	Stamping	09
Mismatch	05	Rust	10

Table 3: CTQ Tree Representing Needs, Quality Drivers and Parameters Effecting Quality

NEED Factor expressed by the customer as being important to quality	QUALITY DRIVERS Understanding what is the meaning of "Poor" for customer	CRITICAL TO QUALITY A measurable form of Quality Driver
Reduction in Defect Rate	Scaling	Overheating/Temperature. Presence of air or combustion particles during heating.
	Cracks	High Austenizing temperature. Soaking time. Delay after soaking and heating. Type of quenching medium. Temperature of quenching medium. Burring and Cracks formed during shearing.
	Hardness (40HRC-60HRC)	Temperature at hardening stage/ Austenizing Temperature. Type of quenching medium. Temperature of quenching medium. Quench delay.

ANALYZINGTHE DEFECTS

During the analyze phase it has been identified that the temperature of quenching medium and temperature of work piece during hardening is affecting the product quality seriously. Other parameters effecting quality drivers are identified as Type of quenching medium in use, Type of lubrication system and lubricant presently used during forging. These parameters need to be fixed immediately to control the defect rate.

Based on Data analysis and brainstorming sessions of production and quality personnel's of company following Alternatives are suggested:

1. Use of water-soluble polymers for controlling hardness range and cracks occurred during hardening:

By carefully selecting oil minerals, polymers for quenching purpose required mechanical properties can be achieved without tempering operation. Cooling characteristics of a quenchant depend upon the type of polymer, the polymer concentration and the temperature (Adeyemi and Adedayo, 2009). Use of quenching medium depends upon type of steel. Polymer quenchant, works by forming films around the components which act as an insulating layer during the cooling process. Due to this insulating layer, the heat flow from work piece to the quenching medium is reduced and oil like slow cooling is achieved without any defects. Use of aqueous solution of water-soluble polymers can help in present study for controlling the hardness range of hammers.

2. Use of Anti Scale coating to prevent quench cracks and scaling in forging:

A number of protective atmospheres may also introduce like liquid dissociated ammonia, hydrocarbon, nitrogen, endothermic gas and exothermic gas. These processes are very much costly and it is difficult to afford such operations by a small scale industry. Protective coatings are better and less costly as compared to these methods (Shenoy, 2014).

Anti scale coating prevents the reaction of oxidation and decarburization and prevents the effect of Scale pits during forging. These coatings are applied before forging process with help of paint brush, spray gun or dip method. Uniform layer of coating gives good results. Anti scale coatings helps in reducing Decarburization during forging operations and Reducing quench cracks also. Coatings does not react with steel surface and don't even release any toxic fumes during heat treatment (Thomas et al., 2009).

RESULTS AND DISCUSSION

ANTISCALE COATINGS: In order to observe the performance of anti scale coatings, two types of anti-scale coatings ESPON-HR and ESPON-HF were applied to 30 billet samples each.

After the complete forging operations each sample is tested for hardness on the both faces (A and B). Then all the samples are inspected for cracks using magna flux testing machine. Figure 1 and Figure 2 shows graphically the average hardness of hammers, after using ESPON-HF and ESPON-HR coating respectively.

Figure 2 shows graphically the presence of cracks on two samples (One face each) for ESPON-HF coating. Graph plotted for ESPON-HR coating shown in Figure 1, shows that no crack is observed. This indicates that after using the anti scale compounds (ESPON-HF and ESPON-HR), the scaling and crack tendency decreases.

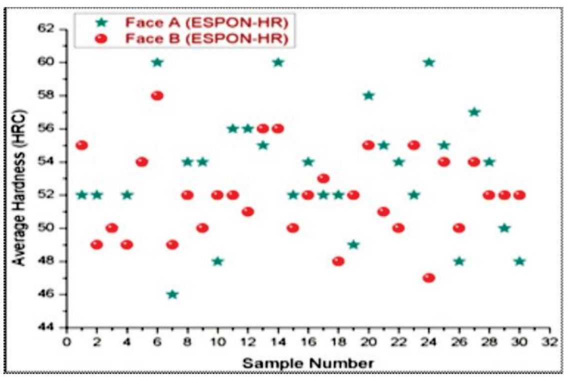

Figure 1: Average Hardness for ESPON-HR

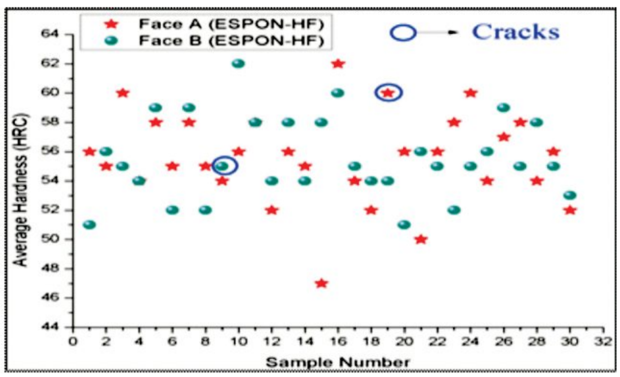

Figure 2: Average Hardness for ESPON-HF

WATER-SOLUBLE POLYMERS: HIQUENCH-P polymer based quenchant is bought from the market to test the implementation of water-soluble polymer mixed with the water to form a solution.

Polymer solution is mixed with water during the hardening operation. Earlier water was used as quenching medium and now water + polymer solution has been used on trial basis. 8% Polymer to that of water is mixed in tank. The temperature of the quenching medium is to be maintained between 40^{0}C to 50^{0}C, it is same as for the earlier system. 20 pieces each hardened with water + polymer and plain water has been inspected and the hardness observations are plotted to compare the hardness observed during Water + Polymer mixture and plain water as quenching medium.

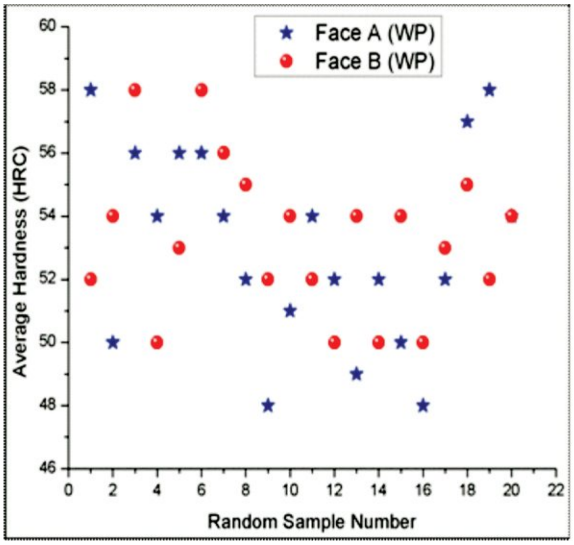

Figure 3: Average Hardness for Water + Polymer Mixture as Quenchant

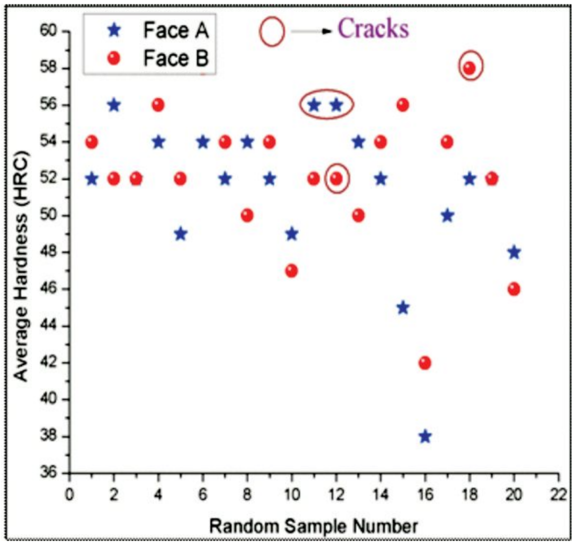

Figure 4: Average Hardness for Plain Water as Quenchant

Figure 3 and Figure 4 shows average hardness graphs plotted when quenching medium used is water + polymer mixture and plain water respectively. The plot shows that there is a significant reduction in the quenching cracks (shows by circle) on the two faces of the hammer when polymer is added in the water in a fixed proportion (8% of water) for a random sample of 20 specimens as compared to normal quenching. Encircled data in the plot shows the presence of quench cracks which are found when water is used as quenchant without any addition of polymer solution.

It can also to be noted that with water + polymer (WP) quenchant, the hardness is achieved within the acceptable range, which is generally required. Thus, the usage of polymers in the water will lead to significant reduction in the quenching cracks and this alternative is acceptable to the organization also.

Polymer is now regularly used with water during hardening process and has shown a significant change in controlling the defect of cracks. Table 4 shows the inspection report for the month of August 2014.

Table 4: Defects Detected in Month of August 2014

S. No.	Month	Quantity inspected	Defect type				Total defects	Defect %
			Scaling	Crack	Cut mark	Unfilled		
1	Aug. 2014	2585	51	21	14	16	102	3.9%

Total of 2585 forged products of various types has been inspected and total of 102 defects has been detected. From these 102, cracks tend to 20.5% of the total defects detected in month of August 2014. Earlier the percentage of cracks was higher. With decrease in defect of cracks there is significant reduction in total defects also, in month of August 2014 total defect rate has also decreased to 3.9% of the quantity inspected. With these changes, DPMO (Defect Per Million Oppourtunities) calculated for the month of August 2014 is 3,946, which is equal to 4.16 Sigma levels.

CONCLUSION

The main objective of this case study was to control the quality issues faced by the company during manufacturing. Applied approach helped in detecting the reasons for rejection and rework.

Quality control data has been collected from the forging unit and then verified by having data sampling phase. Collected data has been analyzed and defects with higher effect on quality are identified by brainstorming session and data analysis. Then Cause-and-effects matrix was used to draw out some common reasons having major impact on the identified defects. On basis of prepared matrix alternatives have been proposed to control the major defects.

On basis of present study following conclusions are drawn:

i. It is concluded that defects like Cracks, Scaling/Scale pits and Low hardness are the main reasons behind higher rejection.
ii. Three defects were interlinked, controlling cracks leads to lower hardness and scaling/Scale pits.

iii. Use of water soluble polymers during hardening process was tested and implemented successfully, which helped in decreasing the contribution of cracks to 20.5% from the detected defects.

iv. Anti scale coatings were tested to control the defect of scaling and positive results were obtained. But due to higher initial cost of this particular operation and long hours of application these coatings cannot be implemented in the present industry.

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Investigating The Designing Of Domestic And Commercial Air Conditioning Systems In Context To Human Health

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Abstract-

The paper described how to go about understanding the concept of architecture of building and air conditioning so as to generate a healthy indoor environment. The work presented in this paper addresses 'Design of air conditioning systems for changing lifestyles to match human comfort ', shape them to conform the needs of people and their health. 'People ignore design that ignores people'. This has led to an increased interest in modeling and real-time tracking of location, activity, and thermal comfort of building occupants for better HVAC management. It is difficult to measure in real-time environments where user context changes dynamically, still important contextual information for measuring thermal comfort is O_2 and CO_2 level which affect Metabolism rate and also change it based on current physical activities in different A/C designs.

Key words- air conditioning, IAQ, ventilation, thermal comfort, HVAC, Heat load.

INTRODUCTION

While development on one hand goes hand in hand with architecture, the architect plays a very important role on both the macro and micro level. "Architecture has a very big role in improving the quality of life for all. Thoughtfully designed individual tenements give joy to families, while innovatively designed public spaces benefit the community. Environmentally sound structures contribute a great deal to reducing carbon emissions and improving the living environment. Engineers are trying to implement these measures in air conditioning designs so as to improve human comfort level.

PRESENT DAY APPLICATIONS OF INDOOR AIR CONDITIONING

The engineers of the green revolution and social reformers became national celebrities in past decades dominated by rural priorities, an India with an urban majority could very well make architects the folk heroes of the next few decades.

Almost all rooms rooms in major hotels, all department stores, major office building, hospitals operation theatres and waiting rooms, and homes etc. are air conditioned. This application of air-conditioning can be broadly classified in two types as per the nature of requirement. An air conditioning system, or a standalone air conditioner, provides cooling, ventilation, and humidity control for all or part of a house or building.

Types of Air Conditioning systems

Air conditioners today have not only become a luxury item but also a need of every household owing to the increasing global warming and temperatures. Following are few most common designs of air conditioning systems used in India:

Industrial Air Conditioning- The requirement of specific condition of air in the space is for an equipment or a process. Large main frame computers, electronic microscope and other such electronic equipments require effective dissipation of heat for accurate results. So air conditioning is provided in the space for these equipment. Similarly, there are industrial processes which require stringent conditions of environment. A spinning section in textile mill and paper making require high humidity for good quality of thread and paper while watch making requires controlled temperature for accuracy. Pharmaceutical industry and clean rooms in some industries require high purity of air to prevent contamination and malfunctioning of micro parts respectively.So the emphasis of industrial air-conditioning is on the requirement of the equipment and process and not that of occupants.

Comfort Air Conditioning- This class of air conditioning is meant to ensure human comfort in the space. As we all are aware human body is a slow combustion engine. It burns fuel (food) to produce energy for all the activities of the human being. This energy, as it happens in all machines, degenerates into heat and needs to be dissipated to maintain body temperature. Though nature has provided means of dissipation the human being would be comfortable if heat is transmitted out without physical discomfort like wetting of clothes or cracking of skin etc.A comfortable environment would increase the efficiency of a worker in the office. It would be essential for life sustenance in operation theatres, ICU's, burn sections etc. Then affluence makes air-conditioning necessary for human beings in theaters, shops households and restaurants.

BIOLOGICAL CONSIDERATIONS RELATED TO HUMAN HEALTH

The comfort feeling of the people in an air-conditioned plant depends upon following five main factors :

1. Supply of oxygen and removal of carbon-dioxide.
2. Removal of body heat dissipated by the occupants.
3. Removal of body moisture dissipated by the occupants.
4. To provide sufficient air movement and air distribution in occupied space.
5. To maintain the purity of air by removing odour and dust.

The ASHRAE precisely defines the parameters to be considered in an indoor environment and they are:

1. Indoor air temperature (IAT) and mean radiant temperature (MRT).
2. Indoor relative humidity (IRH).
3. Outdoor ventilation rate provided.
4. Air cleanliness.
5. Air path and movement.
6. Sound level.
7. Pressure difference between space and surroundings.

Table 1: Metabolic rate as a function of physical activity for a 70 kg adult (Source – ASHRAE).

Type of activity	Metabolic rate (W)	Metabolic rate (kcal/hr)
sleeping	72	62
seated, quiet	108	93
standing, relaxed	126	108
walking about the office	180	155
seated, heavy limb movement	234	201
flying a combat aircraft	252	217
walking on level surface at 1.2 m/s	270	232
housecleaning	284	244
driving a heavy vehicle	333	286
calisthenics/exercise	369	317
heavy machine work	423	364
handling 50-kg bags	423	364
playing tennis	432	372
playing basketball	657	565
heavy exercise	900	774

So the main physical and mechanical factors that affect human comfort are temperature, humidity, air movement and air purity.

Required oxygen by human brain

Human brain roughly makes 2-3% of total body mass and yet it consumes 20-25% of total oxygen used by the blood supply. However oxygen requirements increases during times of mental activities or hard training because brain requires increasing demands of oxygen from your blood in order to generate the energy levels needed to function at peak performance. Essentially brain uses oxygen as food.

Table 2: Effects and symptoms of oxygen depletion

In general, oxygen deficiency leads to a loss of mental alertness and a distortion of judgement and performance. **THIS HAPPENS WITHIN A RELATIVELY SHORT TIME, WITHOUT THE PERSON'S KNOWLEDGE AND WITHOUT PRIOR WARNING.**	
21 -14%	Increasing pulse rate, tiredness
14 - 11%	Physical movement and intellectual performance becomes difficult
11 - 8%	Possibility of headaches, dizziness and fainting after a fairly short period of time
8 - 6%	Fainting within a few minutes, resuscitation possible if carried out immediately
6 - 0%	Fainting almost immediate, death or severe brain damage

Table 3: Effects and symptoms of carbon dioxide enrichment

The UK has assigned an 'workplace exposure limit' of 5,000 ppm (0.5%) over 8 hours and 15,000 ppm (1.5%) for 10 minutes. Carbon dioxide vapour is not truly inert. It is mildly toxic.	
1%	Slight, and un-noticeable, increase in breathing rate
2%	Breathing becomes deeper, rate increase to 50% above normal. Prolonged exposure (several hours) may cause headache and a feeling of exhaustion
3%	Breathing becomes laboured, rate increases to 100% normal. Hearing ability reduced, headache experienced with increase in blood pressure and pulse rate
4 - 5%	Symptoms as above, with signs of intoxication after 30 minute exposure and slight choking feeling
5 - 10%	Characteristic pungent smell noticeable. Breathing very laboured, leading to physical exhaustion. Headache, visual disturbance, ringing in the ears, confusion probably leading to loss of consciousness within minutes
12%	Characteristic taste
10 - 100%	Loss of consciousness more rapid, with risk of death from respiratory failure. Hazard to life increased with concentration, even if no oxygen depletion. Concentrations of 20-30% and above are immediately hazardous to life.
The gasping reflex is triggered by excess carbon dioxide and not by shortage of oxygen.	

O_2 (Volume %)	Effects and symptoms
18-21	Individual can detect no visible symptoms at this percentage. Risk assessment must be assumed to understand the reasons and whether it is safe to continue working.
11-18	Decline of physical and thinking performance without the patient being aware.
8-11	Possibility of headaches, dizziness, chance of fainting within few minutes without earlier warning. Risk of death below 11%.
6-8	Collapsing strikes after short period of time, recovery possible if carried out immediately.
0-6	Immediate fainting, brain damage, even if rescued.

CALCULATIONSANDOBSERVATIONS FOR WINDOW & SPLIT A/C SYSTEMS

Oxygen depletion ratein different type of activities As stated by psu.edu the lowest % volume of O2 a person can survive at standard pressure is about 17.5%.

Calculation for how long would it take to use up just the O2 in 1m3 for life Volume: 1000L/m3

21% of the atmosphere consists of oxygen volume.

For 1000L of air: $0.21 \times 1000L = 210L \text{ of } O_2$

If 17.5% of the atmosphere consists of oxygen by volume

Then 1000L of air would consist:

$$1000L \times 0.175 = 175L \text{ of } O_2$$

$$\text{Therefore useable oxygen } 210L - 175L = 35L \text{ for a person}$$

$$\frac{35L}{22.4L/\text{mole}} = 1.6 \text{ mole oxygen}$$

$$\text{The mass of 1.6 mole of oxygen is: } 1.6\text{mole} \times 32\,\frac{\text{grams}}{\text{mole}} = 51 \text{ grams}, 0.051\text{kg}$$

How long would 3 persons under different exercise modes last in an airtight enclosure of 1m3 that has 0.3Kg of oxygen, but only .051Kg is useable

Table 4: Calculation of air quality w.r.t O_2 content.

	For a person at rest	For a person doing NASA type activity	For a person exercising hard all day
Oxygen needed by 1 person per day	0.617Kg/day	0.84Kg/day	7.2Kg/day
Length of time needed to use all the useable oxygen in $1m^3$.	$\frac{0.051Kg}{0.617Kg/day}$ = 0.083 day or 2 hours	$\frac{0.051Kg}{0.84Kg/day}$ = 0.061 day or 1.5 hours	$\frac{0.051Kg}{\frac{7.2Kg}{day}}$ = 0.0071 dayor 10minutes

CALCULATIONSANDOBSERVATIONS FOR CENTRAL A/C SYSTEMS

Right-sizing the HVAC system begins with an accurate understanding of the heating and cooling loads on a space. The values determined by the heating and cooling load calculation process dictate the equipment selection and the duct design needed to deliver conditioned air to therooms of the house to meet the occupant's comfort expectations.The heat gain of a room or building depends on the size of the area being cooled, the size and position of windows, and whether they have shading, the number of occupants, heat generated by equipment and machinery, heat generated by lighting. By calculating the heat gain from each individual item and adding them together, an accurate heat load figure can be determined. Following is actual sample of head load chart generated for a library of a college in Chandigarh as per ASHRAE guidelines:

AIR CONDITIONING FOR PEC LIBARARY, CHANDIGARH										
PROJECT:		**(AC Area)**					DATE .		Rev:	
SPACE:		**Library First Floor**						.	Estim ated	
AREA:	7733	Sqft	69597	Cu ft		Estim ate for:	**SUM MER**			
SOLAR GAIN GLASS				**HE AT GAI N**	CON DITI ON	DB (°F)	WB (°F)	% RH	DP (°F)	G R/ L B
ITEM	Area	Sun Gain	Factor	**Btu/ hour**	OUT SID E	110	75	20		77 .5
	(Sqft)	(Btu/h.sq ft)			ROO M	75		55		71 .5
N - Glass		23	0.56	0	DIFF ERE NCE	35	XXXX	XX XX	XXX X	6
NE - Glass		11	0.56	0						
E - Glass		12	0.56	0	OUTSIDE AIR (VENTILATION)					
SE - Glass		11	0.56	0	258	Peopl e X	5.0	CFM/Person		12 89
S - Glass		12	0.56	0	6959 7	Cu ft X	0.0	Air change per hour		41 76
SW - Glass		66	0.56	0				CFM VENTILATI ON		54 65
W - Glass	612	163	0.56	5586 3						
NW - Glass		148	0.56	0	EFF. SENSIBLE HEAT FACTOR (ESHF) =				0. 8 5	
Sky light				0	Indicated ADP =		55	°F		
SOLAR & TRANS. GAIN WALLS & ROOF					Selected ADP =		52	°F		
ITEM	Area	Eq. temp. diff	U		Dehum. temp rise =		19.55	°F		
	(Sqft)	(°F)	(Btu/h.sqft)		DEHUMIDIF IED CFM =		15399			
N - Wall		19	0.36	0	CFM BASED TR		**38.5**			

NE - Wall		27	0.36	0			
E - Wall		27	0.36	0			
SE - Wall		35	0.36	0			
S - Wall		31	0.36	0			
SW - Wall		31	0.36	0			
W - Wall	318	27	0.36	3091			
NW - Wall		23	0.36	0			
Roof Sun		47	0.48	0			
Roof Shaded		31	0.12	0	**NOTES**		
TRANS. GAIN EXCEPT WALLS & ROOF					Occupancy =	258	Nos
ITEM	Area	Temp. diff.	U		Lighting =	1.0	W/Sqft
	(Sqft)	(°F)	(Btu/h.sqft)		Eq. Load =	0.5	W/Sqft
All Glass	612	35	1.13	24205	Height =	9.0	FT
Partition	684	30	0.32	6566	Fresh Air=		Cfm per person
Ceiling	7733	30	0.32	74237	=		Air changes per hour
Floor		30	0.12	0	**Internal Heat - People**		
INTERNAL HEAT GAIN					Sensible Heat	245	
People	258	Nos X	245	63153	Latent Heat =	205	
Light	7733	W X 1.25	3.41	32962			
Eq. Load	3867	W X	3.41	13185	**Recommended Configuration:**	40.85	TR
ROOM SENSIBLE HEAT (RSH)				273262			
Supply duct heat gain +	Supply duct leak. loss +	Heat gain from fan HP(%)	4	10930			
		Safety factor (%)	8.5	23227			

OUTSIDE AIR						
CFM	°F	BF	FACTOR			
5465	20	0.15	1.08	17705		
EFFECTIVE ROOM SENSIBLE HEAT (ERSH)				325125		
LATENT HEAT						
People	258	Nos X	205			
			ROOM LATENT HEAT (RLH)	52842		
	Supply duct leakage loss +	Safety factor %	5.0	2642		
OUTSIDE AIR						
CFM	GR/LB	BF	FACTOR			
5465	6	0.15	0.68	3344		
EFFECTIVE ROOM LATENT HEAT (ERLH)				58829		
EFFECTIVE ROOM TOTAL HEAT (ERTH)				383953		
OUTSIDE AIR HEAT (SENSIBLE)						
CFM	°F	1 - BF	FACTOR		Btu/h/ Sqft =	67.0
5465	20	0.85	1.08	100331	CFM / Sqft =	1.99
OUTSIDE AIR HEAT (LATENT)					Sqft / TR =	179
CFM	GR/LB	1 - BF	FACTOR		CFM/ TR =	356
5465	6	0.85	0.68	18951	Sqft / Person =	30.00
			HEAT SUB TOTAL	503236		
Return duct heat gain & leak. loss +	HP Pump +	Dehum. & Pipe loss (%)	3.0	15097		
TR	**43.19**		**GRAND TOTAL HEAT**	518333		

CONCLUSION AND FUTURE SCOPE

The present review work investigates the effect of hypoxia on judgment and decision making which occurs in air conditioned environment with low ventilation rates or systems like window and split if installed in isolated environments for achieving higher thermal efficiency. Thus such research is worth pursuing for two reasons. First, people frequently experience mild tiredness during prolonged exposure to insulated air conditioned environment. Second, bad judgments and decisions during these activities can be fatal. Example driver fatigue due to these effects has been the cause of accidents due to amount of time drivers spend in vehicles because of complex city life's and traffic congestions.Literature reveals that subjective fatigue feeling ishigher in the low rate (18%) oxygen conditions and it decreased to certain degree in higher rate (30%) oxygen conditions. Also, reaction time for braking after being ordered to suddenly stop following more than two hours of continuous driving reduces in the high-rate oxygen conditions when compared to low-rate oxygen conditions. As it was clearly showed from the above results, drivers fatigue can be reduced according to the supply of oxygenvia controlled ventilation (21% of oxygen inhaled produces 4.5% of carbon dioxide exhaled. As the normal human breathing task exhales carbon dioxide. An average breathing rate of 500ml, 15-20 times a minute will produce co2 production rate of almost 0.4 litres per minute average. Assuming normal human activities can continue until oxygen is minimal to less than 18 per cent when inside enclosed air conditioned environment. Due to low O2 levels, exposure to moderate level carbon dioxide produce short-term health effects and high-level exposure ultimately leads to fatigue and tiredness.

Thus wide use of air conditioning helps to improve thermal comfort, but health problems associated with poor indoor air quality now appear more frequently.Even on the face of these facts, the fundamental concepts of air conditioning are not understood or even thought about by millions of people who enjoy the comfort produced by it. The poor air quality is detrimental for human health and adversely affects the productivity and comfort also. As an average person spends more than 80 % of the day in an indoor environment, either at home or at workplace, a vehicle, a public building etc. It is need of the hour to investigate and analyse the cooling technology integrated with indoor air quality control for human comfort.

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Lean And Six Sigma An Integrated Approach For Waste Reduction In Indian Smes: A Review

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Abstract

In present manufacturing scenario Lean manufacturing is among the major businessesinitiatives which has been taken around the globe in order to remain competitive in ever increasingly global market demandswhere as Six Sigma is atechniqueto measure the number of "defects" inthe process, As "Zero Defect" can be systematically figured out in order to get close to accuracy as possible. The combinedapproach of Lean manufacturing and Six Sigma methodology may can lead to higher benefits including reduction in process variation and dramaticimprovement in business. Ultimately combination of Lean manufacturing and Six Sigma can be used in order to get optimal results.In beginning the process of Six Sigma can be changed from slow to fast by Lean Manufacturing. Last, Lean manufacturing and Six Sigma can provide the structure easily for optimum flow. In simple language the ultimate goal is to create value to the customer for the company hence the customer settles the quality for the product. The quality of the product is its ability to satisfy and preferably exceed the needs and expectations of the customers. Lean Six Sigma's growing prevalence and importance in industry, presently companies have acknowledged that Lean and Six Sigma share a common objective: to create value based end customer requirement.

Keywords: Lean manufacturing; Six Sigma; Lean Six Sigma; SMEs; Business Performance.**1.**

INTRODUCTION

In present manufacturing scenario waste reduction is one of the prime objectives of all industrial organizations in order to maximize the profits. Industrial waste is the unwanted wastage of resources produced during industrial activities which may include any material that is rendered useless during a manufacturing process. Indian Small and medium enterprises (SME'S) are facing huge losses due to controlled and uncontrolled wastage of available resources. Even though many efforts are done by various researchers to optimize the whole manufacturing process by using various techniques in order to minimize the losses beard by Indian SME's due to wastage of resources. But still there is a huge scope of improvement in this field. Lean six sigma is one of the major tools that can be used by the manufacturing organizations to achieve this target. The goals in implementing the Lean Manufacturing are lower production costs; increased output and shorter production lead times. [Mekong"s capital review (2004)]. Waste can be defined as unwanted and useless material and resources which increases the cost of final products.

Broad classification of the waste is as follows.

Controlled waste: Controlled waste is that waste which can be prevented by small human efforts and proper process awareness. Example operator skill (highly skilled worker can perform significant role minimizing the waste of raw material.), maintaining adequate inventory, improper working environment etc.

Non Controlled Waste: Those wastes which cannot be prevented by human efforts such as due to climatic damages, sudden accidents, electricity breakdowns etc.

1. Literature Review

Thorough literature survey has been carried out to capture the voice of concerned people and their relevant works as far as implementation of Lean manufacturing and Lean six sigma implementation in various (Large, Medium and MSME's) industrial organizations. Brief description of these has been represented below. Literature based upon waste management has been reviewed. P.UMA (2013) discussed that Industrialization is an effective means for solving the problems of economic and social progress in developing countries of the world. Gunwar Myrdal has rightly described the relationship of industrialization to economic development when he observes "the manufacturing industry represents, in a sense, a higher stage of production in advanced countries. Vinesh V. Rakholiyaetal (2012) Modern environmental legislation is becoming much more internationally coherent and less prescriptive, and focused on prevention of pollution through control of hazardous materials and processes as well as on protection of eco-systems. Girish. C. Pude (2012) purposed Value Stream mapping technique involves flowcharting the steps, activities, material flows, communications, and other process elements that are involved with a process or transformation. E. M. Elsayed (2009) studied that This paper investigates a method to electro reduce toxic hexavelent chromium to trivalent state using rotating disc electrode (RDE) and rotating cylinder electrode (RCE) cell. Electrolysis of acidic hexavalent chromium solution using a rotating lead cathode reduces the hexavalent chromium Cr to trivalent chromium. G. Tamizharasietal (2014) Discussed in paper regarding benefits of implementing lean concept and focuses on Value Stream Mapping (VSM) and Single Minute Exchange of Dies (SMED) in Carriage Building Press shop. As VSM involves in all of the process steps, both value added and non-value added, are analysed and using VSM as a visual tool to help see the hidden waste and sources of waste. Rakesh Kumar etal (2014) focused on Lean Manufacturing system has been acknowledged by Indian industry as a capable system in enhancing organisational performance by focusing on elimination of waste from the manufacturing system and thus improving effectiveness of the organisation. M.C. Prieto-avalos (2014) studied that organizations are involved in a complex environment with continues changing, that should impels the innovations looking for increase production performance, quality improvement, customer satisfaction and create a competitive advantage. Mohamed K. Hassan (2013) this study was applied in a welding wire manufacturing plant to improve the quality of the manufactured welding wires, reduce the manufacturing waste and increase the yield of the manufacturing process, by applying the Lean Six Sigma (LSS) methodology and waste management. LLS is considered one of the successful approaches in the field of quality improvement and cost reduction. Man Mohan Siddhetal (2013) put emphases on Lean manufacturing is one of the initiatives that major businesses all around the world have been trying to adopt in order to remain competitive in the increasingly global market and Six Sigma was an American “invention”. The Central idea behind Six Sigma is that if you can measure how many “defects” you have in process, you can systematically figure out how to eliminate them and get as close to “Zero Defect” as possible. Akhilkumaretal (2014) examined efforts have been made to identify the barriers to lean implementation and then to develop the relationships among these identified barriers. While literature survey suggested some important barriers in the lean implementation, additional few barriers were identified through discussions with the subject matter experts from the industry.

1. SME'S AND THEIR SIGNIFICANCE IN INDIA

Small and medium enterprises are playing an important role in the economic growth of india. As per available data SME's are contributing 18% in the GDP growth of India (FY 2014-2015). SME's are also a source of employments for the 50% of Indian population. Today SME's are flourished in a well-organized clusters based manner.

The main barrier in the growth of SME's is the optimum utilization of available resources. Even National manufacturing competiveness Council (NMCC) has proposed the various schemes for developing the global competitiveness of Indian SME's but still they are facing huge losses due to wastage of available resources.

1. LEAN MANUFACTURING Lean", is a systematic method for the elimination of waste within a manufacturing process. Basically lean is a methodology which makes improvement in the processes in order to get an overall improved system.Lean also takes into account waste created through overburden and waste created through unevenness in workloads. Working from the perspective of the client who consumes a product or service, "value" is any action or process that a customer would be willing to pay for.

Essentially, lean is centered on making obvious what adds value by reducing everything else. Lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS).

SIX SIGMA

Six sigma is a well-established approach that seeks to identify and eliminate defects, mistakes or failures in business processes or systems by focusing on those process performance characteristics that are of critical importance to customers (Snee, 2004). Six sigma provides business leaders and executives with the strategy, methods, tools and techniques to change their organisations. Six sigma has been on an incredible run for the last ̣ ve years producing signị cant savings to the bottom-line of many large manufacturing organisations. There are four aspects of the six sigma strategy that are not emphasised in other business improvement methodologies and total quality.management (TQM). First of all, six sigma places a clear focus on bottom-line impact in hard dollar savings. No six sigma project will be approved unless the team determines the savings generated from it. Second, six sigma has been very successful in integrating both human aspects (culture change, training, customer focus, etc.) and process aspects (process stability, variation reduction, capability, etc.) of continuous improvement. Third, six sigma methodology (dẹ ne-measure-analyse-measure-control or DMAIC) links the tools and techniques in a sequential manner. Finally, six sigma creates a powerful infrastructure for training of champions, master black belts, black belts, green belts and yellow belts (Harry and Schroeder, 2000; Pande et al., 2000; Adams et al., 2003).

1. LEAN & SIX SIGMA (LSS): A COMBINED APPROCH

The "lean" concept has often successfully allowed companies to deliver bottom-line savings in production through improves process efficiency. Lean is aimed at reducing waste and adding value to production systems so that systems performance is significantly improved and a company "does more with less". A typical example is applying TPM techniques to poorly maintained machinery. This provides for value-added inputs by way of ensuring machinery remains in productive operation for longer periods of time (Jostes and Helms, 1994). Maintenance procedures and systems are designed so that they are easier to accomplish and this is achieved through machine redesign and modifications in order to facilitate this process. The basic lean philosophy relies on a five phase approach. This is:

Identify value (from the point of the customer).
Measure the value stream.
Pull on customer demand.
Create flow.
Achieve perfection.

Employing therefore a standard operational framework for implementing both lean and six sigma approaches is seen as an obvious and necessary step for companies to achieve simultaneous benefits from the both strategies (George, 2002). To this end the DMAIC process is used as the main functional system for the implementation of lean six sigma (LSS) approach. framework. The main phases of the integrated LSS approach are:

Define – what is the problem? Does it exist?
Measure – how is the process measured? How is it performing
Analyse – what are the most important causes of defects?
Improve – how do we remove the causes of the defects?
Control – how can we maintain the improvements?

CONCLUSION

Lean and Six Sigma are evolved into business strategy in many large originations and also having a very important place in ever-growing SMEs of India. Lean and six sigma are emerging as a new wave for changing the financial culture of industrial organizations. The development of a LSS model developed a culture towards continuousimprovement and the systematic implementation of the approach throughout the organisation.The application of the LSS approach allowed the company to develop advanced statistical techniques and to become generally more "technical" in their approach to problem solving.

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Adoption Of Lean Culture In Indian Context: Literature Review And Research Directions

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ABSTRACT

The purpose of this study is to review regarding adoption of lean culture and lean thinking in Indian Industry correlated to various sectors for almost a decade. Lean manufacturing got widely attention after the publication of the book "The machine that change the world". The concept of lean is known universally not only for its remuneration but making the products more valuable. The success stories of lean outside its ancestral place bats for its Universality. The admittance of Lean in Indian industries was around two decades ago. In Indian context, it is the need of the hour to draw the accurate picture of lean inside the plants considering the regional constraints. The reason for this issue to be raised as India is drawing the major attention of emerging as favorable destination for investors. The degree of implementation of lean in industries, Lean culture and approach of lean thinking are no. of aspects to be looked at. The relentless growth of manufacturing sector would not possible without economic friendly environments provided by government of India. With the timely interventions, inquiring about age of lean in plants would not be deviating factor from the route of progress and how much attainment of leanness is there.

Keywords: Lean Manufacturing (LM), Lean thinking, Lean culture, Lean approach, Lean audits

INTRODUCTION

In this era of globalization, fluctuating market and rapid fierce competition among manufacturers is often seen for giving better products at reasonable price to customers is only perspective for survival in this volatile scenario. This led towards a management system targeting a cost reduction mechanism with fewer resources but on the track of continuous improvement. Lean manufacturing or Lean production is the only key not for survival but a long term approach for existence in the spirited markets where heavyweight force like china is a biggest intimidation (Mahapatra et al., 2007).

Lean manufacturing is defined as systematic and collective approach for reducing waste and increasing value of the products. LM focusing on the products to be manufactured with better quality and less use of resources at rational prices. The birth of LM was from Toyota production system from year 1950, although concept of Lean was introduced by Kracik, 1988. The concept of Lean got widely acknowledged with publication of the book "The machine that changed the world" (Womack et al.,1990).

LITERATURE REVIEW

The Literature review was reviewed for different aspects from some certain recent publications in the field of Lean manufacturing across various sectors.

LM in various sectors Lean philosophy was applied on forging shop floor. The effective tool of LM named as Value stream mapping (VSM) not only eradicate the waste but also cleared the confusion of implementing LM tools in forging environment (Sahoo et al.,2008). Looking at other aspects of LM, it also signified its importance in continous and discrete production systems (Mahapatra et al.,2007). LM principles were successfully applied in machine tool sector (Eswamoorthi et al.,2011). Lean manufacturing is also viewed as dominant approach for increasing the value of products and services (Panizollo et al., 2012).

Linking LM to financial aspects (The link to be revisited) LM is a powerful tool for converting weaknesses into strengths and revealed some authentic issues towards LM implementation in the country (Upadhye et al.,2010).The Degree of penetration of lean inside Indian industries is another feature to be looked at. Intensity of lean is disheartening in various sectors (Thanki et al., 2014). It is progressing of lean at very slow pace is a matter of concern (Eswamoorthi et al.,2011). Leanness index was developed for computing and Leanness measurement method was used with performance measurement team and the assessment parameters were supplier issues, investment priorities, Lean practices, various wastes and customer issues (Singh et al., 2010).

Data analysis Techniques and sample size: Structural equation modeling (SEM) was used to build the measurement and analysis helped to determine whether to accept or reject the hypothesis that has been stated based on structural model. Lean manufacturing practices helped in improving organizational performance among the industries being surveyed for 60 SMEs in India (Vinod et al, 2012). Hierarchical cluster analysis, ANOVA were used to analyze the data for 32 industries in India (Thanki et al.,2014). In another study the survey was limited to 79 industries across various regions in India (Ghosh et al., 2012).

Lean hurdles Towards successful implementation of Lean in a industry, certain barricades are to be removed. Major of these are cost, management (Kumar et al., 2014). The correlation of LM with Human related issues cannot be deserted (Thanki et al.,2014). The set mentality worker is another major illustration (Eswamoorthi et al.,2011). However tremendous efforts were seen in cases in India where implementing lean also hike the Brand image of company in market (Panizollo et al., 2012).

These hurdles may be diverse at different type of industry, nature of product, volume to be manufactured and socio economic environments (Bhasin et al., 2012).

WHY LEAN MANUFACTURING

India is emerging as hot destination for investment opportunities for investors (The Tribune). In this Competitive era, LMS is the most suitable improvement strategy for MSMEs (Upadhye et al., 2010). LM implementation identifies and completely reduces waste from the system. Waste is anything other than minimum amount of equipment, materials, parts and working time that are quite essential to production systems. Lean manufacturing system also got the attention of Govt. of India for its ample share towards the GDP of country with growth in Industrial sector (Govt. of India). Under the banner of NMCP, Lean implementation initiatives working towards micro, small and medium sectors of government intention to increase the GDP growth rate for nearby future. But certain factors are to considered for the identification of lean barriers and adoption of lean culture in these organizations. Behind successful business transformations, no. of pros and cons are to be kept in mind.

The influx of lean in Indian industries around two decades ago still Lean benefits are not recognized in Indian industry (Singh et al.,2010) Lean implementation in India is not so encouraging and the rationale was that human related issues are not tackled properly (Thanki et al.,2014). Low level of lean implementation in Indian machine tool industries was also reported (Eswamoorthi et al.,2011) and other issues were anxiety in changing the mind set of workers, lack of awareness and training about the Lean concepts, cost and time. Cost, Culture and employees attitude are reported for smaller organisations (Bhasin et al., 2012) Management is cited as major attribute for lean barrier in medium and large size organizations (Kumar et al.,2014)

First pass correct output, reduced manufacturing lead time and increased productivity are three main drivers of lean implementation (Ghosh et al., 2012). Learning culture and awareness within organization for effective implementation of lean manufacturing (Kumar et al.,2014). LM tools must be situation specific and according to the type of industry (Upadhye et al., 2010).

Lean Production elements (LP practices)

Lean manufacturing techniques follow the sequential and systematic implementation of elements like :Scheduling, Employee perceptions, value stream mapping(VSM), Takt time, bottleneck process, group technology, cellular manufacturing(CM),, u-line manufacturing system, line balancing, Flow manufacturing, Single minute exchange of dies(SMED), small batch size, Inventory, Pull system, kanban, production leveling, Quality at source, kaizen, Standardized work (Sundar et al.,2014).

Benefits of lean manufacturing

Implementation of Lean manufacturing in industry is not limited to minimization of waste but to make more products more valuable (Dixit et al., 2015). LM improves operations and increases customer satisfaction in addition of continual improvement enhancing efficiency of the system. Apart from above some Benefits of LM are: cost reduction, Improved service, Improve on time delivery, Reduced manufacturing lead time, Improved manufacturing flexibility, Improved customer satisfaction, Improved product development (Mahapatra et al.,2007). These are also classified in two categories: Qualitatative and Quantitative, both of this escort towards significant increment in market share of the company which is also a good source of enthusiasm for management and morale boosting for employees engaged directly with LM practices on shop floor (Panizollo et al., 2012). Implementation of LM system pin pointing on certain room for spreading out is: Reduction in defects, Inventory reduction, Return on investments, Manpower utilization, Machine availability, Machine set up time reduction, Reduction in cycle time, Increase current capacity, Quality improvement, Reduction in floor space, Productivity (Upadhye et al., 2010).

CONCLUSIONS AND FUTURISTIC TRENDS

This review study about adoption of lean culture in Indian industry is limited to certain publications for almost last decade. The above mentioned survey about Lean manufacturing signifying that uniqueness of LM is not confined towards particular sector i.e. automobile sector (Panizollo et al., 2012). The intent behind the study is also to view the contribution to Lean manufacturing by no. of authors from India which also reporting the thirst of about LM system across the globe (Moyano et al., 2012). The involvement towards publications is in agreement with mentioned fact (Jasti et al., 2015). The coverage of literature review is indicating that Lean manufacturing as widely acknowledged Universal approach for its benefits and learning approach. Its journey started over a century ago from its birth place towards outside countries. But its journey started in India over two decades ago. The degree of leanness of firm that has achieved over a time since Lean introduced may become topic of research. The existence of govt. implementation initiatives at grass root level may be a trend to be look at adding the regional factors plus the regime on it. Another area in which significant gap is the thrust of basic lean practices in which firm is advancing. Lean audits, Lean appraisals and Lean performance culture should be given priority for advancing in this competitive world in which weaknesses converting into strengths at rapid rate (Bhasin et al.,2012).

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Optimization Of The Machining Parameters For Surface Roughness During Cnc Vertical Milling Of D2 (die Steel)

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ABSTACT

With the more precise demands of modernengineering products and competition to provide good quality, the surface finish together with dimensional accuracy plays a very important role. The selection of optimum cutting conditions (depth of cut, feed rate and cutting speed) is an important element of process planning for every machining operation. Optimum machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in competitiveness in the market.

In this paper, the selection of optimal machining parameters (i.e., spindle speed, depth of cut and feed rate) for end milling operations was investigated in order to minimize the surface roughness. An effect of selected parameters on process variables (i.e., surface roughness) was investigated using Response Surface Methodology (RSM) technique. The experimental study was carried out on Mitsubishi M70 Vseries CNC vertical milling center (VMC). Spindle Speed (N), Feed Rate (F) and Depth of Cut (DC) are the considered cutting conditions for minimizing the surface roughness (Ra) are determined using Minitab Software.

Key words: D2 (Die Steel), Carbide End Mill Tool, Vertical Machining Center, Response Surface Methodology (RSM), Optimum Cutting Condition, Milling Operations.

INTRODUCTION

Machining isa manufacturing process in which unwanted material is removed from the work piece to get the desired shape and dimensions. During milling process we expect minimum surface roughness. There fore it becomes important to optimize milling parameters to achieve the minimum surface roughness. The parameters during CNC milling which affects the sere sponses are cutting speed, feed, depth of cut, tool material, environmental conditions, cool ant used, operator skill etc. Surface roughness has great impact on the mechanical properties such as corrosionresistance, fatigue and creep. It also impacts on the functionality of the machine such as friction, wear, heat transmission etc. Optimum machining parameters can be done by considering a single objective function like desired surface finish, maximum material removal rate or maximum tool life. Optimum machining parameters achieved for a objective function may not be suited for another objective function. Optimization of machining parameters, surface roughness in end milling of mold surface of an ortez part by coupling neural network and genetic algorithm was studied by Hason Oktem (2006).

D2 is very wear resistant but not as tough as lower alloyed steels. The mechanical properties of D2 are very sensitive to heat treatment. It is widely used for the production of shear blades, planer blades and industrial cutting tools like Hobbs, Dies, Chasers, and Taps etc. Researchers are working to optimize the machining parameters to reduce the surface roughness in order to minimize the manufacturing expenses.D2 finds it application in manufacturing of various cutting tools.The effects of each parameter on obtained results were determined for different materials, tools and machining operations. Some people have even explained the relationship between dependent and independent machining parameters through regression models.

In this work, the machining parameters such as depth of cut (dc), spindle speed (N) and feet rate (f) that affect the surface roughness in the milling operation was studied. Response Surface Methodology is used to plan the experiments. Machining was done on Mitsubishi M70 V series CNC Vertical Milling Machine with 4 flute carbide tool using the RSM matrix of input parameters. Then analysis work was carried out using regression test. Further, the optimized values were obtained for cutting speed, feed and depth of cut. The material removal rate has been noticed under these set of parameters.

Fig.1: D2 (die steel) slabs.

Fig. 2: CNC Milling Center Mitsubishi M70 V series at Sood Industries, Phase II Chandigarh.

1. EXPERIMENTAL DETAILS

Experimentation has been done by considering the following levels of process variables. These parameters have been decided by consulting **Mohindra Precision Works (Focal Point, Patiala)** and also by considering Machining Parameters of CNC Milling Center.

Process Variables	Lower Limit	Upper Limit
Spindle Speed (rpm)	1159	2841
Feed (mm/min)	300	1507
Depth of cut (mm)	0.01	0.15

Table 1: Process Variables and their limits

1.1 Orthogonal Matrix of RSM

Experiments have been carried out using response surface method, experimental design which consists of 20 combinations of cutting speed, feed rate and depth of cut. Experiments are executed as per the orthogonal matrix generated by RSM with 3 factors at 2 levels while 0 blocking and replicate value of 1 (refer table 2 for designed experiments).

Std Order	Run Order	Spindle Speed	Feed rate	Depth of cut
16	1	2000	750	0.08
10	2	2841	750	0.08
20	3	2000	750	0.08
9	4	1159	750	0.08
5	5	1500	300	0.12
4	6	2500	1200	0.04
1	7	1500	300	0.04
12	8	2000	1507	0.08
6	9	2500	300	0.12
7	10	1500	1200	0.12
15	11	2000	750	0.08
13	12	2000	750	0.01
19	13	2000	750	0.08
3	14	1500	1200	0.04
8	15	2500	1200	0.12
18	16	2000	750	0.08
14	17	2000	750	0.15
17	18	2000	750	0.08
11	19	2000	-7	0.08
2	20	2500	300	0.04

Table 2: Orthogonal Matrix of RSM

1.1 CALCULATIONS FOR SURFACE ROUGHNESS -

Surface roughness need to the minimum for goodquality product (Lower is the better). The surface roughness, R_a

Min R_a (s, f, d)

MRR need to be maximum for increasing theproduction rate (Higher is the better)

The material removal rate, MRR

Max MRR (s, f, d)

RESPONSE SURFACE METHODOLOGY AND ITS IMPORTANCE

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building (Adesta and Riza, 2009). The objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). Response-surface methodology comprises a body of methods for exploring for optimum operating conditions through experimental methods. Typically, this involves doing several experiments, using results of one experiment to provide direction for what to do next (Fang and Wu, 2005). This next action could be to focus the experiment around a different set of conditions, or to collect more data in the current experimental region in order to fit a higher order model or confirm what seems to have found. An experiment is a series of tests, called *runs*, in which changes are made in the input variables in order to identify the reasons for changes in the output response.

The application of RSM is also aimed to reduce the expenses of other difficult analytical methods (like; Finite Element Method or CFD analysis etc.) and their associated numerical noises (Srikanth and Kamala, 2008). The problem can be approximated with smooth functions of Central Composite Design of RSM that improve the convergence of the optimization process because they reduce the effects of noises and inherent errors, substantially (Thamizhmanii et al., 2007). The responses can be represented graphically, either in the three-dimensional space or as contour plots that further help to visualize relation of response surfaces with input variables more clearly.

RESULTS AND DISCUSSIONS

RSM STATICS FOR Ra

To minimize surface roughness (Ra), Minitab has performed RSM on selected input milling variables. Roughness factors have been measured with profilometer for eachexperimental run. Firstly, Ra data has been checked for its normality and found ok (Fig 4).As data points are distributed all along the normal line and having negligible outliers, so datacan be concluded as normally distributed. The second plot doesn't show any trend whileplotting residual versus fitted values of data which implies RSM model chosen is well fittedwith given data set. Third plot is frequency histogram showing data distribution and at lastresidue versus order plot highlights the random data points which signifies non-significanceof experimental order as far as second response (Ra) is concerned.

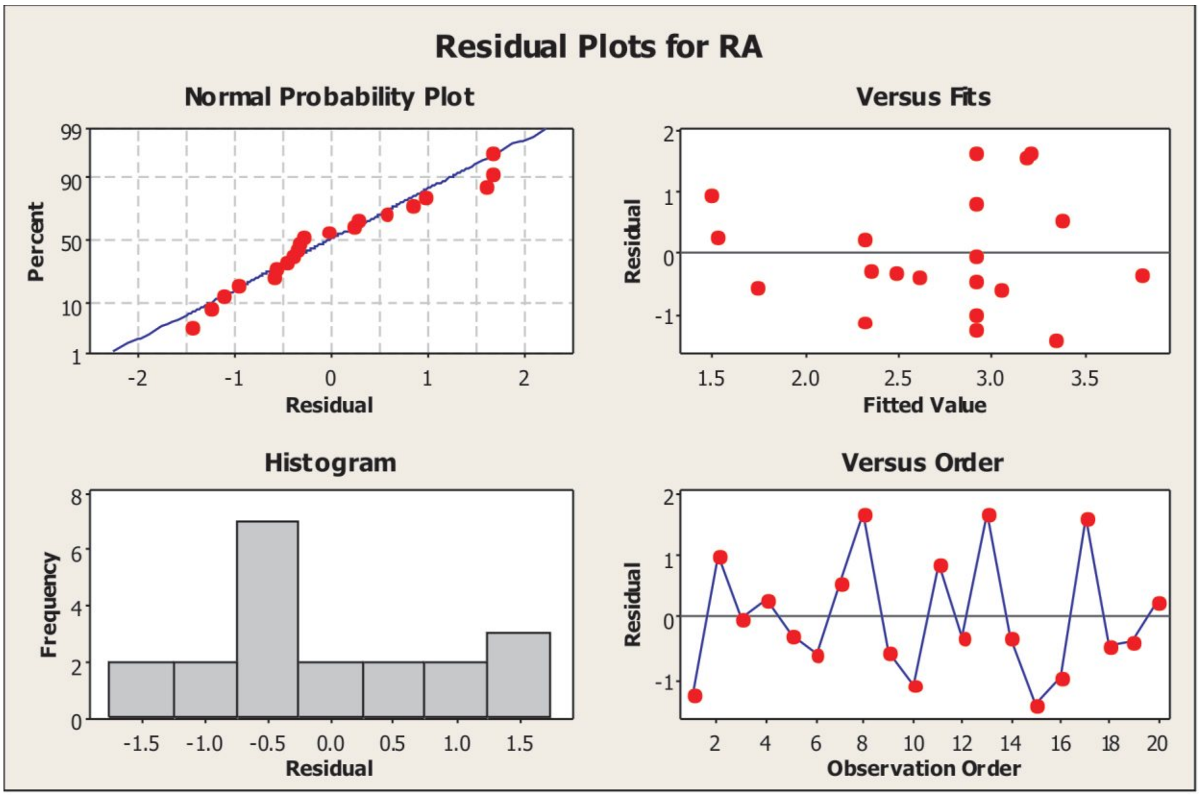


Fig.4: Data Normality Testing for Ra

P-values have been generated for each factor and its interaction and demonstrated as below through table 3. Square of Feed rate along with its interaction (Feed x Depth of Cut) have been realized as non-significant, as far as optimization of Ra isconcerned.

Term	Coef	SECoef	T	P	Significant Not Significant
Cutting Speed	-0.01196	0.6022	-0.020	0.005	Significant
Feed rate	0.30930	0.6023	0.514	0.019	Significant
Depth of cut	-0.30534	0.6180	-0.494	0.032	Significant
Cutting Speed*Cutting Speed	-1.41944	0.9855	-1.440	0.018	Significant
Feed rate*Feed rate	-0.00409	0.9858	-0.004	0.997	**Not Significant***
Depth of cut*Depth of cut	0.62167	1.0366	0.600	0.032	Significant
Cutting Speed*Feed rate	1.16009	1.3229	0.877	0.041	Significant
Cutting Speed*Depth of cut	0.33367	1.3566	0.246	0.011	Significant
Feed rate*Depth of cut	0.63115	1.3568	0.465	0.652	**Not Significant***
S = 1.32244	PRESS = 94.0851				
R-Sq = 92.61%					**R-Sq(adj.) = 94.38%**

Table 3:Estimated Regression Coefficients for Ra

ANOVA has been applied to check the lack-of-fit or residue in Ra model and indicatessubstantial significance of above findings made during linear, square and factors ininteractions. On next page analysis on variance is shown in table no. 4.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Significant / Not Significant
Regression	9	7.3563	7.3563	o.81737	0.47	0.006	Significant
Linear	3	0.9160	0.8888	0.29626	0.17	0.015	Significant
Cutting Speed	1	0.0014	0.0007	0.00069	0.00	0.005	Significant
Feed rate	1	0.4348	0.4612	0.46119	0.26	0.019	Significant
Depth of cut	1	0.4799	0.4269	0.42688	0.24	0.032	Significant
Square	3	4.6112	4.6112	1.53708	0.88	0.044	Significant
Cutting Speed*Cutting Speed	1	3.9751	3.6277	3.62769	2.07	0.180	**Not Significant ***
Feed rate*Feed rate	1	0.0072	0.0000	0.00003	0.00	0.047	Significant
Depth of cut*Depth of cut	1	0.6290	0.6290	0.62901	0.36	0.022	Significant
Interaction	3	1.8290	1.8290	0.60968	0.35	0.043	Significant
Cutting Speed*Feed rate	1	1.3448	1.3448	1.34480	0.77	0.041	Significant
Cutting Speed*Depth of cut	1	0.1058	0.1058	0.10580	0.06	0.081	**Not Significant ***
Feed rate*Depth of cut	1	0.3784	0.3784	0.37845	0.22	0.002	Significant
Residual Error	10	17.4885	17.4885	17.4885	------	------	
Lack-of-Fit	5	11.2239	11.2239	2.24479	1.79	0.029	
Pure Error	5	6.2645	6.2645	1.25291	-----	------	
Total	19	24.8448	------	-------	----	-----	

Table 4: ANOVA to Check RSM Statics (Ra)

ʼoint	Fit	SE Fit	95% CI	95% PI
1	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
2	1.47504	1.03057	(-0.82121, 3.77130)	(-2.26061, 5.21070)
3	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
4	1.50863	1.03057	(-0.78763, 3.80489)	(-2.22702, 5.24429)
5	2.33828	1.08228	(-0.07318, 4.74974)	(-1.46927, 6.14584)
6	3.05007	1.08228	(0.63861, 5.46153)	(-0.75748, 6.85763)
7	3.37819	1.08228	(0.96673, 5.78965)	(-0.42937, 7.18575)
8	3.20692	1.03057	(0.91066, 5.50317)	(-0.52874, 6.94257)
9	1.72831	1.08228	(-0.68315, 4.13977)	(-2.07925, 5.53587)
10	2.31014	1.08228	(-0.10133, 4.72160)	(-1.49742, 6.11769)
11	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
12	3.81710	1.03057	(1.52084, 6.11336)	(0.08144, 7.55276)
13	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
14	2.48004	1.08228	(0.06858, 4.89151)	(-1.32751, 6.28760)
15	3.34016	1.08228	(0.92870, 5.75163)	(-0.46739, 7.14772)
16	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
17	3.18658	1.03057	(0.89032, 5.48284)	(-0.54908, 6.92224)
18	2.91093	0.53935	(1.70917, 4.11268)	(-0.27130, 6.09315)
19	2.60676	1.03057	(0.31050, 4.90302)	(-1.12890, 6.34242)
20	2.30822	1.08228	(-0.10324, 4.71968)	(-1.49934, 6.11577)

Table 5: Predicted Responses for New Design Points Using Model for RA

GRAPHICAL INFERENCES FOR Ra

Graphical implications of RSM for second response (Ra) have also been chalked out. Variation of Surface Finish with considered input factors, have been drawn in figure 5. Remember, as Surface Roughness (Ra) increases than its corresponding Surface Finish decreases and vice versa. In Fig 5 cutting speed graph, there is an increase in the Ra when the cutting speed raises from 1159 to 2000 rpm but with the further rise of cutting speed the value of surface roughness decreases and after 2500 the Ra again start increasing. Where as in feed rate graph it has been shown that the value of surface roughness is lesser at lower feed rate i.e. up to 300 and the surface roughness is least at 1200. Similarly in depth of cut graph it has been shown that the value of surface roughness is less at depth of cut 0.12 mm.

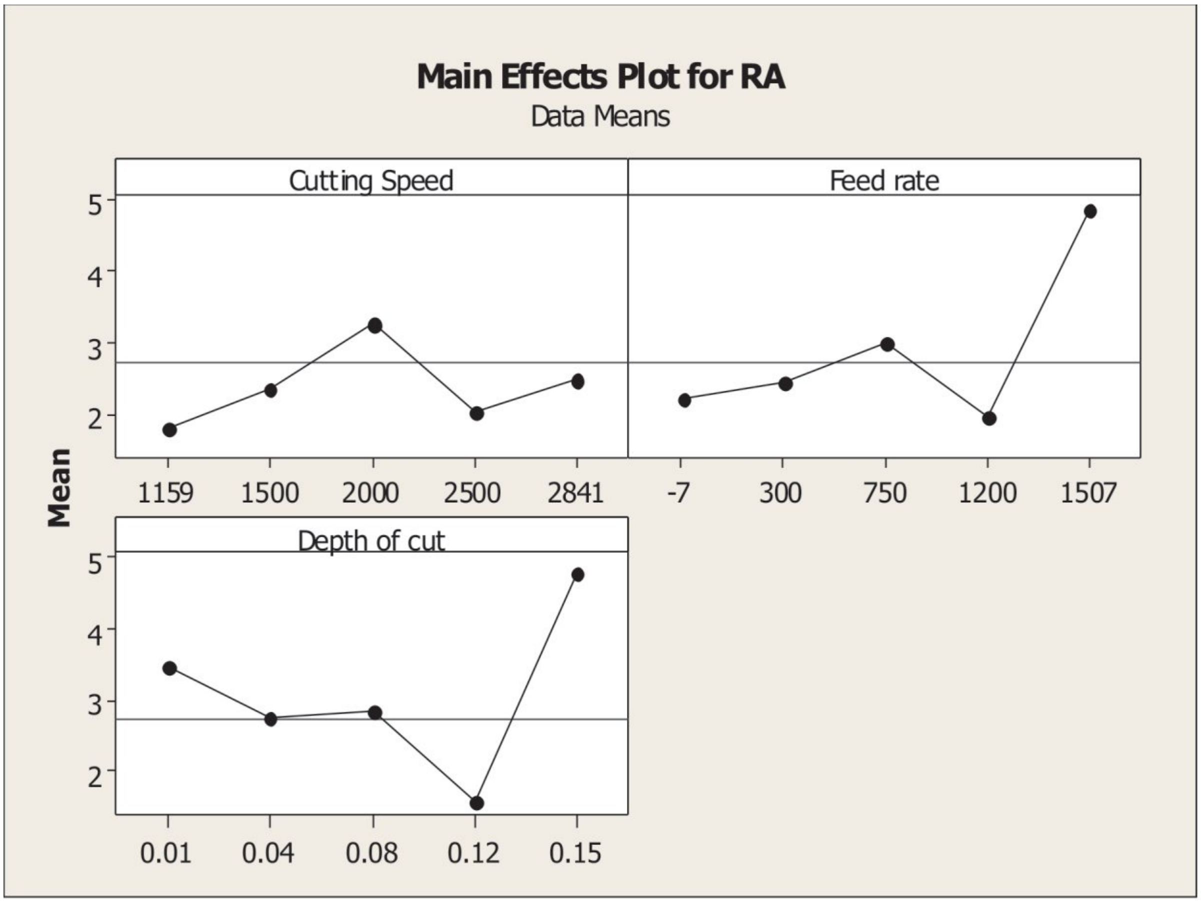


Fig. 5: Main Effect Plots for Ra

Impact of two factors at a time (TFAT) on Ra has been freezed by figure 6.

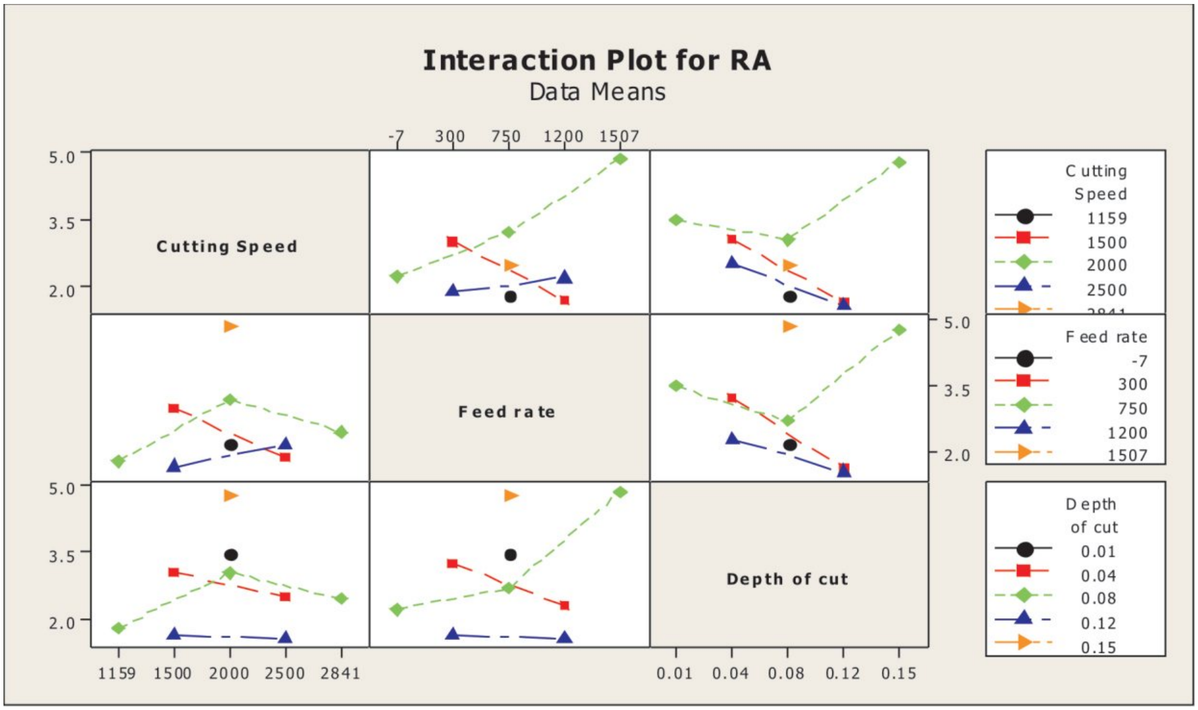
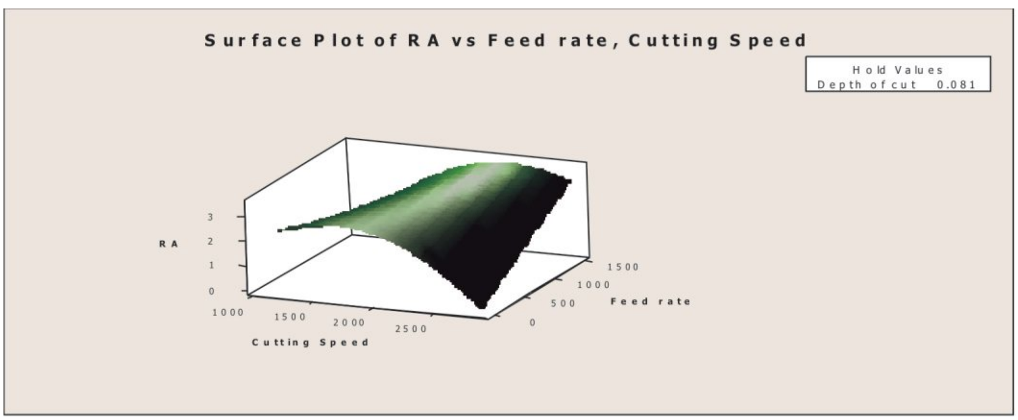


Fig.6. Two-Way Interaction Plot for Ra

The 3-D surface plots as a function of two factors at a time, maintaining all other factors atfixed levels not only provides understanding of both the main and the interaction effects ofthese two factors, but also helps to identify the optimum level of each variable for maximum response. See figure 7 containing surface plot and its corresponding 2-D contour plot ofRa versus feed and cutting speed at a holding value of depth on 0.081.



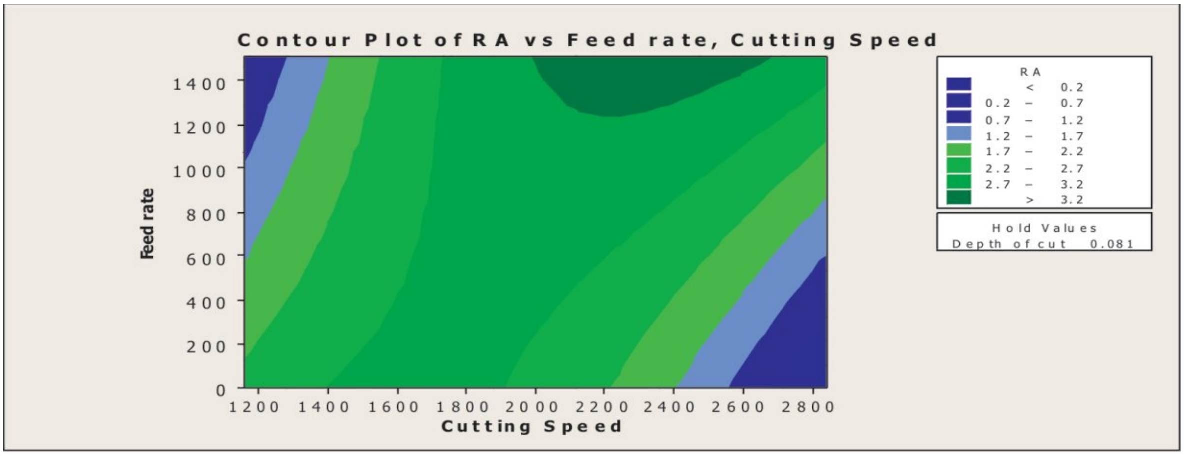


Fig.7: Surface Plot of Ra Vs Feed & Cutting Speed

At end, Minitab has created Estimated Regression Coefficients for Ra in terms of its significant factors and their interactions, as detailed below in table 6.

Term	Coef
Cutting Speed	0.00618093
Feed rate	-0.00420390
Depth of cut	-46.1408
Cutting Speed*Cutting Speed	-2.00689E-06
Feed rate*Feed rate	-7.13462E-09
Depth of cut*Depth of cut	130.575
Cutting Speed*Feed rate	1.82222E-06
Cutting Speed*Depth of cut	0.00575000
Feed rate*Depth of cut	0.0120833

Table 6: Estimated Regression Coefficients for Ra using data in uncoded units

Optimization Equation of Ra

Ra = 0.00618093 (Cutting Speed) - 0.00420390 (Feed) - 46.1408 (Depth) -2.00689E-06 (Cutting

Speed*Cutting Speed) + 130.575 (Depth of cut*Depth of cut) + 1.82222E-06 (Cutting Speed*Feed rate) + 0.00575000 Cutting Speed*Depth of cut.

From coefficients factors like Feed, Depth of Cut and (Dept of Cut) ^{2} seem to be more influential on surface roughness (Ra).

After analyzing the data of experiments, software has provided the solution at 98%composite desirability that at Cutting Speed at2840.9 rpm, Feed of 818.8 mm/minand Depth of Cut of 0.06 mm, minimum Ra of 1.614 μmcan be achieved. Lower half of figure 8 reflects graphical representation of Variation Ra with focused input variables beside pin-pointing desired optimal points by bluedotted line.

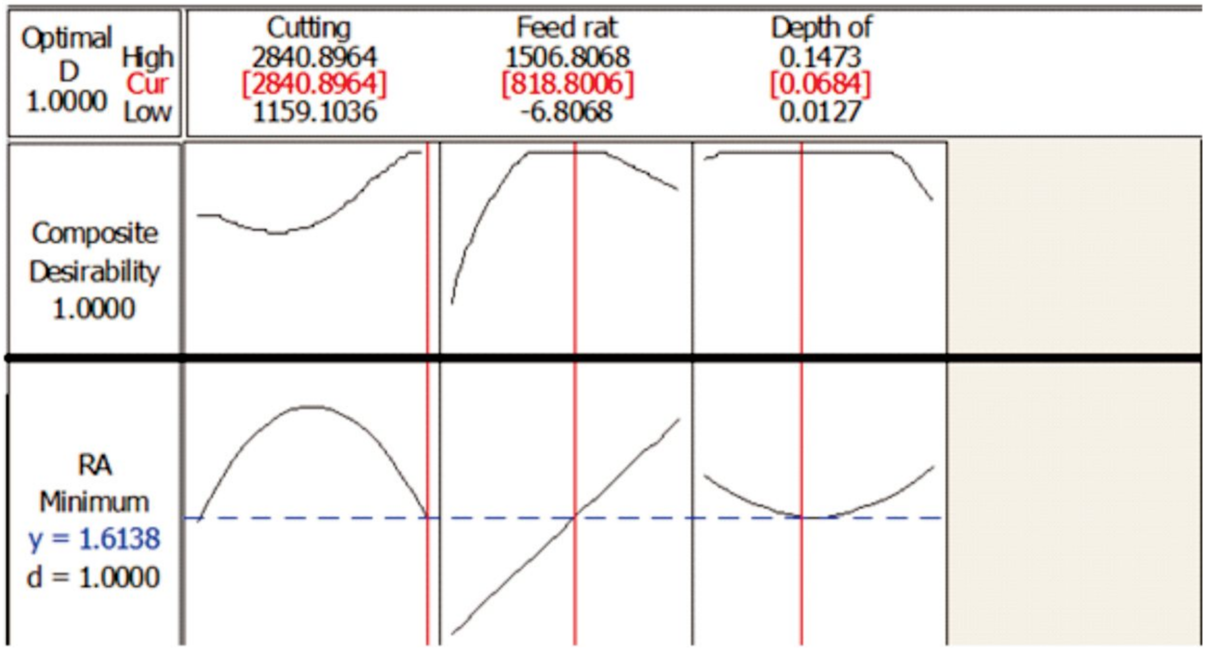


Fig. 8: Predicted responses

Operation	Speed (rpm)	Feed (mm/min)	Depth of Cut (mm)	Ra (μ m)
Finishing Case	**2840.9**	**818.8**	**0.06**	**1.614**

Table 7: Optimization Values of RSM

Concluding Remarks

Experiments have been carried out using response surface method, experimental design which consists of 20 combinations of cutting speed, feed rate and depth of cut. Experiments are executed as per the orthogonal matrix generated by RSM with 3 factors at 2 levels while 0 blocking and replicate value of 1.

After analyzing the data of experiments, software has provided the solution at 98%composite desirability that at Cutting Speed at2840.9 rpm, Feed of 818.8 mm/min and Depth of Cut of 0.06 mm got minimum Ra of 1.614 μmcan be achieved. The optimized results obtained by RSM are closely matched with actual one. Best milling parameters found for minimum Ra for D2 steel are; Cutting Speed at 2840.9 rpm, Feed= 665.910 mm/min and Depth of Cut= 0.06 mm. This study has not only formulated statistical optimizing equations for Ra for D2 steel, but also tries hard to define relation between them through co-relation.

Based on the conducted experiments and accomplished analysis, the following conclusions can be made:

1. The Material removal rate and surface roughness could be effectively predicted by using spindle speed, feed rate, and depth of cut as the input variables.
2. The average actual roughness Ra value had been obtained as 2.71 μm and the corresponding predicted surface roughness value is 1.33 μm.
3. The speed and feed rate are the most significant factors in surface roughness model.
4. RSM provide a very good process modeling. It provides the better data coverage value.
5. The excellent accuracy (nearly null error) of the RSMoptimization procedure is observed during finishing machining.

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Development Of Magnetic Abrasive Finishing Rig To Machine Surface Of Aluminum 5083 Alloy

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ABSTRACT

Magnetic abrasive finishing (MAF) process is one of the non-conventional machining processes which were introduced in Soviet Union in 1938 with further fundamental research in various countries including Japan. MAF was used for finishing non-ferrous materials, in which cutting force is controlled by given input current. In the present study MAF setup was prepared and mounted on milling machine for finishing Al 5083 flat plates. Effect of process parameters such as (working gap, machining time, current and grit size of abrasives) was calculated. Experiments were designed by 2 level full factorial approach and critical analysis of study was performed by using MINITAB software. The results for working gap and machining time indicated that surface finish increased with increase in machining time and decrease in working gap.

KEYWORDS Magnetic Abrasive Finishing, 2 Level full factorial method. Aluminium alloy, Surface finish.

INRODUCTION

The surface roughness plays an important role in product quality and precision fits. High strength applications and polishing of brittle materials is high in demanded [1].Conventional finishing surfaces such as grinding, super finishing, lapping and honing are good. However problems has such as high cost when finishing high strength material accurately, high energy consumption, ecological less safe are worth considerations. Moreover the pressure applied on the surface is high and sometimes may damage the surface finish [2].In the traditional finishing processes higher tool hardness requirement and precise control of finishing forces during the process are required. The traditional finishing processes are alone not capable of producing required surface finish [3].

The quality of precision parts can be evaluated by the surface and edge quality .The surface quality is determined by surface roughness and the stress state of the surface. Recent advances in various technological fields demand development and use of advanced engineering materials like different types of steels, nonferrous metals, and brass [4].

Surface finish is a key factor in functional properties, such as wear resistance and power losses due to friction in many of engineering components [5].Magnetic Abrasive Finishing (MAF) has been explored in numerous applications for good finish of a wide range of metallic and non-metallic materials and various components like solid rods, hollow pipes, plain surfaces and etc.[6]**.** This method use for finishing of bearings, precision automotive components, shafts, gears and artificial hip joints made of oxide ceramic and cobalt alloy are some of the products for which this process can be applied [7].

WORKING PRINCIPLE

Magnetic abrasive finishing of plane surfaces involves filling the gap between the cylindrical magnetic pole and the work piece with magnetic abrasives. The end face of the magnetic pole absorbs magnetic abrasives and forms a closed-loop magnetic field with the work piece holder [8].When current is passed through the coils of the electromagnet, the poles of DC electromagnet generate the magnetic field. The magnetic field attracts the magnetic abrasives to the finishing area in the plate and presses the magnetic abrasive particles against the surface of the plate [9]. Magnetic abrasives are generated in a non-uniform magnetic field in which the abrasives join each other and follow the direction of the magnetic force to form a flexible magnetic brush. Figure illustrates how a magnetic brush acts on a plane surface. Magnetic force lines generate power to apply pressure from the magnetic abrasives to the work piece [10]. The magnetized brush becomes a tool for finishing the work piece as the magnetic abrasives in the brush adhere to the work piece. As the magnetic pole rotates and moves with the work piece, a frictional force is generated from MAF which causes the abrasives to finish uneven plane until the surface becomes smooth [11]. The magnetic abrasive finishing process in free-form surface operations using the full factorial design, considering the effect of magnetic field, working gap and abrasive. By this study they revealed that MAF provides a highly efficient way of obtaining surface finish [12].

Figure1. MAF setup in a milling machine

EXPERIMENTATION

Workpiece and abrasive details

In the present study, MAF process experimental setup was developed on a milling machine to finish Al 5083 flat work piece. The MAF rig was designed for surface finishing on flat work pieces on a milling machine in the university campus. Its pictorial view is shown in **Fig.1**.The design was prepared with the help of Autocad software. The mild steel rod was wrapped around a coil of aluminium wires to prepare an electromagnetic and continuous current was supplied to the by D.C. power supply. The other important dimensions taken are as mentioned below

Diameter of iron core =40 mm.

Length of mild steel rod =400mm.

Number of turns =2750.

Silicon carbide was used as an abrasive medium and it was mixed with the Fe particles 80% and 20%. The average grain size of the abrasives and Fe powder was in range of 90 µm to 150µm.

2 Performance and analysis

The selection of experimental design plays a significant role in studying the effect of process parameters on. Two Level Full Factorial design was used to gauge the performance of experimental set up viz. process parameters on performance characteristics. The four factors were selected after running trial experiments and 2 level full factorial design were conducted at two levels low and high resulting in 2^4 i.e. (sixteen experiments) with 4 main effects. Table 2 shows the process parameters and their levels. The parameters selected for the present investigation are: working gap, mesh size, machining time and current mixing ratio. Table 3 shows the results outcome.

Table 1: Process parameters selected and their levels

PROCESS PARAMETERS	UNITS	LEVEL 1	LEVEL 2
Working Gap	mm	3	5
Mesh Size	µm	90	150
Machining Time	min.	8	14
Current	amp.	2.5	4

Table 2: Constant Parameters

PARAMETERS	VALUE
% Composition of Fe Powder and SiC	20 and 80
Speed	360 rpm

Measurement of surface finish

The average surface roughness values of the aluminium specimens are measured before and after MAF process using **Telysurf**surface tester.The Ra value is measured at three different locations on the workpiece and averaged. It can be observed that there is a reduction in surface roughness of the specimens due to MAF process. Percentage improvement in surface finish (%ΔRa) values have been calculated using the Eqn.

$$\Delta Ra = \frac{\text{Initial roughness -Final roughness}}{\text{Initial roughness}} \times 100$$

Table 3: Percentage improvement of surface roughness of steel specimens at various process parameters

RUN	FACTORS				RESPONSE
	Current (amp)	Gap (mm)	Grit Size (µm)	Machining Time (min.)	%age of Surface Finishing
1 (1)	2.5	4	90	8	35
2 (a)	4	4	90	8	24.9
3 (b)	2.5	6	90	8	34.2
4 (ab)	4	6	90	8	33
5 (c)	2.5	4	150	8	21
6 (ac)	4	4	150	8	45
7 (bc)	2.5	6	150	8	47.8
8 (abc)	4	6	150	8	12.6
9 (d)	2.5	4	90	14	28.8
10 (ad)	4	4	90	14	33.8
11 (bd)	2.5	6 1	90	14	23.9
12 (abd)	4	6	90	14	44.3
13 (cd)	2.5	4	150	14	32.39
14 (acd)	4	4	150	14	34.5
15 (bcd)	2.5	6	150	14	25.8
16 (abcd)	4	6	150	14	37.32

RESULTS AND DISCUSSIONS

The experimental setup designed to finish flat surfaces was successfully used to produce values of surface finish. It was observed from the results that the value of % age of surface finish increases by increasing the current and by increasing the machining time, however % age of surface finish decreased with increase in the the grit size. Moreover by increasing the working gap up to certain value the % age of surface finish increased and it decreased by further increase in working gap. Table 4 shows the average of each response characteristic (means) for each level of each factor. The table also shows the ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. The ranks are assigned based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response.

Table 4: Response table for means

Levels	Current (Amp.)	Working gap(mm)	Grit size(μm)	Machining time(min.)
1.	31.11	31.92	32.23	31.68
2.	35.15	32.36	32.05	32.60
Delta (Δ)	4.04	0.44	0.18	0.92
Rank	1	3	4	2

Effect of magnetic flux density (current) on change in surface finish

Figure 2 a shows the effect of magnetic flux density. It can be seen that at low values of magnetic flux density % age of surface finish was less it may be attributed to the fact that at low current the magnetic stress generated in weaker form and an iron particle weakly magnetized. So at low current the indentation of the abrasives is less, so value of ΔRa less. However at increased value of magnetic flux density % age of surface finish increases. The results obtained are similar to the studies [13].

Effect of working gap on change in surface finish

Figure 2 b shows the effect of working gap. By increasing the working gap up to certain value the % age of surface finish increased and it decreased by further increase in working gap. It is due to the fact that as the working gap increases the flux density of the flexible magnetic abrasive brush decreases and thereby % age of surface finish was less. The results obtained are similar to the earlier work reported [14].

Figure 2: Main Effect of process parameters on % ΔRa

Effect of grit size on change in surface finish

Figure 2 c shows the effect of abrasive size. The %age improvement in surface roughness (ΔRa) decreases on increasing the size of abrasive size. It is due to face that by higher the value of the abrasive sizes more the scratches on the specimen thereby affecting value of surface finish. The results obtained are similar to the earlier work reported [15].

Effect of machining time on change in surface finish

Figure 2 d shows the effect of machining time. It was observed that in that surface finish improved with increase in machining time. It may be attributed to the fact that at higher values of machining time comparatively more polishing is achieved on the surface thereby improved surface finish. The results obtained are similar to the earlier work reported [16].

Conclusions

In the present work, MAF setup has been designed and fabricated. The performance of the MAF setup for different parameters was successfully studied. Experimental MAF process on Al 5083 with the use of loosely bounded MAPs has been carried out. It is concluded from the results and discussion that time, grit size of abrasive particles, current and working gap of workpieces are the parameters which significantly influence the change in surface finish value (ΔRa). It was observed from the results that the value of % age of surface finish increases by increasing the current and by increasing the machining time, however % age of surface finish decreased with increase in the the grit size. Moreover by increasing the working gap up to certain value the % age of surface finish increased and it decreased by further increase in working gap.

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Flexural Strength Of Polyester Polymer Concrete Fabricated From Industrial Waste Materials

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Abstract

Polyester polymer composite has been fabricated using aggregates as Fly Ash and Red Mud. Utilization of waste Fly ash and Red mud in polymer concrete is promising; it may enhance the physical properties and mechanical strength of the polymer concrete. The mechanical properties of PCs with variation of different compositions of Fly ash (10, 14%), Red mud (20, 25%) and resin (30, 35%) were investigated. The silica powder in different percentage (12, 16%) used as filler in polymer concrete enhanced the mechanical properties of polymer concrete. The casted PCs were also investigated for their flexural strength. For the preparation of Samples a statistical techniques such as ANOVA method are used. The PCs specimen with 35% resin, 25% fly ash and 15% silica fume resulted in maximum flexural strength. Generally, fine fillers may result in high mechanical strength as the fine fillers have high molecular compaction. The values of flexural strengths were 21.53 N/mm^2.

Keywords: Polymer concrete, Red Mud, Fly Ash, Silica powder, Flexural strength.

Introduction

It has been significantly important to develop the technology to treat or recycle the waste from industrial materials such as red mud and fly ash due to the enormous production of them as the industry and economy of the world are growing (Cunliffe, A.M. et al, 2003). There have been several ways to treat the wastes such as landfill, incineration, chemical recycling, material recycling and the utilization of energy from combustion (Palmer, J. et al, 2009). Most methods excluding material recycling are known to have critical limitations in economic, technical and environmental manners. Material recycling is expected to be more feasible in a way that the simplicity of pretreatment, and the reduction of energy consumption and environment pollution can be satisfied (Ohama, Y. et al, 2002). Furthermore, the waste red mud and fly ash as is categorized and treated as industrial wastes. It means it should be disposed or burned to destroy, resulting in the air pollution and environmental pollution (Hwang, E.H. et al, 2008). The importance of how to recycle or reuse waste red mud and fly ash became an important technological issue recently, and a countermeasure was usage of the waste red mud and fly

ash as an aggregate in the production of PC (Meyer, C., et al, 1998). However, the recycling of waste red mud and fly ash could cause lowering of the performance or mechanical properties of the final PC (Meyer, C., et al, 1998). An organic polymer or resin, so-called polymer modifier is expected to overcome the problems described above because the polymer-modifier is well known to offer to the final PC the improvement of higher strength, durability, good resistance to corrosion, and strong resistance to damage from freeze-thaw cycles (Conroy, A., et al, 2006). In this study the polymer concrete composite using recycled red mud and fly ash fine aggregate were investigated for flexural strength with two different percentage of resins i.e. 30% and 35% with required amount of accelerator and fillers.

Materials and Methods

Materials

Resin and Hardener: Specimens were prepared utilizing Polyester resin based. No solvent or dilutor was added to prevent any possible changes in chemical properties of the samples. Methyl-Ethyl ketone peroxide was used as hardening agent (Golestaneh, M. et al, 2010). The ratio of resin: hardener as recommended by the manufacturer and also based on literature for polyamine as curing agent was 2:1 (Varughese, K.T. et al, 1996).

Filler and Aggregate: Industrial Waste materials such as fly ash and red mud are used as aggregates in PC. Silica fumes use as a filler in PCs.

Mix Design and Casting Process

The fabrication was carried out on the use of grinded Pultrusion waste in polymer based concrete. Mix design of plain formulation was in accordance with previous studies. Polymer concrete specimens were prepared by mixing an Polyester resin with different weight percentage of solid waste such as fly ash, red mud, silica fume and sand percentage. Processed pultrusion wastes, with eight different %, were used as a partial substitute for sand aggregates at the different proportion of % (w/w). Plain or control polymer concrete specimens were also cast and tested in order to compare mechanical and functional properties. Mixing Process: for mixing five different materials a Experiment with a L_8 (2^5) orthogonal array (8 test, 5 variables, 2 levels) were used. Eight different solid waste admixed polymer concrete formulations were analyzed by varying the types and content of solid waste. mix. Proportions of different raw materials shown in table 1.

Table 1 Mix Proportions (W/W) of raw materials of Polyester Polymer Concrete Formulation

Fly ash (%)	Red mud (%)	Silica fume (%)	Polyester resin (%)	Sand (%)	Sand Size(μm)
10	20	12	30	28	300
10	20	12	35	23	600
10	25	16	30	19	300
10	25	16	35	14	600
14	20	16	30	20	600
14	20	16	35	15	300
14	25	12	30	19	600
14	25	12	35	14	300

Casting of Specimen

Specimens were prepared according to ASTM (Materials, A.S.F.T.A., 2002) standards with several combinations of filler and aggregates. Initially, Polyester resin and hardening agent were weighed and blended. Filler and aggregates were added to the mixture with given proportion and were gently mixed. In three steps, the mixture was placed in molds. After each step was performed the mixture was compacted using a rod to prevent any void formation. The specimens were air dried at room temperature and then the molds were removed. The flexural strength of fabricated PCs was measured according to ASTM C 579-01(Materials, A.S.F.T.A., 2002). The rectangular shaped specimens of polymer concrete with ($40\times45\times250mm^2$) are fabricated. Furthermore, the recorded data were the mean of triplicate values for all specimens.

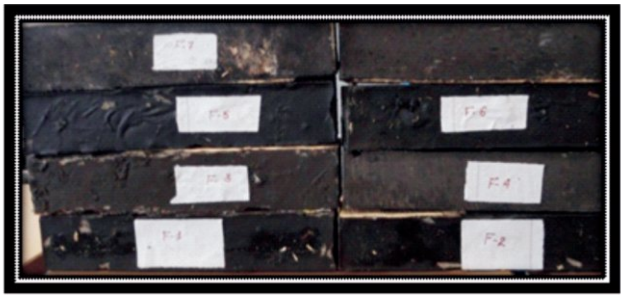

Figure 1 Polymer Concrete Specimens for Flexural Test (One of each formulation)

Testing Procedures: The **flexural strength** of a material is defined as its ability to resist deformation under load. For materials that deform significantly but do not break, the load at yield, typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength. The test beam is under compressive stress at the concave surface and tensile stress at the convex surface.

Prismatic polymer concrete specimens were tested in three points bending up to failure at the loading rate of 1 mm.min -1, with a span length of 100 mm, according to RILEM CPT PCM-8 standard test method (Materials, A.S.F.T.A., 2002).

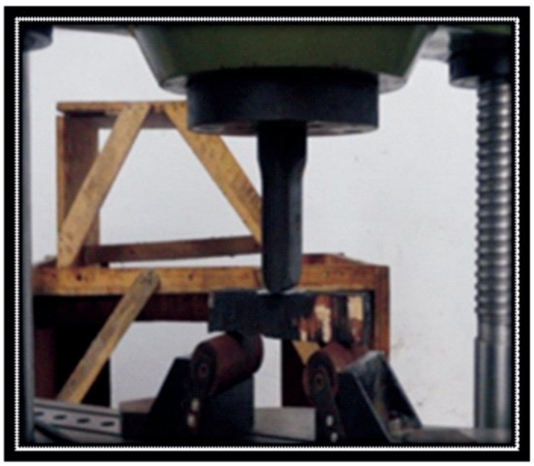

Figure 2 Specimens under Flexural Tests

Figure 3 Specimens after flexural Test

Results and Discussion

Mechanical Properties of PC

Flexural Strength: Results of flexural strength test are summarized in Table 2. The obtained values for this experiment showed that these polymer concrete compositions reached to great flexural strength. The highest value for flexural strength related to sample 4 and sample 6 was 20.983 N/mm^2 and 20.976 N/mm^2.Fig. 15 shows Another considered parameter is increase in resin content of polymer concrete from 30 to 35%, had great effect on flexural strength of the specimens. Overall, higher concentrations of filler and resin yielded high strength an increase in amount of resin had favorable effect on flexural strength of the specimens. This value was found through actual experimental runs and data analysis.

Sample No.	Flexural Strength			
	1st reading	2nd reading	3rd reading	Av. Value
1	17.71	17.83	17.76	17.66
2	20	20.1	20.12	20.07
3	19	19.01	19.1	19.03
4	21.48	20.46	20.66	20.983
5	20.14	20.2	20.24	20.19
6	20.57	21.4	20.56	20.976
7	19.95	19.98	20.05	19.99
8	20.86	20.82	20.96	20.88

Table 2 Flexural Strength of different Samples

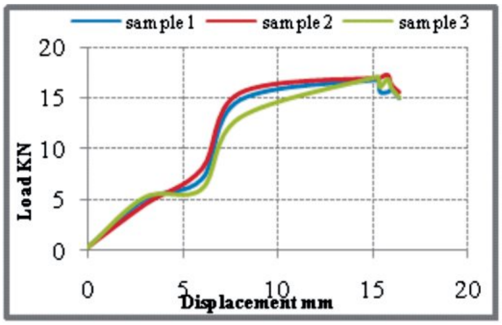

Figure 4 Load v/s Displacement of sample 1

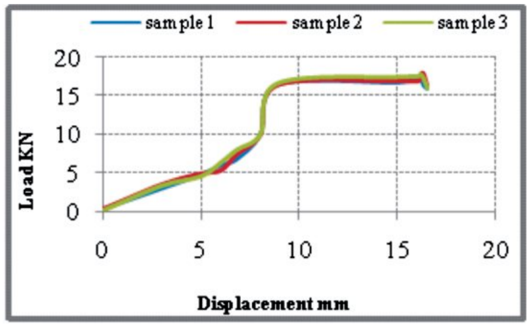

Figure 5 Load v/s Displacement of sample 2

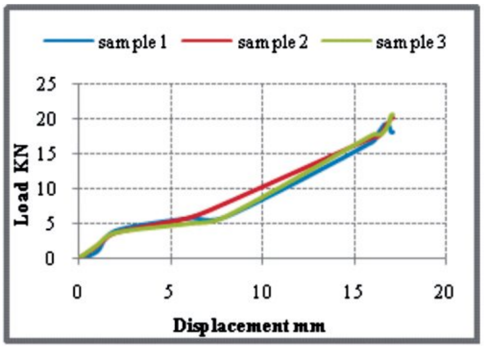

Figure 6 Load v/s Displacement of sample 3

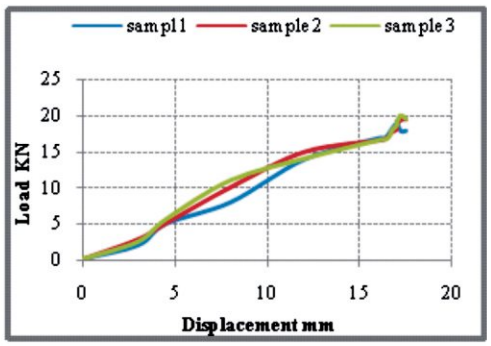

Figure 7 Load v/s Displacement of sample 4

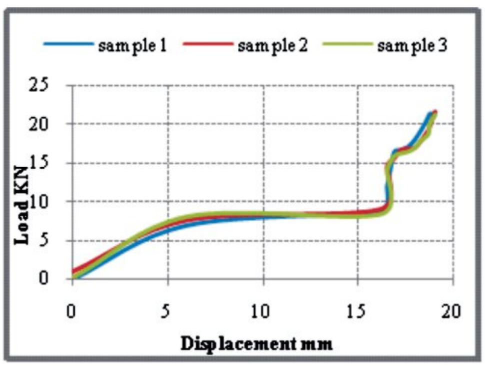

Figure 8 Load v/s Displacement of sample 5

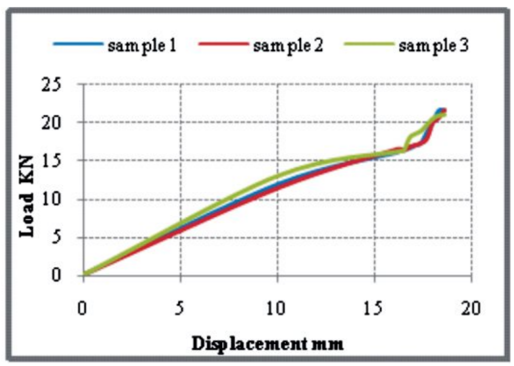

Figure 9 Load v/s Displacement of sample 6

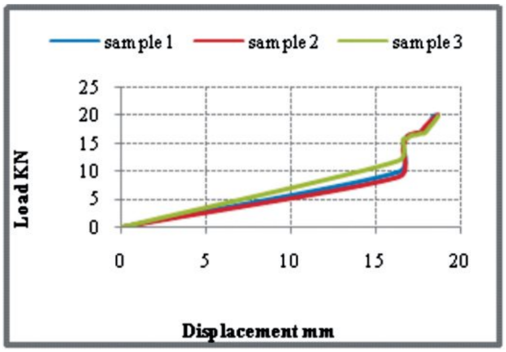

Figure 10 Load v/s Displacement of sample 7

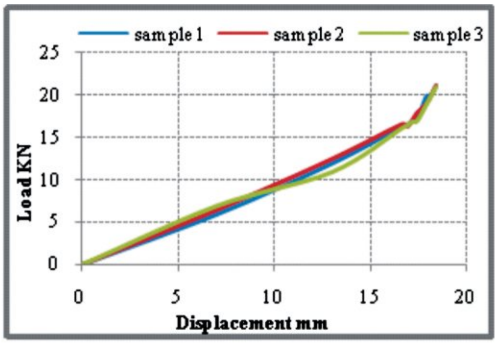

Figure 11 Load v/s Displacementof sample 8

The Effect of the different %age of Solid Wastes on Flexural Strength of PC

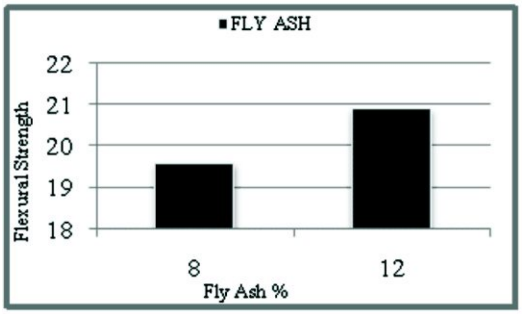

Figure 12 Fly Ash % age V/s Flexural Strength

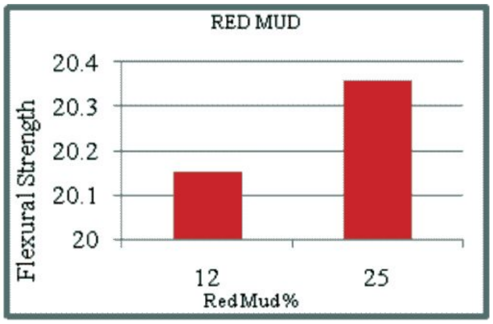

Figure 13 Red Mud % age V/s Flexural Strength

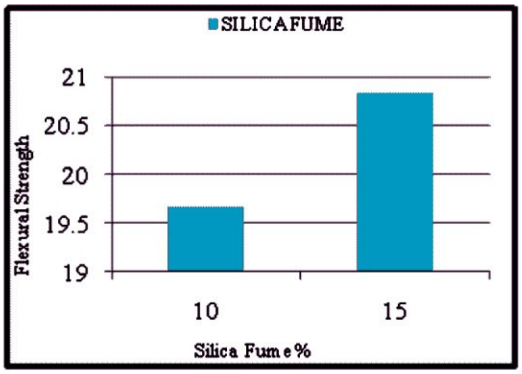

Figure14 Silica Fumes%age V/s Flexural Strength

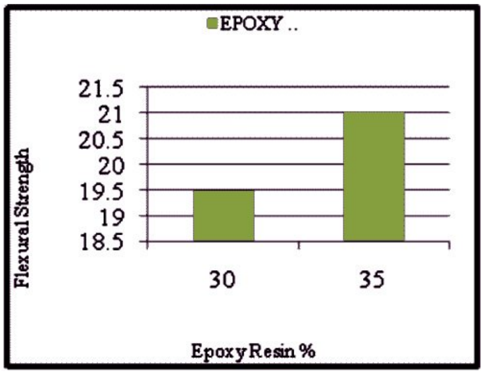

Figure15 Polyester Resin % age V/sFlexural Strength

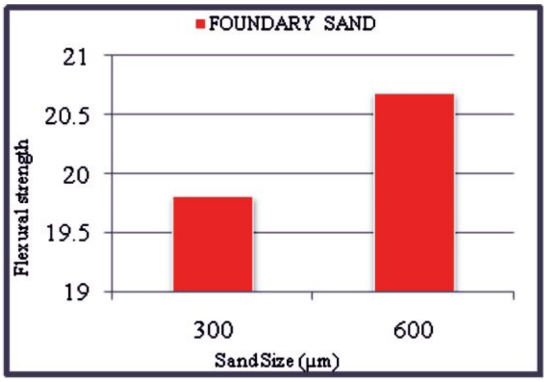

Figure 16 Sand Size % age V/s Flexural Strength

Effect of Solid Waste and Polyester Resin on Mechanical Behavior

A. Effect of Fly Ash on Mechanical Behavior: Fig. 12 show the mechanical behavior of fly ash which shows that with the increasing the percentage of fly ash (10-14%) flexural strength increasing.

B. Effect of Red Mud on Mechanical Behavior: Fig. 13 show the mechanical behavior of red mud which shows that with the increasing the percentage of red mud (20-25%) flexural strength also increasing.

C. Effect of Silica Fume on Mechanical Behavior: Fig. 14shows the mechanical behavior of silica fume which show that with the increasing the percentage of silica fume (12-16%) flexural strength and tensile strength increasing.

D. Effect of Polyester Resin on Mechanical Behavior: Fig. 15 show the mechanical behavior of Polyester resin which shows that with the increasing the percentage of Polyester resin (30-35%) flexural strength increasing.

E. Effect of Foundry Sand on Mechanical Behavior: Fig. 16 show the mechanical behavior of foundry sand which show that with the increasing the size of foundry sand(300-600µm) flexural strength, increasing.

Conclusions

It was concluded that the amount of resin and filler in chemical composition of the fabricated PCs had great influence on identification of the maximum physical strength. The PCs specimen with 35% resin, 10% fly ash, 25%red mud and 16% silica fume resulted in maximum flexural strength. Generally, fine fillers may result in high mechanical strength as the fine fillers have high molecular compaction. The maximum flexural strengths are 20.983 N/mm^2.Also the manufacturing time is less as compare with traditional materials. Hence it provides an alternative to traditional materials for machine tool manufacturing.

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Physical Modelling Of Multi-domain Systems- A Bondgraph Approch

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ABSTRACT

Multi-domain (electrical, mechanical, hydraulic, acoustical, thermodynamic, material) systems are comprises of more than one systems. it's difficult to model these systems. Bond graph is a domain-independent graphical approach to describe the dynamic behavior of the physical systems. The basis is that bond graphs are based on energy and energy exchange. Bond-graph modelling is a powerful tool for modelling engineering systems, especially when different physical domains are involved. In this paper, the physical model of electro-mechanical system is described by using bondgraph approach. The results show the validation of the model.

Keywords: **Multi-domain system, electro-mechanical, bond graph, energy exchange.**

INTRODUCTION

Bond-Graph is a integrated approach to the modeling of multi-disciplinary physical systems. It was formulated by Henry Paynter from MIT, brought to firm applicability by later researcher **[J. Granda]**. By its nature of a power conserving description of a system, the Bond-Graph method is especially practical when several physical domains have to be modeled within a system simultaneously.

Bond Graph Theory

Bond graphs are based on the splitting of engineering systems in separate components that exchange energy or power through identifiable connections or ports**. [P.C. Breedveld]** The energy flux or power in a bond is always the product of two variables — a potential variable called effort and a flow or current variable, simply referred to as flow. The behavior of a real physical system is controlled by accumulation, dissipation and interchange of various forms of energy. The behavior of a real physical system is controlled by accumulation, dissipation and interchange of various forms of energy.

Bond graphs are useful for interdisciplinary systems since the energy transport is generally the product of an effort and a flow variable.**[J.F. Broenink]**, Also important, apart from the product, is the ratio of effort and flow referred to as impedance with its reciprocal, the admittance.

Bond Graph Elements

The standard form of a bond graph consists of 5 types of one port elements, 2 types of two port elements and 2 types of junctions as multiport elements to define their connections. One port element includes effort source (Se), flow source (Sf), capacitor (C), resistor (R) and inertia (I). One port elements are generalized versions of subsystems in real physical domains. **[J.U. Thoma]**, The capacitor and the inertia are called storage elements; their function is to maintain the state of the system by maintaining the energy variables. Two port elements. It includes transformers (TF) and gyrators (GY) which is used to conserve power. The transformer relates the effort to effort and the flow to flow between its two bonds and the gyrator relates flow to effort and effort to flow between its two bonds. Multi ports elements. It includes 0-junction and 1 -junction. Bonds are representing by half arrow and its direction denotes the positive direction of power exchange between the components **[J. V. Amerongen]**. A negative value of power indicates that the direction of power flow is opposite to the direction of the bond.

OBJECTIVE

The objective of this paper is to build a bond graph model of electromechanical system. The figure 1 shows the one of the example of multi-domain system. The model is consisting of two systems electrical and mechanical. The input of the system is a voltage source and output is displacement of the hanging weight. The elasticity of the wire rope is not considered in whole modelling process. The word bondgraph is shown in figure 2.

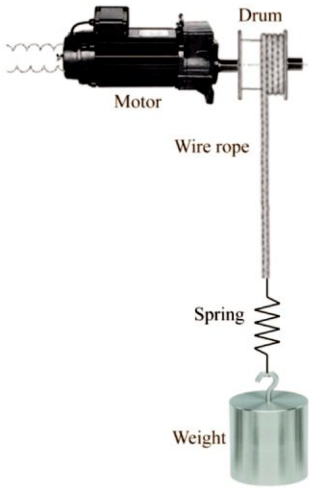


Figure 1. Electromechanical system (hoist)

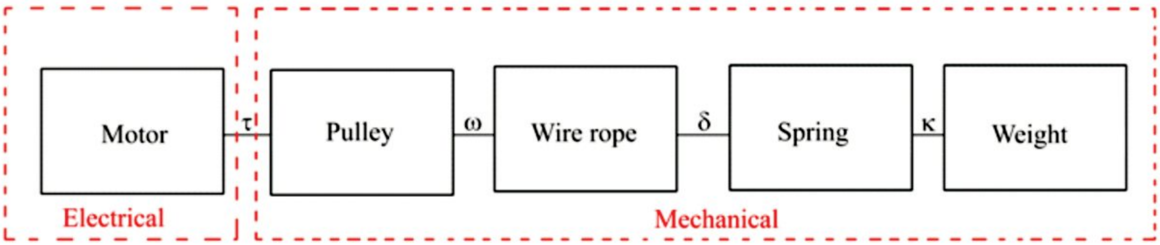
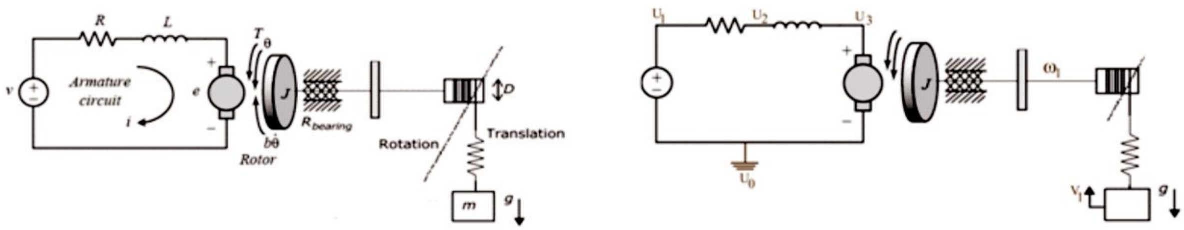


Figure 2. Word bondgraph model

The domain information of the system is shown in figure 3(a). The Bond graph model is developed by considering reference velocities of the system from figure 3(b).



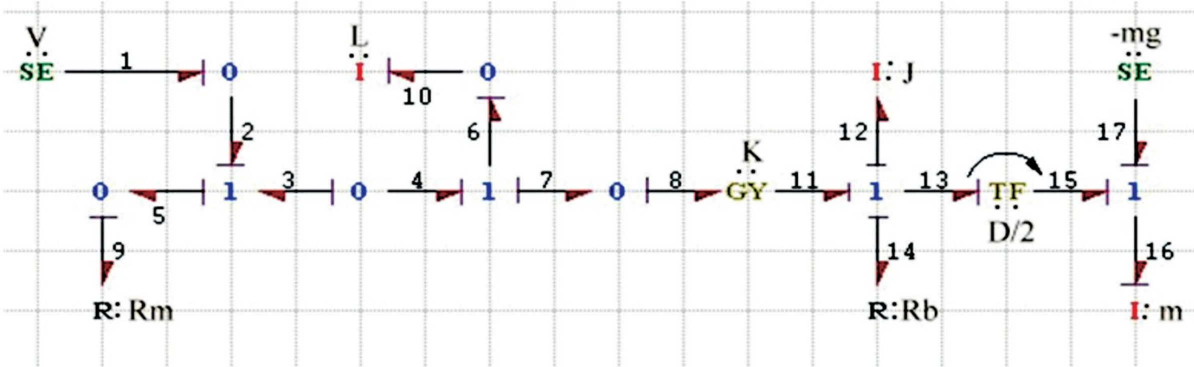


Figure 3. (a) Domain information (b) Reference velocities model

Bondgraph model

The bond graph model for the system is divided into two parts.

-Motor (Electrical)

-Displacement of weight (Mechanical)

Further the motor is divided into input voltage and actual motor. The input voltage is pass away from inductor and resistor and then to the motor. Therefore the bond graph of an input voltage includes electric potential (Se), inductor (I) and resistor (R). In case of motor the inertia of a motor (I) and the resistance at bearing (R) are taking into consideration. The mechanical part is divided into pulley (mass of pulley, m), spring (stiffness co-efficient, k) and weight (mass & gravity, mg). The complete bond graph of the system is shown in figure 4**.[W. Borutzky]** The equations from (1 - 6) are derived from the bondgraph.

$$d(P_{13}) = SE_{11} - K_{16} * Q_{16}$$

$$d(P_6) = k * P_2 / M_2 - R_7 * P_6 / M_6 - d * SE_{11}$$

$$d(P_2) = SE_1 - R_3 * P_2 / M_2 - k * P_6 / M_6$$

$$d(Q_{16}) = P_{13} / M_{13}$$

$$d(Q_{15}) = P_2 / M_2$$

Figure 4. Bondgarph of Hoist model

$$d(Q_{14}) = P_6 / M_6$$

The figure 5 shows the simplified form of the bondgraph for the system.

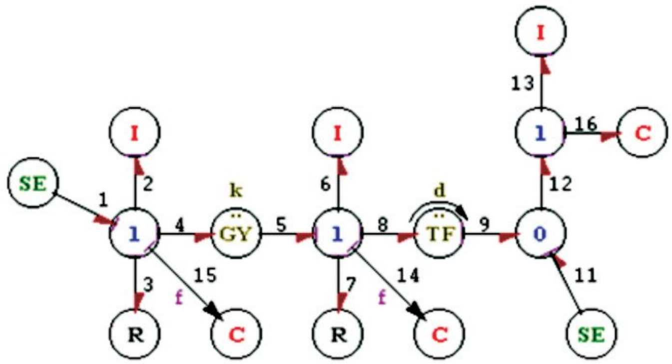


Figure 5. Simplified bondgraph

ANALYSIS AND RESULTS

The analysis of the bond graph is possible with simulation used in Symbols software. For analysis the system, values of related terms are given in parameters table I.

Simulation parameters			
Voltage	240 v	Bearing resistance	10 ohms
Motor inductance	25 H	Diameter of pulley	1.5 m
Motor resistance	9 ohms	Weight	1000kg
Motor co-efficient	0.6	Spring stiffness	$1x10^4$ N/m
Polar moment of inertia	25 m^4		

The results are shown in figure 6. The simulation run time is 10 sec. The value of torque is 149.04 Nm and increasing w.r.t. time. The figure 7 shows angular velocity is start from zero and increases to 15.96 rad/s for time 3.49 sec then value is constant.

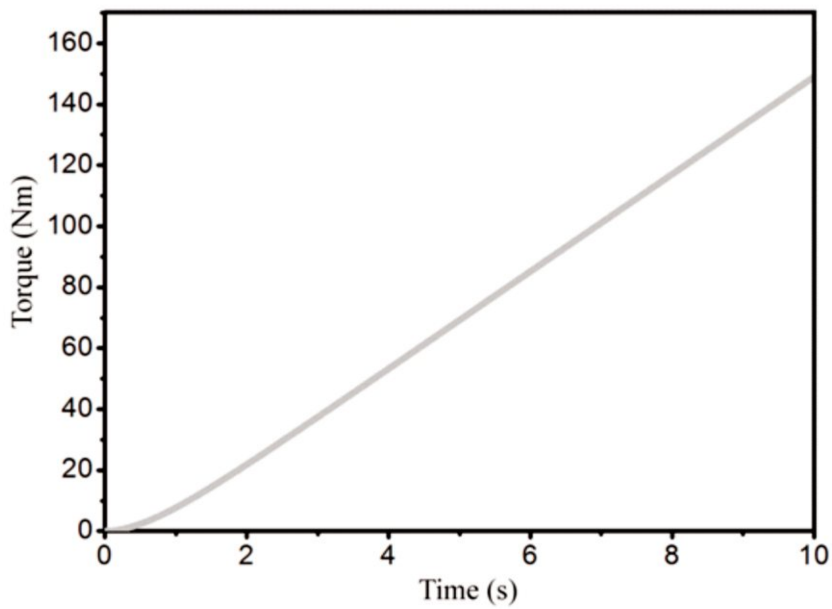


Figure 6 Torque v/s time

CONCLUSIONS

In this paper the study on the bond graph is presented. The importance of the bond graph for multi-domain system is discussed. The modeling and simulation of the electromechanical system is done by using Symbol Shakti software.

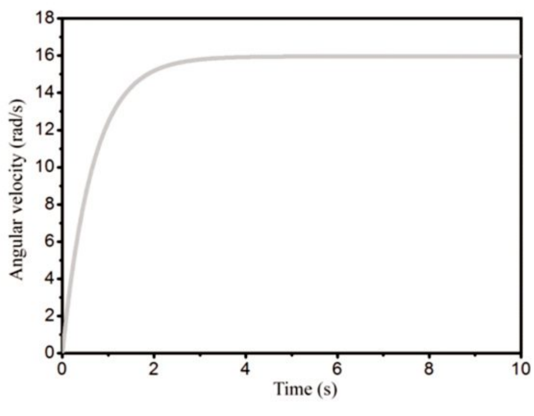


Figure 7 Angular velocity v/s time

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Nomenclature

e	Generalized effort
f	Generalized flow
g	Acceleration due to gravity
k	Spring stiffness
m	Mass of pulley
m_u	Motor co-efficient
L	Motor Inductance
R_m	Motor resistance
D	Diameter of pulley
J	Polar moment of inertia

Process Parameter Optimization Of Magnetic Abrasive Finishing For The Improvement Of Surface Finish By Using Boron Carbide Abrasive

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ABSTRACT

With the development in the high tech industries the need of part surface finish and geometric precision has increased drastically. The Magnetically Abrasive Finishing (MAF) processes are emerging as one of the most suitable techniques for obtaining quality finish. In MAF processes, Ferromagnetic particles are mixed with fine abrasive particles like Al2O3, SiC, B4C and Diamond etc to form flexible brush at the finishing area under the influence of magnetic force. In this study Brass Pipe (CuZn35) used as work-piece with Boron Carbide abrasive. The objective of the present study is to investigate the effect of input process parameters on the improvement of surface finish and to determine the best composition of abrasive with ferromagnetic particles. Taguchi L9 experimental design with MINITAB 17 software and ANOVA method used to analyze the process parameters in study. In this work, current is found to be the most significant parameter. However, the Boron Carbide percentage composition in MAPs and rotational speed of workpiece seems to be having very small influence for improving Ra value.

Keywords: Magnetic abrasive machining, surface finish, abrasive particles, Taguchi approach, ANOVA.

Introduction

Part's manufacturing using casting, forging and shaping processes does not have good surface finishing but for functionalize properly and good service lives reliability moveable parts used in many engineering applications need controlled dimensional accuracy and surface qualities during manufacturing [1]. Due to peaks of micro irregularities the poor surface finish leads to separate of oil layers, which further lead to accessing dry friction, and output in excessive wear of the contacting surfaces [2]. Hence manufacturing parts required up to few nanometers range surface finish in various industrial applications [3]. Finishing attributes of parts manufactured by using conventional finishing techniques depend on the machine tool system which is least controllable and poor accurate and leads to using advanced finishing processes [4]. Magnetic Abrasive Finishing is one such advanced finishing process which was introduced in the Soviet Union in 1938 for the efficient finishing of internal and external surfaces, which may be made from any magnetic or nonmagnetic materials [5]. Process able to removes the material with the controlled magnetic field in the finishing zone and the surface modification and deburring of material performed at the same instant [6]. MAF process is free from most of the ill effects like geometrical errors work surface's distortion and micro cracks, due to finishing produced by using hard grinding wheels conventionally [7]. MAF possesses many attractive advantages like Self-sharpening, Flexibility, Controllable [8].

In the present study Brass Pipe (CuZn35) finished using unbounded Boron Carbide abrasive to investigate the effect of input process parameters on the improvement of surface finish and to determine the best composition of abrasive with iron and steel ferromagnetic particles. Also compare the finishing characteristics of Iron and Steel ferromagnetic particles.

Literature Review

Fundamental research has been done in the Soviet Union, Bulgaria, Germany, and the USA [9]. More comprehensive research has been done in Japan since 1980[10]. Shinmura et al [11] studied the basic finishing principle of magnetic abrasive and analyze the basic effective parameters of finishing process. Bonded or unbounded and sintered mixture of ferromagnetic particles and abrasive powders used to form magnetic abrasive particles for finishing also studied elsewhere [12][13]. Chang et al [8] also described the finishing feature of unbounded SiC and ferromagnetic particles inside cylindrical magnetic abrasive polishing. Theoretic investigate of MAF process to measure the distribution of magnetic forces on the workpiece surface [14] .Wang and Hu [15] studied the effect of finishing variables like speed, magnetic abrasive supply, abrasive material, grit size have most significant on the material finishing rate. Girma et al [16] investigated the effect of grain size and size-ratio on machining process. Yamaguchi et al [17] conduct the internal finishing of capillary tubes using a MAF process with three-point tube support to reduce the run-out of the capillary tube during rotation at high speed. Yang et al [18] Analyze magnetic field behavior for solid cylindrical pole, hollow cylindrical pole, and hollow cylindrical magnetic pole with groove designs using finite element method. Singh et al [19] Singh and Singh [20] Worked upon sintered magnetic abrasives for finishing the brass pipes and [21] conduct an experiment on a brass shaft of CuZn37 using bounded abrasive and founded that surface finish was significantly influenced by magnetized density.

Experimental Setup

Experimental setup was mounted on lathe machine and consists three main parts: Main frame, Electromagnets, Dimmer.

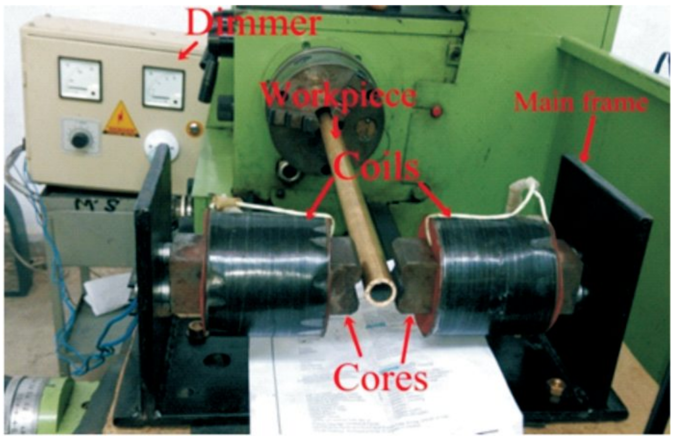

Figure 1 Setup for MAF experiment (Pictorial view)

Table 1 Specifications of MAF setup

Magnetic Flux Density	1.20 Tesla (12000 Gauss) at 4 amp
Maximum Current (I) capacity	5 Amperes
Dimmer Current Range Core & Frame Material	0-10 Amperes Mild Steel
Number of turns on coil	2133 turns each coil, Copper wire

Experimental procedure

Experiment conditions

In Magnetic Abrasive Machining, the machining is associated with many factors. There are two types of parameters in process, Fixed and Independents. The independents parameters are those whose effect we want to study against fixed parameter's value. For the finishing of non ferrous brass pipe (CuZn35) the following fixed and independents parameters were studied and their values or ranges are listed below:

Table 2 Fixed Parameters

Machining Time	30 Min
Grit Size Abrasive (B_4C)	150
Grit Size Ferromagnetic particles Working Clearance	180 8 mm

Table 3 Levels of independent parameters

Parameters	Level 1	Level 2	Level 3
Current (A)	2	3	4
Composition of MAPs (%)	75:25	65:35	55: 45
Speed (RPM)	180	280	450

Observation Table

Taguchi L9 orthogonal array table prepared using Taguchi experimental design for 3 parameters and their 3 levels.

Table 4 Experimentation L9 OA Table

S.NO.	Current(A)	Composition of MAPs (%)	Speed(RPM)
1	2	75:25	180
2	2	65:35	280
3	2	55:45	450
4	3	75:25	280
5	3	65:35	450
6	3	55:45	180
7	4	75:25	450
8	4	65:35	180
9	4	55:45	280

Procedure

The initial surface roughness value of brass pipe is 0.70µm measured by using surface roughness tester Mitutoyo SJ-201. Working conditions was set according to observation . When current is passed through the coils of electromagnet, the poles of DC electromagnet generate the magnetic field, Due to which the abrasive particles join each other along with the lines of magnetic force due to dipole–dipole interaction and generate a Flexible Magnetic Abrasive Brush (FMAB) inside the pipe. Now the circumferential speed given to workpiece through lathe machine and finishing process started. The congregated flexible magnetic abrasive brush (FMAB) along with the lines of magnetic field gives micro indentations in surface of work material with high finishing pressure. The relative motion between workpiece and FMAB lower the surface finish value. On the complete of finishing time the surface roughness measured again.

Result analysis

After the data collection, analysis of variance (ANOVA) analyzed using statistical software MINITAB17 to identify the significance of the factors considered in study. The P ratio of the predictive model was calculated and compared with the standard tabulated value of the P ratio for a specific confidence interval. It can be seen from and the Current, percentage composition B_4C and rotational speed are the factors which present a P-value lower than the α-level of confidence (which is assumed to be 0.05), that the model qualifies the adequacy test as the P value of the model is smaller as compared to the tabulated p value at 95% confidence level.

1.1.1 Analysis of Iron and Boron carbide MAPs roughness data

Table 5 ANOVA for Iron and B4C MAPs

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Current(A)	2	0. 027489	75.20%	0.027489	0.013744	176.71	0.006
% B_4C	2	0.002956	8.09%	0.002956	0.001478	19.00	0.050
Speed (RPM)	2	0.005956	16.29%	0.005956	0.002978	38.29	0.025
Error	2	0.000156	0.43%	0.000156	0.000078		
Total	8	0.036556	100.00%				

Results indicated that Current significantly influenced the surface roughness of the workpiece based on the statistical P values of Current. The contributions of each factor were current 75.20%, % of B_4C 8.09%, Speed 16.29%.

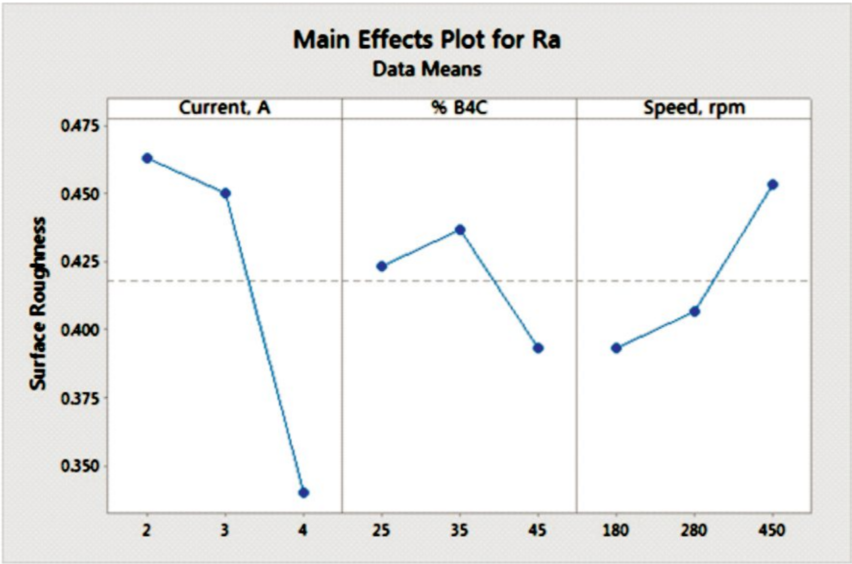

Figure 2 Main effects plot for process parameters in Iron and B_4C MAPs

1.1.1 Analysis of Steel and Boron carbide MAPs roughness data

Table 6 ANOVA for Steel and B_4C MAPs

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Current(A)	2	0.034822	46.58%	0.034822	0.017411	223.86	0.004
% B_4C	2	0.005489	7.34%	0.005489	0.002744	35.29	0.028
Speed (RPM)	2	0.034289	45.87%	0.034289	0.017144	220.43	0.005
Error	2	0.000156	0.21%	0.000156	0.000078		
Total	8	0.074756	100.00%				

Results indicated that Current and Rotational speed significantly influenced the surface roughness of the workpiece based on the statistical percentage contribution chart. The contributions of each factor were Current 46.58%, % B_4C 7.34%, Speed 45.87%.

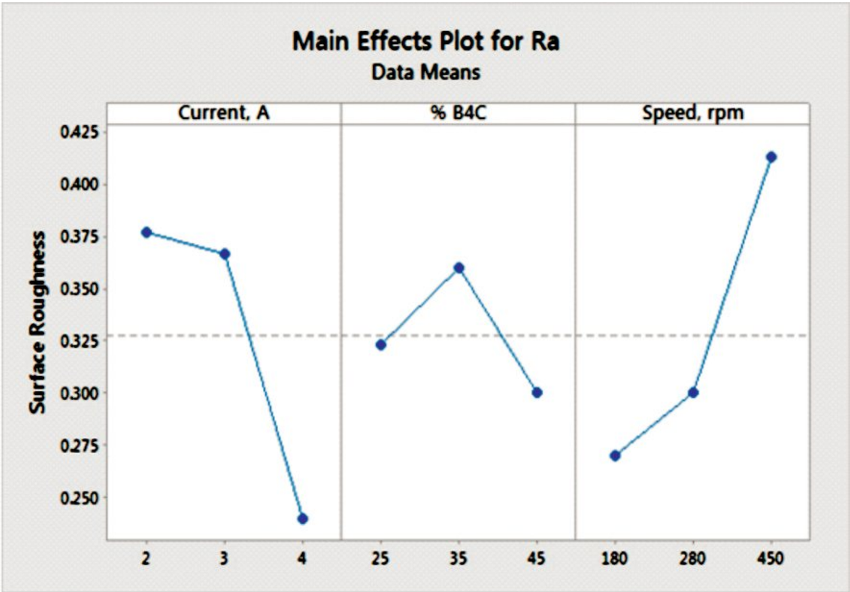

Figure 3 Main effects plot for process parameters in Steel and B_4C MAPs

Results and Discussions

It is not always necessary that all the input process parameters have significant contribution in surface response. Some of the parameters may be very much significant than other parameters.

Influence of Current on Finishing Characteristics

In Iron MAPs from the trends on bar chart its seems that current interval 2 to 3 amperes having not any significant variation in roughness but after the 3 amp current the surface roughness value start decreasing to obtained optimal value up to 4 amp current. The overall decrease is 0.36 µm from initial value in brass pipe recorded. In Steel MAPs from the trends on bar chart its seems that current interval 2 to 3 amperes having less variation in roughness decrease but after the 3 amp current the surface roughness value start decreasing to 0.27 µm at 4 amp current. The total drop is 0.43 µm from the initial 0.70 µm roughness.

It is also observed by [22] that increase in current increase in magnetic forces, resulting in increased packing density of FMAB and hence mass of abrasive particles in the FMAB gets increased. Therefore more number of abrasive particles comes in contact with the workpiece surface which results increase in rigidity of the FMAB for micro indentations further increase in roughness value. But due to fine abrasive particles it show opposite variations that's surface roughness decreased at higher currents. Finer abrasives smoothly finish the material surface with stronger FMAB than coarse abrasives particles.

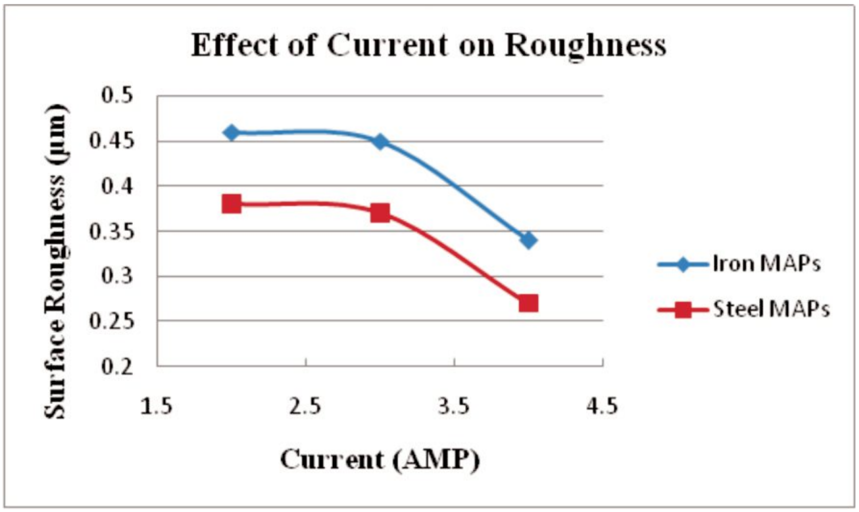

Figure 4 Iron & Steel MAPs Roughness Variation at same Current

Influence of percentage of B_4C on Finishing Characteristics

With increasing the composition of B_4C 25 to 35% the surface roughness also starts increasing but after 35% composition it seen that surface roughness decrease with respect to increase in composition up to 45% and obtained its optimal value 0.39 µm in case of iron MAPs. With increasing the composition of B_4C 25% to 35% the surface roughness also starts increasing but after 35% composition it seen that surface roughness decrease with respect to increase in composition. The beat roughness provided at 45% composition of abrasive which is equal to 0.30 µm.

Similar effect found by [23] stated that change in surface roughness has been found to lower with increase in percentage weight of abrasives. This is because of more cutting edges available per unit volume of MAPs, which may finish the peaks of workpiece top surface effectively to give larger change in surface roughness.

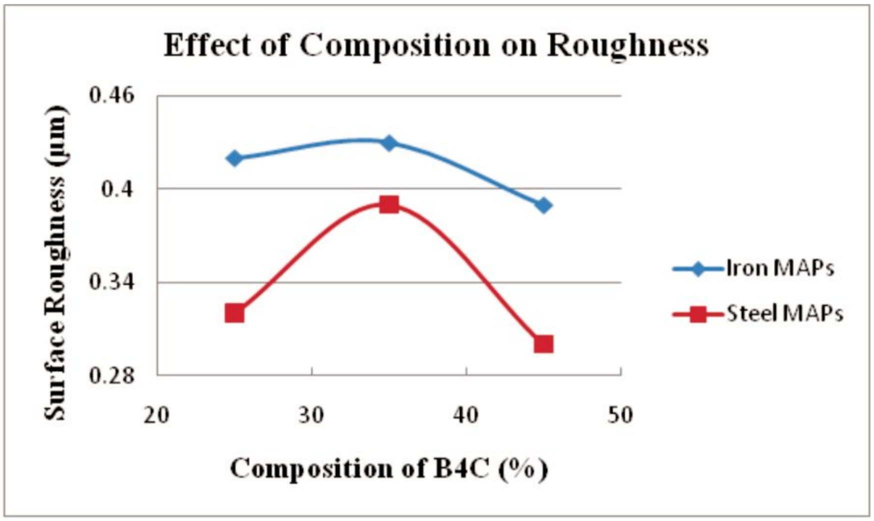

Figure 5 Iron & Steel MAPs Roughness Variation at same Composition

Influence of Circumferential Speed on Finishing Characteristics

The rotational speed of work piece was varied between 180 to 450 rpm during the test. It is evident that the Surface Roughness is directly varied with rise in circumferential speed of Brass pipe. The best roughness value obtained at 180 rpm which is 0.39 μm in case of Iron MAPs. But in case of steel MAPs the surface roughness start increase when the rotational speed increases from 180 to 450 rpm. The optimum roughness value is 0.26 μm at 180 rpm.

This might be due to the fact that increase in circumferential speed has increased the centrifugal force acting on the abrasive grains which leads to ejection of grains from the internal surface of work piece [24]. Due to fly out abrasive particles from machining area the number of sharp edges of abrasive particles reduced and show poor surface roughness value at higher circumferential speed of workpiece.

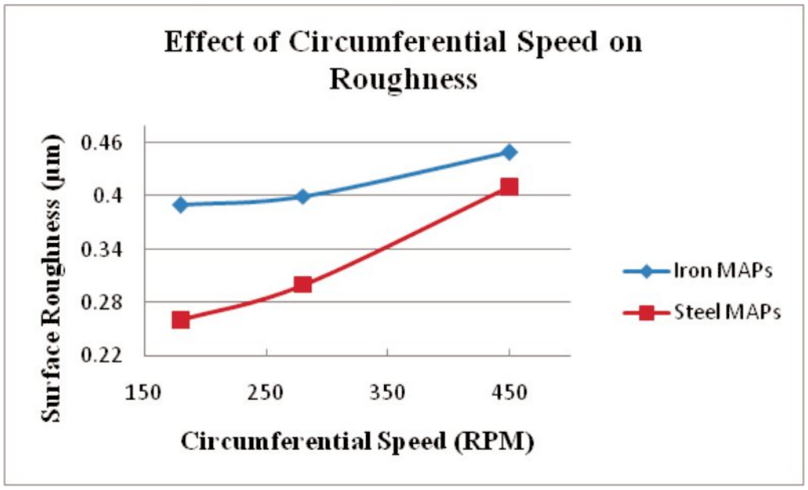

Figure 6 Iron & Steel MAPs Roughness Variation at same Speed

1. Optimal finishing conditions

From results of Iron and Steel MAPs the best finishing condition obtained are same and tabulated as:

Current (Amp)	Composition of B_4C (%)	Rotational Speed (RPM)
4	45	180

In case of fine abrasive particles, high value current make strong magnetic brush with higher abrasive compositions than ferromagnetic particles at low rotational speed to avoid fly out of abrasive make optimal finishing conditions.

Confirmatory test

Here optimal operation condition was used to confirm the experimental results; usually if the results values from the confirmation test could achieve the 95% confidence interval then the optimal operation condition will be verified statistically. In the confirmatory tests collected Ra value of both MAPs successfully achieved the level of confidence and validates the optimal results.

Conclusions

Based on the above results, Current is found to be the most significant parameter. However, the Boron Carbide percentage composition in MAPs and rotational speed of workpiece seems to be `having very small influence for improving Ra value.

It's also concluded from the investigated that for the internal finishing of Brass pipe Steel ferromagnetic particles help in achieving more surface roughness degree than the Iron particles at same experimental conditions due to its superior hardness and polyhedron shape.

In case of fine abrasive particles, high value current make strong magnetic brush with higher abrasive compositions than ferromagnetic particles at low rotational speed to make optimal finishing conditions.

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An Introduction to Slurry Erosion: A Review

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Abstract

This paper describes the pioneering work related to the development of slurry erosion test rigs and studies of various researchers in the field of slurry erosion performance of different coatings fabricated by various thermal spray methods. The study also detailed the influence of various significant tribological parameters on the slurry erosion of different materials. The overall study concluded that slurry erosion performance can be improved in a significant manner by the proper selection of coating compositions, process involved and various controllable tribological parameters such as slurry concentration, impact velocity of erodent on the target surface, impingement angle, particle size and shape of erodent particles, hardness of the striking particles, etc.

Introduction

Slurry erosion is caused by the interaction of solid particles suspended in a liquid (usually water) and a surface (called as substrate material) which experiences loss of mass by the repeated impacts of particles (called as erodent). It is one of the main reason of failure of several hydraulic components used in many industrial applications. Therefore, there is an urgent need to solve this problem or at least minimize its effects [More et al. (2014)]. Slurry erosion may be broadly defined as the phenomenon whereby the material is lost from a surface in contact with the moving particles suspended in liquid by mechanical interaction. It is an extremely serious problem for the performance, reliability, and operation life of the slurry equipment used in many industrial applications such as: oil field mechanical equipment, solid-liquid hydro- transportation systems, hydroelectric power stations, coal liquefaction plants, and industrial boilers where coal is carried directly as a fuel in water or oil [Tsai et al. (1981), Li et al. (1995), Fang et al. (1998)]. In rainy season, Slurry erosion problems more serious in hydroelectric power plants due to the increase in the number of solid particles impacting the surfaces, especially in systems where the installation of an exhaustive filtration process is not possible [Kachele (1999)].

Figure 1: Erosion on Pelton bucket, erosion on guide vane and erosion on Francis turbine runner respectively [Thapa et al. (2012)**]**

Due to the dependence on number of factors acting simultaneously, slurry erosion becomes a complex phenomenon and it is not yet fully understood. These factors can be broadly classified into three types: impingement variables describing the particle flow, particle variables and material variables.

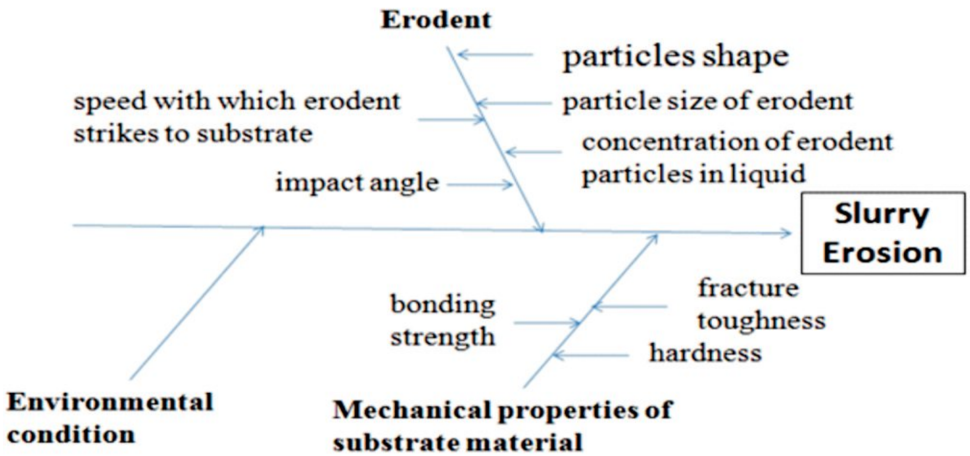

Figure 2: Ishikawa cause and effect diagram

The primary impingement variables are particle velocity, angle of incidence, flux (particle concentration) and target temperature. Particle variables are related to striking particle's characteristics i.e. particle shape, size, hardness and friability (ease of fracture). Material variables include all the material properties, such as hardness, work hardening behavior and microstructure [Krishnamurthy et al. (2011)]. Surface modification technology, especially coating technology provides an efficient way of protecting the components against various types of material degradation [Singh et al. (2011)]. This can be achieved by thermal spray coatings which are often considered for its potential alternative to its traditional coating [Chatha et al. (2012)]. Thermal spraying is a general term to describe all methods in which the coating is formed from melted or semi-melted droplets. In thermal spraying the material is in the form of powder, wire or rod and is fed into the flame produced by a spray gun, where it melts and the formed droplets are accelerated towards the substrate to be coated [**Oksa et al. (2011)**]. Several researches had done work in the field of improving the tribological parameters to enhance the slurry erosion performance for many applications. The research results show that the influence of tribological parameters on the slurry erosion is found to be significant and need to be investigate and analyzed properly. The slurry erosion can be minimized by proper selection of materials and/or by providing the suitable protective coating on the material which can enhance the surface properties.

Studies related to fabrication of slurry erosion test rig

Slurry erosion test methods fall basically into two categories: pipe wear tests and laboratory simulation tests. Simulation testing is widely adopted because it is low in cost, relatively easy to set up and operate, and quick to produce results, although pipeline testing provides conditions, which are closer to industrial practice. In wear testing of pipes, pipe samples are fixed either in operating industrial pipelines or, in most cases, in closed loops. Wear caused by the slurry flow is then recorded by weighing or by monitoring the change in the pipe wall thickness. Although some research was carried out by pipe wear testing. Laboratory tests on slurry erosion were carried out to understand the basic mechanisms of the wear process to explore the effect of the different parameters on the rate and distribution of material loss and for ranking resistance to slurry erosion of different materials [Roco et al. (1987), Gupta et al. (1995), Wood and Jones (2003)]. Various researchers had done work in the field of developing test rig to evaluate the performance of different coatings against the slurry erosion. Rai et al. (2015) had developed a test rig to measure the hydro-abrasive erosion in Pelton turbine. The paper presents recent studies related to hydro-abrasive in pelton turbine and on the basis of conclusion, they had constructed a test rig is proposed to simulate hydro-abrasive conditions in laboratory similar to Pelton turbine actually installed. Erosion velocity, sediment concentration and sediment size were considered as influencing factors for the proposed study. The methodology for erosion measurement for the proposed test rig was also suggested by them. They conclude that the presented methodology provides an added advantage of measuring depth and volume of erosion over an area of cross-section, which was not considered in case of weight loss method. The hydro-abrasive erosion in the proposed experimental set-up is similar to erosion in Pelton turbines with respect to parameters like sediment properties (concentration, size, shape and mineral composition), material of bucket, and flow conditions. Kasem et al. (2010) had constructed a slurry erosion whirling arm test rig and also performed a series of erosion tests on it. A paint erosion indication technique was used by them to analyze the erosion phenomenon. They had observed that the rebounding of the erodent particles from the sample surface plays significant role in developing erosion for the proposed tester.

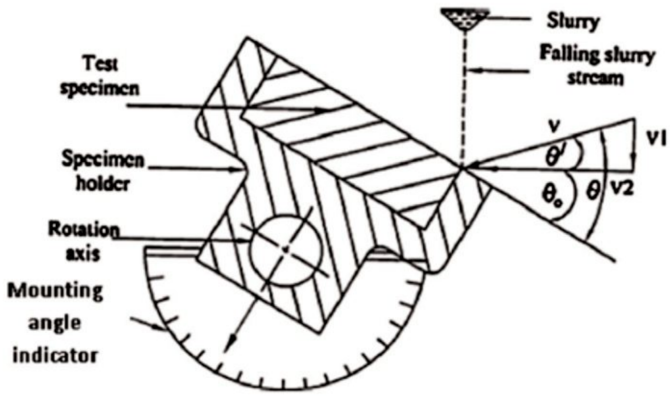

Figure 3: impact velocity and impingement angle [Kasem et al. (2010)**]**

On the basis of test experiments they had suggested that the developed slurry whirling arm erosion tester seems to be promising for simulating the slurry process in real cases. More et al. (2014) had developed a pot tester to simulate the erosion wear. This design of pot tester is intending to conduct wear tests at moderate solid concentrations and actual flow of velocities to simulate the wear conditions for pipeline, bend, pump etc. and may provide more realistic results. They had provided all the arrangements in the pot tester to evaluate the effect of impact angle, concentration, velocity, particle size etc. on erosion wear. The contributions of cutting wear and deformation wear at any orientation angle was investigated using correlations developed for ductile materials. The predicted erosion wear data is well in agreement with the experimental data. Patil et al. (2011) had studied the effect of various parameters on the performance of ductile materials. The aim of present study was to analyze the parametric dependence of erosion wear of Aluminum in sand water suspension. Aluminum had been chosen for target material as representative of ductile material. The effect of various parameters such as impact angle, particle size, velocity and solid concentration on erosion wear of Aluminum had been analyzed. For analyzing the effect of these parameters, a pot tester was fabricated and special fixtures had been developed to conduct erosion wear tests at various impact angles ranging of from 15° to 90°, in steps of 15°. They had concluded that, the erosion wear of Aluminum increases with increase in impact angle attaining a maximum at 45° and then reduces at 90° and erosion wear of Aluminum increases linearly with increase in particle size. The rate of increase at low impact angles are lower compared to that at higher impact angles. They had also investigated the effect of solid concentration (by weight) on the erosion wear. They at last concluded that the erosion wear increases with increase in solid concentration.

Studies relevant to slurry erosion of different materials

Santa et al. (2007) evaluated the slurry erosion performance of two coatings i.e. T35 MXC and E-C 2913 applied by oxy fuel powder (OFP) and wire arc spraying processes using a modified centrifugal pump. The AISI 304 steel was used as substrate material. The result of these were compared with AISI 431 and ASTM A743 grade CA6NM material. They concluded that the coated surfaces show higher erosive resistance than the uncoated stainless steel. Moreover, they also reported the best slurry erosion resistance by E-C 2913 coating applied by OFP process in comparison to other tested materials.

The erosion performance of various coatings i.e. Al_2O_3, Ni-Cr-B-Si, H.T., Al_2O_3-13TiO_2 and TiC-CrC-82Co on the different substrate materials was investigated by Sharma et al. (2008). The study revealed that the sample coated with Al_2O_3-13TiO_2 by Detonation Gun process had shown best results in the direction of resistance towards slit erosion. Also the D-Gun process showed the best results of bond strength in comparison to other coating processes. The experiments also concluded that the sample coated with Al_2O_3 coating with plasma spray process have shown poorest results. Santa et al. (2009) had experimentally studied the slurry and cavitation erosion resistance of six thermal spray coatings. The commonly used turbine steel material, CA6NM was used as substrate material. The three coatings namely nickel, chromium oxide and tungsten carbide coatings were applied by oxy fuel powder process and chromium and tungsten carbide coatings were fabricated by HVOF process. The slurry erosion testing was on the modified centrifugal pump tester and cavitation erosion resistance of the coatings was measured in a vibratory apparatus. The results showed that the slurry erosion resistance of the steel can be improved upto 16 times by the application of thermally sprayed coatings. The study also reported that the cavitation erosion resistance of the studied coatings was lower than that of uncoated stainless steel in all the cases. High porosity, low cohesion was attributed the main reason behind this. On the other hand, WC/Co-Ni coating showed the better result against the resistance of slurry erosion as compared to other studied coatings. Desale et al. (2011) studied in the field of developing correlations for predicting the slurry erosion of ductile materials. The seven different ductile materials viz. aluminum alloy (AA6063), copper, brass, mild steel, AISI 318L stainless steel and turbine blade grade steel were used for the present study. To study the slurry erosion effect, the three different erodent namely quartz, alumina and silicon carbide were used. The results show that the cutting wear rate increases with increase in the orientation angle, reaching to a maximum value at a certain angle and then decreases with further increase in the angle till 90^0. The study also concluded that the angle for maximum wear rate is found to depend on target material hardness. The author also developed a functional relationship between maximum cutting rate and target material hardness. Ramesh et al. (2011) had experimentally investigated the effect of Plasma sprayed Inconel-718 coatings on slurry erosion wear behavior. The Al6061 alloy was used as a substrate material. The effect of slurry concentration and the effect of coating thickness had been analyzed during this study. The results show the significant increase in slurry erosion wear rate with increase in slurry concentration and on the other hand slurry erosion wear rate decreases with increase in coating thickness. Thakur et al. (2013) had presented a comparative study on slurry and dry erosion behavior of HVOF sprayed WC-CoCr coatings. The experimental data reviles that reducing the size of WC grains from conventional to nanometers had resulted in enhance properties of the coatings. The results also concluded that NWC coating has better wear resistance over CWC coating. This improved erosion resistance is mainly due to enhanced properties like microhardness and fracture toughness of the coating. Kumar et al. (2012) had experimentally examined the erosive wear on the high chrome cast iron impeller of slurry disposal pump. They had used the response surface methodology for analyzing the results. The high speed slurry erosion tester (DUCOM Bangalore Make, TR-401) was used for the experimentation. The results show that the erosive wear of the pump impeller would decreases with decreasing ash concentration, rotation speed and particle size. Kaushal et al. (2013) had investigated experimentally the performance of D-gun sprayed Cr_3C_2-25NiCr coating on ASTM A743 CA6NM turbine steel. In the present study, slurry erosion behavior of the coated and bare steel was investigated using a high speed erosion test rig at 30^0 impact angle. Commercial available silica sand was used as abrasive media. Effect of concentration, average particle size and rotational speed was evaluated during the study. The results concluded that, under all the investigated experimental conditions, specific mass loss values were higher for 13Ni4Cr steel than Cr_3C_2-25NiCr coated steel. Grewal et al. (2013) had worked in the field of slurry erosion of thermal spray coatings. Coatings were developed using high velocity flame spray process

(HVFS). They had used commonly used hydroturbine steel i.e. CA6NM as substrate material. Slurry erosion performance of prepared coated and bare steel was investigated using a specially designed jet type test rig with sand as erodent particles. The erosion experiment was done at different concentrations of slurry. The results showed the improvement in erosion resistance of all the coatings as compared to bare steel, with the maximum erosion resistance with one containing 40 wt.% Al_2O_3 and 60 wt. % Ni. Singh et al. (2013) had determined experimentally the slurry erosion behavior of thermal sprayed satellite-6 and Cr_3C_2-25NiCr coatings. The commonly used hydroturbine steel namely CA6NM was used as substrate material. Commercial available silica sand was used as the abrasive media. The slurry erosion experiment was performed on high speed erosion tester, DUCOM TR-401. The experiment was conducted under the different condition of slurry concentration, different erodent size and different rotational speed. The results showed that the satellite-6 coating performed better than Cr_3C_2-25NiCr and uncoated steel when comparing them at 30^0. On the other hand, uncoated CA6NM specimens showed good performance at 90^0 in comparison to coatings. Singh et al. (2014) had investigated the slurry erosion behavior of plasma sprayed (50%)WC-Co-Cr and (50%) Ni-Cr-B-Si coatings of different thickness. The commonly used CA6NM was used as substrate material. In their study, the samples were coated by (50%)WC-Co-Cr and Ni-Cr-B-Si coatings. The study revealed that the impact velocity, slurry concentration and impact angle were most significant factors. The study also detailed that the coated samples showed better resistance to slurry erosion as compared to uncoated samples. Dhawan et al. (2015) had experimentally evaluated the erosion behavior of stainless steel grade-316. Silica sand was used as erodent to perform the slurry erosion test. The slurry erosion experiments were performed on high speed erosion tester DUCOM TR-401. The effect of slurry concentration, average particle size and rotation speed on the slurry erosion behavior of selected material was investigated under different experimental conditions. The results depicted the significant effect of these factors on slurry erosion performance.

Conclusion

The slurry erosion can be significantly control by the appropriate selection of tribological parameter's values.

Selection of the suitable substrate material or composition of coating material is very much important to enhance the capabilities against the slurry erosion resistance. The study of physical, chemical and mechanical properties of materials can help for the selection of material.

There is further need to explore the capabilities of various thermal spray coatings methods.

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Studying Effect of Erosion Corrosion In Heat Exchanger Components And Its Prevention

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Abstract

Erosion corrosion becomes major problem in industry such as oil industry, power plant, chemical plant where hot chemical, steam supplied through pipes. This paper provides you information about what is erosion corrosion, mechanism, factor effecting rate of this corrosion and various methods to prevent from this corrosion. It contains which parameter should have in terms of temperature and flow velocity of fluid while using copper tubes in hot water circulation. If we are using hot water circulation through copper pipes beyond this limit then copper tubes will damage and leakage will occur which may stop process of recirculation. Carbon steel is using in pipelines for transporting oil and water system which cause corrosive environment for pipes. Due to high velocity of water and oil in pipes corrosion rate is increases and solid particle which may contain water will break protective film increases corrosion rate. This paper will provide an overview of the materials that have been tested on in-bed, furnace, super heater, and boiler tubes. The test results will be based on laboratory analysis used to evaluate these corrosion and erosion protection solutions.

INTRODUCTION

Two different material loss mechanisms are involved in erosion-corrosion of metals, mechanical erosion, and electrochemical corrosion. This is result of mechanical forces applied by solid particle present in fluid, attack of liquid particle and cavitations due to air bubble present in fluid. This combine action is known as erosion-corrosion. High velocity and high temperature increases this corrosion rate. There are various mechanical component where erosion corrosion occur e.g. Pipelines of oil refinery, water pipelines, refinery components like pumps, pipes elbow, nozzle, hot water tubes in power plant, turbines etc. Prevention of this corrosion is control of various parameter of fluid flowing, control of contains of fluid like solid particle, air bubbles etc.

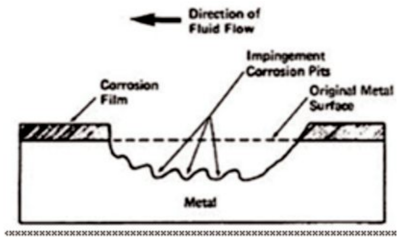

Figure: Erosion process.

Two different material loss mechanisms are involved in erosion-corrosion of metals, mechanical erosion, and electrochemical corrosion. The mechanical erosion relates to plastic deformation and rupture in surface layer. Small pieces of metal are removed from the surface by various mechanical forces before being ionized. The electrochemical corrosion relates to the metal being dissolved into the slurry after it is ionized. Therefore, the total material loss rate is the sum of material loss rates caused by erosion and corrosion.

FACTOR AFFECTING RATE OF EROSION CORROSION

Solid suspended particle

Abrasive suspended solids, including sand and iron oxide, can further promote Erosion-Corrosion because they contribute to the damage of protective films. As might expected that erosion rate is depend impact velocity and impact angle of solid particle.

Erosion of brittle material by slurries reach maximum at 90° and ductile material develop maxima in range of 15° - 40°.[S.Nesic et al, 2000]

Flow condition

Turbulence causes local impingement velocities that are higher than the general flow velocity.

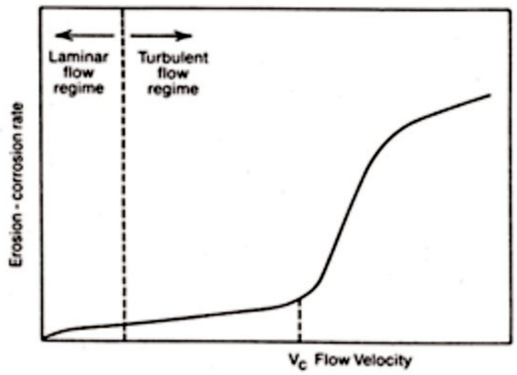

Figure: EC rate vs. Flow Condition

Turbulence is promoted by any deviation from smooth transitions in the pipe's internal profile. At even relatively low flow velocities, it is possible for turbulence to promote Erosion-Corrosion[S.Nesic et al, 2000].

High velocity factor

Velocity is the most commonly cited influence, although it is important to recognize that it is not the only significant factor. There is a critical velocity above which Erosion-Corrosion is a serious risk and below which it should not usually occur.

Temperature

It has been recognized that flow velocity and temperature must be considered together. Permissible water velocities are recognized to decrease as temperature increases from cold (<25°C) to warm (~25–49°C) to hot (~54–60°C) to very hot (~71°C1 – 82°C)[3]. At temperatures above 71°C the increase in severity of Erosion-Corrosion is said to be associated with a change in the oxide type, from cuprous to a less protective cupric form

Liquid droplet impingement

Erosion by impinging liquid droplet carried in high pressure gas or vapor is called liquid droplet attack. Repeated discrete impact by liquid droplet generates impulsive contact pressure which erode solids. It has been problem in low pressure steam turbine blade and rain corrosion of aircraft and helicopter.

Air bubble impingement or cavitations

The erosion corrosion of heat exchanger inlet has been linked with local damage of protective film by impinging air bubble.

Pressure

In addition to high velocity and elevated temperature, high water pressure may also promote Erosion-Corrosion. According to the U.S. Copper Development Association, even in cold water the pressure should be limited to a maximum of about 550 kPa[BAOTONG LU , 2013].

Liquid chemistry

Hard waters with a positive calcium scale-formation tendency are generally less corrosive (both to copper and to steel alloys) than very soft waters. Similarly, waters with pH above 6.9 are generally less corrosive than waters with lower pH. These general corrosion tendencies are reflected in the tendency for Erosion-Corrosion, with higher flow velocities permissible in high pH, positive scale-forming waters than in softer, lower pH waters. Water with high dissolved CO_2 (10 ppm) is also more aggressive for Erosion-Corrosion.

VARIOUS MECHANICAL COMPONENTS WHICH EFFECTED BY EROSION CORROSION:

A few typical problems of erosion-corrosion in oil and gas production.

The down hole components. Petroleum and mining drill bits.

The systems used to contain, transport and process erosive mineral slurries. This is particularly important for the oil sand industry.

With the technique of CO2 injection for enhanced oil recovery and active exploitation of deep nature gas reservoirs containing CO2, server corrosion of carbon steel is experienced.

Petroleum refinery equipment components, typically, pump internals, thermo wells, piping elbows, nozzle, valves seats, and guides, experience varying degrees of high temperature erosion and corrosion.

Boilers, produce very corrosive and erosive environments which can significantly reduce the life of furnace, super heater, boiler, and in-bed tubes.

Hot water copper tubes.

Pump, turbine in steam power plant affected by liquid droplet impingement.

RECOGNITION AND CONTROLLING OF CORROSION

Recognition of the type of erosion- corrosion is sometimes by presence of smooth groves, gullies, shallow pits, waves. With cavitations and liquid droplet attack, the damage starts in the form of steep sided pits, which may coalesce into a honeycomb like structure.

For controlling there should be two steps:

1. Take step to protect film to damage.
2. Accept film damage and take corrosion controlling method

Design and material selection

Design involves optimizing the particle size and the flow velocity, The flow velocity system should be designed to minimize ant effect of flow particles, by using long radius elbows, gradual change in flow cross section, increasing the thickness of material in critical areas and chose an alloy which may harder than solid particle. Plastics insert can solve heat exchanger inlet problems.

If necessary more corrosion resistant materials than carbon steel pipe can be chosen including, stainless alloy, ceramics (cast blast lined pipe) and plastics (e. g high density polyethylene pipe). Plastics and ceramics may not have the mechanical and thermal properties for construction of process equipment.

Design modification in steam turbine blade with wet vapor low pressure section have included, extracting moisture between blade row, increasing axial spacing between stator and rotor, flame hardening at leading edge of blade.

Chemistry of water

Raising the pH and deareation, both of this method control corrosion control have been applied to long distance slurry pipelines. A problem with raising the pH is the greater likehood of pitting at elevated pH values where thick scales are easily formed. Deareation can be achived with oxygen scavengers, sodium bisulphite, or hydrazine or by nonchemical steam stripping or vaccume deareation.

Inhibitors

Inhibitors used in recirculating cooling water system and steam condensate return pipe line but it has limited application because of cost. A notable exception is extensive use in oil\gas industry.

Chromates and nitrates at high concentration act as passivating inhibitors and at low concentration act as active inhibitors.

ANALYSIS OF SOME CASE STUDIES

S.No.	Case	Environmental effects	Findings/Failure observed	Micro graphs	Preventive measures	Ref. No.
1.	Corrosion in pipes in Oil industry	Oil sand slurry produced from well, presence of water, CO_2, salts containing Cl- , HCO3 - and SO4 – ions	Degradation Experienced in transportation lines		Use of corrosive inhibitors 100ppm reduce degradation by 92.5%	[BAOTONG LU , 2013].
2.	Corrosion in copper pipes in hot recirculation system	High temperature and high velocity of water	Hot water pipes suffered no. of leakages a wide variety of locations, including branch lines, droppers, the lower manifold		Make a standard limit of water temperature , velocity	[J.D. Gates 2014]
3.	Corrosion on Boiler tubes in power plant	Deposition of chloride compounds, high flue gas velocities and soot blowing required to remove ash and slag deposits	furnace, super heater, boiler tubes		Use of high wear resistant material on tubes (Cladding)	[Randall Doolev I et al ,2009]

CONCLUSION

Erosion of tubes may increase possibility of further corrosion of tubes which is protected using taking prevention such as coating, oxide layer formation. Corrosion may decrease life of tubes or failures of tubes take place. Erosion – Corrosion in heat exchanger tubes can be control at some extent by proper design and selection of tube material, control flow condition, velocity, temperature and control chemistry of water such as pH value, chlorine contents.

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Studying Effects Of Explosive Forming On Mechanical Properties Of Commonly Used Metallic Materials

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Abstract

The work presented in this paper results from a global review of activities undertaken in the area of explosive forming. Explosive Forming is a manufacturing technique that uses explosions to force metal into dies and molds. The technique is useful for short production runs of conventionally difficult to manufacture parts .In this study we studied that forming of thin wall spherical parts by explosive forming. It was also studied that how to control of explosive forming for metallic decorating sphere. And an extra circular sheet welded to the inner surface of the top and bottom end sheet of the shell is an ideal shell before the forming. It was also studied that explosive forming is an economical technology for aerospace structures and fabrication of cylindrical uni-directional porous metal with explosive compaction. And Influence of the explosive treatment on the mechanical properties of different materials were also studied.

Key words- rust, mill scale, abrasives, blast pots, wet and dry blasting.

INTRODUCTION

Explosive forming is a metalworking technique in which an explosive charge is used instead of a punch or press. It can be used on materials for which a press setup would be prohibitively large or require an unreasonably high pressure, and is generally much cheaper than building a large enough and sufficiently high pressure press; on the other hand, it is unavoidably a batch process, producing one product at a time and with a long setup time.

Types of Explosive Forming

Unconfined type or Standoff technique: In this technique places the explosive charge some distance away from the workpiece as shown in fig. 1.

Confined type or Contact technique. In this technique place the explosive in direct contact with the metal as shown in fig. 2.

Explosives Used :

TNT (Trinitrotoluene),
Tetryl (Trinitrophenylmethylntramine),
RDX (Cyclotrimethylenetrinitramine),
NG(Nitroglycerin) etc.

For over 100 years it has been recognised that explosives can be used in deforming metals . It was reported that the first application of explosives to metalworking was undertaken by Daniel Adamson of Manchester in the United Kingdom in 1878. Adamson's technique, free forming was developed to assess the strength of boilerplates.The recent investigation resulted in development of a new method for fabrication of porous metal with longer and uniform unidirectional pores, named “UniPore”, using explosive compaction of cylindrical metal pipe assembly. The experiments were performed by explosive compression of a bigger outer pipe completely filled with smaller inner pipes, which in turn are filled with a paraffin filler to prevent their complete compaction. The explosive forming processing methods present a series of important advantages, being recommended for the wide-scale application in the aerospace industry. Economically, there is the possibility of costs decreasing of the forming operation, below 1/10th of those necessary for classic forming technologies, especially in what concerns the prototype and small-scale production.

Metallic decorating sphere is a product for non-industrial usage. Due to its specific function of decoration, it requires high precision in dimension and high surface quality. It is very hard to form this kind of thin wall sphere using traditional metal sheet forming. From many years of research and experience, the authors developed a new technology for non-die explosive forming of ultra-thin wall metallic decorating sphere.

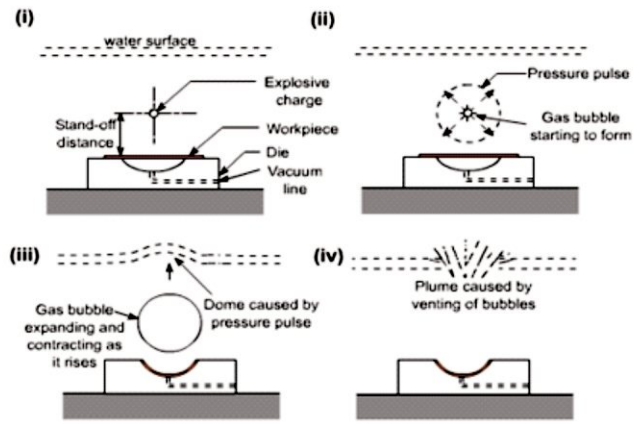

Figure 1: Sequence of underwater

The technology provides a simple but effective way for the forming of different components. General steps in explosive forming operations: (i) explosive charge is set in position (ii) formation of pressure pulse during detonation of charge (iii) work piece deformation and (iv) gas bubbles vent at the surface of the water

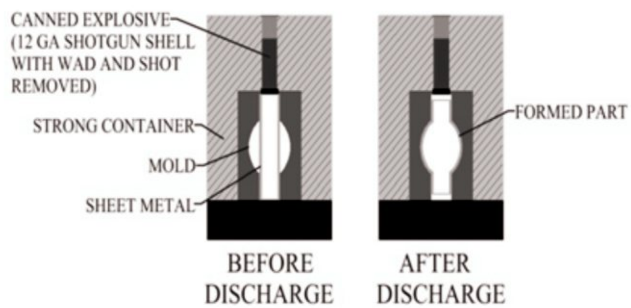

Figure 2: Schematic Illustration of contact technique of explosive forming

LITERATURE REVIEW

TECHNICAL PARAMETERS

Table 1: Process parameters

S.No.	Component	Material	With explosive forming Yield strength	Without explosive yield strength	Findings	Ref.
1	Railway coaches	A285 steel	319 (MN/In^2)	269 (MN/In^2)	There is a little difference in tensile strength regardless of method used for inducing strain or when compared to the as-received steel. The tensile strength are all within range specified in ASTM specification A285. The increase in yield strength for the explosively formed material is matched by a corresponding drop in ductility.	[H. E. Otto et al 1973]
2	Air conditioning component	Copper	271.2 (MPa)	204.6 (MPa)	It was observed that explosive treatment increases Young's modulus and the yield stress of copper. Due to explosive forming: (i) intensive fragmentation of coarse grains and (ii) formation of sub-grain structure	[A. Sato,2015]
3	Pressure vessel	A515 steel	441 (MN/In^2)	394 (MN/In^2)	At low strain level explosively formed A515 steel had better impact properties than cold rolled steel. But at high strain level cold rolled steel had better impact properties than explosively formed.	[[H. E. Otto et al 1973]]

EFFECT OF TECHNICAL PARAMETERS ON FORMED MATERIAL

Achievable Tolerances - The precision obtainable with explosively forming can be illustrated by the rectangular tubes with corner radii of 1.3 mm that have been formed . In addition, tolerances of 0.025 mm have been obtained on small explosively formed parts. For a given die forming operation, it appears that theamount of spring back can be controlled to a certain extent,depending on the material, by varying the amount of explosiveand the stand-off distance. Increasing the charge size orreducing the stand-off distance increases the force and hencedeformation seen by the workpiece. The increased force istransmitted through to the die whose elastic deformation willbe greater than before. Hence, the additional deformationseen by the workpiece will compensate for its elastic recoveryand the final workpiece dimensions will be closer tothose of the elastically recovered die.

Table shows the tolerances achieved in forming large domes with diameters in the range of 1000–1500 mm from AMS 6434 high strength steel, with thicknesses ranging from 2.3 to 3.8 mm

Table 2: Tolerances obtainable when explosive forming large domes

Dimension	Normal Tolerance (mm)	Possible Tolerance (mm)
Diameter	0.254	0.128
Thickness	0.100	0.050

APPLICATIONS

Explosive forming is used for tube making , plate forming , sheet forming. This forming process also used for Fabrication of cylindrical uni-directional porous metal and also used for fabrication for **aerospace structures like** nozzle of the space shuttle, spherical cap Radar dishes Elliptical domes etc. This forming process also used for Crimping of metal strips and In ship building – to form large plates. Explosive forming recommended as the preferred process for vacuum vessel, forming dome shapes,beaded panels, large shallow reflectors, shallow and deep rectangular boxes etc. Explosive forming can be used for forming the **metallic decorating sphere by adding** an extra circular sheet welded to the inner surface of the top and bottom end sheet of the shell for forming complete sphere.

CONCLUSION AND FUTURE SCOPE

From the above study it is clear that explosive forming enhances the mechanical properties and meets the ASTM specification. Explosive forming is a versatile process requiring low capital investment and has great application potential. The ability to vary the distribution, intensity and of the forming pressure and energy levels over wide ranges provides greater capabilities than conventional forming methods. Another advantage that is common to all high energy rate forming processes is the increased ductility that may be obtained at certain deformation velocities. The process does have disadvantages including the requirement of specialist process knowledge and the need to handle explosives.

It is thought that explosive forming has potential for the future Gas turbine exhaust structures, Fiber metal laminates, Propellant pressure tanks and Other Gas turbine applications.

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Total Quality Management: Similarities In The Concept Of Various Quality Gurus

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Abstract

TQM has assumed a great importance in today's highly competitive manufacturing industry. TQM has been widely implemented throughout the world. Many firms have arrived at the conclusion that effective TQM implementation can improve their competitive abilities and provide strategic advantages in the marketplace. Quality is at the top of consumers' lists of demands, and many companies have been forced to assign priority to the development of high-quality products. In particular, Total Quality Management (TQM) programs have been attracting the attention of many organizations and are likely to remain a key issue for change management in this century. There are many approaches to the concept of TQM but it is mainly the various approaches given by the five quality gurus which form the basis of TQM implementation. This papers aims to discuss the various approaches given by the five quality gurus viz. Deming, Juran, Ishikawa, Crosby and Feigenbaum and thus aims to discuss the basic concept of TQM from the view point of these quality gurus.

Key Words: Total Quality Management (TQM), Quality gurus

INTRODUCTION

TQM is a management philosophy developed by Deming based on his experiences in US industry before and during the II World War. The TQM philosophy has also been explored by a number of prominent researchers like Crosby (1979, 1984), Ishikawa (1983, 1985), Juran (1988, 1989) etc. Although TQM was originally intended for the industrial sector, Deming (1986) pointed out in the preface to his book

'Out of the Crisis' that his management principles could be applied equally well in service sectors. In fact, whenever an organization has a sequence of activities directed towards a defined end result, it has business processes which can be analyzed and improved by TQM techniques (Crawford and Shutler, 1999). TQM can be defined as a general management philosophy and a set of tools which allow an institution to pursue a definition of quality and a means for attaining quality, with quality being a continuous improvement ascertained by customers' contentment with the services they have received (Michael et al., 1997). According to Witcher (1990), TQM is composed of three terms: Total: meaning that every person is involved including customer and suppliers, Quality: implying that customer requirements are met exactly and Management: indicating that senior executives are committed. TQM has three essentials: total commitment from the top management, total involvement of all employees and stakeholders and use of scientific knowledge, tools and techniques. Following definition of TQM explains the integration of above three essentials:

“Total Quality management is a culture; inherent in this culture is a total commitment to quality and an attitude expressed by everybody's involvement in the process of continuous improvement of products and services through the use of innovative scientific methods” (Singla et al, 2008).

TQM definitions available in literature can be classified under the following broad headings:

TQM as a *culture* (Ghobadian and Speller, 1994; Kettinger and Lee, 1995).
TQM as a *management and institutional-wide process* (Ross, 1994).
TQM as a *management philosophy and as a guiding principle* (Elton 1992).
TQM as a *strategy* (Dean and Bowen, 1994; Reed et al., 2000).
TQM as a system (Eriksen 1995; Evans and Lindsay, 1999; Dale and Plunket 1991).

The introduction of TQM concepts can be traced to the first management consultant, an engineer named Frederick W. Taylor whose application of science to complex human endeavors was further developed by Walter A. Shewhart, a statistician who developed work sampling and control charts, which attracted the interest of another statistician, Edwards Deming. Joseph M. Juran, an investigator at the Hawthorne Works experiments (US), also drew inferences from Shewhart's work and recognized that system problems could be addressed through three fundamental managerial processes - planning, control and improvement. Philip B. Crosby advocated the 'zero-defects' program adopted by the US federal government defining quality as 'conformance to requirements'. In 1960, the first quality control circles were formed for the purpose of quality improvement within work groups. Simple statistical techniques were learned and applied by Japanese workers. By the late 1970s and early 1980s U.S. managers were making frequent trips to Japan to learn about the Japanese miracle of quality. Nevertheless, a quality renaissance began to occur in U.S. products and services and by the middle of 1980s the concept of TQM was being widely publicized. In the late 1980s the automotive industry began to emphasize statistical process control (SPC). Suppliers and their suppliers were required to use these techniques. The Malcolm Baldrige National Quality Award was established and became the means to measure TQM. Genechi Taguchi introduced his concepts of parameter and tolerance design and brought about a resurgence of design of experiments (DOE) as a valuable quality improvement tool. In addition, ISO 9000 quality standard was developed and quickly became the worldwide model for a quality system (Besterfild, 2007).

Concept form Various Quality Gurus

An extensive review of literature was carried out to identify the concept of TQM from various quality gurus such as Deming (1986), Juran (Juran and Gryna, 1993), Crosby (1979), Feigenbaum (1991) and Ishikawa (1985). Their findings serve as the base for understanding the concept of TQM. The main principles and practices of TQM as proposed by these quality gurus are:

(a) Deming's Approach to TQM

The theoretical essence of the Deming approach to TQM concerns the creation of an organizational system that fosters cooperation and learning for facilitating the implementation of process management practices, which in turn leads to continuous improvement of processes, products and services as well as to employee fulfillment, both of which are critical to customer satisfaction and ultimately to firm survival (Anderson et al., 1994). Deming (1986) stressed the responsibilities of top management to take the lead in changing processes and systems. Deming proposed 14 points as the principles of TQM (Deming, 1986), which dealt with the importance of issues like identification and measurement of customer requirements, creation of supplier partnership, use of functional teams to identify and solve quality problems, enhancement of employee skills, participation of employees and pursuit of continuous improvement.

(b) Juran's Approach

According to Juran, it is very important to understand customer needs. This requirement applies to all involved in marketing, design, manufacturing and services. Identifying customer needs requires more vigorous analysis and understanding to ensure that product meets customers' needs and is fit for its intended use, not just meeting product specifications. Thus, market research is essential for identifying customers' needs. In order to ensure design quality, he proposed the use of techniques including quality function deployment, experimental design, reliability engineering and concurrent engineering (Juran and Gryna, 1993). Dr. J. M. Juran developed a useful framework to what he referred to as "a universal thought process-a universal way of thinking about quality, which fits all functions, all levels, all product lines." He called it the "quality trilogy": The underlying concept of the quality trilogy is that managing for quality consists of three basic quality oriented processes which are quality planning, quality improvement and quality control.

(c)Crosby's Approach

Philip B. Crosby (1979) was corporate vice president for quality at International Telephone and Telegraph (ITT) for 14 years after working his way up from line inspector. While Deming and Juran described the TQM philosophy and Ishikawa provided the tools and techniques, Crosby offered a detailed guide to implementation. He proposed a quality management grid that described the stages of TQM implementation relative to management's understanding and problem-solving techniques, the organizational approach and the results achieved. Each stage of Crosby's matrix represents an increasingly mature implementation of the TQM philosophy (Crosby, 1981**).** The essence of Crosby's teaching is contained in the 'Four Absolutes of Quality'. These are: the definition, the system, the performance standard and the measurement

The definition: Quality is conformance to requirements not goodness

The system: Prevention, not appraisal

The performance standard: Zero defects

The measurement: The price of non-conformity to requirements, not quality indices (Charantimath, 2008).

(d) Ishikawa's Approach

Professor Kaoru Ishikawa (1915-89) is known as the 'Father of the Quality Circles' for his role in launching Japan's quality movement in the 1960s. Ishikawa (1985) argued that quality management extends beyond the product and encompasses after-sales service, the quality of management, the quality of individuals and the firm itself. He claimed that the success of a firm is highly dependent on treating quality improvement as a never-ending quest. A commitment to continuous improvement can ensure that people will never stop learning. Ishikawa advocated the following principles:

- Quality is companywide issue and must be an all pervasive influence on the way every issue of business is conducted.
- Seven simplified tools of quality control to be used by all the people in the organization.
- Quality circles

In his book 'What is Quality Control ', Ishikawa said that the seven basic tools viz. Pareto analysis, fishbone diagram, stratification, tally charts, histograms, scatter diagrams and control charts, were indispensable for quality control.

(e)Feigenbaum's Approach to TQM

The emphasis of Feigenbaum is not so much to create managerial awareness about quality but to assist an organization to design its own quality system which involves every employee (Kruger, 2001). Feigenbaum (1991) is considered as the originator of the concept of TQC. Feigenbaum developed the concept of *quality at source* which means that every employee will have to do his/her work with perfect quality. He said that the quality is the responsibility of everyone in an organization. It is the total participation of all employees and the total integration of all the company's technical and human resources that will lead to long term business success.

Commonality among Quality Gurus

Though the approach of each quality guru has been different yet there are many commonalities in their work (refer table I). From this table, it can be noted that customer satisfaction and reducing costs are the two outcomes of TQM while leadership, training, use of teams and having the appropriate culture are the four processes by which the two outcomes can be achieved.

Table I: Commonalities among Seminal TQM Work

Author / Concept	Crosby (1979,1984)	Deming (1986)	Feigenbaum (1991)	Ishikawa (1985)	Juran(1988, 1989)
Customer Satisfaction	Delighting the customer to satisfaction and conformance.	Customers define quality; are important part of production line.	Quality is what customer says; customer focus is embedded in quality.	TQC means having a consumer orientation.	Customer satisfaction drives market share and profits.
Cost Reduction	The price of nonconformance means that quality is free.	Doing it right first time means less waste, less rework and less cost.	Controlling quality costs less than correcting mistakes.	TQC reduces cost over the long term, not the short term.	Costs of poor quality remain unknown, but they are very high.
Leadership and Management Commitment	Leadership commitment is demonstrated by participation/ attitude.	Management's Job is to show constancy of purpose in quality.	Requires complete support of top management	Top management commitment should lead in implementation	Top management job is to motivate and participate in quality.
Training and Education	Continuous training /education in quality from top to bottom.	Vigorous (re) training of employees in new knowledge/ skills.	Training and education for achieving full commitment to quality.	Training and education must be continuous for all employees.	Training should include the entire hierarchy.
Teams	Mgmt. team for internal; quality council for external communication.	Cross functional teams create improvement in product, service and quality and reduce cost.	Quality control committees should have representatives from all functional areas.	Cross-functional committees facilitate development of quality assurance.	Major quality Improvement projects require multi functional teams.

CONCLUSION

There are many approaches to the concept of TQM but it is mainly the various approaches given by the five quality gurus which form the basis of TQM implementation. This papers aims to discuss the various approaches as given by the five quality gurus and thus aims to discuss the basic concept of TQM from the view point of these quality gurus.

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Tribological Behavior Of Bare And Thermally Coated Tool Steels At Room Temperature

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ABSTRACT

The recent years have witnessed an increasing usage of high-strength steels as structural reinforcements and in energy-absorbing systems in automobile applications due to their favorable high-strength-to-weight ratios. High-temperature tribology plays an important role in many engineering applications such as metal forming operations and aerospace industry. The severe problem bound with hot forming process is the failure of the die due to oxidation and scaling of workpiece surface. Complex shaped components of high-strength steel are though being produced using hot-metal forming process irrespective of its poor formability.[1] Due to the application of repeated contact between the tool and the workpiece the degradation of the tool occur under the effect of many conditions. Therefore, the present research work concentrates to analyze, understand and enhance the life of hot forming tool steels under dry conditions at room temperatures. AISI H11 tool steel was selected as substrate for conducting the experiment. NiCrBSi+(WC-CO) powder coating was developed on the substrate using plasma spray process. Room temperature wear performance of uncoated and the coated tool steels were evaluated on the pin-on-disc tribometer in laboratory, so as to ascertain the usefulness of the developed coating composition. As-sprayed and the worn samples were analyzed for their in depth characterization using X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectrometry (EDS).

Keywords: Hot forming, Sliding Wear, Plasma spray process, Pin-on-disc tribometer, Scanning Electron Microscope.

INTRODUCTION

The use of high-strength steels as a structural reinforcement and in energy-absorbing systems in automobile applications in past few years is increasing due to their favorable high-strength-to-weight ratios. Several hot forming processes are bound with severe problem of sliding wear resulting in die failure. The surfaces of the tools get damaged severely due to the application of repeated cyclic contact between the hot work-piece and the tool. The failure of the tool material is due to the degradation of the materials used for high temperature applications. This degradation occurs due to hot corrosion, erosion-corrosion, overheating, solid particle erosion, wear etc. Wear is a serious issue in hot forming of hot die steels. Sliding wear is a process in which the material loss takes place during the sliding of one material surface over the other surface. There are many ways to protect the surface of the substrate material from wear and one possible way of controlling friction and reducing wear is to utilize the latest developments in surface engineering and modify or coat the tool surface with some thermally stable layer.

One of those surface protection methods is thermal spraying processes, which includes High velocity oxy-fuel (HVOF), Detonation gun (G-Gun), Plasma spray process and many more. Plasma spray process is a well established and versatile technique, and has been widely applied in modifying surface properties of metal components (Vencl A et. al,2011). Plasma spray coatings may be used to perform various functions such as improving wear resistance and thermal or chemical resistance. Plasma spray coatings finds its wear resistant applications in a variety of industrial environments such as thick coatings are applied in many industrial areas to restore or attain desired work piece dimensions and specifications (Heimann RB, 1996,Koutsomichalis A et. al 2009) for example. Plasma spray coating characteristics are very dependent on spray parameters. There are more than 50 macroscopic parameters that influence the quality of the coating some researchers(Lugscheider E et. al,1996) said. Depending on the application of plasma spray coating, different characteristics are important but there are some characteristics that are the same for all applications such as porosity, thickness, presence of un-melted particles, microstructure, cracks and oxides, micro-hardness and bond strength etc. The mechanical property values of plasma spray coatings considerably reduced when the bonding between splats and the imperfections in the form of pores or thermal cracks is poor (Erickson LC et. al, 1998).

The objective of this research work is to study the sliding wear behavior of NiCrBSi+(WC-CO) powder coating deposited by Plasma spray process on the selected tool steel. In-depth characterization of the as-sprayed coatings was done by X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS) analysis. Sliding wear behavior was studied according to ASTM, Standard G99-03 on a Pin-on-Disc Wear Test Rig. Cumulative wear volume loss, wear rate and coefficient of friction (μ) were calculated for the specimens for 20 N normal loads. The variations of wear rate with the sliding distance for all the specimens studied were plotted and analyzed.

EXPERIMENTAL DETAILS

Substrate materials

The substrate material selected for the study was iron based tool steel AISI H11 with the chemical composition as shown in Table I. The samples were cut to form a pin of diameter 8mm and length 50mm for the wear tests. The specimens were polished and grit-blasted with alumina (Al_2O_3, grit 45, 0.355 mm)prior to the application coating. The workpiece material 20MnCr5 was also procured in consultation with the actual hot press forging industry.

Table I: Chemical compositions (wt %) for the substrate material required and actual

Substrate material	AISI H11	
Elements	Required wt %	Actual wt %
C	0.30-0.40	0.375
Si	0.80-1.20	0.98
Mn	0.20-0.40	0.364
P	0.03 Max	0.02
S	0.03 Max	0.014
Cr	4.75-5.50	4.75
Mo	1.25-1.75	1.75
Al	---	0.071
B	---	0
Co	---	0.02
Cu	---	0.091
Pb	---	0
Ti	---	0.266
V	0.30-0.50	0.379
W	---	0.049
Fe	---	90.65

Coating powders

Nickel based alloy powder NiCrBSi+(WC-CO) as per the chemical composition and grain size given in Table II was used as coating material.

Table II: Chemical composition and particle size of alloy powder.

Powder	Nominal Chemical Composition (wt%)	Particle size
NiCrBSi	Ni-71.7, Cr-15.7, Si-4.27, Fe-4.17, B-3.35, C-0.81 (65%)	-45+15µm
WC+Co	(88WC+12Co) 35%	-45+15µm

Formulation of Coating

The coatings were developed at Metallizing Equipment Co. Pvt. Ltd. (MECPL) Jodhpur (India) on their conventional atmospheric plasma spraying (APS) apparatus operating with hydrogen as fuel gas and argon as powder carrier gas. Hydrogen gas is used to increase the voltage, and oxygen doesn't find any use in plasma spray equipment rather air is used for cooling purpose. The spray equipment was made by Metallizing Equipment Company Pvt. Ltd., Jodhpur (India) and the robotic arm for automatic spray was of make KUKA made in Germany. The spraying parameters adopted for the plasma spray process are given in Table III. All the data was provided by the technical provider of MECPL, Jodhpur. According to him, the values reported are optimized, process controlled and inherent characteristic of this technology. It was aimed to achieve a coating thickness in the range of 150±25 µm. After each pass of spray gun the specimen was allowed to cool so that to reduce the oxidation process. For cooling purpose forced air stream is used. After cooling, the specimens were measured for the coating thickness. Using plasma spray system the desired thickness is achieved after 9-10 passes.

Table III: Spray parameters as employed during Plasma spraying

Fuel gas, Hydrogen (SLPM)	9
Powder carrier gas, Argon (SLPM)	41
Powder feed rate (g/min)	5
Spray distance (mm)	75
Flame temperature (ºC)	17000-18000
Particle temperature (ºC)	2500-2700
Particle velocity (m/s)	200-250

Characterization of the As-Sprayed Coating

Scanning electron microscopy (SEM) was done to study the morphology of powder particles. A Scanning electron microscope (SEM), (JEOL, JSM-6610LV) was used for this purpose. X-ray diffraction (XRD) analysis of the samples was carried out using an Expert Pro PAN analytical company (Netherlands) Expert Pro Model MPD with CuKα radiation and nickel filter at 20 mA under a voltage of 35 kV. Surface, as well as, cross-sectional morphology along with elemental composition of the as-sprayed coating was also studied with the help of field emission-scanning electron microscope (FE-SEM, FEI, Quanta 200F Company) attached with EDS Genesis software (Made in Czech Republic) with an aim to understand the structure and composition of the coatings and identify oxide inclusions, unmelted particles, pores etc. The surface roughness values of the as-sprayed coating were recorded on the Mitutoyo Japan Digital Surface Roughness Tester-SJ-301 MODEL. In order to verify the thickness of coatings, as-sprayed specimens were sectioned and mounted. The coated specimens were sectioned on Electrical Discharge Machining (EDM) wire cut machine with EDM wire at Indian Institute of Technology, Ropar. Thereafter, the cut sections were hot mounted in BAINMOUNT-H (Hydraulic Mounting Press, Chennai Metco Pvt. Ltd., Chennai, India) with transoptic powder so as to show their cross-sectional details. This was followed by polishing of the mounted specimens by a belt sanding machine having emery belt (180 grit). The specimens were then polished manually down to 1000 grit using SiC emery papers. Final polishing was carried out using cloth wheel polishing machine with 1 μm lavigated alumina powder suspension. Thereafter the specimens were washed and dried before studying the optical microscopy (OM) of cross-section. Image analyzer was utilized to determine the porosity values.

Sliding Wear Test

To study the sliding wear behavior of tool and workpiece materials, both should be equally hard. To increase the hardness of the 20MnCr5 workpiece (disc) materials, the disc samples were heat treated and plasma nitrided. Sliding wear studies were performed on pin-on-disc wear test rig (TR-20E, Ducom, India) at Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab. The tests were performed according to ASTM wear testing standard G99-04. The surface roughness was brought down to below 1 μm prior to wear test by polishing the pin surface using sand papers of different grit size. The material was pressed against the disc to carry out the tests at nominal normal force of 20N.The total test duration was 26 minutes and the total distance covered was 780 meters. The total test duration was distributed in 13 steps of 120 sec each covering 60 meters in each run. The test velocity of 0.5m/s was selected for each run. During the wear test, the disc rotated horizontally and the sliding velocity was set to 213 rpm at a radius of rotation of 45 mm. The tests were performed in ordinary laboratory environment at 70% RH (relative humidity) and 38-42°C. The coefficient of friction was obtained by means of a torque transducer. The variation in height of the contact between the disc and the composite was registered using a LVDT (linear variable differential transformer, inbuilt provided by Ducom, Banglore, India) with ±1 μm of precision. Both, friction coefficient and wear rate were continuously recorded during the test.

RESULTS AND DISCUSSION

SEM Analysis of coating powder

The SEM morphology of NiCrBSi+(WC-CO) powder is shown in Figure I. The coating powder particles were found to be spherical in shape.

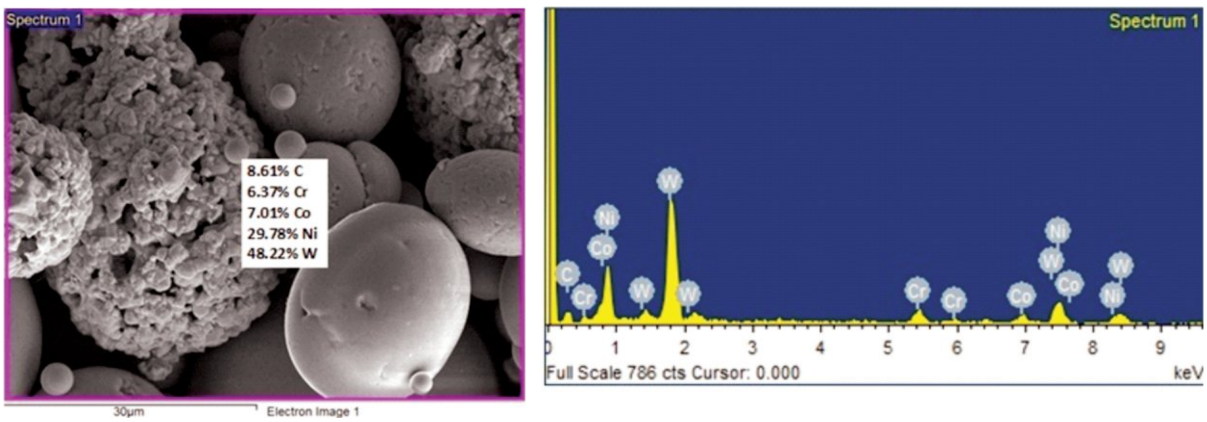

Figure I: The SEM morphology and EDS analysis of NiCrBSi+(WC-CO) particles.

Surface Macrographs

Surface macrographs of plasma as-sprayed NiCrBSi+(WC-CO)**coated H11 tool steel are shown in**

Figure II.

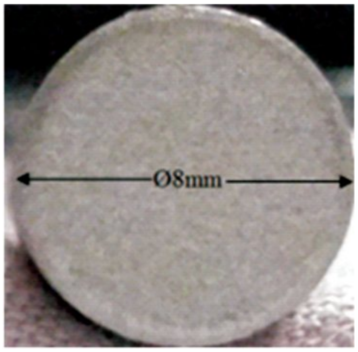

Figure II: Macrographs showing surface of plasma sprayed NiCrBSi+(WC-CO) coated H11 tool steel

XRD of as-sprayed H11

The XRD analysis of plasma sprayed H11 have been shown in figure III. The XRD peaks of NiCrBSi+(WC-CO) coatings revealed the presence of WC and NiC as strong phase and Ni_2B and SiC as weak phase.

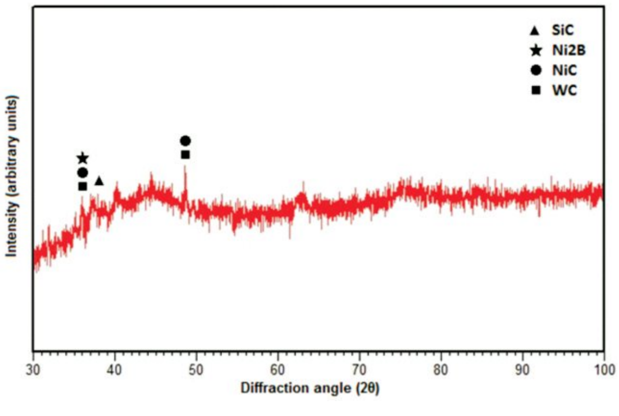

Figure III: XRD of Plasma sprayed NiCrBSi+(WC-CO)coating on AISI H11 die steel

Measurement of coating thickness

To ensure the coatability of coating powders on AISI H11 steel substrate, coating thickness was measured on the polished cross-sections of the samples, using an optical microscope. Average coating thickness, Hardness and Porosity for different coatings is compiled in Table IV. FE-SEM micrographs were taken along cross-sections of the thermal sprayed coated specimens and are shown in figure IV.

Table IV: Average coating thickness and porosity of the plasma sprayed coatings

Substrate	Coating thickness (μm)	Hardness (VHN)	Porosity Range (%age)
H11	138	31	---

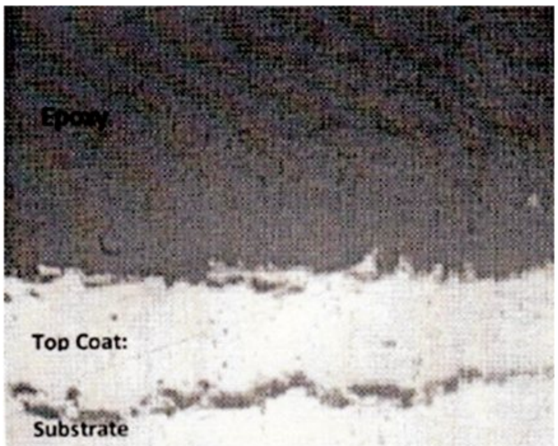

Figure IV: SEM images showing cross-sectional morphology of Plasma sprayed NiCrBSi+(WC-CO)coating on AISI H11 die steel

SEM/EDS analysis of as-sprayed H11 tool steel

The surface morphology of as-sprayed H11 and H13 tool steel has been shown in figure V. The as-sprayed NiCrBSi+(WC-Co) coating is found to have almost splat like morphology on the substrate. The EDS analysis of the coating on H11 steel indicates the presence of mainly nickel (Ni) and chromium (Cr) along with significant amounts of carbon (C) at points 2 and 3. The splats are seen merged with each other and uniformly distributed on the grey matrix. The EDS analysis indicates the presence of mainly Ni and Cr. Significant amounts of B, Si, C, Fe and O are found to be present in the coating. The presence of some amounts of O and C and at the points of analysis indicates the possibility of oxide and carbides formation in the coating microstructure.

Conclusions

1. The NiCrBSi+(WC-Co) coating was successfully deposited on hot forming tool steels by plasma spray process.
2. The SEM analysis showed the splat like morphology of the coatings.

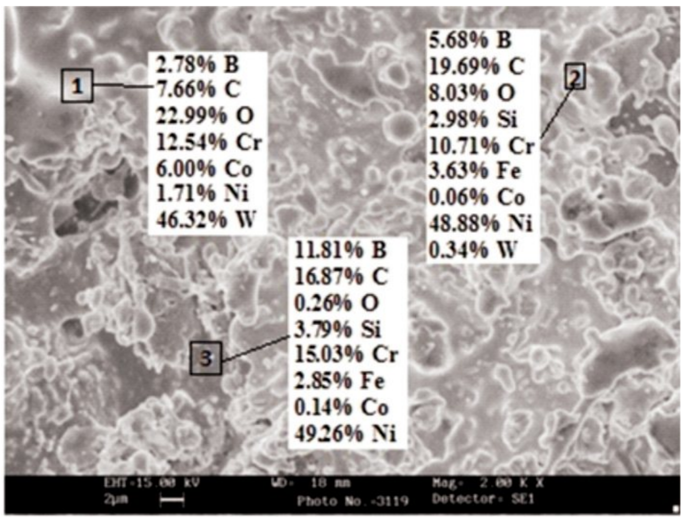

Figure V: Surface morphology and EDS analysis of the plasma sprayed NiCrBSi+(WC-Co) coated H11 tool steel

Acknowledgement

Manpreet Kaur *et al* thankfully acknowledge the research grant from Department of Science and Technology, New Delhi (India) under SERB, Science and Engineering- Engineering Scheme (File No. SR/S3/MERC/0072/2012, Dated: February 28, 2013) to carry out this R & D work, titled "Development of Thermal Spray Coatings to Control Wear during High-Temperature Applications".

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Analysis of Ic Engine Connecting Rod By Using Fem

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ABSTRACT

IC engine connecting rod is the intermediate link between the piston and the crank rod, What's more, is capable to transmit the push and pull from the piston which is a reciprocating motion, hence changing over the responding movement of the piston to turning movement of the crank., by and large connecting rods are produced utilizing carbon steel and as a part of late day's aluminum combinations are discovering its application in connecting rod. In this work we are contrasting the von missesand distortion of two distinctive aluminum alloys with the forged C70S6. FEA investigation was done by considering three materials. The parameters like von misses and distortion were acquired from FEM programming. At that point compared the aluminum alloys with the produced steel and that point aluminum found to have less weight. It brought about diminishment of 59.18% of weight.

Key words- Engine Connecting Rod, Analysis, Strength Evaluation.

INTRODUCTION

The interfacing bar unites the piston to the crankshaft and they frame a basic instrument that changes over straight movement into rotating movement. The most extreme thrust happens in the interfacing of connecting rod close to the piston end because of push of the piston,thus tensile and compressive burdens are delivered because of gas pressure, and bending stresses are created because of radial impact and eccentricity. So the connecting rods are outlined by and large of I section to bear most extreme bending forces with least weight.

The connecting rod is the association between the piston and the crankshaft. It joins the connecting rod with the crankshaft, small end of the connecting rod is associated with the piston and big end to the crankshaft.

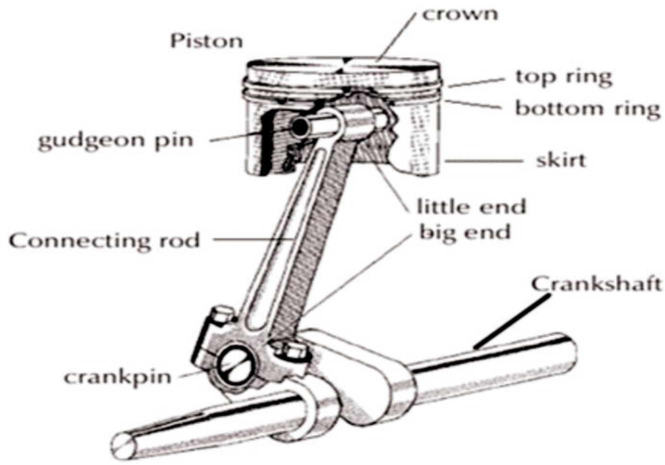

fig.1 piston,con-rod,crankshaft assembly.

The capacity of the interfacing bar is to change over direct movement of the piston into rotating movement of the crankshaft. The lighter associating bar and the piston greater is resulting power and less the vibration because of the reciprocating weight is less. The connecting rod carries the power thrust from piston to the crank pin and hence it must be very strong, rigid and also as light as possible. There are two types of end, small end and big end. Connecting rods are subjected to fatigue due to alternating loads. In the case of four stroke engines, during compression and power strokes the connecting rod is subjected to compressive loads and during the last part of the exhaust and the beginning of the suction strokes, to tensile loads. In double acting steam engines, during the forward stroke the connecting rod is subjected to compressive load and during the return stroke, to tensile load. Connecting rod materials must have good fatigue and shock resistances. Connecting rods for automotive applications are typically manufactured by forging from either wrought steel or powdered metal. They could also be cast. However, castings could have blow-holes which are detrimental from durability and fatigue points of view. The fact that forgings produce blow-hole-free and better rods gives them an advantage over cast rods. Between the forging processes, powder forged or drop forged, each process has its own pros and cons. Powder metal manufactured blanks have the advantage of being near net shape, reducing material waste. However, the cost of the blank is high due to the high material cost and sophisticated manufacturing techniques. With steel forging, the material is inexpensive and the rough part manufacturing process is cost effective. Bringing the part to final dimensions under the tight tolerance results in high expenditure for machining.

LITERATURE REVIEW

For the present study, it is important to examine failure modes of connecting rod, its enhancement procedures, innovation, new materialsetc. This literature survey reviews some of these aspects. Failure of a connecting-rod is one of the most common causes of catastrophic engine failure causing irreparable engine damage.

Chang Ping Zouet et al (2012) found that the connecting rod of a certain type of continuous mill produced crackle & could not work, thus hindering the production. The authors entrusted with the 3D Finite Element Analysis (FEA) of the connecting rod utilizing the large scale Integrated-Design Engineering Analysis Software, I-DEAS. The authors found the solution of several kinds of law of stress distribution and deformation, and reached valuable conclusions.

Mohammad Reza Asadi et al (2009) Performed detailed load analysis for a connecting rod followed by finite element method.in order to calculate stress in connecting rod, the total forces exerted connecting rod were calculated and then it was modeled, meshed and loaded in ANSYS, software. The maximum stresses in different parts of MF-285 connecting rod were determined. The maximum pressure stress was between pin end and rod linkages and between bearing cup and connecting rod linkage. The maximum tensile stress was obtained in lower half of pin end and between pin end and rod linkages.

Ramanpreet (2013) conducted simulation on a model of connecting-rod of a single cylinder four stroke engine. The main objective of his paper was to develop a new insight for the use of composite material in connecting rods. Finite element analysis was done to compare the conventional isotropic material and the orthotropic composite material. Modeling of connecting rod was done using software CATIA V5 and for stress analysis it was imported to MSC PATRAN. Linear static analysis was carried out for both isotropic material and orthotropic composite material with mesh to obtain the stress results. Comparison of both the material was done, keeping the boundary conditions same for both materials.

Suraj and Sunil (2012) evaluated the design parameters of connecting rod using FEM to achieve suitable design for connecting-rod. Finite element analysis of single cylinder four stroke petrol engines was taken for the study. A proper finite element model was developed using cad software Pro/E Wildfire 4.0. Then static analysis is done to determine the von misses stress, shear stress, elastic strain, total deformation in the present design of connecting rod for the given loading conditions using ANSYS v 12. Based on the observations of the static FEA and the load analysis results, the load for the optimization study was selected. The results were also used to determine of various stress and the fatigue model to be used for analyzing the fatigue strength. Outputs of the fatigue analysis of include fatigue life, damage, factor of safety, stress biaxiality indication.

Based on the combination of modal analysis technology and finite element method (FEM), the 3D model of a diesel engine's connecting rod was established with UG software, and then a free modal analysis of it was carried out with ANSYS. Through the analysis, the inherent frequencies and mode shapes of first 5 order modes were obtained respectively. The free modes of the connecting rod were verified by testing using hammer beat method (Shao Zhong Jiang and Wen Bing Yan, 2011).

VatroslavGrubisic (2004) found that component failure due to fatigue arises due to improper material selection, fabrication defects, improper heat treatments, design errors and unexpected operating conditions. Failure of automotive component due to fatigue contributes to 24 %.

Wenzhe Chen et al (2012) Investigated the connecting rod design and optimization of the engineering clamp hanger based on metamodel. The structure of the clamp hanger and the working load status of the connecting rod were firstly analyzed. Then the metamodel theory was applied to the connecting rod design and optimization: The metamodel of the connecting rod was set up in Solid Edge, and the design factors were signed as function-based parameters, with their geometrical relation changeless. Finally, keeping the fine strength security and stability, the structure of the connecting rod was optimized. The presented research in this paper offered a new reference and thought for the hanger design and improvement.

STRUCTURALANALYSIS

The principle focus is to determine the connecting rod structural design to achieve the maximum resistance to bending stress and its structural behavior during its operational period, to avoid its failure under the mass and gas forces acting on it while keeping the rotating and oscillating mass to a minimum. A higher oscillating mass leads to a higher tensile stress on the stem of the connecting rod during the gas exchange phase and can lead to failure. Also, a higher tensile force can lead to a relatively higher ovalization of the big end, because of a combination of all these factors, the choice of the load cases for the structural analysis needs careful attention. Experimental procedure involves modeling of connecting rod using CAD software. Static analysis of connecting rod is done using cad analysis software in order to understand the stress and deformation locations in connecting rod.

fig.2 3D solid model of a connecting rod

MESH GENERATION

The finite element method (FEM) is by far the most widely used method for performing the structural analysis For an accelerated design exploration, approximation techniques such as surrogate models, reduced order models, and reanalysis methods, which are reviewed in, should be used to reduce the computational effort while keeping a certain level of accuracy.

A typical connecting rod is plane or point symmetric. Usually a half or sometimes even a quarter models can be sufficient, but if connecting rod is not symmetric then full assembly has to be considered. From experience, the critical areas of the connecting rod are known to be the areas where there is a sudden change in the profile of the geometry. Additionally, the radius around the stem close to the big end and the transition radius of the bearing cap must be kept in mind. Hence these areas are meshed with a fine mesh and a high mesh quality is maintained and their mass is connected to the connecting rod body at its local COG by using a mass element in order to simulate the exact inertia forces.

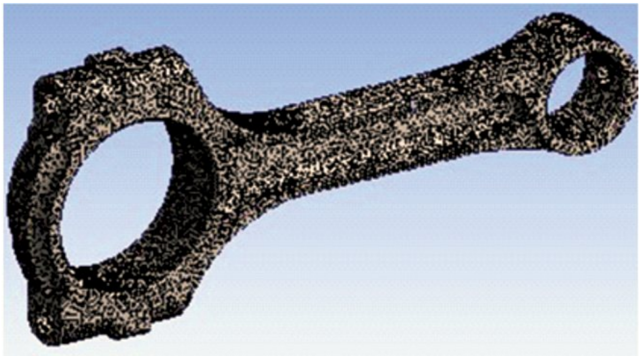

fig.3 meshing is performed with global element length with tetrahedral mesh type.

FEA design. Keep in mind, you'll need nodes and elements for the finite element solution, not just the actual solid model. The solid design does not take part in that specific element solution with this connecting rod, prior to finalization associated with element size pertaining to meshing, a meshing convergence is performed by tetrahedral element with various feature lengths.

RESULTS

In this section results will be obtained pertaining to static stress evaluation in the form of Von-Misses stresses. While performing this static stress analysis in FEM program, connecting rod is to be divided in to different specific zones for understanding stresses at various locations of connecting rod.

fig.4Static results I-Section.

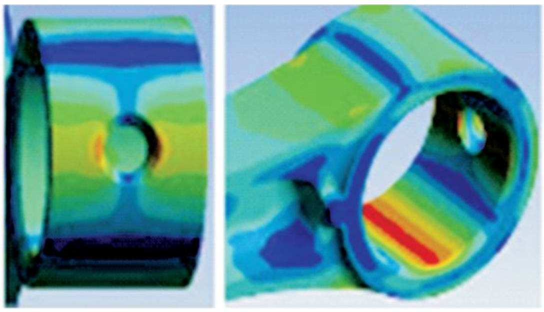

fig.5statics results at small end.

CONCLUSION

From the above analysis we can determine that stresses of all the elements are comparable and also within safe limit. Weight of the connecting rod can be reduced by replacing currently using forged steel in by C70S6 alloy. The section modulus of the connecting rod should be high enough to prevent high bending stresses due to inertia forces, eccentricities, as well as crankshaft and case wall deformations. In order to achieve results that are reliable when using the finite element method one has to use an acceptable element mesh with respect to the shape and size of the elements. As a help to produce an acceptable mesh there are quality criteria that must be fulfilled.

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Comparative HOT Corrosion Behaviour Cr_3C_2-25NiCr Coated with Uncoated T-11 Boiler Steel in Molten Salt Environment

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Abstract

The coating of Cr_3C_2-25NiCr was deposited on ASTM SA-213 T-11boiler tube steel by Detonation Gun (D-Gun) sprayed thermal spray process is being discussed, under various condition viz. High temperature corrosion studies were conducted to investigate the performance of the coating. The tests were conducted for the coated and uncoated T-11 boiler steel in a simulated boiler environment (Na_2SO_4-60%V_2O_5) at 900°C for 50 cycles. Every cycle consisted 1 hour of heating in the silicon carbide tube furnace followed by 20 min of cooling in air. The weight change measurements were recorded after each cycle to establish the kinetics of high temperature corrosion. The corroded samples were characterized by SEM/EDS and XRD analysis. The results revealed the formation of defensive oxides on coated material which are beneficial to corrosion resistant environment of boiler.

Keywords: Hot Corrosion; D-Gun; Cr_3C_2-25NiCr; Boiler Steel

Introduction

Hot corrosion has been consider as a serious problem for many of the high temperature aggressive environment applications, such as boilers, internal combustion engines, gas turbines, fluidized bed combustion and industrial waste incinerator [R.A. Rapp]. Alloys used at high temperature should possess superior mechanical properties along with erosion-corrosion resistance. It is entirely unthinkable that one material to have all these properties. In this way composite system of a base material providing necessary mechanical properties with a protective surface layer, diverse in structure or chemical composition can be an ideal decision in combining mechanical properties. In recent years it has become very popular and common to use substrate as base material and to use some protective layer or coating to provide thermal insulation, corrosion and wear resistance and in chemical process plants or boilers to protect the surface of structural steels against surface degradation processes such as wear, oxidation, corrosion and erosion [R. A. Rapp and Singh et al.]

Oxidation

Oxidation is a type of corrosion involving the reaction between a metal and air or oxygen at high temperature in the absence of water or an aqueous phase. It is also called dry corrosion. The rate of oxidation of a metal at high temperature depends on the nature of the oxide layer that forms on the surface of metal. Most metals are thermodynamically unstable in air and react with oxygen to form an oxide. This oxide usually develops a layer or scale on the surface of the metal or alloy. The establishment of oxide scale on an alloy occurs by a nucleation and growth process, when the clean component is exposed to an oxygen rich gas, small, impinging nuclei of all the thermodynamically stable oxides on the surface [Chen et al.].

Hot Corrosion Hot corrosion process is critical in coal fired boilers, as metallic components are exposed to severe corrosive atmospheres and high temperatures. In this process the combination of high temperature with contaminants from environment and low grade fuels, such as sodium, sulphur, vanadium and chlorine involved in the gas turbine and boiler environments lead to accelerated material degradation and results in premature failure of materials and components made of these materials need to be replaced due to failure. Hot corrosion results in plant shut downs, loss of valuable and costly material resources furthermore decreases the efficiency and finally results in costly maintenance. To understand the behavior of metals and alloys at elevated temperature and primarily their corrosion behavior has became an important area of scientific research [Singh et al.]

Experimentation The boiler tube steel, ASTM SA-213 T-11(C 0.15 Mn-0.3-0.6, Si-0.5-1, S-0.03, P-0.03, Cr-1-1.5, Mo-0.44-.65, and Fe-Bal.) have been used as a candidate material which is currently used as boiler tube material in some of the power plant in northern India. The samples were cut to form approximately 20x15x5 mm^3 sized specimens. The specimens were polished and grit blasted with Al_2O_3 (grit-60) prior to the applications of Detonation Gun (D-Gun) spray coatings. Detonation-gun process was used to apply coatings on the super alloys at SVX Powder M Surface Engineering Pvt. Ltd, New Delhi (India).

Visual Examination and Thermogravtimetric Studies A visual examination of the specimens was made after each cycle and changes in appearance, color, cracks and tendency of spalling were noticed. Specimens were photographed and examined carefully after completion of 50 cycles. The weight change measurements were taken at the end of each cycle using electronic weight balance machine made of Citizen TOYO HECIO (Class II) a sensitivity of 1 mg to understand the kinetics of corrosion. The weight change per unit area with respect to number of cycles was plotted for each cycle specimen. Comparisons of cumulative weight change gain per unit area of coated/uncoated specimen's fir and hot corrosion were also recorded [Bedi et al.]

Characterization of Coating SEM/EDS analyses of the hot corroded specimen were done before and after the completion of 50 cycles. The specimen were scanned under the microscope and photographed at particular points to identify, cracks and morphology of surface scale along with the percentage of the composition of various phases at those points in oxide scale. The XRD analysis of the coating powder and coated samples with and without heat treatment was carried out using X-ray Diffractometer (Model: PW 1840).

High-Temperature Oxidation Studies (Molten Salt bath environment) Cyclic corrosion studies were performed in molten salt (Na_2SO_4-60 wt. % V_2O_5) for 50 cycles [4]. Each cycle consisted of 1-h heating at given temperature, i.e. 900°C in a silicon carbide tube furnace followed by 20 min cooling at room temperature. The cyclic conditions have been chosen to create a more aggressive situation of corrosion attack. The mixture of Na_2SO_4 and V_2O_5 in the ratio of 40:60 constitutes and provides a very aggressive environment for hot corrosion to occur and the corrosion increases with the increase in the temperature and V_2O_5 content in the mixture [Bedi et al. and Sidhu et al.].

RESULTS

Visual observation and Thickness measurement of As-Sprayed Coating

The as-sprayed D-Gun coated Cr_3-C_2-25%NiCr coating was bright grey in colour. The thickness of the coatings was found with the help of an Elcometer. The thickness of as-sprayed D-Gun Cr_3-*C_2-25%NiCr* coating was found to be within the range of 200-250 μm.

Coating Characteristics of As-Sprayed Cr_3C_2-25NiCr

XRD analysis Cr_3C_2-25NiCr coated phase the major phases present in the coating powder were Cr_3C_2 and chromium nickel and very small amount of Cr_3O_2 was also found [Kaushal et al, and Nelson et al]. This is expected in case of thermal spray coating deposition, which involve rapid cooling of molten particles onto the relatively cooler substrate material and results in the formation of non-equilibrium and meta- stable phases in the sprayed coating. Ni-Cr binder is likely to melt first and dissolve some chromium carbide to form a liquid phase which may be rich in Cr and C and become supersaturated also, a very small amount of Cr_2O_3 was detected in the spray coating. The intensity also found to increase following heat treatment at higher temperature.

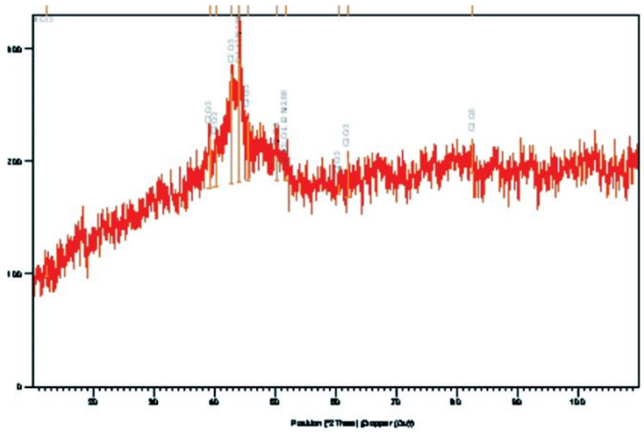
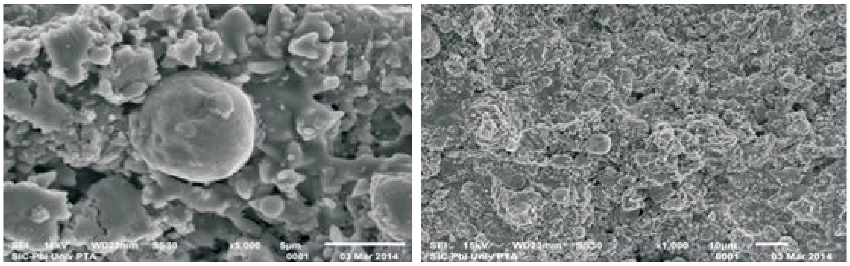


Fig.1. XRD diffraction pattern for Cr_3C_2-25NiCr Coated T-11 boiler steel before hot corrosion in molten salt environment

SEM/EDS Analysis of As-Sprayed Cr_3C_2-Ni-Cr Coated Substate The SEM/EDS images show microstructure of As-sprayed coating as shown in Fig 2. The microstructure of the as-sprayed coating shows fairly uniform distribution of the primary carbides. In some regions small carbide particles are also noticed. Fractured large carbide occurs upon impact on the substrate under high impact velocities in D-Gun process. The region of the binder has seen bright and grey area of different shades as shown in Fig 2 (a) at point 1. This binder region having different shades of grey consist Cr and C from Cr_3C_2 dissolve in

Ni-Cr in varying amounts. The results are in agreement with reports published earlier in various researchers [Zhao et al. and



Surface analysis
C -5.42 %
P -0.28%
S -0.17%
Cr-61.54%
Mn -0.37 %
Ni-

Fig: 2.(a)&(b) Show the Surface scale morphology SEM images and EDS analysis for the D-Gun As-sprayed Cr_3C_2-25NiCr coated on T-11 boiler steel elemental composition (wt %)

Corrosion Kinetics (Thermo gravtimetric Studies)

Weight change/area vs number Of cycles Plot of un-coated and coated as-sprayed Cr_3C_2-25NiCr coated ASTM A213T-11 bolier steel to corrosion testing in molten salt enviroment at 900ºC for 50 cycles. Mass change data in mg/cm^2 as a function of number of cycles for the uncoated and the coated substarte ASTM SA213 T-11 steel subjected to Corrosion testing in the Molten salt enviroment 1173 K (900°C) for 50 cycles are compiled in Figure 5. It is obvious from the figure that the uncoated T-11 steel showed an overall mass loss. The overall mass loss for the T-11 steel has reduced by 94 pct after Cr_3C_2-Ni-Cr as shown in bargraph

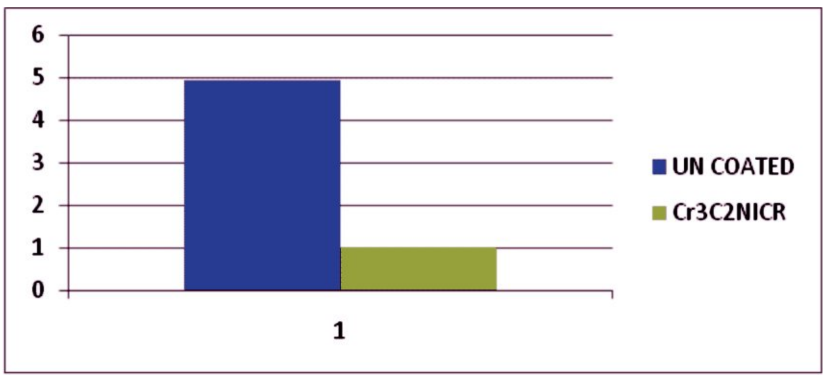


Fig.3. Bar Graph has shown the overall weight change /area after corrosion in test in Molten Salt Environment

XRD Analysis Corroded Samples of Uncoated and Coated T-11 Boiler Steel Substrate

The XRD pattern of Un-Coated and coated ASTM-SA213 T-11 boiler steel subjected to corrosion testing in the molten salt environment at 900°C for 50 cycles are depicted.

XRD Analysis of Un-Coated Sample X-ray diffraction of un-coated specimen as shown in Fig.6 subjected to corrosion testing in molten salt environment. The oxide scale of uncoated steel is found to have presence of mainly in higher intensity Cr-O and higher amount of Fe and O in the scale along with Cr_2O_3 and Mg_2Si0_4. Some small peaks of SiO_4 and CrP_4 (Chromium phosphide) are also observed.

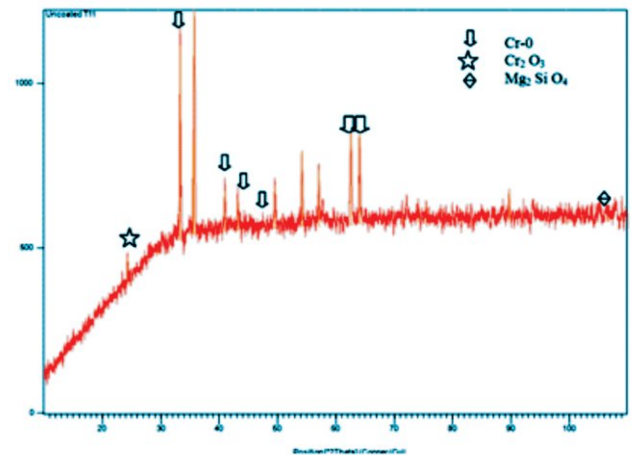


Fig: 4. XRD analysis of Un-Coated T-11 Boiler Steel showing XRD Diffraction Pattern After Hot Corrosion in Molten Slat Environment at 900°C

XRD analysis Corroded Cr_3 C_2-25NiCr Coated Sample The main phases present in the coating powder were Cr_3C_2 and chromium nickel and very small amount of Cr_3O_2 was also found. This is expected in case of thermal spray coating deposition, which involve rapid cooling of molten particles onto the relatively cooler substrate material and results in the formation of non-equilibrium and meta-stable phases in the sprayed coating. Researchers reported that Ni Cr binder is likely to melt first and dissolve some chromium carbide to form a liquid phase which may be rich in Cr and C and become supersaturated also, a very small amount of Cr_2O_3 was detected in the spray coating. The intensity also found to increase following heat treatment at higher temperature [Guilemany et al. and Chatterjee et al.].

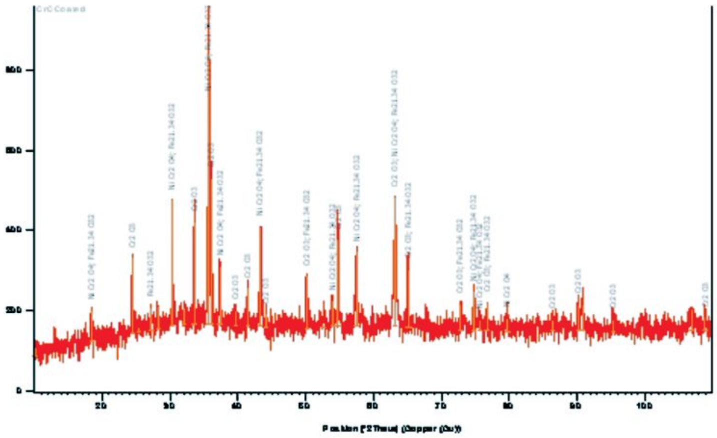


Fig.5 XRD analysis of Cr_3C_2–25% Ni-Cr coated T-11 Boiler Steel showing XRD Diffraction Pattern after Hot Corrosion in Molten Slat Environment at 900°C

SEM/EDS analysis after Hot Corrosion in Molten Slat Environment

The surface SEM/EDS analysis of exposed examples coated and uncoated T-11 steel subjected to oxidation in molten slat environment at 900°C for 50 cycles. A corresponding analysis for the bare and coated sample are shown

Analysis of Un-Coated substrate T-11 Boiler Steel The Oxide layer for T-11 steel consists of an upper sub layer dispersed in matrix. The furthermore EDS analysis of these particles corresponding to spectrum indicated. This might have deposited during the exposure. The EDS composition at spectrum indicate that the scale mainly consist of Fe and O, thereby signifying the formation of Fe_3O_2. There is presence of some globular particles in the scale, excessive presence of Si, Cr and S elements (Fig.6).

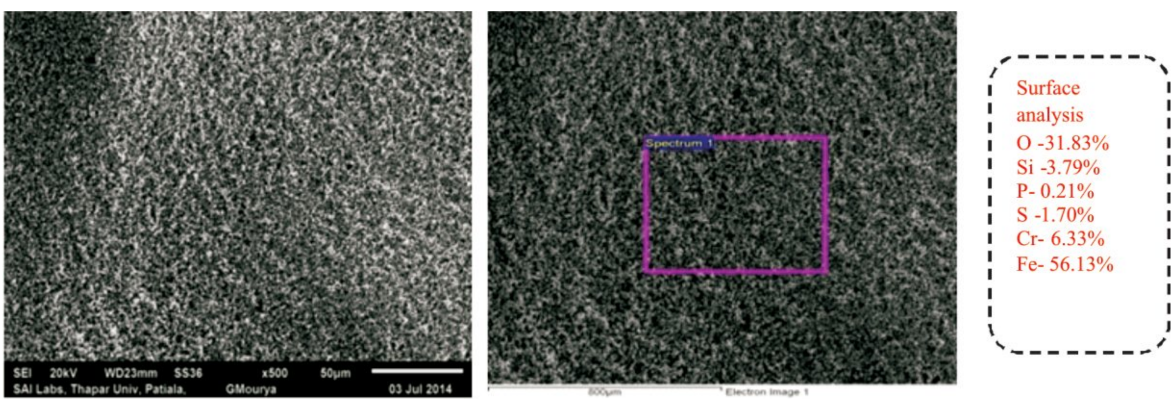


Fig. 6.(a)&(b) SEM/EDS Analysis of Un-Coated T-11 showing its Elemental Composotion (wt%) at selected specturm after Hot Corrosion study in Molten Salt Enviroment at 900°C

Analysis of Coated Cr_3C_2Ni-Cr on substrate T-11 The surface analysis of SEM/EDS corrodeed Boiler Steel at 900°C reveals relativelty lesser weight percentage of Na,V and S indicate at the top surface. Diffusion of these elements in to the substrate to form agrassive enviroment and starting the corrosive attack. Even at this temperature of Fe is marginal. Conversely, sufficient percentage of Cr (37.95%) and Ni (16.62%) can be observed at the points as shown in spectrum (Fig.7).

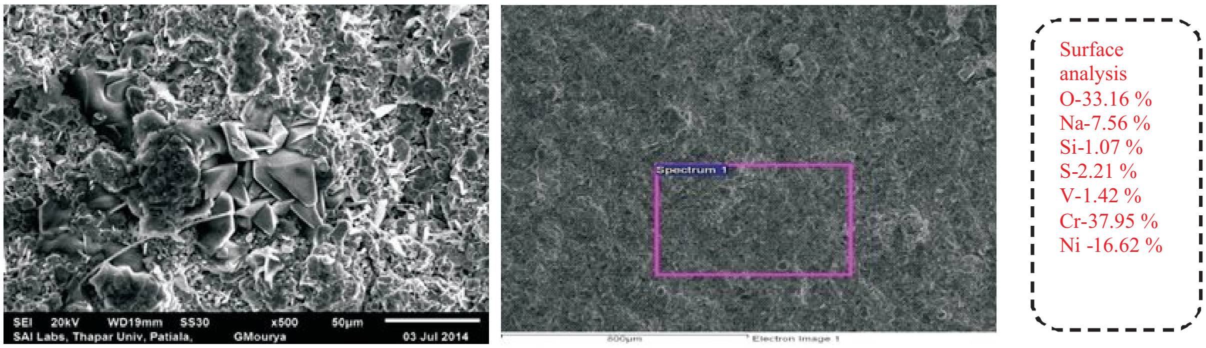


Fig7. SEM/EDS Analysis of Cr_3C_2Ni-Cr Coated T-11 showing its Elemental Composition (wt %) after Hot Corrosion Study in Molten Salt Environment at 900°C.

Discussion

The Cr_3C_2-25%Ni-Cr powder was successfully deposited on the chosen substrate by D-Gun spary process. Dense coating provide better corrosion resistance than the porous coatings. The coatings should have minimum possible porosities because they can do harm to the persistent corrosion resistance of thermal spray coatings [Zhao et al]. The surface FE-SEM analysis of the D-Gun sprayed coating represented that most of the deformed particles were interlocked to each other in the coatings [9,10] suggested that the void reduction of interparticles is enhanced mainly by mechanical interlocking among the fine-fragmented particles with highly irregular shapes, therefore the particles are well packed and interlocked with each other in coating. Moreover, as in Cr_3C_2-25%Ni-Cr coating, the XRD graph shows C_2Cr_3 and small amount of Cr_2O_3 along with marginal amount of C (5.42%) coating were found, which showed that coating was sucessfully deposited on substrate.The coating substrate interface has no gaps or cracks, which is a characteristic feature of good adhesion between coating and substrate.The uncoated steel showed higher rates of hot corrosion in comparison with its coated counter part[Fig 3]. It was concluded that in the temperature range of 1173 K (900°C), the Na_2SO_4 and V_2O_5 will react to form $NaVO_3$ which acts as a catalyst and also serves as an oxygen carrier to the base alloy through the open pores present on the surface, which in turn leads to rapid oxidation of the base elements of the substrate [Kolta et al]. Fe_2O_3 was observed as a main phase in the oxide scale of the uncoated steel. This was further supported by FE-SEM/EDS analysis (Fig. 4), which reveals higher amounts of Fe and O in the surface of scales of the uncoated substrate. The presence of Fe_2O_3 in the scale has been reported to be nonprotective[Das et al.]. The D-gun coating reduced the mass gain by 93 pct followed by Cr_3C_2-25%Ni-Cr coatings less mass loss compartively to uncoated substrate respectively. In other words, the D-gun coating looked towards Cr_3C_2-25%Ni-Cr coatings from the stand point of molten salt corrosion resistance. The XRD analysis of the D-gun spray coated T11 substrates [Fig 9] after corrosion studies revealed the presence of NiO phase along with Cr_2O_3 and $NiCr_2O_4$ phases. The presence of these protective scales consisting of protective phases increases the life of material in aggerasive environment.The surface FE-SEM/EDS analysis of the coated steel further supported the formation of these oxides [Fig 7]. These mixed oxides are known for providing superior corrosion resistance, as has been reported by several investigators [Guilemany et al., Chatterjee et al.]. This might be the reason for better protection offered by the D-gun-sprayed coating.

Conclusions

1) Cr_3C_{2-}25%Ni-Cr has been sucessfully deposited by Detonation Gun spraying technique on ASTM-SA213 T-11 boiler steel. The coating thickness has been found along the cross-section of sample and found be in the range of 250-300 μm.
2) In case of Un-coated T-11 boiler steel Cr–O, $Mg_{2,}$ SiO_4 were identified as main phase by XRD and EDS.
3) In Cr_3C_{2-}25%Ni-Cr coated Cr_2O_3, $NiCr_2O_4$ and $Fe_{21.34}O_{32}$ was identified as major phases in aggressive environment as revealed by XRD and EDS.
4) The D-gun spray coated Cr_3C_{2-}25%Ni-Cr was found to good corrosion resistant due to the formation of a protective Cr_2O_3 phase along with $NiCr_2O_4$ in its oxide scale.
5) The coating was found to have significant resistance to its oxide scale spallation during cyclic exposures. Moreover, the coating was found to have retained its continuous contact with the substrate steel during these thermal cycles. This indicates that the coating has good adhesion

strength.

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A Literature Review Of Agile Manufacturing

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ABSTRACT

The objective of this article is to understand the concept of agile manufacturing; it's philosophy, agile manufacturing implementation benefits and barriers towards agile manufacturing implementations. Agile manufacturing is defined as the proficiency of an organization to prosper in the competitive environment of continuous and unanticipated changes and to respond quickly to rapid changing markets driven by customers based valuing of products and services. The need to implement agile manufacturing is to meet varied customer requirement in terms of price, specification, quality and delivery. Reported article presents a review of literature on agile manufacturing and attempts to identify the useful contribution to this field. Companies following agile manufacturing have better flexibility and a good market share.

Keywords: agile manufacturing

INTRODUCTION

From past few decades, organizations are facing the problem of how to deal with unpredictable, dynamic, and constantly changing environment prevailing in the market. Customer's demands are becoming vibrant and they demand finish goods within short period of time. To thrive in unanticipated and dynamic change in the environment, organizations and their production systems need to respond rapidly and efficiently. In order to accomplish this goal, organizations must acquire extraordinary capabilities that synergistically include those one finds in flexible manufacturing systems, lean production systems and firms with mass customization strategies. Considering this intense competition imposed by customers' dynamic demand, organizations are required to have flexible strategies. On realizing this requirement, researchers at Iacocca Institute, Lehigh University, in USA in the year 1991, brought out the term *agility*and concerned field was named *agile manufacturing* (Ramasesh et al. 2001).Agility is defined as the capability to flourish in a competitive environment, which is characterized by unpredictable changes. According to Gunasekaran (1999), agile manufacturing refers to ability of prospering in a competitive business environment of unanticipated changes by reacting quickly to dynamic markets, driven by customer-defined products and services. Agile manufacturing and the concept of agility is the ability of the companies to react quickly and efficiently to unexpected changes in market demand with an aim to satisfy customers' requirement in terms of price, specification, quality, quantity and delivery.

LITERATURE REVIEW

The literature on agile manufacturing is divided into three sections, namely agile philosophy, Agility assessment and agile manufacturing case studies.

Agile Philosophy

The definition of agile manufacturing, main concepts and its enablers, come under the heading philosophy.Goldman et al. (1995) presented the idea that the concept of an agile organization has the following four dimensions:

(1) the enrichment of customers;
(2) competitive enhancement by cooperation;
(3) the mastery of uncertain change; and
(4) leverage of key people as well as information, indicating that agile organizations can survive and operate profitably in a competitive environment.

Zhang and Sharifi (2007) suggested a framework of agility that comprisedof three main categories, namely agility drivers, agility capabilities, and agility providers. This framework is very beneficial for understanding the whole concept of agility in the manufacturing system. Agility drivers represent changes in the business environment, which include the marketplace, competition, customer requirements, technology, and social factors. Agility capabilities denote to the skills that the manufacturing system needs in order to survive with the unexpected changes. Agility providersare set of tools or practices to attain the required capabilities. Tseng and Lin (2011) proposed an agility development method for dealing with the interface and coalition issues among the agility drivers, capabilities and providers using the QFD relationship matrix and fuzzy logic approach.

Agility Assessment

This section deals with the literature reviewed from the orientation of agility assessment. Yang and Li (2002) have contributed a model for the agility assessment especially for mass customized products. They evaluate the mass customization enterprise with three indices and calculated using multi-grade fuzzy assessment. This evaluation index system includes three aspects, namely, enterprise organization management, product design and processing and manufacturing.

Lin *et al.* (2006) contributed an article related to agility index for appraising supply chains. They computed the agility index using Fuzzy logic approach.. This article provides knowledge about how to measure and improve agility level.

Vinodh*et al.* (2010) have performed agility assessment as a result of implementing a new model called total agile design system (TADS) and followed scoring approach to evaluate the agility level of organization. He have used a 20-criteria model for evaluating agility and provided proposals to improve the weaker part of the firm after the study.

Garbie (2011) developed a conceptual model built on prevailing technologies, production strategies, level of qualifying human resources and organization management systems to assess the level of agility of the petroleum companies.

Sreenivasa et al. (2012) have proposed a thirty criteria agility assessment tool. This agility assessment tool is the extension of twenty agile manufacturing criteria suggested by Ramesh and Devadasan (2007) with incorporating additional ten AM criteria

CASE STUDIES

Cheng et al. (1998) presented a new approach to implementing agile design and manufacturing concepts. The approach was based on the integration of artificial intelligence (AI) and Internet technologies with the conventional design and manufacturing techniques. Architecture based on AI and Internet programming was proposed for remotely and quickly accessing bearing design and manufacturing expertise at low cost and thus implementing design and manufacturing agility. They concluded with a discussion on the potential benefits, and the future applications of AI and Internet based agile manufacturing technology.

Huang(1999) developed a generalized label-correcting (GLC)approach to analyze the models represented with logical networks. The paths resulted with the GLC approach supported the decision making in production control and circuit product design/testing.

Coronado (2003) identified the role of information systems within the concept of agile manufacturing. He concluded that Skills and expertise of people as an important factor behind the achievement of agility in industry. The results of the conducted case showed that the definition and implementation of a sound business strategy is critical for moving towards the agility of business processes.

Vinodh et al. (2007) reported a research work in which they have examined the usefulness of CAD/CAM technology and its utilization in imparting agility. They stated that applying CAD/CAM model with the orientation of achieving agility is very effective in enabling companies to progress towards reaching world class manufacturing status but its success depends upon management's commitment, trust and involvement in using this methodology.

Vinodh et al. (2010) examined the potential to device agile characteristics in the pump industry. They suggested four new models for impeller and casing. The prototypes of impeller were developed using Rapid Proto-tying techniques. They concluded that CAD and RP technologies could turn as agility enablers.

Sreenivasaet al. (2013) portrayed a methodology to be adopted for theoretically mapping product characteristics with agile manufacturing perspectives. They choose air dryer as the case product.

BARRIERS TOWARDS IMPLEMENTATION

The concept of agile manufacturing might seem easy but its implementation is not an easy job. The introduction of agile manufacturing into an organization tends to change its working culture. Such changes are considered to be barriers to the implementation process of agile manufacturing.Adoption and instillation of agility and agile manufacturing principles in manufacturing organizations requires a systematic study of the various pathways that may be taken along with a elimination of barriers that would exist within this path, allowing efficient and effective introduction of these practices. Using the literature, experts' and practitioners' opinion,Hasanet al. (2007) arrived at 11 barriers towards facing agility and agile manufacturing adoption. These barriers are as follows (as stated by Hasan):

- Lack of top management support and commitment.
- Fear of and resistance to organizational change.
- Inappropriate measurement approaches for qualitative benefits and agility.
- Lack of methodologies to enhance agility.
- Lacking in customer feedback systems integration.
- Insufficient training, education and rewards system.
- No sound appraisal technique to justify high investment in Advanced Manufacturing Technology (AMT).
- Poor design–manufacture interfaces.
- Poor partnership (supply chain) formation and management.
- Poor incorporation of flexibility measures into management.
- Unavailability of appropriate technology

CONCLUSION

There is a enormous literature available on agile manufacturing, which gives a wide view of previous practices and research across the world. At present, the successful organizations are those, which rapidly run novel strategies based on competitive advantages, and learning from unanticipated market and customers (Beikkhakhianet al. 2015). They modify and improve their processes and customers as per requirement.Uncertain and unexpected market conditions can be tackled by adopting Agile Manufacturing (AM) principles (Brown and Bessant, 2003).

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Sliding Wear Behaviour Of High Velocity Oxy Fuel Spray Coated Tool Steels

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ABSTRACT

In hot forming operations due to repeated contacts between tool steels and workpeice, surfaces of the tool steels (dies) are damaged. Sliding wear has been recognized as a severe problem on tool steels. In order to improve the life and serviceability of tool steels, the work was planned to deposit High Velocity Oxy Fuel (HVOF) thermal spray coatings on the surface of tool steels. Cr_3C_2-NiCr coating was deposited on to AISI H11 and AISI H13 tool steels. Characterization of as-sprayed substrates was done with X-ray Diffraction (XRD), scanning electron microscope (SEM) and Energy dispersive spectroscopy (EDS). Surface roughness, microhardness and porosity of the coatings were evaluated. Sliding wear and friction behavior of the uncoated and HVOF spray coated tool steels was studied on the pin-on-disc tribometer at room temperature and under dry conditions. Coefficient of friction and wear rate were evaluated and plotted against the sliding distance. It was found that Cr_3C_2-NiCr coated H13 steel showed lesser wear rates.

Keywords: Tool steels, HVOF spray coatings, Cr_3C_2-NiCr, Sliding wear, Characterization

INTRODUCTION

High Velocity Oxygen Fuel (HVOF) is a coating deposition process whereby a powder coating material is heated rapidly in a hot gaseous medium. Simultaneously the powder material is then projected at a high particle velocity onto a prepared substrate surface where it builds up to produce the desired coating. [1]. HVOF sprayed coatings have been used widely throughout the last decade mainly in industrial applications, aerospace, and power plants, because of the coatings express low porosity and oxide content, high hardness and high adhesion. [2-6]. HVOF thermal spraying process has shown to be one of the best methods for depositing conventional Ni based and Cr feedstock powders, because the hypersonic velocity of the flame shortens the time of interaction between the powder and the flame [8,9]. Figure 1 shows the schematic representation of the HVOF spray process.

Thermally sprayed Cr_3C_2-NiCr coatings are used in applications that demand protection against surface degradation due to oxidation, wear and corrosion under severe conditions of excessive heat and load [10]. These coatings show good tribological properties in rigorous working conditions such as at high temperatures or in aggressive environments. Sidhu et al [11] studied the wear behavior of Cr_3C_2-NiCr coatings deposited on Fe based steels. The wear mechanism was mild adhesive wear in nature.

It was pointed out that the wear behaviour of cermet based coatings depends on the microstructure and the volume fraction of carbides being preserved during the deposition process [12, 13]. The aim of this work was to develop Cr_3C_2-NiCr coatings by the HVOF spray technique and to study their microstructure and properties. Further the sliding wear behaviour of the uncoated and coated specimens was studied using Pin-on-disc trobometer. Wear rate of the coating on two die steels was evaluated by recording the weight change values.

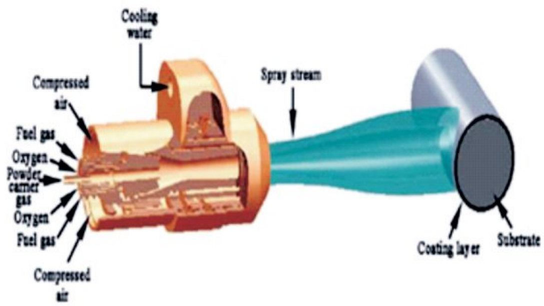


Figure 1: Schematic representation of HVOF system

Experimental procedure

Substrate Materials

The substrate materials selected for the study were hot forming chromium tool steel AISI H13 and AISI H11 with the chemical composition as shown in Table 1. The workpiece material 20MnCr5 was also procured in consultation with the actual hot press forging industry. The steel is a high strength alloy steel being used these days for preparing pinions by hot press forging. The tool steel samples were cut to form pins of diameter 8mm and length 50mm for the wear tests. The specimens were polished and grit-blasted with Al_2O_3 (grit 45) prior to the application of HVOF spray coating. Chemical compositions of coating powders are also given in the table 2.

Table: 1 Chemical compositions (wt %) for the substrate material required and actual

Substrate material	AISI H11		AISI H13	
Elements	Required wt %	Actual wt %	Required wt %	Actual wt %
C	0.30-0.40	0.375	0.32-0.45	0.389
Si	0.80-1.20	0.98	0.80-1.20	0.894
Mn	0.20-0.40	0.364	0.20-0.50	0.344
P	0.03 Max	0.02	0.03Max	0.0276
S	0.03 Max	0.014	0.03 Max	0.0099
Cr	4.75-5.50	4.75	4.75-5.50	5.23
Mo	1.25-1.75	1.75	1.10-1.75	1.26
Al	---	0.071	---	0.0278
B	---	0	---	0.00083
Co	---	0.02	---	0.0183
Cu	---	0.091	0.25 Max	0.0495
Pb	---	0	---	0
Ti	---	0.266	---	0.00064
V	0.30-0.50	0.379	0.8-1.2	0.87
W	---	0.049	---	0.05
Fe	---	90.65	---	90.7

Table: 2 Chemical composition and particle size of alloy powder

Powder	Chemical Composition (wt%)	Particle size
Cr_3C_2-25(NiCr)	75%Cr_3C_2-25%NiCr	-45 µm +15µm

Formulation of Coating

Cr_3C_2-NiCr coating with an average grain size of -45+15 µm was used as spray material. The substrates were pre-cleaned in acetone for 5 min, and then blast-cleaned by 60 mesh aluminum oxides for 5 min to improve the adhesion of the coating onto the substrate. The spraying was carried out with the HIPOJET 2700 HVOF system (Metallizing Equipment Company Pvt. Ltd. (MECPL) Jodhpur (India). The spraying parameters optimized to produce the coatings on the steel substrate are summarized in Table 3. Propane gas was used as a fuel gas. During spraying, the pressures of the propane and oxygen were fixed at 5 bar and 7 bar, respectively. The flow of oxygen was set to 439 l/min. The flow of the propane was 35 l/min and 55 l/min for Cr_3C_2-NiCr powders. Nitrogen gas was used as powder feed gas, which was operated at a pressure of 5 bar. The spray distance from the gun exit to the substrate surface was kept at 180-200 mm throughout the spraying process. The coatings thickness of approximately 150 µm, was developed on the substrates.

Table 3. Spray parameters employed during HVOF spraying.

HVOF gun type	HIPOJET 2100
Oxygen gas pressure (bar)	7
Fuel gas (C_3H_8) pressure (bar)	5
Compressed air pressure (bar)	5
Powder feed rate (g/min)	55
Spray distance (mm)	180-200
Gun speed (mm/sec)	3
Carrier gas (N_2) pressure (bar)	5

Characterization of the As-sprayed Coating

The as-coated samples were characterized by XRD and FE-SEM/EDS analyses to investigate their surface and cross-sectional microstructures and compositions. Surface roughness of both the as sprayed and polished surfaces of coatings was evaluated by Talysurf at Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab. For the measurement of thickness of the coating, the substrates were cross-sectionally cut on the Electric Discharge Machine at India Institute Technology, ROPAR. Thereafter, the cut sections were hot mounted in BAINMOUNT-H (Hydraulic Mounting Press, Chennai Metco Pvt. Ltd., Chennai, India) with transparent acrylic powder so as to show their cross-sectional details. This was followed by polishing of the mounted specimens by a belt sanding machine having emery belt (180 grit). The specimens were then polished manually down to 1000 grit using SiC emery papers. Final polishing was carried out using cloth wheel polishing machine with 1μm lavigated alumina powder suspension.

Wear Tests

The wear tests were performed using a pin-on-disc type sliding wear apparatus. To study the sliding wear behavior of tool-workpiece materials, both should be equally hard. To increase the hardness of the 20MnCr5 workpiece (disc) materials, the disc samples were heat treated and plasma nitrided. The wear samples were in the form of the cylindrical shape with dimension 8mm in dia and 50 mm in length. To eliminate the initial as-grown coating roughness, the surface roughness was achieved less than 1 μm prior to wear tests. Coatings were tested at sliding speed of 0.5m/sec and at constant load of 20N and 40N to a constant sliding distance of 900m. The wear tests were performed in air with a relative humidity of 70%. A load cell torque arm arrangement that was attached to the drive motor of the wear machine was used to measure the coefficient of friction. The variation in height of the contact between the disc and the composite was registered using a LVDT with ±1μm of precision. Both, friction coefficient and wear rate, were continuously recorded during the test. The wear rate (mm^3/m) was calculated as the volume loss per sliding distance. A scanning electron microscope (SEM) equipped with energy dispersive spectroscopy (EDS), were used to characterize the composition and morphology of as sprayed surfaces and cross sections.

Results and Discussion

SEM Analysis of Coating Powder

The SEM morphology of Cr_3C_2-NiCr powder is shown in Fig. 2. The coating powder particles were found to be spherical in shape. The Cr-Ni powder particles are found in the form of lumps of irregular sized particles [Fig. 2]. These powder particles have a porous appearance.

a. Cross-sectional Analysis of the As-sprayed Coatings

The SEM micrographs at the cross-section of Cr_3C_2-NiCr spray coating are shown in Fig. 3(a and b). The thickness of the coatings was measured from the micrograph, taken along the cross-section of the mounted samples. All coatings have a thickness of about 150 μm and bond well to the substrate.

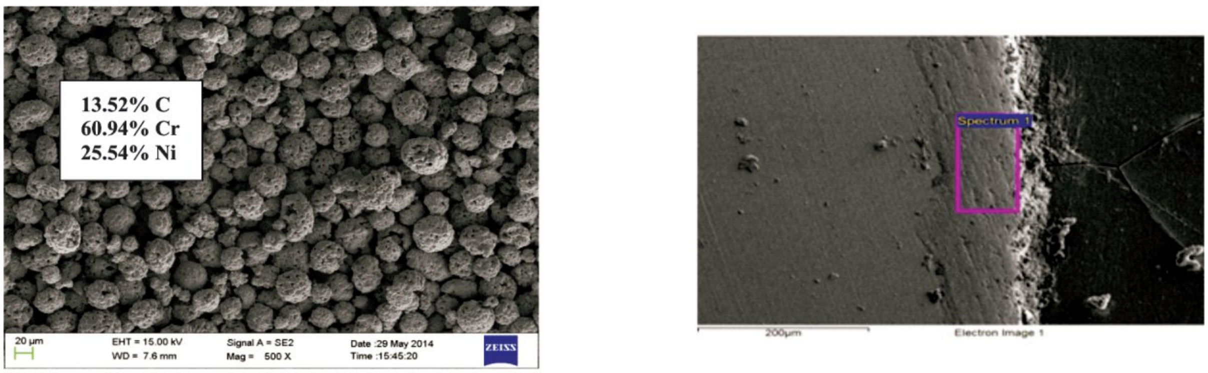


Figure 2: The SEM morphology and EDS analysis of Cr_3C_2-NiCr particles

Substrate Epoxy

Coating

a)

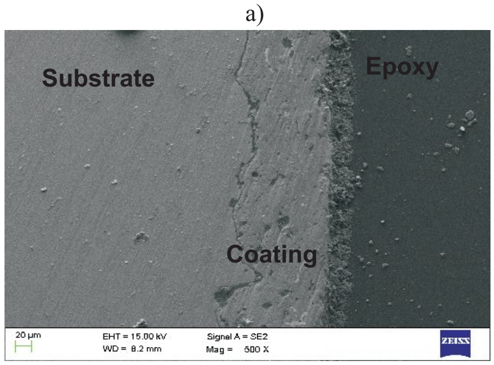
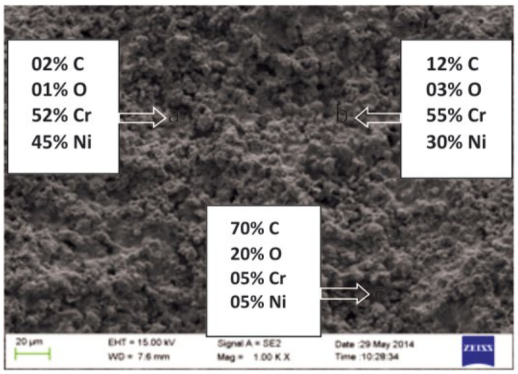


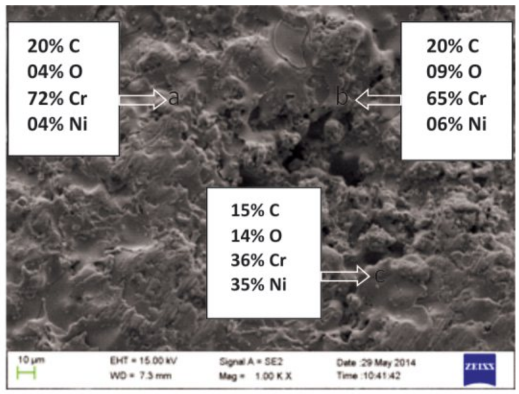
Figure 3: SEM micrographs showing cross-sectional morphology of HVOF Cr_3C_2-NiCr **coated (a) H11 and (b) H13 tool steel.**

For the HVOF sprayed nickel-based coating, the typical coating thicknesses are in the range of 50–200 μm as suggested by Sidhu [14]. All coatings were completely crack-free. However, porosity value in the HVOF coatings is low. The microcrystalline HVOF coating shows a very homogeneous microstructure and a porosity of less than 1%. Adherence between substrate and coating seems to be good with a low presence of either cracks or voids in the interface.

a. Surface SEM-EDS analysis of as-sprayed Coating



a)



b)

Figure 4: Surface morphology and EDS analysis of the HVOF as-sprayed Cr_3C_2-NiCr **coated (a) H11 and (b) H13 tool steel.**

The surface morphology of as-sprayed Cr_3C_2-NiCr coated H11 and H13 tool steel has been shown in Fig. 4 (a) and (b) respectively. The coatings have a uniform microstructure (Fig.4a and 4b). Some limited porosity is visible as dark contrast spots, but generally the coatings have dense morphology. The EDS analysis of the coating indicates the presence of mainly Nickel (Ni) and Carbon (C) on two positions along with significant amount of Chromium (Cr) and Oxygen (O). The fact that there is oxygen element in small amounts, indicates the probability of formation of oxides in the coating.

a. XRD of As-sprayed H11 and H13 tool steels

The XRD analysis of HVOF as-sprayed Cr_3C_2-NiCr coated H11 and H13 have been compiled in Fig. 5. The XRD peaks of Cr_3C_2-NiCr coatings revealed the presence of Cr_3C_2 as a very strong phase. Cr and Cr_7C_3 had medium intensity. It was also found from the XRD patterns of coatings that they also had the strong intensity of Cr_3C_2. And other phases except $Cr_{23}C_6$ were found in smaller intensities on the coatings Figure 5(b). It is also clear that there are no new phases formed in the coating during the thermal spray process.

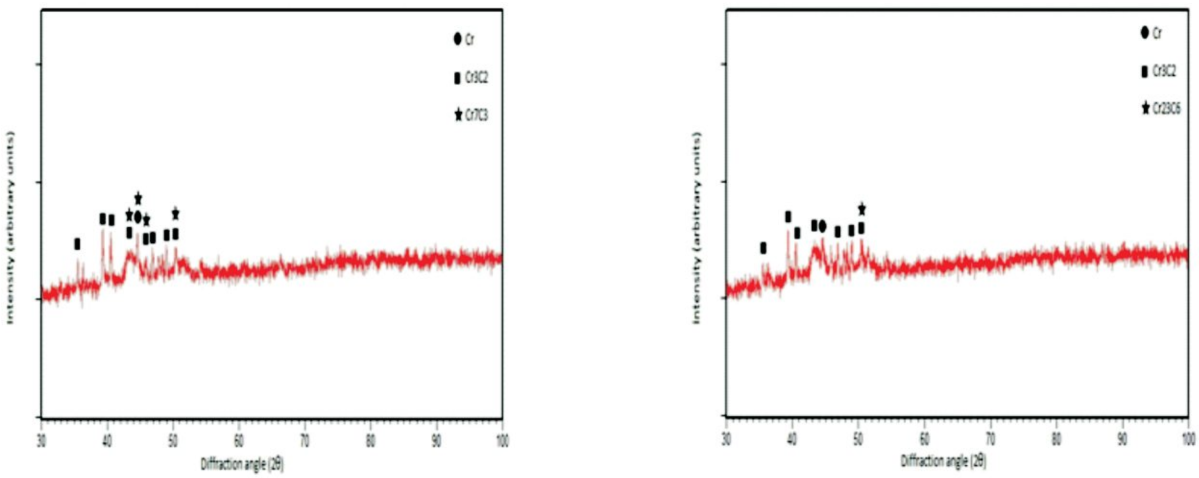


Figure 5: Consolidated XRD pattern showing phases of Cr_3C_2-NiCr as-sprayed a) AISI H11 and b) H13 substrates.

3.5 Surface Roughness of As-Sprayed Coatings

The initial surface roughness of as-sprayed samples was measured and average of three readings was taken that comes out to be 5.421 for Cr_3C_2-NiCr coated H11steel and 5.134 in case of Cr_3C_2-NiCr coated H13 coating. Further the samples were polished down to average surface roughness values 0.613 and 0.553 for H11 and H13 Cr_3C_2-NiCr coated respectively in order to perform wear test as per the literature studied.

3.6 Wear Rate

The variation of wear rate with the sliding distance for Cr_3C_2-NiCr coated H11 and Cr_3C_2-NiCr coated H13 at 20 N and 40 N normal loads is plotted in Figure 6.

i. Wear Rate at a Normal Load of 20 N

At 20 N normal load the wear rate of both the coated tool steels decrease linearly with the sliding distance, as shown in [Figure 6 (a)]. Both the tool steels at 20N load showed higher values of wear rate during the initial stages of the run.

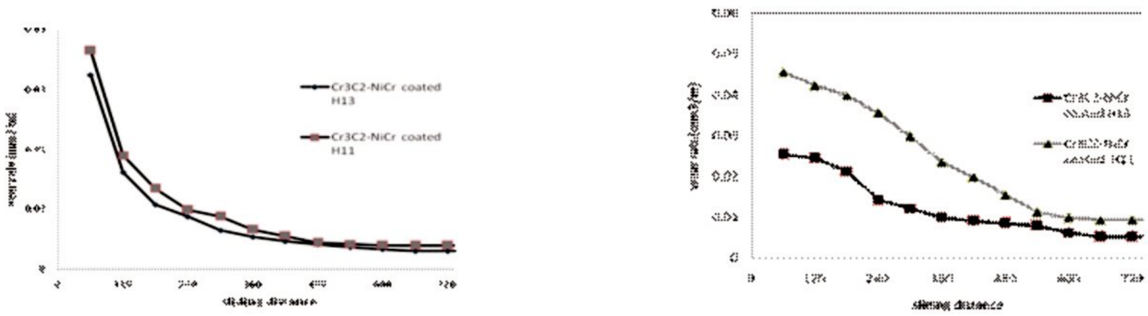


Figure 6: Variation of sliding wear rate with sliding distance for Cr_3C_2-NiCr as-sprayed H11 and H13 at (a) 20N load (b) 40N load

But in the later stages (after 180 m) wear rate goes on decreasing and tends to become uniform towards the end of run. Comparing both the substrates H13 showed the lower wear rates than H11 for same coating powder and for same process used. The wear rate keeps on decreasing up to 780m and after that wear rate was steady till the end run. H13 showed the least wear rate at 20N load.

i. Wear Rate at a Normal Load of 40 N

At a normal load of 40 N, the wear rate of both the coated tool steels was also decreasing linearly with the sliding distance, as shown in [Figure 6 (b)]. But at a load of 40N, Cr3C2-NiCr coated H13 again showed lesser wear rates than Cr_3C_2-NiCr coated H11 steel.

b. Uncoated Wear Analysis

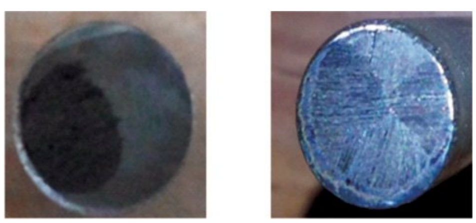


Figure 7 : Macrographs of worn surfaces of uncoated H11 at (a) 40 N load (b) 20 N load

i. Coefficient of Friction

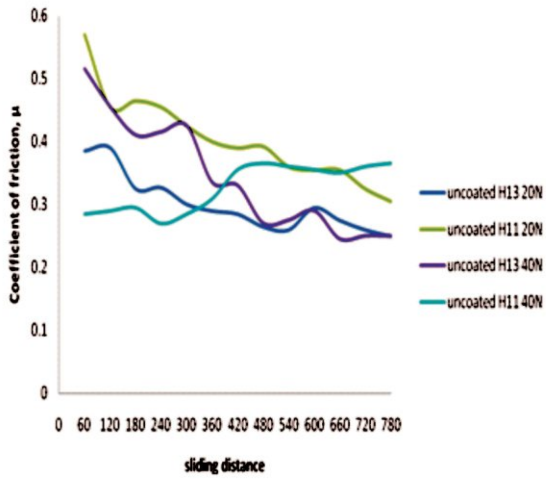


Figure 8: Variation of Coefficient of Friction with sliding distance for 20 N & 40N loads for various uncoated steel substrates.

Variation of coefficient of friction has been plotted against sliding distance for the various steel substrates at 20N and 40N in the figure 8. For 20 N load the average value of coefficient of friction for coated H11 found out to be 0.374 and for H13 average value was 0.346. At 40N uncoated H13 the value of COF was 0.299 and for H11 the average value of COF was reported as 0.391. Uncoated H13 reported the minimum value of coefficient of friction and uncoated H11 reported maximum value of COF at a load of 20N.

Conclusions

Cr3C2-NiCr coating was successfully deposited by HVOF spray process on AISI H13 and H11 steel substrates. The SEM images showed the splat-like morphology. At both the loads that is 20N and 40N, the Cr_3C_2-NiCr coated H11 steel showed the lesser wear rates.

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Bremsstrahlung Cross Sections In Metallic Compounds At Incident Electron Energies (10 Kev, 20 Kev And 30 Kev)

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ABSTRACT

In the present study Bremsstrahlung cross sections for different metallic compounds like $AlCl_3$, $ZnCl_2$, $PbCl_2$ and $SnCl_2$ were calculated theoretically by using Z_{eff} of metallic compounds at different incident electron energies (10 keV,20 keV and 30 keV) in the photon energy regions of energy (1-10 keV,1-20 keV and 1-30 keV). The cross sections were calculated by using Elwert corrected (non relativistic) Bethe Heitler (1934), Modified Elwert factor (relativistic) Bethe Heitler theory for ordinary Bremsstrahlung and modified Elwert Factor(relativistic) Bethe Heitler theory which includes the polarization Bremsstrahlung (PB) into OB given by Avdonia and Pratt(1999).

The effect of effective atomic number of the metallic compounds on the Bremsstrahlung cross sections is studied. Comparing the results of above theories the dependence of PB and OB on energy of incident electrons and the energy of emitted photon is studied. The results clearly indicate the importance of PB, particularly in the studied energy regions.

Keywords: Ordinary Bremsstrahlung, Polarization Bremsstrahlung, Metallic compounds.

Introduction:

Ordinary Bremsstrahlung is the phenomenon of emitting photons by incident electrons on target atom. The static behaviour of target atom in this phenomenon has been studied theoretically and experimentally at different range of energies of incident electrons and at different energies of emitted photons.[Bethe and Heitler (1934), Elwert (1939), Kotch and Motz (1959), Tseng and Pratt(1971), Quarles and Heroy (1981), Singh et al.(2009)]. Buimistrov and Trakhtenberg (1975) reported that due to the field of electron the behaviour of target atom gets changed and it gets polarized. This phenomenon of emission of energy due to polarization of target atom is termed as polarization Bremsstrahlung (P.B).The total Bremsstrahlung (BS) is the sum of ordinary Bremsstrahlung and polarization Bremsstrahlung.

There are different theories of calculation of Bremsstrahlung cross sections at different range of energies of incident electrons and at different energies of emitted photons. Bethe and Heitler(1934) first formulated the relativistic theory by using Dirac's electron theory and the Born approximation. Schiff (1951) developed a theory that included screening effects due to the atomic electrons. Bethe and Maximon (1954) have presented a theory, exclusive of the Born approximation, that is valid only in the extreme relativistic region above 20 MeV. Subsequent developments have included various corrections to the Born approximation, valid in specialized energy ranges, that account for atomic screening and Coulomb effects not included in the Bethe-Heitler (1934) theory, Koch and Motz (1959) published a detailed review of Bremsstrahlung cross-section formula and related data. Seltzer and Berger (1985) provided a data set for the Bremsstrahlung cross section differential in emitted photon energy, for electrons in the range 1 keV to 10 GeV incident on neutral atoms with atomic numbers Z=1 to 100.

For non-relativistic electron energies, in the Born approximation, Amusia et al. (1985) has described that PB can be added with OB in a stripped approximation (SA). Avdonina and Pratt (1999) have given the equivalent method for the total Bremsstrahlung spectra in the stripped approximation, which is efficient for obtaining the BS spectra for photon energies greater than the ionization potential of the outer shell electrons of the target atom. In SA, the decrease of OB due to screening of outer shell electrons is completely compensated by additional PB produced by the same outer shell electrons.

Avdonina and Pratt (1999) modified the Elwert corrected (non-relativistic) Bethe and Heitler (1934) theory for OB and described the BS spectra i.e. (OB + PB) over a wide range of photon energies by applying the SA. They further described that in the non-relativistic case PB decreases with increasing photon energy in the same way as the screening contribution to OB, leading to the Columbic behaviour of the spectrum.

The theories discussed above are applicable to thin target OB or BS spectra only, in which the mono-energetic electron has only a single radiative interaction. In the case of a thick target, processes such as electron scattering, excitation and ionization that compete with Bremsstrahlung must be taken into account.

Most of Bremsstrahlung (BS) work of beta particles has been done on the metal as a thick target, but using compound as a thick target is rarely available. Some work is available in metallic compounds to study the relation between Zeff of compounds and Bremsstrahlung [Manjunatha et al.(2010,2011), Manjunatha and Rudraswamy (2011)].

Present study is technique to apply the existing theory to compounds and to focus on various compounds which can be used as targets for incident beta particles to produce EB spectrum. This method provides a Comparison of theoretical results at different energies of incident electrons and at different photon energies. In the present study, compounds $PbCl_{2,}$ $AlCl_3$, $Zncl_2$ and $SnCl_2$ have been used.

Methodology

In the present work, Zeff has been calculated from the formula

$$Zef \quad \sqrt[2.94]{f1 \times Z_1^{2.94} + f2 \times Z_2^{2.94}} \quad f$$

Zeff- The effective atomic no. Of metallic compound

$Z_{1,}$ Z2- atomic no. Of first atom and 2[nd] atom

$f_{1,}$ f_2- fraction of total no. Of electrons of 1[st] atom and 2[nd] atom

The expression for ordinary Bremsstrahlung cross section in born's approximation is called Bethe –Heitler formula. The Bethe–Heitler OB cross section(σ_{BH}($W_{e,K,Z)}$ differential in photon energy k is given as,

$$\sigma_{BH}(W_{e,K,} \quad \frac{Z^2 r_0^2}{137}\frac{dk}{k} \quad \frac{P}{P_e}\left[\frac{4}{3} - 2w_e w\frac{P_e^2 + P^2}{P_e^2\, P^2} + \frac{E_e\, W}{P_e^3} + \frac{E_e W_e}{P^3} - \frac{E_e E}{P_e\, P} + L(A+B)\right] \quad _{Z)}$$

$W_{e,}$W=initial and final total energy of electron

P_e,P=initial and final momentum of electron

The multiplicative coulomb correction factor(F_{elwert}) for Bethe-Heitler OB cross section is given as

$$F_{elw} \quad \frac{W/P[1-\exp(-2\pi\alpha Z(2\pi\alpha Z W_e/P_e)]}{W_e/P_e[1-\exp(-2\pi\alpha Z W/P)]}$$

T_{if}=initial and final kinetic energy

Modified elewert factor is given as $F_{mod} = \left[\frac{P_i(1-\exp(-2\pi Z/\alpha P_i)}{P_f(1-\exp(-2\pi Z/\alpha P_f)}\right]$

Corrected modified OB cross section $\sigma_{cor}(W_{e,k,Z}))$ is given by

$\sigma_{cor}(w_{e,}k,z)) = C(T_{i,}Z)\, F_{mod}\, \sigma_{BH}(w_{e,K,Z)}$

Further Avdonina and Pratt has proposed an expression for cross section which includes polarization Bremsstrahlung in SAA with ordinary Bremsstrahlung

$$\sigma(W_{e,K,Z}) = \sigma_B(k) \quad \frac{\sqrt{3}}{\pi} ln \frac{q_+}{q_-} + \sigma_{cor}(w_{e.K.Z)}$$

Results and discussions:

Programmes were made to calculate the Bremsstrahlung cross sections theoretically at different energy range of incident electron and at different range of energy of emitted photons using the theories of Bethe–Hietler (1934), Bethe-Heitler corrected theory [Elwert(1939)] and Avdonina and Pratt (1999) expression.

From the theoretical results calculated below (Table 1-4), we see that there is visible effect of PB in metallic compounds at lower value of emitted photon energies and this effect goes on reducing as energy of emitted photon goes on increasing .Further this effect also decreases with the increase in energy of incident electrons. Similarly it is observed that PB effect is slightly more in compounds having more Zeff. So there is need to study the effect of PB in metallic compounds at low energy theoretically and experimentally in detail and the effect of Zeff and energy of emitted photon on the PB is also needed to study theoretically and experimentally in different energy regions.

Table 1.Bremsstrahlung cross section table for $Sncl_2$ compound at 10 Kev incident electron energy In the range of 1-10 kev,1-20 keV,1-30 keV photon energy (Zeff=42.11)

	Te=10 keV				
S.No.	Photon energy k	$\sigma_{mod}(W_{e,k,Z}))$	$\sigma_{cor}(W_{e,k,Z}))$	$\sigma(W_{e,K,Z})$+PB	Deviation= $\sigma(W_{e,K,Z})$+PB - $\sigma_{cor}(W_{e,k,Z})$
1	1	2.85×10^{-19}	2.95×10^{-19}	3.01×10^{-19}	5.61×10^{-21}
2	2	1.21×10^{-19}	1.27×10^{-19}	1.28×10^{-19}	2.2×10^{-21}
3	3	7.31×10^{-20}	7.73×10^{-20}	7.73×10^{-20}	1.2×10^{-21}
4	4	5.18×10^{-20}	5.49×10^{-20}	5.49×10^{-20}	7.95×10^{-22}
5	5	4.07×10^{-20}	4.30×10^{-20}	4.30×10^{-20}	5.4×10^{-22}
6	6	3.50×10^{-20}	3.70×10^{-20}	3.70×10^{-20}	3.8×10^{-22}
7	7	3.37×10^{-20}	3.57×10^{-20}	4.26×10^{-20}	2.7×10^{-22}
8	8	4.03×10^{-20}	4.26×10^{-20}	8.67×10^{-20}	1.8×10^{-22}
9	9	8.16×10^{-20}	8.67×10^{-20}	8.67×10^{-20}	1.1×10^{-22}
	Te=20 keV				
1	2	7.25×10^{-20}	7.55×10^{-20}	7.83×10^{-20}	6.7×10^{-21}
2	4	3.06×10^{-20}	3.19×10^{-20}	3.30×10^{-20}	1.6×10^{-21}
3	6	1.84×10^{-20}	1.93×10^{-20}	1.99×10^{-20}	8.0×10^{-22}
4	8	1.30×10^{-20}	1.37×10^{-20}	1.41×10^{-20}	4.8×10^{-22}
5	10	1.02×10^{-20}	1.07×10^{-20}	1.10×10^{-20}	3.2×10^{-22}
6	12	8.72×10^{-21}	9.27×10^{-20}	9.46×10^{-20}	2.2×10^{-22}
7	14	8.39×10^{-21}	9.00×10^{-20}	9.13×10^{-20}	1.5×10^{-22}
8	16	1.00×10^{-20}	1.08×10^{-20}	1.09×10^{-20}	1.1×10^{-22}
9	18	2.03×10^{-20}	2.28×10^{-20}	2.29×10^{-20}	7.2×10^{-23}
	Te=30 keV				
1	3	3.28×10^{-20}	3.41×10^{-20}	3.60×10^{-20}	4.86×10^{-21}
2	6	1.38×10^{-20}	1.44×10^{-20}	1.51×10^{-20}	7.38×10^{-22}
3	9	8.26×10^{-20}	8.69×10^{-21}	9.11×10^{-21}	4.12×10^{-22}
4	12	5.81×10^{-20}	6.15×10^{-21}	6.41×10^{-21}	2.63×10^{-22}
5	15	4.52×10^{-21}	4.81×10^{-21}	5.00×10^{-21}	1.80×10^{-22}
6	18	3.86×10^{-21}	4.13×10^{-21}	4.26×10^{-21}	1.26×10^{-22}
7	21	3.71×10^{-21}	3.99×10^{-21}	4.08×10^{-21}	8.95×10^{-22}
8	24	4.41×10^{-21}	4.78×10^{-21}	4.85×10^{-21}	6.12×10^{-23}
9	27	8.97×10^{-21}	9.80×10^{-21}	9.84×10^{-21}	3.70×10^{-23}

Table 2.Bremsstrahlung cross section table for $PbCl_2$ compound at 10 Kev incident electron energy In the range of 1-10 kev,1-20 keV,1-30 keV photon energy Zeff=72.92

	Te =10 keV				
S.No.	Photon energy	$\sigma_{mod}(W_{e,k,Z}))$	$\sigma_{cor}(W_{e,k,Z}))$	$\sigma(W_{e,K,Z})$+PB	Deviation= $\sigma(W_{e,K,Z})$+PB - $\sigma_{cor}(W_{e,k,Z})$
1	1	8.47×10^{-19}	9.65×10^{-19}	9.81×10^{-19}	1.68×10^{-21}
2	2	3.59×10^{-19}	4.10×10^{-19}	4.16×10^{-19}	6.68×10^{-21}
3	3	2.17×10^{-19}	2.49×10^{-19}	2.52×10^{-19}	3.73×10^{-21}
4	4	1.54×10^{-19}	1.77×10^{-19}	1.79×10^{-19}	2.38×10^{-21}
5	5	1.21×10^{-19}	1.39×10^{-19}	1.40×10^{-19}	1.63×10^{-21}
6	6	1.04×10^{-19}	1.20×10^{-19}	1.20×10^{-19}	1.15×10^{-21}
7	7	1.00×10^{-19}	1.16×10^{-19}	1.17×10^{-19}	8.11×10^{-22}
8	8	1.20×10^{-19}	1.38×10^{-19}	1.39×10^{-19}	5.55×10^{-22}
9	9	2.43×10^{-19}	2.83×10^{-19}	2.83×10^{-19}	3.35×10^{-22}
	Te =20 keV				
1	2	2.16×10^{-19}	2.46×10^{-19}	2.54×10^{-19}	8.39×10^{-21}
2	4	9.09×10^{-20}	1.04×10^{-19}	1.07×10^{-19}	3.32×10^{-21}
3	6	5.48×10^{-20}	6.30×10^{-20}	6.48×10^{-20}	1.85×10^{-21}
4	8	3.87×10^{-20}	4.46×10^{-20}	4.58×10^{-20}	1.19×10^{-21}
5	10	3.03×10^{-20}	3.50×10^{-20}	3.58×10^{-20}	8.11×10^{-22}
6	12	2.59×10^{-20}	3.01×10^{-20}	3.06×10^{-20}	5.71×10^{-22}
7	14	2.50×10^{-20}	2.91×10^{-20}	2.95×10^{-20}	4.04×10^{-22}
8	16	2.98×10^{-20}	3.48×10^{-20}	3.51×10^{-20}	2.76×10^{-22}
9	18	6.04×10^{-20}	7.10×10^{-20}	7.12×10^{-20}	1.67×10^{-22}
	Te =30 keV				
1	3	9.76×10^{-20}	1.11×10^{-19}	1.17×10^{-19}	5.58×10^{-21}
2	6	4.10×10^{-20}	4.70×10^{-20}	4.92×10^{-20}	2.21×10^{-21}
3	9	2.46×10^{-20}	2.84×10^{-20}	2.96×10^{-20}	1.24×10^{-21}
4	12	1.73×10^{-20}	2.01×10^{-20}	2.08×10^{-20}	7.89×10^{-22}
5	15	1.35×10^{-20}	1.57×10^{-20}	1.62×10^{-20}	5.39×10^{-22}
6	18	1.15×10^{-20}	1.35×10^{-20}	1.39×10^{-20}	3.80×10^{-22}
7	21	1.10×10^{-20}	1.30×10^{-20}	1.33×10^{-20}	2.68×10^{-22}
8	24	1.31×10^{-20}	1.56×10^{-20}	1.58×10^{-20}	1.83×10^{-22}
9	27	2.67×10^{-20}	3.19×10^{-20}	3.21×10^{-20}	1.11×10^{-22}

Table 3.Bremsstrahlung cross section table for $ZnCl_2$ compound at 10 Kev incident electron energy In the range of 1-10 kev,1-20 keV,1-30 keV photon energy (Zeff=23.99)

Te =10 keV					
S.No.	Photon energy	$\sigma_{mod}(W_{e,k,Z}))$	$\sigma_{cor}(W_{e,k,Z}))$	$\sigma(W_{e,K,Z})$+PB	Deviation= $\sigma(W_{e,K,Z})$+PB - $\sigma_{cor}(W_{e,k,Z})$
1	1	9.74×10^{-20}	9.30×10^{-20}	9.48×10^{-20}	1.82×10^{-21}
2	2	4.12×10^{-20}	3.95×10^{-20}	4.02×10^{-20}	7.22×10^{-22}
3	3	2.50×10^{-20}	2.40×10^{-20}	2.44×10^{-20}	4.03×10^{-22}
4	4	1.77×10^{-20}	1.70×10^{-20}	1.73×10^{-20}	2.58×10^{-22}
5	5	1.39×10^{-20}	1.34×10^{-20}	1.36×10^{-20}	1.76×10^{-22}
6	6	1.19×10^{-20}	1.15×10^{-20}	1.17×10^{-20}	1.24×10^{-22}
7	7	1.15×10^{-20}	1.11×10^{-20}	1.13×10^{-20}	8.78×10^{-23}
8	8	1.37×10^{-20}	1.33×10^{-20}	1.34×10^{-20}	6.00×10^{-23}
9	9	2.79×10^{-20}	2.72×10^{-20}	2.73×10^{-20}	3.63×10^{-23}
Te =20 keV					
1	2	2.47×10^{-20}	2.37×10^{-20}	2.46×10^{-20}	9.09×10^{-22}
2	4	1.04×10^{-20}	1.00×10^{-20}	1.04×10^{-20}	3.60×10^{-22}
3	6	6.26×10^{-21}	6.07×10^{-21}	6.28×10^{-21}	2.6×10^{-22}
4	8	4.41×10^{-21}	4.30×10^{-21}	4.43×10^{-21}	2.01×10^{-22}
5	10	3.44×10^{-21}	3.38×10^{-21}	3.47×10^{-21}	1.28×10^{-22}
6	12	2.94×10^{-21}	2.90×10^{-21}	2.97×10^{-21}	8.78×10^{-23}
7	14	2.83×10^{-21}	2.81×10^{-21}	2.85×10^{-21}	6.19×10^{-23}
8	16	3.37×10^{-21}	3.36×10^{-21}	3.39×10^{-21}	4.37×10^{-23}
9	18	6.85×10^{-21}	6.85×10^{-21}	6.87×10^{-21}	2.19×10^{-23}
Te = 30 keV					
1	3	1.12×10^{-21}	2.43×10^{-18}	2.48×10^{-18}	5.74×10^{-20}
2	6	4.67×10^{-21}	1.02×10^{-18}	1.04×10^{-18}	2.28×10^{-20}
3	9	2.79×10^{-21}	6.20×10^{-19}	6.32×10^{-19}	1.27×10^{-20}
4	12	1.95×10^{-21}	4.38×10^{-19}	4.46×10^{-19}	8.12×10^{-21}
5	15	1.51×10^{-21}	3.43×10^{-19}	3.49×10^{-19}	5.54×10^{-21}
6	18	1.29×10^{-21}	2.95×10^{-19}	2.99×10^{-19}	3.90×10^{-21}
7	21	1.23×10^{-21}	2.85×10^{-19}	2.88×10^{-19}	2.76×10^{-21}
8	24	1.47×10^{-20}	3.41×10^{-19}	3.43×10^{-19}	1.89×10^{-21}
9	27	2.98×10^{-21}	6.99×10^{-19}	7.00×10^{-19}	1.14×10^{-21}

Table 4.Bremsstrahlung cross section table for $AlCl_3$ compound at 10 Kev incident electron energy In the range of 1-10 kev,1-20 keV,1-30 keV photon energy Zeff= 11.99

	Te =10 keV				
S.No.	Photon energy	$\sigma_{mod}(W_{e,k,Z}))$	$\sigma_{cor}(W_{e,k,Z}))$	$\sigma(W_{e,K,Z})$+PB	Deviation= $\sigma(W_{e,K,Z})$+PB - $\sigma_{cor}(W_{e,k,Z})$
1	1	4.23×10^{-20}	2.29×10^{-20}	2.34×10^{-20}	4.5×10^{-22}
2	2	1.78×10^{-20}	9.74×10^{-21}	9.92×10^{-21}	1.8×10^{-22}
3	3	1.08×10^{-20}	5.91×10^{-21}	6.01×10^{-21}	1.0×10^{-22}
4	4	7.61×10^{-21}	4.20×10^{-21}	4.26×10^{-21}	6.4×10^{-23}
5	5	5.96×10^{-21}	3.30×10^{-21}	3.35×10^{-21}	4.40×10^{-23}
6	6	5.11×10^{-21}	2.85×10^{-21}	2.88×10^{-21}	3.10×10^{-23}
7	7	4.93×10^{-21}	2.75×10^{-21}	2.78×10^{-21}	2.19×10^{-23}
8	8	5.87×10^{-21}	3.29×10^{-21}	3.31×10^{-21}	1.50×10^{-23}
9	9	1.19×10^{-21}	6.72×10^{-21}	6.73×10^{-21}	9.05×10^{-24}
	Te =20 keV				
1	2	1.07×10^{-20}	5.86×10^{-21}	6.09×10^{-21}	2.26×10^{-22}
2	4	4.47×10^{-21}	2.48×10^{-21}	2.57×10^{-21}	8.98×10^{-23}
3	6	2.67×10^{-21}	1.50×10^{-21}	1.55×10^{-21}	5.01×10^{-23}
4	8	1.87×10^{-21}	1.06×10^{-21}	1.09×10^{-21}	3.20×10^{-23}
5	10	1.45×10^{-21}	8.37×10^{-22}	8.59×10^{-22}	2.10×10^{-23}
6	12	1.23×10^{-21}	7.20×10^{-22}	7.36×10^{-22}	1.50×10^{-23}
7	14	1.18×10^{-21}	6.99×10^{-22}	7.10×10^{-22}	1.00×10^{-23}
8	16	1.40×10^{-21}	8.44×10^{-22}	8.51×10^{-22}	7.40×10^{-24}
9	18	2.84×10^{-21}	1.77×10^{-23}	1.78×10^{-23}	4.40×10^{-24}
	Te = 30 keV				
1	3	4.83×10^{-21}	2.65×10^{-21}	2.80×10^{-21}	1.5×10^{-22}
2	6	2.00×10^{-21}	1.12×10^{-21}	1.18×10^{-21}	5.9×10^{-23}
3	9	1.19×10^{-21}	6.76×10^{-22}	7.09×10^{-22}	3.3×10^{-23}
4	12	8.24×10^{-22}	4.78×10^{-22}	4.50×10^{-22}	2.1×10^{-23}
5	15	6.33×10^{-22}	3.74×10^{-22}	3.89×10^{-22}	1.5×10^{-23}
6	18	5.33×10^{-22}	3.21×10^{-22}	3.32×10^{-22}	1.0×10^{-23}
7	21	5.06×10^{-22}	3.11×10^{-22}	3.18×10^{-22}	7.2×10^{-24}
8	24	5.96×10^{-22}	3.72×10^{-22}	3.77×10^{-22}	5.0×10^{-24}
9	27	1.20×10^{-21}	7.63×10^{-22}	7.65×10^{-22}	3.0×10^{-24}

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Experimental Investigation On Material Removal And Tool Wear Rate In Powder Mixed Electric Discharge Machining By Using Taguchi Method

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ABSTRACT

Electric discharge machining (EDM) is one of most popular machining methods to manufacture dies and press tools because of its capability to produce complicated shapes and machine very hard materials. The present study was undertaken to identify the appropriate parameter settings for rough and finish machined surface for H11, and high carbon high chromium (HCHCr) die steel materials in a powder-mixed electric discharge machining process. The effect of different input parameters, namely, current, workpiece material, electrode material, dielectric medium, pulse on time, pulse off time and powder on the MRR, TWR has been studied.

Keywords: EDM, MRR, TWR, Powder.

INTRODUCTION:

Electrical discharge machining has been widely used for manufacturing various components such as moulds, dies and complex shapes on the hard materials with higher surface finish. This process enables machining of any conducting material, which is electrically conductive. The process removes the metal with sparks generated between electrode tool and the workpiece. A lot of work has been carried out on the different aspects of EDM such material removal rate, tool wear rate, surface modification with or without mixing of powder particles in the dielectric fluid. There is no direct contact between the electrode tool and workpiece. The sparks flow through the dielectric fluid at a controlled distance [Fuller, Pandey & Shan, McGeough]**.** Uno et al. proposed a surface modification technique to obtain high surface wear resistance using EDM with powder mixed fluid and it has been observed that that EDMed surface with nickel powder mixed fluid has smaller surface roughness than that in EDM with kerosene type fluid. Additionally, Pecas and Henriques recommended that powder particles to the EDM dielectric fluid modifies some process variables and creates the conditions to achieve a higher surface quality in large machined area. Accurate control of powder concentration and flushing flow is a requirement for achieving an improvement in the process polishing capability. Jeswani had used graphite powder in kerosene dielectric fluid. Experimental results revealed that the addition of about 4g of fine graphite powder (10μ m in average size) per litre of kerosene increases the metal removal rate (MRR) by 60% and tool wear rate (TWR) by 15% in electrical discharge machining.

Moreover, Ming and Liu investigated the effects of additives in kerosene used as dielectric fluid for EDM. They showed that additives can increase the MRR and decrease the TWR and improve the surface quality of work, especially in mid-finish machining and finish machining. Furthermore, Mohri et al. used 0.1 mm diameters wires of tungsten, copper and brass as electrode on AISI-1049 steel workpiece material to observe the effects of electrode materials on material accretion process using EDM. Under the same machining conditions, tungsten was the deposited on the workpiece, while the workpiece drilled with copper and brass electrode. Finally, **Roethel and Garbajs** observed that the properties of machined surfaces depended on the properties of alloys which were formed in the surface layers due to diffusion of the tool electrode material and breakdown of the dielectric. By microprobe analysis, it was possible to study the phase changes of the material in the surface layers.

EXPERIMENTAL SETUP AND PROCEDURE

The experiments were conducted on the Electrical Discharge Machine, Model T-3822. A separate tank of size 330X180X187mm and of 9 liter capacity was fabricated using 3mm thick mild steel with motorized stirrer for mixing the suspended powder particles. The machine, experimental setup, and schematic are shown in Figure 1. Two work piece of alloy steels namely, H11 (0.39% C,1% Si, 0.5% Mn, 0.03% P, 0.02% S, 4.75% Cr, 1.1% Mo, 0.01% Co, 0.01% Cu, 0.5% V, balance Fe), and HCHCr (1.6% C, 0.5% Si, 0.55% Mn, 0.03% P, 0.03%S, 13.3%Cr, 0.05% Mo, 0.07% Ni, 0.01% Co, 0.05% Cu, 0.02% Ti, 0.02% W, balance Fe) were cut to a size of 100X50X10mm for the experimentation. The electrode of tungsten-copper, copper and graphite material were used. Three powder different powders i.e. copper, graphite and mix (50-50% copper & Graphite), mixed in kerosene oil for experimentation. Various process parameters are enlisted in Table 1 which are considered during experiment.

Fig. 1: Electrical Discharge Machine & Dielectric Tank with Stirrer Attachments

Table1. Different Level of Parameter Settings for Experimentation

S. No.	Parameter	Value
1	Open circuit voltage	135+/-5%
2	Polarity	Positive
3	Machining time	10 minutes
4	Dielectric	Kerosene
5	Spark energy	Low
6	Powder concentration	10g/l
7	Powder	Copper, Graphite, Mix
8	Current	2, 5, 8 A(3 values)
9	Pulse on	10, 50, 100µs(3 values)
10	Pulse off	38, 57, 85µs(3 values)

ANALYSIS TECHNIQUE

The effect of various input parameters i.e. pulse on time, pulse off time, current, electrode, workpiece material and powder were investigated through the experimentation. Two responses were selected for pilot experimentation namely material removal rate (MRR) and tool wear rate (TWR). The assignment of factors was carried out using statistical software MINITAB. All the factors were varied at three levels except workpiece material, which was varied at two levels. The degrees of freedom required for the experiment was calculated to be 11, thus the orthogonal array that can be used should have degrees of freedom (dof) greater than 11. L18 which can accommodate a combination of 2-level and 3-level factors was thus used for conduct of experiments to measures two response values namely, MRR and TWR. After the conduct of the 18 trials the mean values for MRR and TWR are tabulated in Table 2. For the analysis of the result, Analysis of Variance (ANOVA) was performed.

Table 2: L18 Orthogonal Array for different Runs

Trial No.	Workpiece	Pulse on time (µs)	Current (Amp)	Pulse off time (µs)	Electrode	Powder	MRR (mm^3/min)	TWR (mm^3/min)
1	HCHCr	10	2	38	Copper	Copper	2.98	0.011
2	HCHCr	10	5	57	Graphite	Graphite	11.92	5.024
3	HCHCr	10	8	85	W-Cu	Mix	37.26	0.616
4	HCHCr	50	2	38	Graphite	Graphite	0.99	1.256
5	HCHCr	50	5	57	W-Cu	Mix	14.03	0.136
6	HCHCr	50	8	85	Copper	Copper	14.03	0.449
7	HCHCr	100	2	57	Copper	Mix	1.36	0.112
8	HCHCr	100	5	85	Graphite	Copper	15.65	3.14
9	HCHCr	100	8	38	W-Cu	Graphite	1.61	1.57
10	H13	10	2	85	W-Cu	Graphite	4.91	0.205
11	H13	10	5	38	Copper	Mix	10.89	0.449
12	H13	10	8	57	Graphite	Copper	34.97	3.14
13	H13	50	2	57	W-Cu	Copper	3.89	0.068
14	H13	50	5	85	Copper	Graphite	9.87	0.112
15	H13	50	8	38	Graphite	Mix	1.43	4.71
16	H13	100	2	85	Graphite	Mix	3.35	0.628
17	H13	100	5	38	W-Cu	Copper	8.5	0.068
18	H13	100	8	57	Copper	Graphite	11.49	0.157

RESULTS AND DISCUSSION

The relationship of MRR with current, pulse on time and pulse off time during the machining using copper, graphite and tungsten- copper electrode in powder mixed dielectric is shown in the Fig. 2. It was observed that at low current, MRR is low but increases sharply with increased current. ANOVA for MRR is given in Table 3. The current was observed to be most significant factor affecting MRR. The MRR increased with increase in the pulse on time and decreased with increase in pulse off time. The workpiece material and the electrode material had insignificant effect on MRR. Further, the MRR was observed to increase when copper powder was suspended in dielectric and reduce with graphite-powder.

Table 3: ANOVA Result for Material Removal Rate (MRR)

Source	SS	v	V	F	$F_{critical}$ 95% confidence level	P
Workpiece	6.16	1	6.160	0.10		0.766
Pulse off time	398.17	2	199.085	3.15		0.116
Current	593.65	2	296.827	5.22	5.14	0.049
Pulse on time	340.26	2	170.130	2.69		0.147
Electrode	38.88	2	19.441	0.31		0.746
Powder	135.21	2	67.605	1.07		0.401
Residual error	379.42	6	63.237			
Total	1891.76	17				

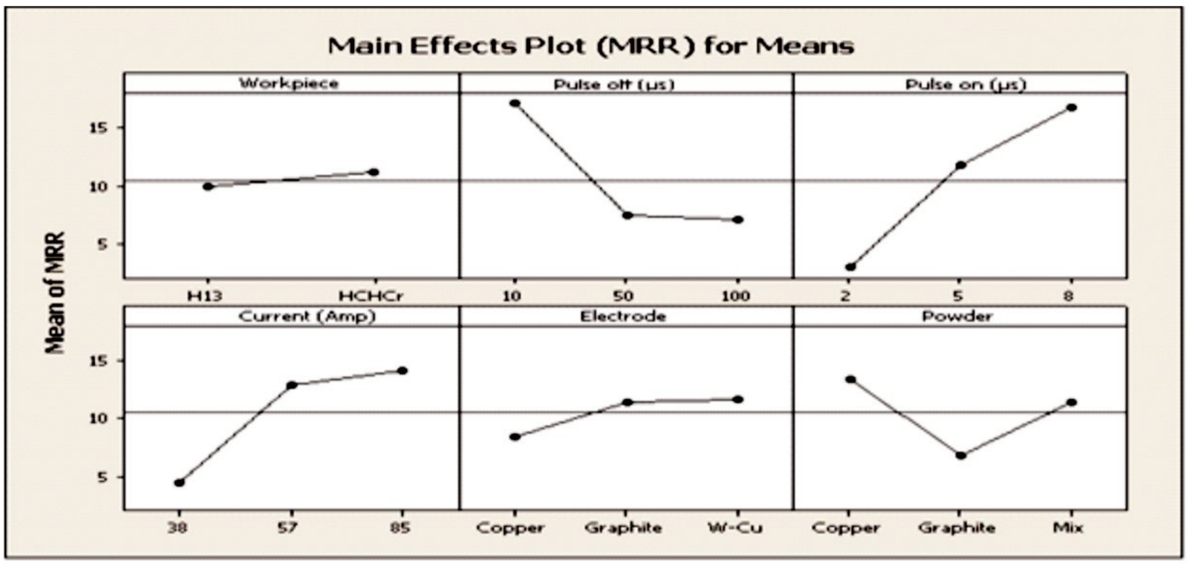

Figure 2: Main Effect Plot for MRR

The relationship of TWR with the current, pulse on and pulse off during the machining with copper, graphite and tungsten-copper electrode in powder mixed dielectric is shown in the Fig. 3. The electrode material was found to be most significant factor effecting TWR. With copper electrode showing least TWR while graphite electrode has maximum TWR. Also, increase in current caused high tool wear, while all other factors had insignificant effect on TWR.

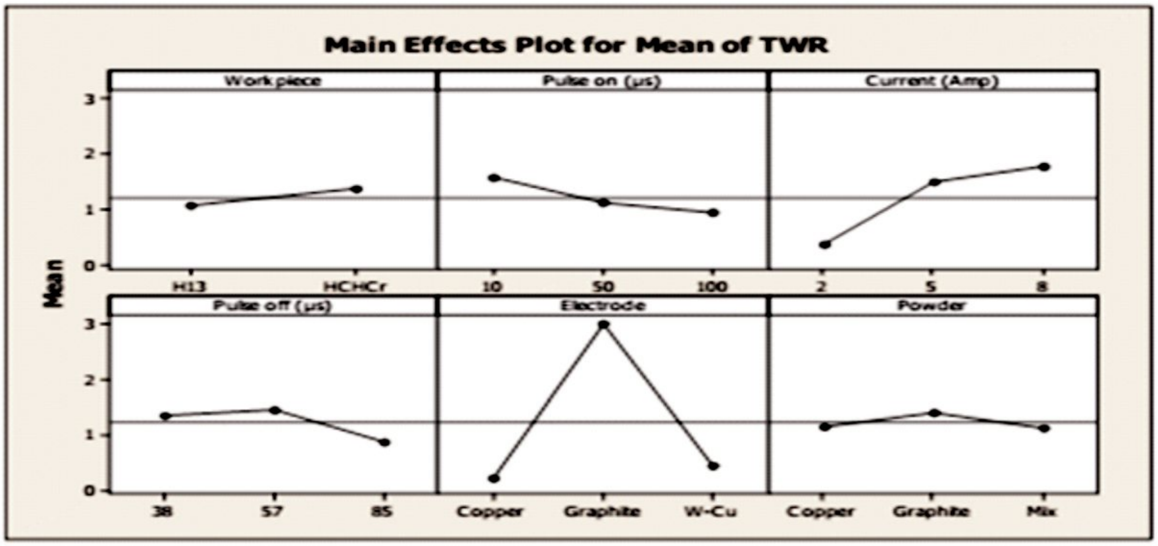

Figure 3: Main Effect Plot for TWR

Table 3: ANOVA Result for Tool Wear Rate (TWR)

Source	SS	v	V	F	$F_{critical}$ 95% confidence level	P
Workpiece	0.4284	1	0.4284	0.32		0.591
Pulse off time	1.2608	2	0.6304	0.47		0.645
Current	6.5037	2	3.2519	2.44		0.168
Pulse on time	1.1655	2	0.5827	0.44		0.665
Electrode	28.3231	2	14.1616	10.62	5.14	0.011
Powder	0.2748	2	0.1374	0.10		0.904
Residual error	8.0008	6	1.3335			
Total	45.9571	17				

CONCLUSIONS

1. It was observed that at low current, MRR is low but increases sharply with increased current.
2. MRR was observed to increase when copper powder was suspended in dielectric and reduce with graphite powder.
3. The electrode material was found to be most significant factor effecting TWR. Increase in current caused high tool wear.

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Optimization of Process Parameter For Al/Fly Ash Metal Matrix Composites By Taguchi Method

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ABSTRACT

Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that are encouraging every sphere of engineering applications. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuously dispersed solids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. The present investigation has been focused on the waste fly ash in useful manner by dispersing it into Aluminium /Fly ash metal matrix composites to produce by stir casting technique. There are three parameters that are particle sizes of reinforcement (53, 74 and 105 micron), weight percentage of reinforcement (4, 8 and 12%) and stirring time (15, 20 and 25 minute) were used to make different sample of composites. L9 orthogonal array was used for design of experimentation. The mechanical properties such as hardness, tensile strength and impact strength have been studied. The percentage contributions of each parameter for different mechanical properties have been calculated by using analysis of variance. Results show that weight percentage of fly ash, stirring time and particle size have significantly effect on hardness, impact strength and tensile strength.

Keywords: - Metal Matrix Composites, Stir casting, orthogonal array, Analysis of variance, Mechanical properties.

INTRODUCTION

Metal-matrix composites have emerged as a class of materials capable of advanced structural, aerospace, automotive, thermal management and wear application. The performance advantage of metal matrix composites is their mechanical, physical and thermal properties that include low density, high tensile strength, high impact strength, high thermal conductivity and wear resistance. Conventional composite materials have limitations with respect to achievable combinations of strength and density. In order to overcome these shortcomings and to meet the ever-increasing engineering demands of modern technology, metal matrix composites are gaining importance (et.al Mahendra). Now a days the particulate reinforced Al matrix composite are gaining importance because of their low cost with advantage like isotropic properties. The strengthening of aluminum alloys with dispersion of fine ceramic particulate composite materials were developed as an alternative of unreinforced alloy, for obtaining materials with high strength and low density (et.al Mohanty)

Aluminum alloys reinforced with ceramic particles exhibit superior mechanical properties to unreinforced Al alloys and hence are candidate for engineering applications. The aluminum metal matrix composites are produced either by casting route or by powder metallurgy (et.al Rana R. S). The former has the advantages of producing the composites as lower cost of production and possibility of producing larger components. However, the inherent difficulties of casting route are non wettability of ceramic particles by liquid aluminum, segregation of particles, and reaction due to higher processing temperature. Wettability of the particles can be improved by addition of active elements such as Mg into liquid aluminum or preheating of the particles before addition into liquid aluminium. The method of production of composites by casting route v where the liquid aluminum containing 1-5% Mg. Addition of Mg into the liquid metal reduces the surface tension and there by avoids the rejection of the particles from the melts. Without addition of Mg recovery of the particles into the melt is quite low (et.al Rohatgi, P.K)The present investigation has been focused on utilization of waste fly ash in useful manner by dispersing it in aluminum matrix to produce composite. Fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides, was used as the reinforcing phase.

DESIGN OF EXPERIMENTS (DOE)

Design of Experiment is one of the important and powerful statistical techniques to study the effect of multiple parameters simultaneously and involves a series of steps which must follow a certain sequence for the experiment to yield an improved understanding of process performance (et.al Dharmalingam)All designed experiments require a certain number of combinations of factors and levels be tested in order to observe the results of those test conditions. Taguchi approach relies on the assignment of factors in specific orthogonal arrays to determine those test combinations. The DOE process is made up of three main phases: the planning phase, the conducting phase, and the analysis phase. A major step in the DOE process is the determination of the combination of factors and levels which will provide the desired information.

Analysis of the experimental results uses a signal to noise ratio to aid in the determination of the best process designs. In the present work, a plan order for performing the experiments was generated by Taguchi method using orthogonal arrays (et.al Basavarajappa). This method yields the rank of various parameters with the level of significance of influence of a factor or the interaction of factors on a particular output response.

Experimentation

PLAN OF EXPERIMENTS

Composite was performed with three parameters weight percentage (wt. %), particle size of reinforcement and stirring time and varying them for three levels shown in table 1:

Table 1 Casting process parameter

S no.	Parameter	Parameter designation	Level 1	Level 2	Level 3
1.	Particle size (reinforcement)	A	53	74	105
2.	Wt.%	B	4	8	12
3.	Stirring time (minute)	C	15	20	25

A three parameter and three level L9 orthogonal array used to manufactured different sample of composites (et.al Muhammed) shown in table 2:

Table 2 Orthogonal array

S. No.	Particle size (A)	Wt. % (B)	Stirring time (C)
1.	1	1	1
2.	1	2	2
3.	1	3	3
4.	2	1	2
5.	2	2	3
6.	2	3	1
7.	3	1	3
8.	3	2	1
9.	3	3	2

In this research nine different composite were manufactured. The effect of parameters on the response i.e. the hardness, impact and tensile strength of the composite were studied using Analysis of variance (ANOVA).

Degree Of Freedom (DOF) = number of levels -1 …… (1)

For each factor, DOF equal to:

For (A); DOF = 3-1=2

For (B); DOF = 3-1= 2

For (C); DOF = 3-1=2

Total DOF=No. of experiments -1 ……. (2)

The total DOF for the experiment is DOF= 9-1 = 8

In the tagauchi method the response variation were studied using signal-to-noise ratio and minimization the variations due to uncontrollable parameter. In this study, "larger the better" characteristics was chosen to analyze the mechanical properties (hardness, tensile strength and impact strength). The S/N ratio for wear rate using "larger the better" characteristic given by Taguchi (et.al Montgomery), is as follows:

S/N dB = $-10\log\left(\frac{1}{r}\sum_{i=1}^{r}\left(\frac{1}{y_i}\right)^2\right)$

Where

y = observation, response, data

r = total number of observation

y_i = i[th] response

The S/N ratio was calculated for hardness, impact strength and tensile strength in each of the nine trial conditions to see the effect of each parameter on the response.

EXPERIMENTATION

Description of material

The matrix material used in the experiment was commercially pure aluminium. Aluminium in the form of plate was purchased from market then plates were cut into small pieces by using power hacksaw. Pure magnesium also used during mixing reinforcement in aluminium. The chemical composition of matrix material is 99% of aluminium and 1% other elements. Chemical composition of matrix material shows in table 3

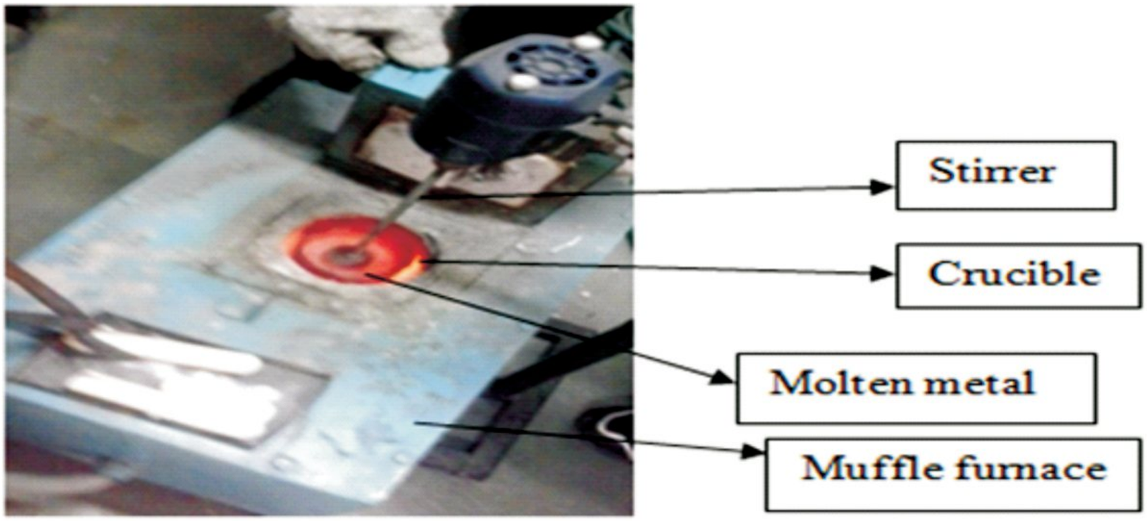
Table 3 Chemical composition of matrix material aluminium

Al	Cu	Si	Fe	Mn	Pb	Sn	Ti	Cr
99	0.01	0.30	0.580	0.024	0.038	0.015	0.012	0.002

The reinforcement material used was fly ash. It was collected from power thermal plant, Bathinda. There were very small size of fly ash particle is used during mixing in matrix material.

Composite preparation

The aluminum fly ash metal matrix composite was prepared by stir casting route. For this we took 400gm of commercially pure aluminum and desired amount of fly ash particles. The fly ash particle was preheated to 300ºC for three hour to remove moisture. Commercially pure aluminum was melted in a resistance furnace. The melt temperature was raised up to 850ºC. Then the melt was stirred with the help of a stainless steel stirrer. The stirring was maintained between 5 to 7 min at an impeller speed of 300 rpm. Then temperature decreased and maintained 750ºC in semi solid state during addition of fly ash particles. Fly ash added into molten metal in three parts step by step. To increase the wettability of fly ash particles 2% magnesium was added. The dispersion of fly ash particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent mold. The melt was then allowed to solidifying the moulds. This process repeated to make different sample according table composition.



The hardness of composites was measured with Rockwell hardness test machine. Similarly the impact strength of these specimens were measured using the Charpy Impact test machine with a dimensions of specimen were 55mm×10mm×10mm. The tensile tests were carried out on a Universal Testing Machine (UTM). The composite were machined to prepare tensile specimens according to ASTM standards.

RESULT AND DISCUSSION

The hardness, impact and tensile test have been done pure aluminium as well as 9 samples of composites with the help of Rockwell hardness testing machine, charpy test machine and universal testing machine respectively. Each sample performed three trials for better result and then means value has written in table 4:

Table 4 Mean of hardness, impact and tensile strength

Trail No.	Particle size (micron) (A)	% wt. (B)	Stirring time (Min.) (C)	Mean hardness (HRB)	Mean impact strength (NM)	Mean tensile strength (N/mm^2)
Pure Al	-	-	-	30	12	96
1	53	4	15	40	16.80	115
2	53	8	20	56	24.25	137
3	53	12	25	65	32.04	155
4	74	4	20	43	18.32	118
5	74	8	25	55	27.54	148
6	74	12	15	47	20.30	130
7	105	4	25	42	17.12	113
8	105	8	15	38	20.11	126
9	105	12	20	52	24.07	143

An average hardness value from 30 HRB to 65HRB were obtained for the fly ash particle reinforced composites. A significant increase in hardness of the matrix can be seen with addition of fly ash particles. Higher value of hardness is clear indication of the fact that the presences of particulates in the matrix have improved the overall hardness of the composites. Similarly the impact strength increased from 12 Nm to 32.04 Nm. The tensile strength of composite reinforced with 12 wt. % fly ash particles is a modest superior than that of the pure aluminium. Fly ash particle reinforced composite exhibited tensile strength up to 155 N/mm^2 while the pure aluminium had a tensile strength 96 N/mm^2.

Table 5 shows the S/N ratio for the response of the composites. From S/N ratio it is cleared that each parameter has different effect on impact strength of composites.

Table 5 S/N ratio table

Trail No.	(A)	(B)	(C)	S/N Ratio for hardness	S/N Ratio for impact test	S/N ratio for tensile test
1	53	4	15	41.58	34.04	50.75
2	53	8	20	44.50	37.23	52.27
3	53	12	25	45.80	39.65	53.34
4	74	4	20	42.21	34.80	50.98
5	74	8	25	44.34	38.34	52.94
6	74	12	15	42.98	35.59	51.82
7	105	4	25	42.00	34.21	50.60
8	105	8	15	41.13	35.61	51.54
9	105	12	20	43.86	37.14	52.64

Effect of various parameters on hardness of composite

Since the experimental design is orthogonal, it is then possible to separate out the effect of each parameter at different levels. For example, the mean S/N ratio for the current at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments 1–3, 4–6, 7–9 respectively. The mean S/N ratio for each level of the parameters can be computed in the similar manner. The mean S/N ratio for each parameter on each level is shown in table 6.

Table 6 Mean hardness S/N ratio different level

Parameter	Level 1(mean S/N ratio)	Level 2(mean S/N ratio)	Level 3(mean S/N ratio)
A	**43.96**	43.18	42.33
B	41.83	43.33	**44.21**
C	41.90	43.52	**44.05**

1. Effect of weight %(reinforcement)

It is clear from the graph that with increase weight % (wt %) of fly ash, the hardness of composite increases. On the hardness of the composite weight % of fly ash was the most influent parameter. Graph shows that up to 8wt% fly ash the hardness increases suddenly and after that with increase in weight % fly ash hardness increases slowly as comparison to last addition of reinforcement. So this is a most effecting parameter on the hardness of composites. As the weight % of Alumina increases the hardness of composites also increased as shown in the figure 2:

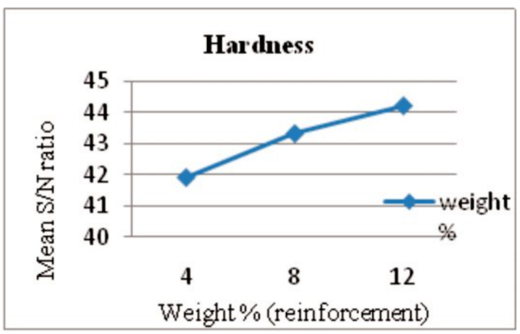


Fig. 2 Effect of weight % (reinforcement) on hardness

Effect of Stirring Time

Stirring time also contributes in the hardness of the composite. Results shows that with increase in the stirring time the hardness of composites increases continuously. The graph showed that at 25 Min. stirring time maximum hardness of composites obtained. The effect of stirring time on the hardness of composite is shown in fig 3:

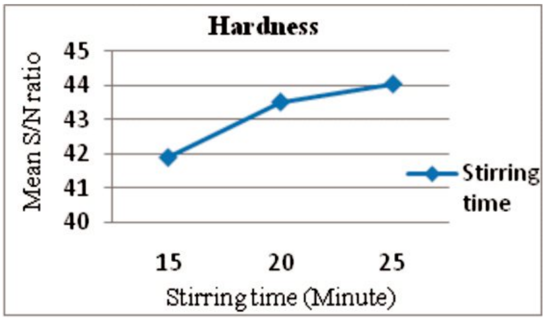


Fig. 3 Effect of stirring time on hardness

3. Effect of particle size

Results shows that as the particle size increases the hardness of composite decreased. Graph shows that with increase in size from 53 micron to 105 micron hardness decreased because of gravity effect on particles in molten metal. The effect of particle size on the hardness of composite is shown in fig 4:

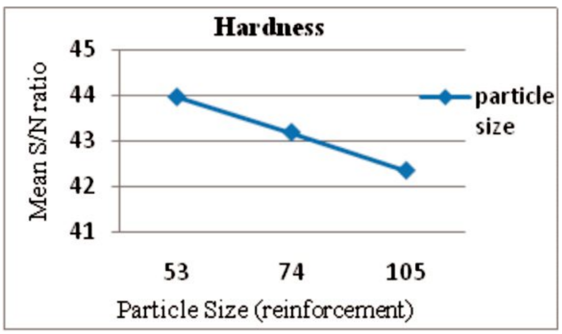


Fig. 4 Effect of particle size (reinforcement) on hardness

Analysis of variance (ANOVA) for hardness of the composites

In fig 2-4 shows the hardness increase or decrease according to parameter. From it is cleared that if volume fraction and stirring time increased then hardness also increased but if particle size increased then hardness decreased. Further find the contribution of each parameter to increase the hardness applied ANOVA and find optimal design for hardness.

Table 7 ANOVA table for hardness

Parameter	D.O.F	Sum of Square	Mean square (variance)	F-ratio	Contribution in %age
Particle size (A)	2	3.97	1.98	57.18	20.35
Wt. % (B)	2	7.93	3.96	114.20	40.66
Stirring time (C)	2	7.54	3.77	108.47	38.62
Residual error	2	0.06	0.034		
Total	8	19.52	2.44		

Table 7 showed the rank importance of the various factors in terms of their relative significance. The table 7 shows the contribution of each parameter in the hardness of the composites. The highest rank 1 of wt. % signifying the highest contribution about 40.66% in the hardness of composites. After that stirring time showed large contribution (38.62%) as compare to particle size (20.35%).

Effect of various parameters on impact strength of composite

Since the experimental design is L9 orthogonal array, it is then possible to separate out the effect of each parameter at different levels. Find the mean S/N ratio for each level of the parameters can be computed in the similar manner. The mean S/N ratio for each parameter on each level is shown in table 8:

Table 8 Mean impact strength S/N ratio for different level

Parameter	Level 1(mean S/N ratio)	Level 2(mean S/N ratio)	Level 3(mean S/N ratio)
A	**36.98**	36.27	35.66
B	34.35	37.06	**37.50**
C	35.11	36.40	**37.40**

1. Effect of wt. %

The experimental results shows that wt. % of fly ash is most influent parameter that affect the impact strength very strongly as compared to stirring time and particle size of fly ash. As the wt. % of fly ash increases in the matrix metal, the impact strength of the composite increases.

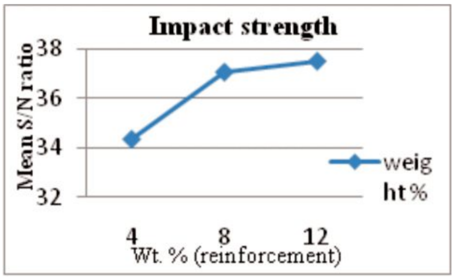


Fig. 5 Effect of weight % on Impact strength

2. Effect of stirring time: - The impact strength of the composite increased by embedding of fly ash in the matrix metal. Results shows that with increase in the stirring time the impact strength of composites increases continuously from 35.11 to 37.40 because of the distribution of reinforcement particles in the matrix metal. The graph showed that at 25 Min. stirring time maximum impact strength of composites obtained. The effect of stirring time on the impact strength of composite is shown in figure 6:

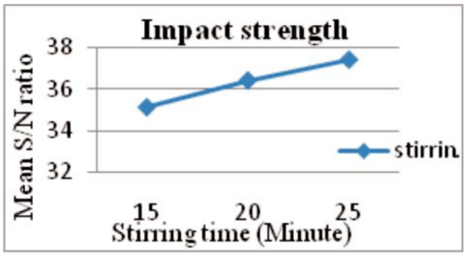


Fig.6 Effect of stirring time on Impact strength

3. Effect of Particle size

The effect of particle size on the impact strength of the composite is shown in fig. 7. Results shows that as the particle size increases the impact strength of composite decreased.

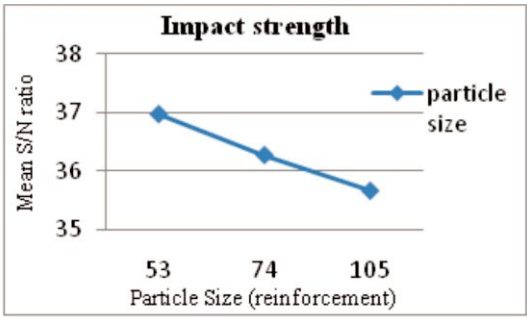


Fig 7 Effect of particle size (reinforcement) on impact strength

Analysis of variance for impact strength of the composites

In graphs shows that the impact strength increase if wt. % and stirring time increased and decreased if particle size increased. Further find the percentage contribution of each parameter to increase the impact strength applied ANOVA and find optimal design for hardness.

Table 9 ANOVA table for Impact test

Parameter	Degree of freedom	Sum of Square	Mean square (Variance)	F-ratio	Contribution In %
Particle size (A)	2	2.5996	1.2998	1.5938	8.7817
Wt. %(B)	2	17.4760	8.7380	10.7146	59.0642
Stirring time (C)	2	7.8814	3.9407	4.8321	26.6371
Residual error	2	1.6310	0.8155		
Total	8	29.5882	3.6985		

From ANOVA table 9 shows the contribution of each parameter in the impact strength of the composites. The highest rank 1 of wt. % signifying the highest contribution about 59.06% to increased the impact strength of composites. Stirring time and particle size contribute 26.63%, 8.78% respectively. Impact strength is increased as increase the reinforcement. Impact strength decreased as increased the size of reinforcement particle.

Effect of various parameters on tensile strength of composite

Effect of Particle size

Table 10 shows the S/N ratio of tensile strength of the composites. From S/N ratio cleared that each parameter has different effect on tensile strength of composites. The mean S/N ratio for each parameter on each level is shown in table 10

Table 10 Mean S/N ratio for each level

Parameter	Level 1(mean S/N ratio)	Level 2(mean S/N ratio)	Level 3(mean S/N ratio)
A	**52.12**	51.91	51.60
B	50.78	52.25	**52.60**
C	51.37	51.96	**52.30**

1. Effect of wt. %

Tensile strength of composites increased as increased the weight percentage of fly ash. Fig 8 shows the effect of weight percentage of fly ash on tensile strength.

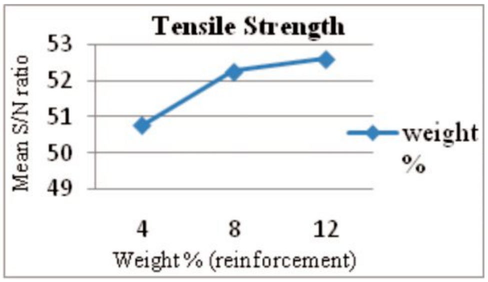


Fig. 8 Effect of weight % on tensile strength

2. Effect of Stirring time

The tensile strength of composite increased as the stirring time increased. From S/N mean ratio cleared that highest value of tensile test at 25 minute stirring time.

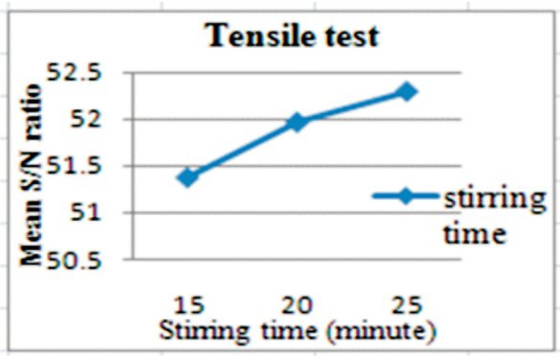


Fig. 9 Effect of stirring time on tensile strengh

Particle size of fly ash shows too much least effect on the tensile strength of the composite. As the particle size increases the tensile strength mean S/N ratio of composite decreased from 52.12-51.60. The effect of particle size on the tensile strength shown in fig 10:

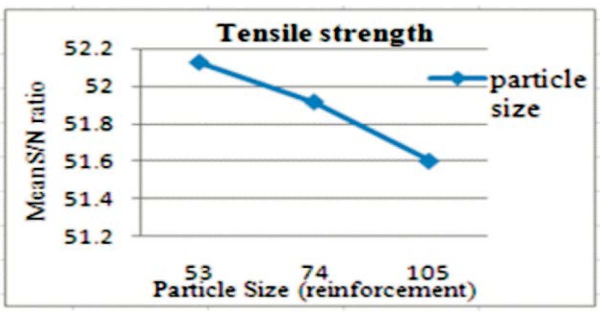


Fig 10 Effect of particle size (reinforcement) on tensile strength

Analysis of variance for tensile strength of the composites

In fig 8-10 shows that the tensile strength increased if wt. % and stirring time increased and decreased if particle size increased. Further find the percentage contribution of each parameter to increase the tensile trength applied ANOVA and find optimal design for hardness.

Table 11 ANOVA table for tensile test

Parameter	Degree of freedom	Sum of Square	Mean square (Variance)	F-ratio	Contribution In %
Particle size (A)	2	0.4211	0.2105	0.8741	5.3578
Wt. % (B)	2	5.6413	2.8206	11.7097	71.7713
Stirring time (C)	2	1.3159	0.6579	2.7314	16.7416
Residual error	2	0.4817	0.2408		
Total	8	7.8601	0.9825		

From ANOVA table shows the contribution of volume fraction 71.77% to increase the tensile strength. Other parameter contribution stirring time and particle size are 16.74% and 5.35% respectively.

CONCLUSION

From the study it is concluded that we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.

Fly ash up-to 12% by weight can be successfully added to commercially pure aluminum by stir casting route to produce composites.

Hardness, tensile strength and impact strength increased from 30HRB-65HRB, 96-155N/mm² and 11-32.04N/m respectively.

The Signal-to-noise ratio showed the effect of each parameter at each level on the hardness, impact strength and tensile strength of composite.

Analysis of variance determined the contribution of each parameter in the hardness, impact strength and tensile strength of the prepared composite.

Mechanical properties hardness, tensile strength and impact strength increased with increase the volume fraction of reinforcement and stirring time but decreased with increased the size of particle.

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Effect of process parameters on the percentage improvement in surface finish for internal finishing of stainless steel (SUS 304) thick tubes using Magnetic abrasive finishing

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ABSTRACT

A magnetic abrasive finishing process is a method of non-traditional precision machining in which the finishing process is completed using magnetic force and magnetic abrasives. In this research, SUS 304 thick cylindrical tube was finished using a magnetic abrasive finishing process with the objective of Development of new MAF setup for finishing of Thick Tubes, to study finishing performance of developed MAF setup for internal finishing of stainless steel tubes (SUS 304) using diamond based sintered magnetic abrasives. This paper describes the development of the high-speed multiple pole finishing equipment and the effects of tube rotational speed on abrasive motion during the finishing experiments.

Keywords: Magnetic abrasive finishing, Flexible magnetic Abrasive brush, Scanning Electron Microscope, Magnetic Abrasive Particles, Percentage Improvement in surface finish

INTRODUCTION

Recent advances in various technological fields demand development and use of advanced engineering materials like different types of steels, nonferrous metals, and ceramics. It is difficult to finish advanced engineering materials by finishing techniques such as lapping, honing, and super finishing cost-effectively. Also, processes need to meet the requirements of high surface finish, accuracy, and minimum surface defects. This has necessitated the development of alternate finishing technologies, namely, magnetic abrasive finishing (MAF) and magneto rheological finishing (MRF) [1-3]. MAF is a process in which work piece surface is smoothened by removing the material in the form of microchips by abrasive particles in the presence of magnetic field in the finishing zone. The working gap between work piece and magnet is filled with a mixture of ferromagnetic and abrasive particles. In some attempts bonded ferromagnetic and abrasive particles are also used. These bonded or unbonded blends of ferromagnetic and abrasive particles are referred as magnetic abrasive particles (MAPs) [4]. The MAPs form a flexible magnetic abrasive brush (FMAB) in the presence of magnetic field and do not require dressing. In this research, a SUS 304 thick cylindrical tube was finished using a magnetic abrasive finishing process with the objective of Development of new MAF setup for finishing of Thick Tubes. The other objective was to study finishing performance of developed MAF setup for internal finishing of stainless steel tubes (SUS 304) using diamond based sintered magnetic abrasives and to investigate effect of input process parameters (circumferential speed of magnets, mesh number, quantity of abrasives, finishing time) on the performance characteristics like percentage improvement in surface finish (PISF) using response surface methodology (RSM) and to develop empirical relationship between process input parameters and the process output characteristics by developing regression model and to investigate the interactions between the various input process and their effect on the process output characteristic like PISF. It has been found that mesh number and quantity of abrasives have significant affect on PISF. Results show that interaction of speed and finishing time also has significant effect on PISF. The maximum Percentage Improvement in Surface Finish was found to be 94.32% at 310 rpm of speed of permanent magnet, 20 gms of quantity of abrasives, 44 mesh number and 20 minutes of finishing time. In addition, the scanning electron microscope (SEM) photographs shows that the surface generated by boring on lathe consists of deep scratches. The peaks have been sheared off too much smaller height by MAF resulting in improved surface finish, but fine scratching marks produced by MAF appear on the surface.

EXPERIMENTAL PROCEDURE AND SETUP

An experimental setup is installed on radial drilling machine of varying rpm, consisting of permanent magnets (6 in number), work piece, working table, x-y stage (Figure1). The permanent magnets fixed in the spindle can rotate at high speed as that of the rpm (varying) of rotating spindle of radial drill machine, while the work piece is fixed on the working table of the machine. When sintered diamond magnetic abrasives are introduced into the gap between the magnetic pole and the work piece, they are magnetically attracted by the magnetic pole and thus rotate following the magnetic pole. The magnetic force required to form the FMAB in MAF process is due to the magnetic field produced by a permanent magnet. The rotor and rotor shaft are machined on lathe. The material used for the rotor and rotor shaft is mild steel. The diameter of the rotor is kept 66 mm. Thickness is kept 20 mm, stroke length is kept equal to 70 mm. Six rare earth permanent magnets are fixed inside the rotor circumferentially and the angle between each of the permanent magnet is kept at 60º. These magnets are fixed with the help of epoxy resin in drilled holes made in the rotor circumference. The spindle of mild steel is turned to size 19 mm which is attached to the socket of radial drill machine.

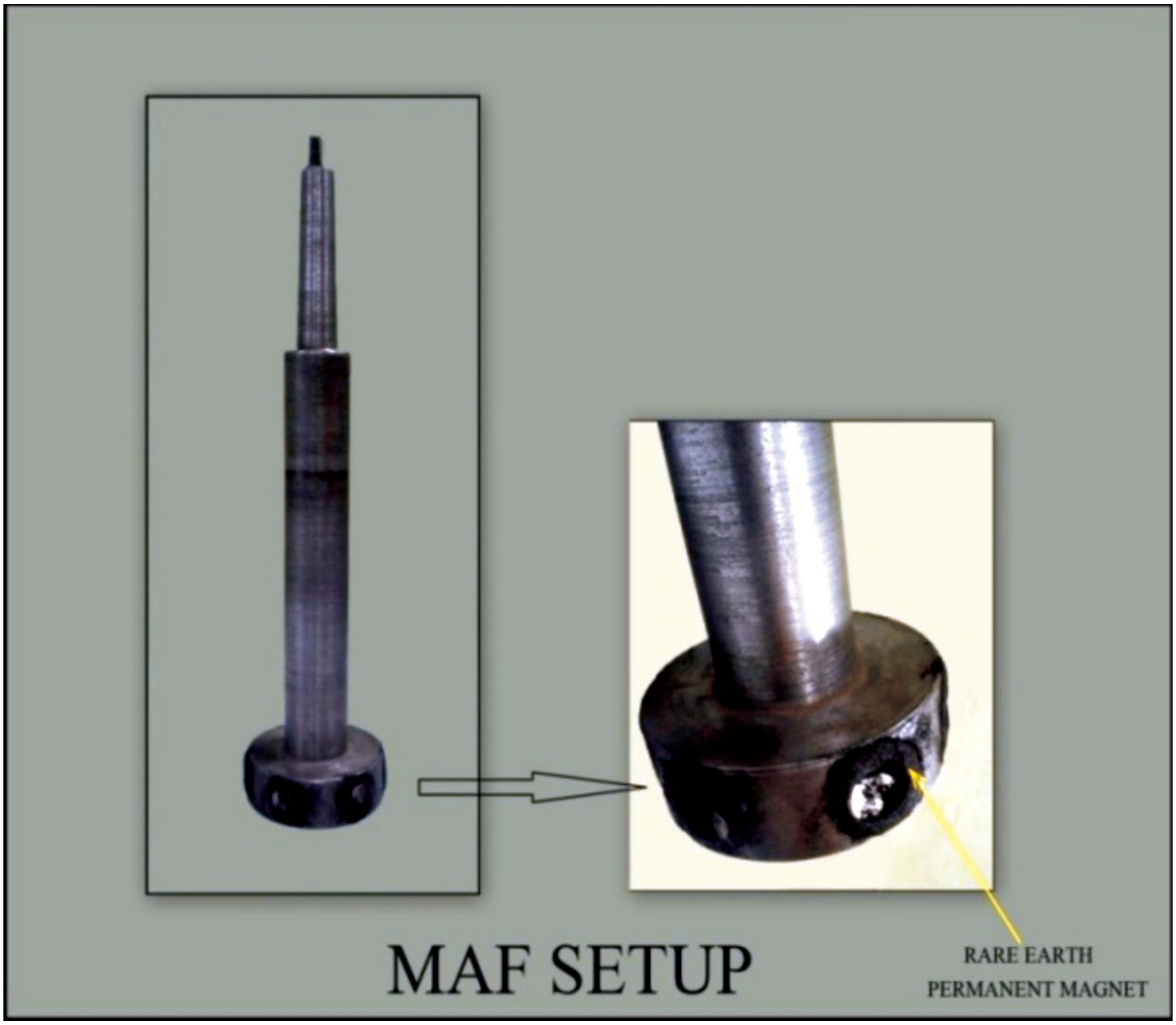


Figure 1 MAF Set up

Before starting experiments, the work piece surface finish is measured. The work piece is fixed between the jaws of bench vice of radial drill machine. The working gap is kept constant during experimentation. The magnetic abrasive powder, which is prepared just before each test by adding the lubricant, is fed to the finishing zone. The rotational motion to the permanent magnets is given through spindle of the radial drill machine. The finishing operation is continued for 300 s, and it is monitored with a stopwatch (0.01 s accuracy) to replace a part of the used magnetic abrasive powder in the finishing zone by the homogeneously sintered fresh (unused) powder. The work piece is taken out from its holder once the finishing operation is over. After cleaning the work piece, its surface finish is measured. Surface finish is measured using a digital surface roughness instrument having a least count of 0.01 μm (cut off length = 0.8 mm). To hold together the mixture of magnetic and abrasive particles for a longer time period as compared to unbounded MAPs, lubricating oil (5 wt.%) is added to the mixture of ferromagnetic and abrasive particles. After addition of oil, mixture forms conglomerate. Fresh sintered abrasive is constantly added to maintain its finishing efficiency. The sintered diamond magnetic abrasive separates as it is attracted to the ends of the six magnetic sections. For the experiments, 4 g of sintered magnetic abrasive (85 wt% iron particles and 15 wt% magnetic abrasive) was introduced. The magnet rotational speeds were varied between 310, 485, 695 and 960 /min.

Finishing Experimental conditions

Material and size of samples	Material: SUS 304 Stainless steel tube Size: OD: 73 mm, ID: 67mm, L: 67mm
Magnetic spindle Revolution	310, 485, 695 and 960 min-1
Working clearance **Magnetic abrasives**	1.5 mm Sintered Iron & Diamond
Lubricant used	Straight oil type grinding fluid:2ml
Processing Time	20, 30, 45 and 60 minutes

Design of Experiments

Response surface methodology (RSM) is used In the present experiment. Four independent parameters, each has four different levels [5] were selected which are: (A) Circumferential speed (rpm), (B) Mesh No. (C) Quantity of abrasives (grams) and (D) Finishing time (Min.).The magnetic abrasive powder used is formed from 85%Fe and 15% Diamond The output data measured is the change in surface roughness (ΔRa) between the arithmetic mean surface roughness (Ra) of the work piece before and after MAF experiments. Surface roughness tester is used to measure the values of Ra at four different places at same line in the work piece after MAF taking the average value and then subtract from the average value of Ra

before MAF which is obtained from 64 readings of *Ra* at different places of the work piece.

Table 2: Level of Independent Variables

Process parameter	Code	Level 1	Level 2	Level 3	Level 4
Rotational speed (RPM)	A	310	485	695	960
Mesh No.	B	44	60	100	160
Quantity of abrasives (gm)	C	20	30	40	50
Finishing time(Min.)	D	20	30	45	60

RESULT AND DISCUSSION

The output response like percentage improvement in surface finish is tabulated and analyzed. Percentage improvement in surface finish is used as a measure of performance of MAF. The results of different experimental investigation carried out under present study are in the form of table, graph and response analysis. The scanning electron microscope images of the magnetic abrasive finished work pieces were taken to provide in depth comparison of the surface generated before and after MAF. The average values of the response characteristics were calculated from experimental data and the response curves were plotted to show variation of process output characteristics. Analysis of variance (ANOVA) on the data was performed to identify the significant parameters and to quantify their effect on the response characteristics. The effect of the individual MAF process parameters on the above mentioned response characteristic is also presented.

Development of Response Surface Model

Second-order response surface models using the process parameter were developed as below.

$$\text{PISF} = +283.032 - 0.410104 * \text{Speed} - 1.42337 * \text{Mesh Number} - 9.29765 * \text{Quantity of Abrasives} + 5.35456 * \text{Finishing Time} + 0.00287525 * (\text{Speed})^2 + 0.00273172 * (\text{Mesh Number})^2 + 0.0859313 * (\text{Quantity of Abrasives})^2$$

- 0.0322124 * (Finishing Time) ² + 0.00136881 * Speed * Mesh Number
+ 0.000441053 * Speed * Quantity of Abrasives – 0.00162316 * Speed *
Finishing Time + 0.0334800 * Mesh Number * Quantity of Abrasives
– 0.0291603 * Mesh Number * Finishing Time + 0.0258798 * Quantity of
Abrasives * Finishing Time. …….. (1)

The coefficients of the independent parameters show the extent of influence of the parameter. Higher the numerical value of a coefficient, greater would be the influence of the parameter. If a coefficient is positive, then with an increase in the value of the parameter, the optimization parameter grows and vice versa.

Analysis of Percentage Improvement in Surface Finish (PISF)

Total 16 experiments were performed to study the effects of various independent variables on % age surface improvement. The independent variables of the process are Circumferential Speed in RPM (A), Mesh Number (B), Quantity of Abrasives in Grams (C) and Finishing Time in Minutes (D). The different tests were applied to select the adequate model that fits the output characteristic namely PISF as shown in Table3. The "Sequential model sum of Squares" test shows how the degrees of polynomial that may be selected for the model contribute to the complexity of the model.

Table 3: ANOVA Results for Percent Improvement in Surface Finish (After Elimination)

Source	DF	Seq SS	Adj SS	Adj MS	F	P-Value Prob>F	
Regression	13	1426.96	1426.96	109.77	68606.25	0.003	Significant
Speed(A)	1	297.10	15.37	15.369	9524.31	0.007	Significant
Quantity of Abrasives (C)	1	1.29	70.16	70.163	43480.65	0.003	Significant
Finishing Time (D)	1	7.28	5.20	5.205	3225.58	0.011	Significant
Speed(A)*Speed(A)	1	1.63	18.79	18.791	11644.95	0.006	Significant
Mesh Number (B)*Mesh Number (B)	1	664.25	95.83	95.827	59384.87	0.003	Significant
Quantity of Abrasives (C)*Quantity of Abrasives (C)	1	49.00	26.19	26.188	16228.94	0.005	Significant
Finishing Time (D)*Finishing Time (D)	1	15.24	19.57	19.575	12130.80	0.006	Significant
Speed(A)*Mesh Number (B)	1	88.83	155.61	155.610	96432.95	0.002	Significant
Speed(A)*Quantity of Abrasives (C)	1	129.41	0.35	0.355	219.99	0.043	Significant
Speed(A)*Finishing Time (D)	1	130.14	112.91	112.911	69971.98	0.002	Significant
Mesh Number (B)*Quantity of Abrasives (C)	1	3.12	22.10	22.096	13693.09	0.005	Significant
Mesh Number (B)*Finishing Time (D)	1	5.02	20.08	20.079	12443.14	0.006	Significant
Quantity of Abrasives (C)*Finishing Time (D)	1	16.00	16.00	16.000	9915.34	0.006	Significant
Residual Error	2	0.00	0.00	0.0016			
Total	15	1426.96					

The effects of interactions of different process parameters such as circumferential speed of the magnet, Mesh Number, Quantity of abrasives and Finishing Time on percent improvement in surface finish (PISF) were analyzed using Response Surface Methodology (RSM). The process yielded best results at Speed (A) - 310 rpm, Mesh Number (B)- 44 Mesh, Quantity of Abrasives (C) - 20 grams, Finishing Time (D) - 20 minutes. The 3D graphs show the effect of simultaneous variation of two factors on PISF.

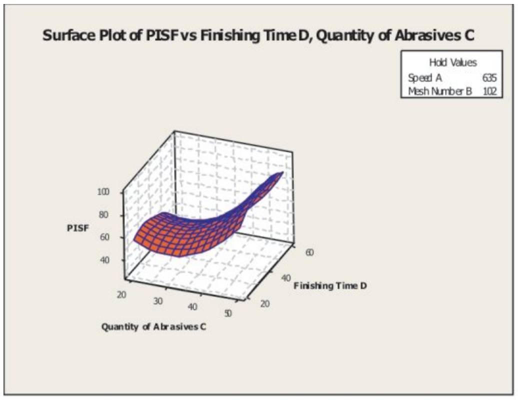


Figure 2: Surface Plot of %age improvements in Surface finish Vs FinishingTime & Quantity No. of Abrasives.

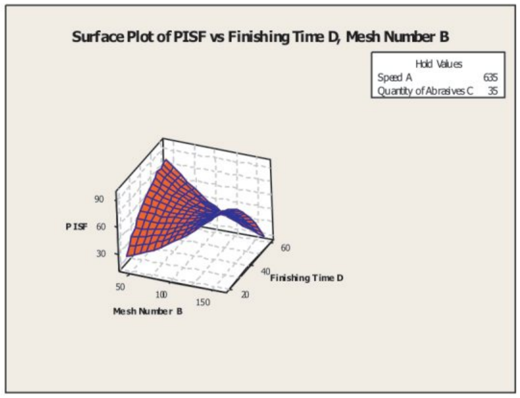


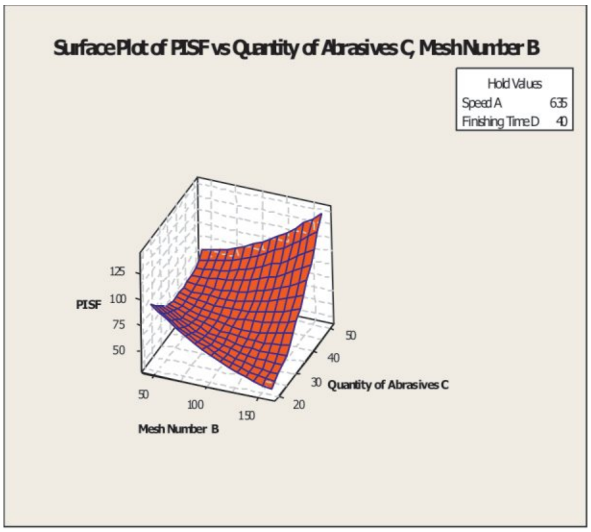
Figure 3: Surface Plot of %age improvement in Surface finish Vs Finishing Time & Mesh

Figure 2 shows the relationship between the Quantity (C) and Finishing Time (D), keeping the value of Speed (A) & Mesh Number (B) to a constant level. As the Finishing time increases at higher level of quantity of abrasives, the surface finish improves but decreases at lower levels of quantity between 25 gm and 30 gm. The surface finish is better at higher values of quantity, and as the finishing time increases the surface finish increases. Figure 3 shows the relationship between the Mesh Number (B) and Finishing Time (D), keeping the value of Speed (A) & Quantity of Abrasive (C) to a constant level. As the Finishing time and Mesh Number increases, the surface finish improves but start decreasing at higher levels of Mesh Number and finishing Time. With increasing the value of Mesh Number & Finishing Time, the value of PISF goes on increasing at different rates, reaches maximum value before it starts decreasing.

Figure 4 shows the relationship between the Mesh Number (B) and Quantity of Abrasive (C), keeping the value of Speed (A) & Finishing Time (D) to a constant level. As the Quantity of Abrasives increases, the surface finish improves but start decreasing at higher Mesh Number.

Figure 5 shows the relationship between the Rotating Speed (A) and Finishing Time (D), keeping the value of Quantity of Abrasives (C) & Mesh Number (B) to a constant level. As the Finishing time and Circumferential speed increases, the surface finish improves but start decreasing between speed level 500 rpm – 600 rpm of Circumferential Speed. With the increasing value of Circumferential Speed and Finishing Time, the value of PISF goes on increasing at different rates and reaches maximum value.

Figure 6 shows the relationship between the Rotating Speed (A) and Mesh Number (B), keeping the value of Quantity of Abrasives (C) & Finishing time (D) to a constant level. As the Mesh Number and Circumferential speed increases, the surface finish improves but start decreasing between speed level 600 rpm to 800 rpm of Circumferential Speed. With the increasing value of Circumferential Speed above 800 rpm and Mesh Number, the value of PISF goes on increasing at different rates and reaches maximum value.



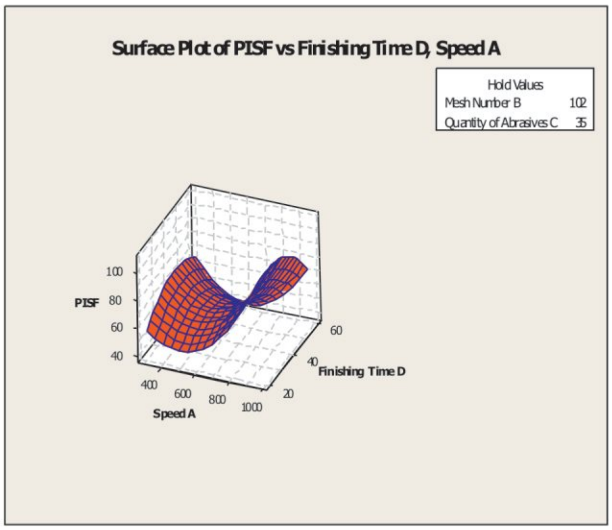


Figure 4: Surface Plot of %age improvement in Surface finish Vs Mesh Number & Quantity of Abrasives.

Figure 5: Surface Plot of %age improvement in Surface finish Vs Finishing Time & Speed.

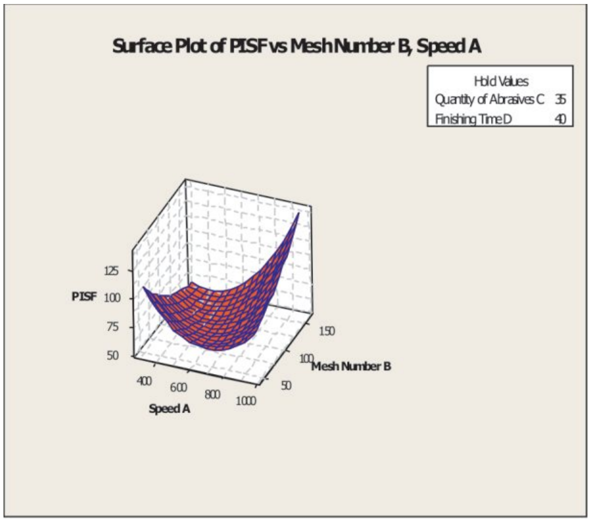


Figure 6: Surface Plot of %age improvement in Surface finish Vs Mesh Number & Speed

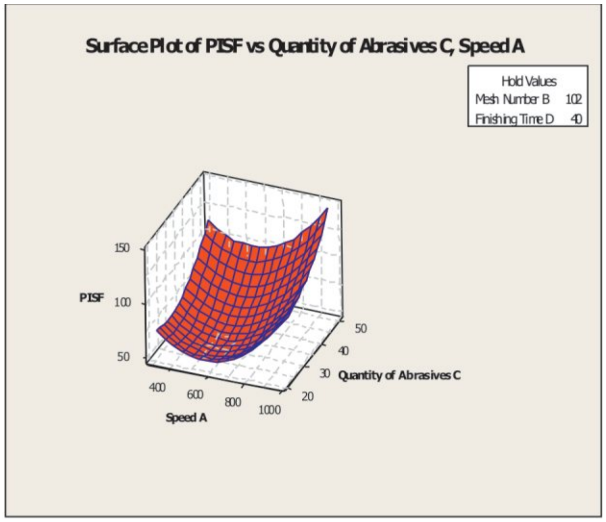


Figure 7: Surface Plot of %age improvement in Surface finish Vs Quantity of abrasives & Speed.

Figure 6 shows the relationship between the Rotating Speed (A) and Mesh Number (B), keeping the value of Quantity of Abrasives (C) & Finishing time (D) to a constant level. As the Mesh Number and Circumferential speed increases, the surface finish improves but start decreasing between speed level 600 rpm to 800 rpm of Circumferential Speed. With the increasing value of Circumferential Speed above 800 rpm and Mesh Number, the value of PISF goes on increasing at different rates and reaches maximum value. Figure 7 shows the relationship between the Rotating Speed (A) and Quantity of Abrasives (C), keeping the value of Mesh Number (B) & Finishing time (D) to a constant level. As the Mesh Number and Circumferential speed increases, the surface finish improves remarkably and the value of PISF goes on increasing at different rates and reaches maximum value.

Micro structural Examination

Scanning Electron Microscope

The surface structure was analyzed by SEM before and after finishing SUS 304 Steel tube. The typical SEM micrographs of as received after boring the work piece and magnetic abrasive finished surfaces are shown in the figures. The initial surface profile has periodic peaks and valleys generated by boring. The observations reveal that finishing of work piece surface in the process is done by scratching or micro-cutting. It is quite clear from the figure 9 that the deep cutting marks left by the boring operation have been removed and replaced by the new texture generated during the MAF process as shown in figure 8 and 9 but fine scratching marks produced by MAF appear on the surface. Most of the peaks have been sheared off to much smaller height by MAF resulting in improved surface finish. Moreover, the micrograph reveals clearly the presence of unfinished surface with non uniformity over the outer layer of the work piece (Figure 8). Some deep scratches appear when finishing operation was performed at higher rotational speed. Also some scratches can be seen when finishing was performed using greater finishing time.

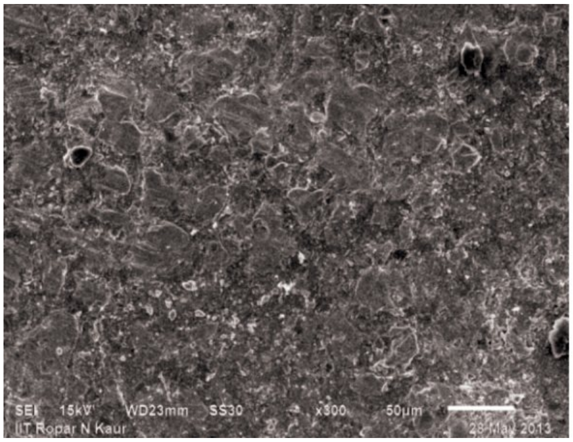


Figure 8 SEM microphotograph of surface finished by boring (Average Ra = 4.58µm)

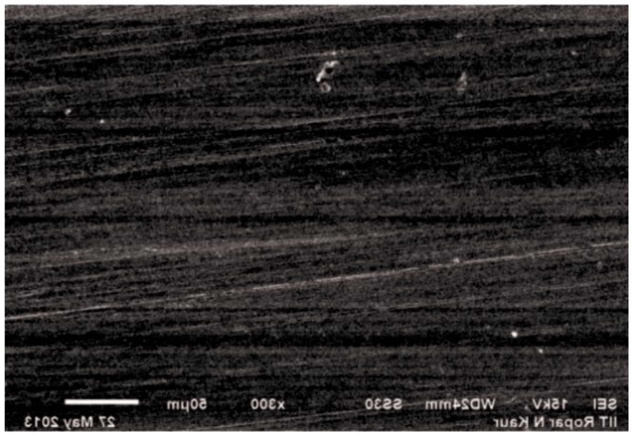


Figure 9 SEM microphotograph of surface finished by MAF at speed 310 rpm, 44 Mesh, 20 gms of abrasive quantity, 20 Min. finishing time (Avg. Ra =0.26µm)

CONCLUSION

The following conclusions are drawn from the present study on 'Internal finishing of Stainless Steel (SUS304) thick tubes using Magnetic Abrasive finishing.' Rotational speed (A), Mesh Number (B), Quantity of Abrasives (C) and Finishing Time (D) is effecting the percentage improvement in surface finish (PISF).The parameters Quantity of Abrasives (C), Finishing Time (D) and Mesh No. (B) significantly effect the percentage improvement in surface finish (PISF). There is a significant effect of interaction of Circumferential Speed (A), Mesh No. (B), Quantity of Abrasives (C) on %age improvement in surface Finish. The process yielded best results at Speed (A)- 310 R.P.M., Mesh Number

(B)- 44 Mesh, Quantity of Abrasives (C) 20 grams, Finishing Time (D) 20 minutes.The SEM analysis shows that the finished surfaces have fine scratches/micro cuts which are farther distant apart resulting in smoothened surface.

ACKNOWLEDGEMENTS

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Wear Behaviour of Aluminium Matrix Composites Reinforced With Nano Sized Alumina And Silicon Carbide

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ABSTRACT

Aluminium based matrix composites (AMCs) possess tremendous potential for number of applications in addition to their present uses in different engineering fields. In the present study, aluminium composite with 10 % by weight reinforcement of nano sized Al_2O_3 and SiC was prepared using a cost effective stir casting technique. Testing of wear behavior was done on pin on disc apparatus. The fabricated composites showed improvement in wear resistance over the pure aluminum metal. Considering all the factors, it can be concluded that aluminium based composite with 10% by weight SiC (nano) reinforcement possess better mechanical and wear resistance properties as compared to other fabricated composites like pure aluminium and Al + Al_2O_3 (nano) composites.

Keywords: Stir Casting, Scanning Electron Microscopy, Wear, hardness.

INTRODUCTION

The term "Composites" can be defined as material system which is composed of the reinforcement distributed in the matrix and which derive its unique characteristics from the properties of its different constituents, from the architecture and the geometry of the constituents of composites and from the interfaces between the different constituents (**Surappa,2003**). Aluminium Matrix Composites (AMCs) offer solution to common problems i.e. strength to weight ratio and wear resistance (Taha et.al,2008). In AMCs one of the main constituent is aluminium or aluminium alloy, which is matrix phase. Another constituent is implanted in the aluminium or aluminium alloy matrix and serves as the reinforcement which is usually ceramic and non - metallic such as SiC and Al_2O_3. Properties of AMCs can be enhanced by changing the nature of constituents and volume fraction of the constituents. Mechanical properties of composites such as strength and ductility may be improved, simultaneously if the dispersed particles are of nano size (Sajjadi et al.2012). Nano composites have become an important area of research studied more widely in academic, government and industrial laboratories. The development of metal matrix nano composites is rapidly emerging as a multidisciplinary research activity whose results could broaden the applications of nano composite to the great benefit of many different industries. The reinforcements of Aluminium composite involve particle size ranging from around 10nm to 500µm. Composite with dispersion of particles in the range of 10 nm to 1µm are termed as "nano composites" (Luster et al.1953)

PREVIOUS RESEARCH

Sajjadi et al.(2012) carried out tensile, hardness and compression tests in order to identify mechanical properties of the composites. The addition of alumina (micro and nano) led to improvements in yield strength, ultimate tensile strength, compression strength and hardness. Emara (2015) evaluated the influence of aluminium oxide particle size on the dimensional stability of pure aluminium matrix. The results showed that effect of nano sized Al_2O_3 on linear thermal expansion of Al are much higher than that of micro sized Al_2O_3. Parvin and **Rahiman(2012)** investigated the influence of Al_2O_3 particle size on the hardness, yield stress, density, microstructure, elongation and compressive strength of sintered Al-Al_2O_3 composites. Compressive strength and yield stress were found higher with Al_2O_3 reinforcement addition. Aliyu et al.(2015) revealed that the low hardness and strength of aluminum, which limits its use in many industrial applications, could be increased through the addition of nano particles. Koli et al. (2013) revealed that mechanical properties of pure aluminium can be enhanced with reinforcement of nano alumina particles. Higher hardness was achieved when the size of reinforcement was small and its volume fraction was high. Nano structured materials have many better properties over conventional coarse-grained material including the good corrosion resistance, improved ductility, hardness, toughness and strength etc.

SYNTHESIS OF NANO SIZED ALUMINA AND SILICON CARBIDE POWDER

Nano structured materials are characterized with grain size less than 100 nm in at least one dimension. When the grain size becomes smaller, more atoms are associated with grain boundaries. Thus, the properties of nano structured material are altered by the grain size effect due to the large volume fraction.

The ball milling machine is used to convert the micron size particles into the nano size particles because of its simplicity. SiC was taken of 400 mesh size and Al_2O_3 was taken of 100-300 mesh size. SiC and Al_2O_3 powder has been converted into the near nano material with the help of ball milling process by using the 20 tungsten carbide ball of diameter 5mm.

Figure 1 Ball Milling Machine

The ball to powder ratio (BPR) for the ball milling was kept 10:1. The rotational speed was 400 rpm and to decrease the temperature, the process was stopped after each 30 minute for 2 minutes. The particles were repeatedly welded; fractured and welded during the process as a result the particle size gets reduced. The milling was done for 15 hr to know the size of the powder. The powders were taken from the vials for the characterization. Scanning electron microscopy was used to study the morphological changes that occurred during the mechanical milling/alloying of the nano sized SiC powder and Al_2O_3 powder. During the milling of the powder, the powder gets crushed. The figure 2 shows the scanning electron microscopy image of 15 hr milled Al_2O_3 powder.

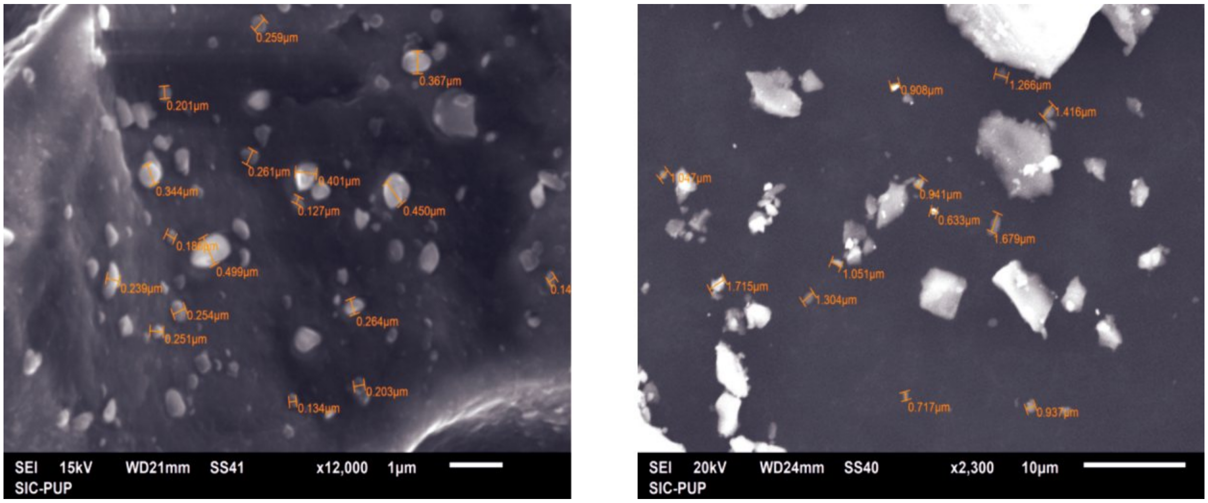

Figure 2 SEM after 15 hr of SiC powder and SEM after 15 hr of Al_2O_3 powder

From the scanning electron microscopy, it is evident that the powder size reduces from micron size to the near Nano size at 15 hr. This decrease in size occurs due to the impact of the balls on the powder as a result of which the powder between the balls and vial get crushed and reduction of the powder size takes place.

EXPERIMENTATION

A. Stir Casting

Stir casting method used for fabrication of composites. In this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. The particles transfer into matrix melt due to the pressure difference between the inner and outer surface of the melt.

B. Specimen preparation

Step1. Samples of nano sized SiC/Al_2O_3 were taken 10% by weight.

Step2. Al metal was cut into small strip. According to the weight of metal (Al) required, samples of Al were prepared.

Step3. Simultaneously furnace was switched on for preheating to remove the moisture.

Step4. Metal (Al) was now placed in the crucible present in furnace.

Step5. Furnace was allowed to heat up to 750^{o}C for melting of metal (Al).

Step6. In between when the temperature of furnace reached 600^{0}C, mould was placed in another furnace generally used in labs i.e. Muffle Furnace for preheating.

Step7. Along with the mould, 10 % by weight nano sized SiC/Al_2O_3 was also placed in the muffle furnace for preheating.

Step8. Now stirrer blade and shaft was also preheated so that molten metal does not stick to it.

Step9. After continuously heating Al for 1 hour at 750^{o} C, nano sized SiC/Al_2O_3 was poured in to the crucible for mixing with Al. For proper mixing of nano sized SiC/Al_2O_3 with Al, Stirring was done for about 20 minutes.

Step10 Mould was taken out of the muffle furnace

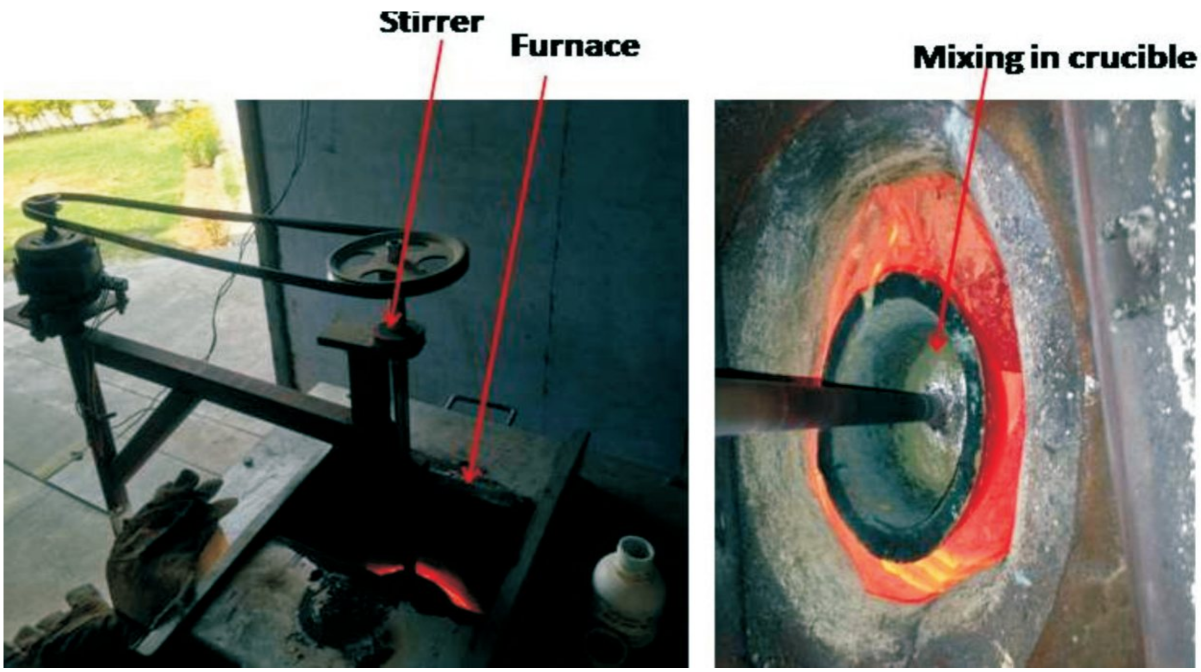

Figure 3 Stirring Process in Furnace

Step11. Crucible was taken out of the furnace & the mixture or composite so prepared was poured into the mould

Step12. Mould was now allowed to cool down for about 15-20 minutes and then the specimens were taken out of the mould for further cooling

Step13. Then the specimens were cut down into desired pieces for their further testing

RESULTS

A. Wear Behavior

The pure Al, Al+Al_2O_3 (nano), Al+SiC (nano) composite specimens were subjected to standard sliding wear testing on a pin-on disk apparatus (ASTM standard G99-03) as per the procedure. The digital weighing scale used to take readings after every 2 minutes. The wear tests were done for two normal loads of 3 Kg and 2Kg at constant speed 500 RPM. The cumulative wear rate with load has been plotted in subsequent graphs.

B. Wear behavior of composites reinforced with Al_2O_3 (nano) and SiC (nano) at normal load 3 Kg

The variation of cumulative wear rate with the time interval for composites reinforced with Al_2O_3 (nano) and SiC (nano) at 3 Kg load has been compared been with the pure aluminium as shown in figure 3. Plot given below shows that nano sized SiC shows the least wear rate.

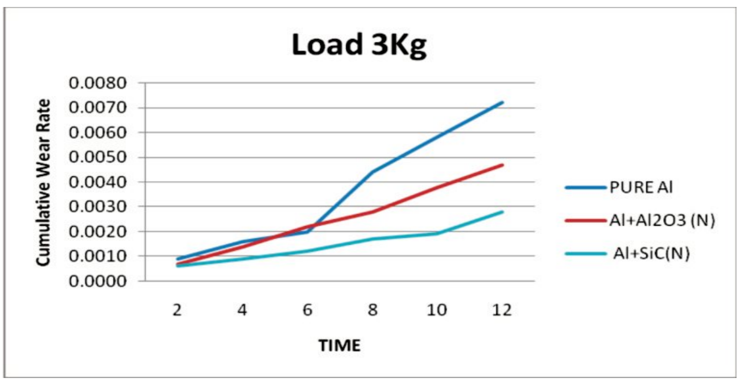

Figure 3 Comparison graph showing Cumulative wear rate of pure Al, Al+Al_2O_3 (nano), Al+ SiC (nano) at normal load of 3Kg

A. Wear behavior of composites reinforced with Al_2O_3 (nano) and SiC (nano) at normal load 2 Kg

The variation of cumulative wear rate with the time interval for composites reinforced with Al_2O_3 (nano) and SiC (nano) at 2 Kg load has been compared been with the pure aluminium as shown in figure 4. Plot given below shows that nano sized SiC shows the least wear rate.

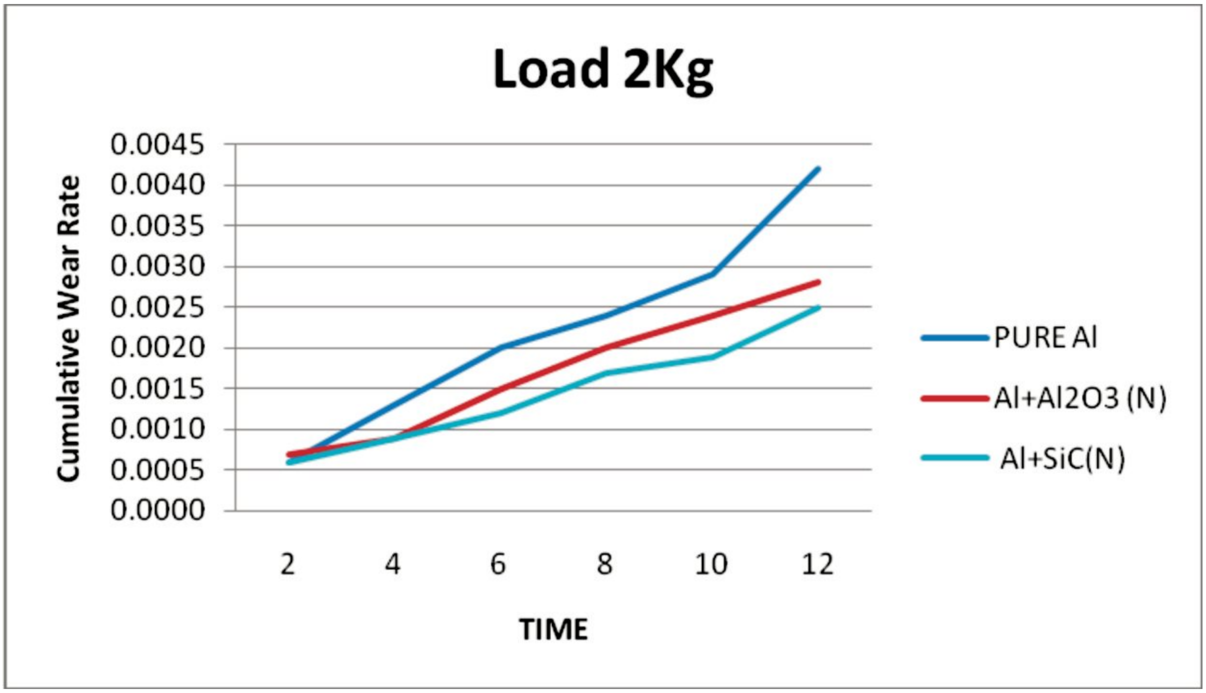

Figure 4 Comparison graph showing Cumulative wear rate of pure Al, Al+Al_2O_3 (nano), Al+ SiC (nano) at normal load of 2Kg

The wear rate of aluminium matrix composites with reinforcement of nano sized particles of Al_2O_3, and nano sized particles of SiC were compared with the wear rate of pure aluminium at 500 RPM and at two different loads i.e. 3Kg and 2 Kg. It was found that at the lower load the wear rate is also lower and then it increases slowly. And it can be seen in figure that the wear rate is extremely high in case of pure aluminium than in case of composites with different reinforcements. It can be concluded that wear rate trend in above figure follows the trend – Pure Al, Al-Al_2O_3 (nano sized) > Al-SiC (nano). The increase in wear rate in case of nano composites is due to higher hardness value of nano composites.

SEM ANALYSIS OF THE WORN SURFACE OF THE SPECIMEN

SEM micrographs of the pure Al, Al+ SiC (nano), Al+Al_2O_3 (nano) are showed that all have specimen have suffered significant damage of its surface in the form of craters or micropits. Figure 5 shows the micrograph for pure Al in which grooves formed can clearly be seen along with the grooves. Most of the grooves are parallel to the sliding direction; it is evident from the worn pins. Such features are characteristics of abrasion, in which hard asperities of the steel counter face, or hard reinforced particles in between the contacting surfaces, plough or cut into the pin, causing wear by the removal of small fragments of material. Similar wear behavior has also been seen in Figure 6 which is the micrograph of Al+Al_2O_3 (nano) composite in which cavities formed due to abrasive wear are shown are clearly seen. Lower wear rates in composites at higher load can be attributed to a transfer layer of compacted wear debris along with the wear tracks can be observed over the sliding surface (Nag, 2013)

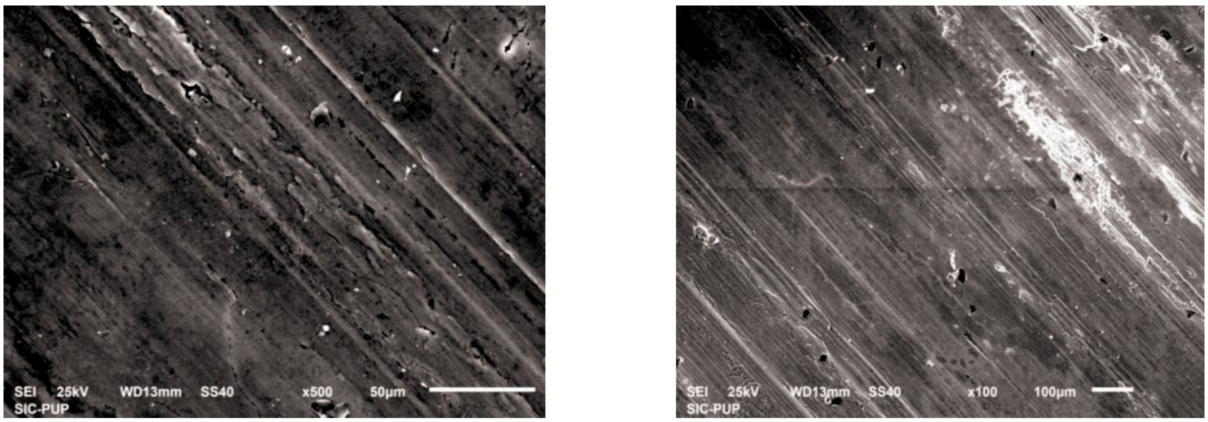

Figure 5 - SEM micrographs of Pure Al

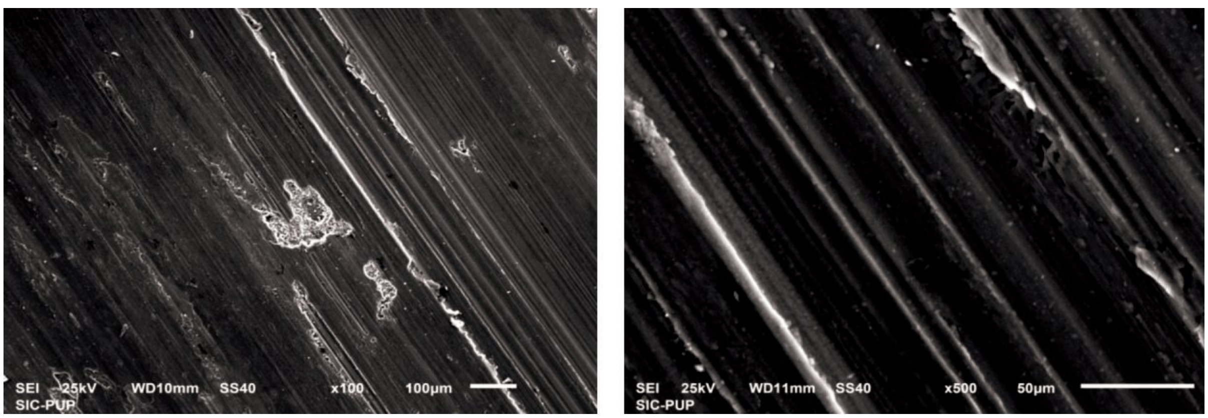

Figure 6 SEM micrographs of Al + SiC (nano)

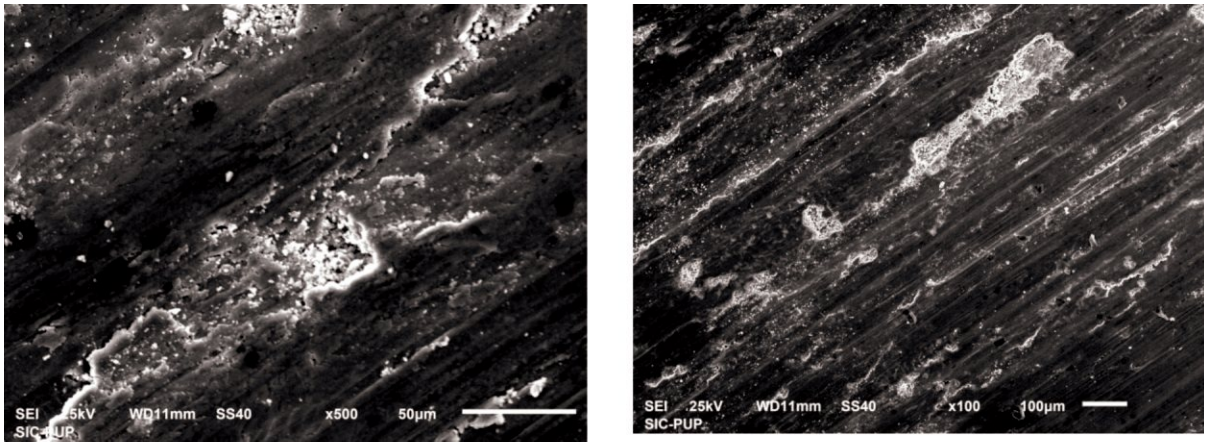

Figure 7 SEM micrographs of Al + Al_2O_3 (nano)

CONCLUSION

1. Wear resistance of Al-SiC (Nano) was found to be highest, while pure Al showed lowest wear resistance. The rate of wear is extremely higher in case of pure aluminium than the composites.
2. Wear rate is found is to be lower in case when lower load is applied while testing.
3. The wear resistances of the Pure Al, Al+Al_2O_3, Al + SiC and Al + SiC (Nano), Al + Al_2O_3 (Nano) composites at normal load of 3 Kg and 500 RPM followed the trend given below:-
   Pure Al < Al-Al_2O_3 (nano sized) < Al-SiC (nano).
4. SEM micrographs of the worn surfaces of the specimens have revealed the formation of craters along with the presence of grooves parallel to the sliding direction which is the result of abrasion by hard asperities of the steel counter face, or hard reinforced particles in between the contacting surfaces cutting into the pin.

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To Study The Effect of Holding Time And Holding Temperature On Hardness And Micro Structure of Alloy Steel Aisi4340

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ABSTRACT

AISI 4340 steel is a widely-used low-alloy steel that provides an advantageous combination of strength, ductility and toughness. AISI 4340 steel can be heat treated to provide a wide range of hardness values. Important properties such as hardness, strength and toughness are greatly influenced by heat treatment processes. It is widely employed for the production of automobile and machine tool parts such as axle shafts, main shafts, spindles, gears, power transmission gears and couplings.

The present work investigates the effect of holding time and holding temperature on hardness,microstructure and tensile strength of AISI 4340 alloy steel at different levels of holding time and temperature. The alloy steel AISI 4340 of circular cross-section has been cut into the specimens to carry out the heat treatment. The different specimens of base alloy are heat treated by Quenching and Tempering to vary the levels of hardness.During tempering three levels are defined for each specimen. Two factors are selected on the basis of work piece material, chemical composition and guidelines by the previous research work. Taguchi's L-9 orthogonal array is selected for plan of experiments.

Higher hardness is observed in workpiece which were quenched but after tempering hardness decreases and tensile strength decreases with increases holding time of workpiece with constant temperature

Keywords: Holding Time and Holding Temperature;Heat treatment;Hardness;Microstructure.,Tensile Strength

INTRODUCTION

Many properties, when in service, are subjected to forces or loads; examples include the aluminium alloy from which an airplane wing is constructed and the steel in an automobile axle. In such situations it is necessary to know the characteristics of the material and to design the member from which it is made such that any resulting deformation will not be excessive and fracture will not occur. To understand the material properties of metals during deformation over a wide range of loading conditions is considerable for engineering applications. The mechanical behavior of a material reflects the relationship between its response of deformation to an applies load or force. Important mechanical properties are strength, hardness, ductility and stiffness.(Boakye-Yiadom et al., 2011)

When discussing high strength steel, it is crucial to realize that the definition of so-called high strength depends upon how the steel is to be used. Works being carried out to develop higher strength steels have to take the manufacturing processes, the heat treatment and the alloying technology into consideration. There are several structures in steel like ferrite /pearlite, bainite, martensite and austenite. To obtain highest strength in steel, generally quenching and tempering are introduced.(Boakye-Yiadom et al., 2011)

Materials and metallurgical engineers are concerned with producing and fabricating materials to meet service requirements are predicted by these stress analysis. This necessarily involves an understanding of the relationships between the microstructure of materials and their mechanical properties(Boakye-Yiadom et al., 2011).There are number of properties that are measured in laboratories for the purpose of comparing materials like Mechanical properties, Chemical properties, physical properties, Electrical properties.

Heat treatment may be defined as an operation involving the heating of solid metals to definite temperatures, followed by cooling at suitable rates in order to obtain certain physical properties which are associated with changes in the nature, form, size and distribution of the micro-constituents. Heat treatment is very important process in the various manufacturing and fabrication operations (Machado ,2006).

The theory of heat treatment is based on the principal that when an alloy has been heated above a certain temperature, it undergoes a structural adjustment or stabilization when cooled to room temperature. In this operation, the cooling rate plays an important role on which the structural modification is mainly based. For steel the eutectoid reaction in the iron-carbon diagram involves the transformation and decomposition of austenite into pearlite, cementite or martensite (Bassin et al.2008).

PROBLEM FORMULATION

There are several structures in steel such as ferrite, pearlite, martensite and austensite. Each of them has different mechanical properties. It is possible to obtain the highest strength from any one of these structures. Generally ,quenching and tempering are introduced to produce strengthening in steel which can be achieved mainly due to the precipitataion of a fine dispersion of alloy carbides during tempering. The martensite structure is rarely used in an untempered condition because a large number of internal stresses associated with the transformation cause the material to be lacking in ductility. However ,low-temperature tempering is sufficient to reduce these stresses considerably without essentially changing the basic features of the martensitic structure. The effect of tempering temperature ,the strength of the martensitic structure is dominated by the carbon content and the temperature range. In the case of low-carbon content martensite, the martensite units form in the shape of lath, grouped into larger sheaves or packets. In the case of high-carbon steels and iron alloys below the ambient, their structure is plate martensite which consists of very fine twins with a space of about 50A.However,in the case of medium-carbon steels, they may contain a mixture of lath and plate martensite, their structure is more complicated. Theses results indicates the mechanical behavior of a quenched and tempered steel depends on its microstructure. Thus, the study of effects of a steel on its strength, fracture characterstics is of great importance from the viewpoint of theory and practice. AISI 4340 steel is widely used low-alloy martensitic steel that provides an advantageous combination of strength, ductility and toughness for the applications of machine part-members, t is susceptible to embrittlement during the tempering procedure within a specified temperature range. In order to prevent this, a study on the microstructure and mechanical properties of AISI 4340 steel under different tempering conditions become necessary.

EXPERIMENTATION

In the present thesis work, the alloy steel AISI 4340 of circular cross-section with 25mm diameter and 20 feet length has been taken. Then the circular bar is cut into the specimens of 25 mm diameter and 150 mm length to carry out the heat treatment and turning operation.The procedure for preparing the specimens:-

The alloy AISI 4340 was cut into pieces of 25mm diameter and 150 mm length from full length bar.

These pieces were machined on ordinary lathe for primary finishing without coolant for experimental work.

After primary machining the heat treatment was performed on the specimens.

Some of the specimens were prepared to check the hardness and chemical composition of base metal.

Fig.1: shows the specimens of alloy steel 4340

HEAT TREATMENT

In this study, three set of specimens (each set having 9 samples) having 25mm diameter and 150 mm length made of AISI 4340 alloy steel were used. Heat treatment was performed in electrical furnace at **CTR, Ludhiana**. For hardening, one specimen were heated to 880 °C for 30 minutes and quenched in brine water. The other samples of specimens were heated for tempering at different temperatures for 1,4 and 7 hour and cooled in still air at room temperature.

TEMPERING CONDITIONS

The factors and levels of tempering are chosen from research papers (Yiadom S.B.,(2010), Khani *et al*.2012). These are shown in table 4.3.

Table 1: Tempering conditions for alloys

Tempering conditions	Level 1	Level 2	Level 3
Holding Time	1	4	7
Holding temperature Holding temperature	350 500	350 500	350 500
Holding temperature	600	600	600

The Taguchi method with L-9 orthogonal array were used to reduce number of experiments. The first column, second column of L-9 orthogonal array were assigned to holding temperature and holding time respectively and accordingly 9 experiments were performed under different combinations of the factor levels as shown in table 4.4. (Gupta *et al.* 2011)

Table 2: Experimental layout plan of L-9 Taguchi orthogonal array

Experiment Perform	Holding Time	Holding Temperature
1	1	350
2	1	500
3	1	600
4	4	350
5	4	500
6	4	600
7	7	350
8	7	500
9	7	600

HARDNESS MEASUREMENT

In general hardness usually implies a resistance to deformation. The harder is the metal, more it resists scratching, wear and penetration, machining and cutting. Hardness measurement can provide the information about the cutting forces of the material. The hardness of the alloys was evaluated using Rockwell hardness tester (RASNB) as shown in figure 4.9 and 150 Kgf load was applied on the indenter penetration.(**Qura'n,2009)**

Figure 2: Hardness Tester used to measure the hardness of different alloys

The hardness of base alloy and new alloys prepared after heat treatment has been studied by using hardness tester.

TENSILE STRENGTH

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.[Dhua *et al.*2011]

The most common type of test used to measure the mechanical properties of a material is the Tension Test.

Tension test is widely used to provide a basic design information on the strength of materials and is an acceptance test for thespecification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS), yield strength or yield point (σy), elastic modulus (E), percent elongation (L%) and the reduction in area (RA%). Toughness, Resilience, Poisson's ratio(ν) can also be found by the use of this testing technique.

RESULT AND DISCUSSIONS

HARDNESS

The variation in hardness before and after heat treatment of base alloy (Alloy A) and heat treated base material (Alloy B, C1 to C9) has been shown in table 5.1 and figure 5.1. The hardness of the alloys is found between 12.33 and 56 HRC. After tempering, the hardness of base material increases from 12.33 HRC to 50.33 HRC. Due to tempering uniformly distributed tempered martensite was formed. This martensitic structure is much harder than pearlite and ferrite structures (**Qura'n ,2009)**. So, the formation of martensite results in higher hardness of Alloy B. After Quenching the hardness of base material increases from 12.33 HRC to 56 HRC. Generally Quenching are well established means to produce strengthening in steel which can be achieved mainly due to the precipitation of a fine dispersion of alloy carbides. Due to quenching, the microstructure of the material form into martensite as a fine, needle-like grain structure was formed. uniformly distributed pearlitic ferritic structure with fine grain structure was formed. After tempering hardness value varies from 41.66 to 50.33. Tempering is done to release the stresses from hardened pieces , due to which pieces become less harder.

Table 3: Variation of hardness in different alloys.

Alloys	Heat treatment process	Hardness (HRC)
Alloy A	Base Alloy (As Brought)	12.33
Alloy B	Hardening	56
Alloy C1	Tempering (At 350^0C temperature for 1 Hour)	50.33
AlloyC2	Tempering (At 500^0C temperature for 1 Hour)	49.33
AlloyC3	Tempering (At 600^0C temperature for 1 Hour)	47.33
AlloyC4	Tempering (At 350^0C temperature for 4 Hours)	46.33
AlloyC5	Tempering (At 500^0C temperature for 4 Hours)	45.33
AlloyC6	Tempering (At 600^0C temperature for 4 Hours)	43.66
AlloyC7	Tempering (At 350^0C temperature for 7 Hours)	42.33
AlloyC8	Tempering (At 500^0C temperature for 7 Hours)	41.66
AlloyC9	Tempering (At 600^0C temperature	38.33

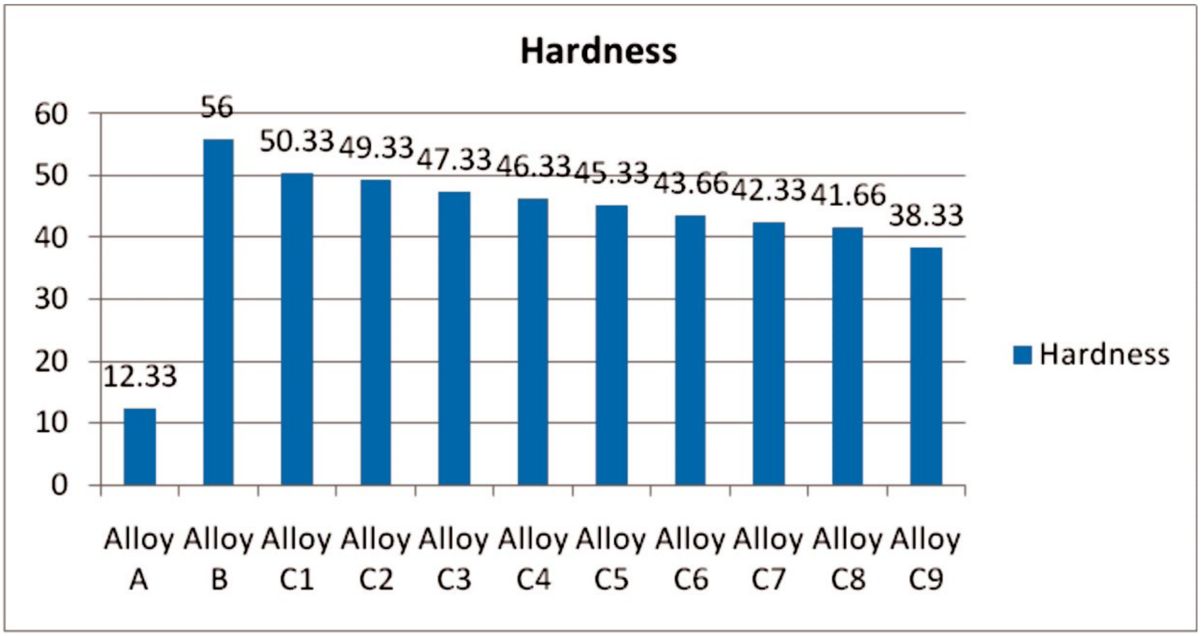


Figure 3 : Shows the variation hardness in different alloys

Alloy	Holding Time	Holding Temperature	Hardness	S/N Ratio
Alloy C1	1	350	50.33	34.0365
Alloy C2	1	350	49.33	33.8622
Alloy C3	1	350	47.33	33.5027
Alloy C4	4	500	46.33	33.3172
Alloy C5	4	500	45.33	33.1277
Alloy C6	4	500	43.33	32.8017
Alloy C7	7	600	42.33	32.5330
Alloy C8	7	600	41.66	32.3944
Alloy C9	7	600	38.33	31.6708

Table 4 :The result of experiments for Hardness and S/N ratio values obtained at temperature 350^0,500^0,600^0 Cfor (1,4,7) hrs of holding time of alloys.

Level	Holding Time	Holding Temperature
1	33.80	33.30
2	33.08	33.13
3	32.20	32.66
Delta(?)	1.60	0.64
Rank	1	2

Table 5: S/N response table for Hardness of Alloys

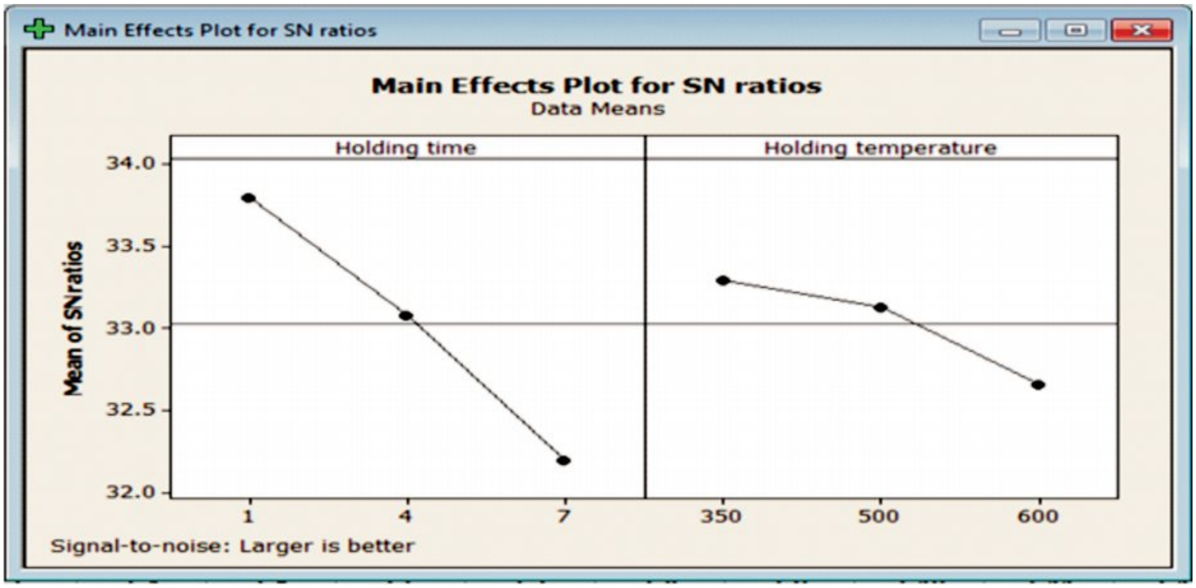


Figure 4: Shows the S/N ratios for holding time And temperature for Hardness

Table 6 :Analysis of Variance for Hardness,using Linear general method for Alloys

Source	DF	Sum OF squares	Mean of squares	F	P
Holding Time	2	101.533	50.767	236.46	0.000
Holding Temperature	2	16.626	8.313	38.72	0.002
Error	4	0.859	0.215	-	-
Total	8	119.018	-	-	-

Table 7: The result of experiments for impact test ,tensile test and S/N ratio values obtained at temperature 350^0,500^0,600^0 Cfor (1,4,7) hrs of holding time of alloys

Alloy	Holding Time	Holding Temperature	Tensile strength	S/N Ratio
Alloy C1	1	350	1737.1	64.7965
Alloy C2	1	500	1396.9	62.9033
Alloy C3	1	600	1258.8	61.9991
Alloy C4	4	350	1696.1	64.5890
Alloy C5	4	500	1361.7	62.6816
Alloy C6	4	600	1211.4	61.6658
Alloy C7	7	350	1657.4	64.3885
Alloy C8	7	500	1354.4	62.6349
Alloy C9	7	600	1154.4	61.2471

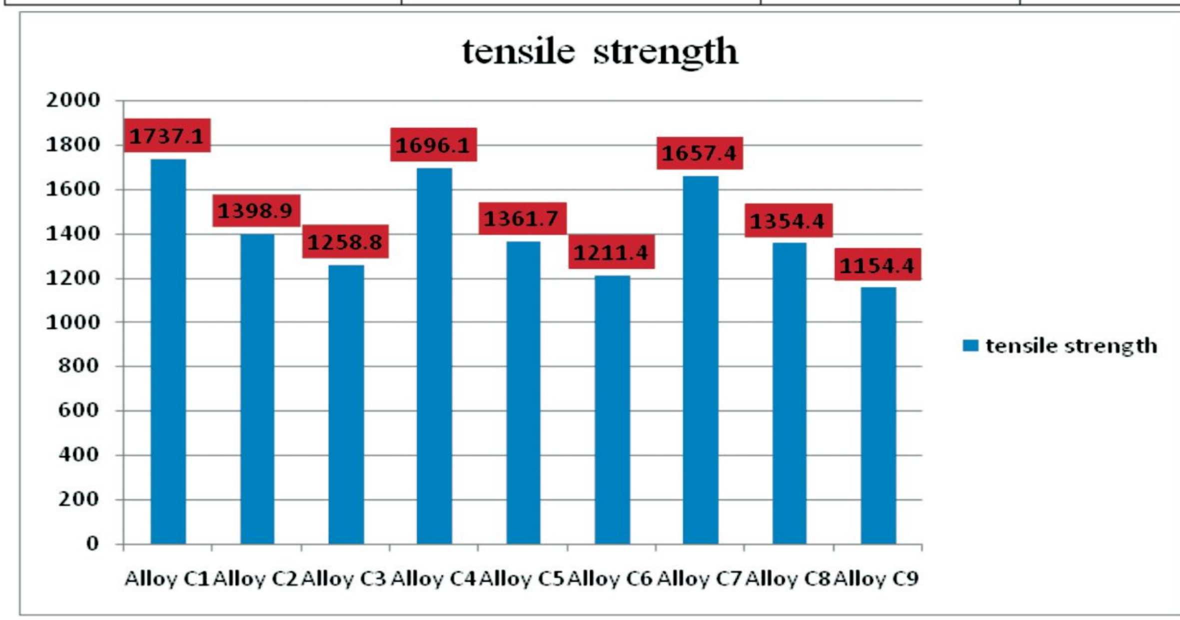


Figure 6 : Shows the variation hardness in different alloys

Table 8: S/N response table for Tensile Test of Alloys

Level	Holding Time	Holding Temperature
1	63.23	64.59
2	63.98	62.74
3	62.76	61.74
Delta(?)	0.48	2.94
Rank	2	1

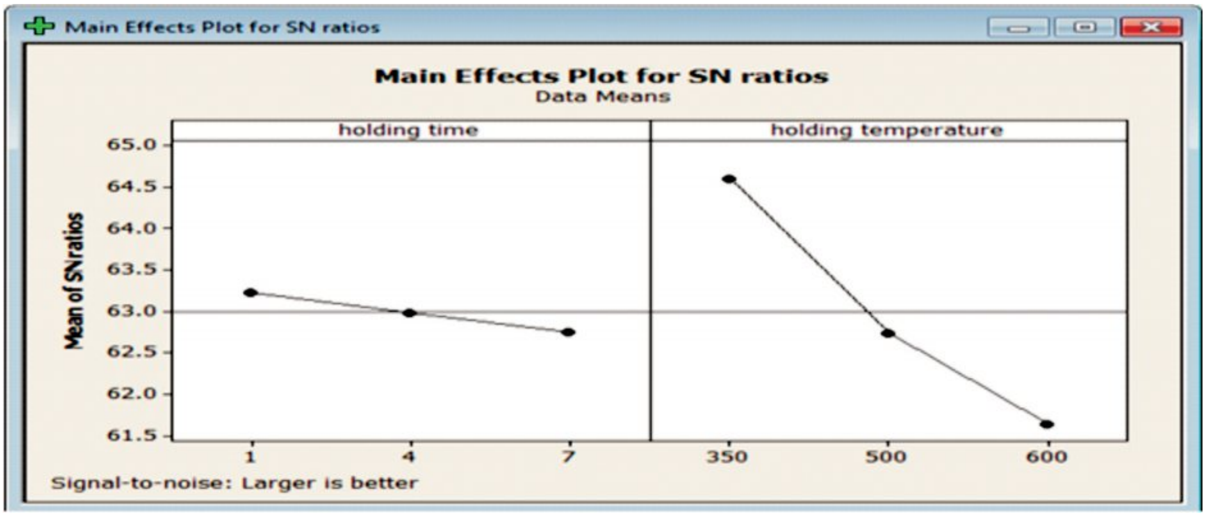


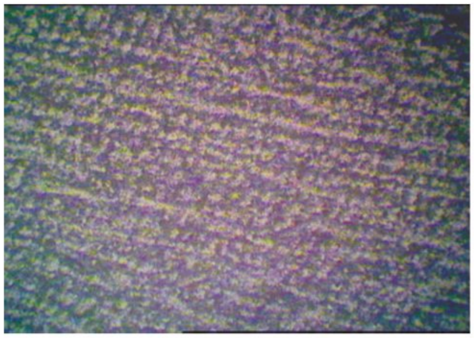
Figure 7: Shows the S/N ratios for holding time And temperature for Tensile test

Table 9:Analysis of Variance for Tensile Test, using Linear general method for Alloys.

Source	DF	Sum OF squares	Mean of squares	F	P
Holding Time	2	8582	4291	15.70	0.013
Holding Temperature	2	371488	185744	679.56	0.000
Error	4	1093	273	-	-
Total	8	381163	-	-	-

MICROSTRUCTURAL STUDY

The micrographs of surfaces of the samples of base alloy and newly formed alloys after heat treatment of base alloy have been carried out to study the metallurgical behavior of the alloys. The investigated micro structural features of the alloys are shown in figure 5.11


(a) Base Alloy


(b) Hard Alloy


(c)Alloy(C1)

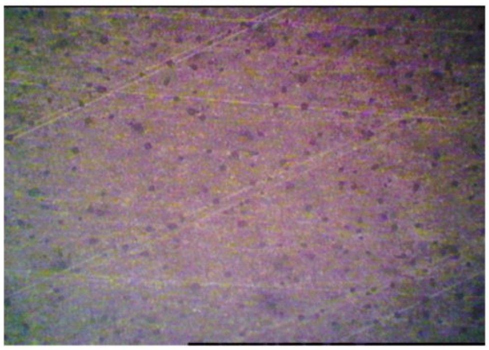

(d)Alloy(C2)


(e)Alloy(C3)


(f)Alloy(C4)

(g)Alloy(C5)

(h)Alloy(C6)



(i)Alloy(C7)

(j)Alloy(C8)

(k)Alloy(C9)

Fig 8: Shows the microstructures of different alloys

Figure 8: Micrographs of Base Alloy A(a),Hard Alloy B(b), Alloy C1 (c) , Alloy C2 (d),Alloy C3(e),Alloy C4(f),Alloy C5(g),Alloy C6(h),Alloy C7(i),Alloy C8(j),Alloy C9(k) at 100X magnification.

Figure.8.(a) shows the micrograph of surface of base Alloy A, which shows non-uniformly distributed pearlitic ferritic structure. This formation of non- uniform distribution of pearlitic ferritic results in coarse grain structure of the material(Lee *et al*.1993).

Figure .8.(b) shows the micrograph of surface of Alloy B formed after quenching the base alloy. The micrograph shows that, Alloy B consist of fine grained martensite structure ..

Figure.8.(c)to(k) shows the micrograph of surface of Alloy C formed after tempering the base alloy. After tempering uniformly distributed tempered martensite was observed. The martensitic structure is much harder than pearlite and ferrite strucutres. So, the formation of martensite results in higher hardness of Alloy C1 to C9.It is observed that there is no major difference in microstructure study due to variation in holding temperature and study.

CONCLUSION AND FUTURE SCOPE

From the investigations, the hardness of the alloys is increased from 12.33 to 56 HRC after hardening but after tempering, the hardness of material decreases from 56 HRC to 38.33 HRC. It is clear that hardness of all the alloy samples A, B, C1 to C9 varies with the holding time and holding temperature of alloys, so it is possible to obtain improvement in hardness of alloys by varying the holding temperature and time. Following conclusions are drawn from the study:

During the process of tempering, hardness of alloys decreases with increasing holding time from 1hr to 7 hr.

Tensile strength decreases with increases holding time of workpiece with constant temperature

SCOPE FOR FUTURE WORK

By other heat treatment processes experiments can be performed.

The study may be further extended for other materials.

Further experiments can be carried out by changing the range of varying holding time and holding temperature.

Impact testing can be performed to check the mechanical properties.

We can further observe the changes in surface roughness of the material with heat treatment processes.

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Investigation on the High Temperature Erosion Behaviour of Boiler Steels using Cold Spray Coatings

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Abstract

Three coatings namely Ni-20Cr, Ni-20Cr+TiC and Ni-20Cr+TiC+Re coating were deposited on ASTM-SA213-T22 boiler tube steel by Cold sprayed thermal spray process is being discussed, under various conditions viz. High temperature solid particle erosion studies were conducted to investigate the performance of the coating. High temperature erosion tests were carried out in high temperature solid particle erosion test rig, in which the samples of T22 steel were placed conveniently to ensure grazing incidence of the particles by using erodent material alumina of irregular shape of size 50 microns and particle velocity of 33 m/s and discharge rate of 6.2g/min. The erosion resistance was determined from the weight loss results. Each sample completes one cycle at an interval of 3 hours. The results of each sample have been shown with the help of bar graph. The study has been carried out with two impingement angles i.e. 30° and 90°. The results of the coated steels have also been compared with the uncoated substrate steel. Experimental results showed that there is more weight reduction in specimen when impinged at 90° than 30° angle. The samples were characterized by SEM analysis. Coating of Ni-20Cr+TiC+Re provides best result than all other coatings provided for T22 steel.

Keywords: High Temperature Erosion; Cold Spray; Ni-20Cr, Ni-20Cr+TiC and Ni-20Cr+TiC+Re; Boiler Steel

Introduction

The attainability of high temperatures has been precious in the growth of civilization for many countries *[Khanna, 2002]*. In various high technology fields, materials have to face severe conditions of temperature, pressure and erosive environment *[Ananthapadmanabhan et al, 1991]*. So material loss at high temperatures is a major issue in various high technology industries. Various examples where erosion and corrosion resist their use or limit their life are boilers, fossil fuel power plants, gas turbines in aircraft and heating elements for high temperature furnaces *[Khanna, 2002]* .High temperature erosion by the impact of fly ashes and unburned carbon particles are the main issues to be point out in these applications. Therefore growth of wear, erosion and high temperature oxidation protection system in industrial boilers is a very precious topic from both engineering and an economic point of view *[Hidalgo et al, 2001]*.In coal fired power stations, about 20% of the ash produced in the boilers is deposited on the boiler walls, economizers, air-heaters and super-heater tubes. The rest of the ash is entertained in the steam of gas leaving the boiler. These ash particles strike with the boiler steel components and results in extensive surface erosion. Once this happens, the power station unit has to be close down in order to change the damaged components. To understand the behavior of boiler steels at high temperature and primarily their erosion behavior has become an important area of scientific research.

Erosion-corrosion at high temperature in boilers is an area within high temperature erosion that is gaining most importance these days *[Norling et al, 2003]*. Material loss is a function of many factors. These are basically expressed in terms of the particles (hardness, impact angle, velocity, shape, and size), target (erosion and corrosion resistance, ductility) and atmosphere *[Stack et al, 1995]*.The selection of material and its preparation are important factors for the efficient functioning of the system components. Materials used at high temperature should possess superior mechanical properties along with erosion-corrosion resistance. It is entirely impossible that one material should possess all these properties. Now a days it has become very popular and common to use substrate as base material and to use some protective layer or coating to provide thermal insulation, erosion and wear resistance and in chemical process plants or boilers to protect the surface of structural steels against surface degradation processes such as wear, oxidation, corrosion and erosion. Thermal spray coatings are applied to improve the wear characteristics of surfaces yet they combine various attractive factors, i.e. resistance to erosion, abrasion, high temperature and corrosive environment *[Luo et al, 1998]*. Different types of thermal spray techniques are applied for coating presently.

From all, cold spray technique is used in this work. Cold spray coatings is a different or unique technology that permits fabricating dense, low oxide-content deposits of ductile materials like copper, titanium, stainless steel and alloys, but it is applicable to ductile material only.In this gas temperature is below the melting point of the material, so that particle present in the jet no longer melts *[Stoltenhoff et al, 2001]*. Erosion is defined as wear caused by hard particle impacting on a surface, carried by a gas stream, or in a flowing liquid medium *[Hutchings et al, 1992]*.The abrasive process on a surface is found out by relative velocity and impact angle of the particle *[Mack et al, 1999]*.Erosion and corrosion resistant coating material can be used evidently on low cost substrates, to give a surface that provides better mechanical and chemical properties *[Alam et al, 2001]*.

High Temperature Solid Particle Erosion

Solid particle erosion (SPE) is the continuous loss of original material from a solid surface due to mechanical interaction b/w solid surface and solid particles. Erosion at high temperatures is a major problem in many engineering systems, considering coal fired boilers, steams and jet turbines, fluidized bed combustion systems and boilers *[Mishra et al, 2006]*.

Experimentation

The boiler tube steel, ASTM SA-213 T-22(C 0.15, Mn0.3-0.6, Si0.5, S 0.03, P 0.03, Cr 1.9-2.0, Mo 0.87-1.13, Fe-Bal) has been used as a main material. This material is used as boiler tube materials in many of the power plant in northern India. The samples were cut to form approximately 20x15x5 mm^3 sized specimens. The specimens were polished and grit blasted with Al_2O_3 (grit-50) prior to the applications of Cold spray coatings. Cold spray process was used to apply coatings on the super alloys at ASB Industries, Inc, Barbeton, Ohio, USA. The system used for the coating process was Kinetics 3000 from CGT Technologies, Germany. Standard spray parameters were used for depositing both coatings. The coating parameters adopted are following Parameters/values, Process gas/ Helium, Gun temperature/ 400^{o}C, Gun pressure/ 20.5bars, Process gas flow rate/ 150m^3/hr, Powder feed rate/ 40g/min, Gas flow rate/ 4m^3/hr, Carrier gas/ Nitrogen, Coating thickness/ 250μm.

Visual Examination and Weight Change Studies

A visual examination of the specimens was made after each cycle and changes in appearance, color, cracks were noticed. The weight change measurements were taken at the end of each cycle using electronic weight balance machine made of Citizen TOYO HECIO (Class II) to understand the effects of erosion. The weight change per unit area with respect to number of different specimens having different coatingwas plotted using bar graph. Comparisons of cumulative weight change gain per unit area of coated/uncoated specimen's at different impingement angles after high temperature erosion were also recorded.

Characterization of Coating

SEM analysis of the hot eroded coated/uncoated specimen was done after completion of one cycle. The specimen were scanned under the microscope and photographed at particular points to identify cracks, change in appearance. Hardness tests were also carried out with a load of 2.942 N using the Digital Micro Vickers Hardness tester at IIT, Ropar for each coated/ uncoated specimen having different cold spray coatings.

High-Temperature Erosion Studies

Erosion testing was carried out using a solid particle erosion test rig TR-471-M10 Air Jet Erosion Tester (Ducom Instruments Private Limited, Bangalore, India) capable of conducting tests at room temperature as well as high temperature. The high temperature erosion testing was performed on uncoated substrate steel and then on coated substrate steel at two different impingement angles i.e. 30° and 90°. The rig consisted of an air compressor, erodent feeding system, mixing chamber, furnace unit, specimen holder, nozzle, erodent collection chamber, pneumatic control box and electrical control box.

Figure 1: High temperature solid particle erosion test rig

Figure 2(a): View of specimen holder of 30° Figure 2(b): View of specimen holder of 90°

The studies were performed for uncoated as well as coated specimens for the purpose of comparison. The erosion test conditions utilized in the present study are listed in Table 1. A standard test procedure was employed for each erosion test. The uncoated as well as the coated specimens were polished down to 1m alumina wheel cloth polishing to obtain similar condition on all the samples before being subjected to erosion run. In the present study standard alumina 50 micron (supplied with Erosion Test Rigby Ducom Instruments Private Limited, Bangalore, India) was used as erodent. Two temperatures were taken for the test (Table 1), sample temperature 500°C and air/erodent temperature 550°C simulated to service conditions of boiler tubes in which sample temperature and flow gas temperature correspond to the inner and outer temperature of water wall pipes. Erosion resistance was measured using weight loss technique by measuring the weights before and after the test.SEM technique was used to analyze the erosion products.

Table 1: Erosion test conditions

Erodent material	Alumina (Irregular shape)
Erodent Specifications	50 micron Al_2O_3
Particle velocity (m/s)	33m/s
Erodent feed rate (g/min)	6.2 g/min
Impact angle (°)	30, 90
Test temperature	Sample Temperature 500°C and Air Temperature 550°C
Nozzle diameter (mm)	4
Test time (Hrs)	3Hours

RESULTS

Micro-Hardness Calculations

The micro hardness of the coatings on substrate steel i.e. T22 has been measured on the surface. The mean values of two reading of micro hardness were taken. The micro hardness value of Ni-20Cr+TiC and Ni-20Cr+TiC+Re has been found to be larger than Ni-20Cr coating. Higher hardness lowers the high temperature solid particle erosion. The micro hardness value for T22 steel has been measured as 180 Hv.

Table 2: Micro Hardness for the T22 steel

S. No.	Coating	Micro hardness(Hv)
1.	Ni20Cr coating on T22 steel	246.8
2.	Ni20Cr +TiC coating on T22 steel	266.29
3.	Ni20Cr +TiC+Re coating on T22 steel	247.06

It has been observed that the value of cold sprayed Ni20Cr+TiC coatings on T22 steel has greater value of micro hardness as compared to the Ni20Cr and Ni20Cr+TiC+Re coatings. Hence it is concluded that the addition of a carbide in metallic coatings lead to the increase in micro hardness of the coatings.

High temperature erosion at 30° impingement angle

a) Comparison of weight loss between coated and uncoated T22 steels at 30°The graph for comparison of the weight loss at 30°for uncoated and coated T22 steels after high temperature erosion at 30° impingement angle has been represented in Figure It can be clearly seen that uncoated T22 steel conceived higher weight loss than the coated T22 steel. This clearly shows that T22 steel having coating NiCr-TiC-Re was less resistant to erosion rate in comparison to other coatings.

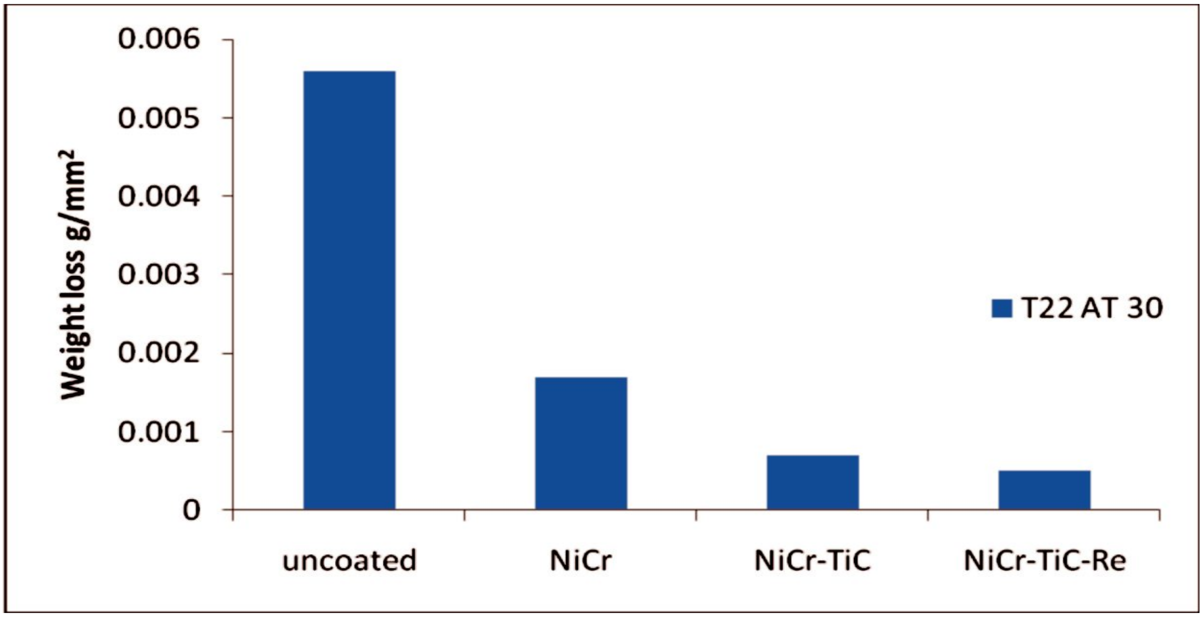

Figure 3: Comparison of weight loss between coated and uncoated T22 steel at 30°

High temperature erosion at 90° impingement angle

a) Comparison of weight loss between coated and uncoated T22 at 90°

The graph for comparison of the weight loss at 90°for uncoated and coated T22 steels after high temperature erosion at 90° impingement angle has been represented in Figure It can be clearly seen that uncoated T22 steel conceived higher weight loss than the coated T22 steel. This clearly shows that T22 steel having coating NiCr-TiC-Re was less resistant to erosion rate in comparison to other coatings.

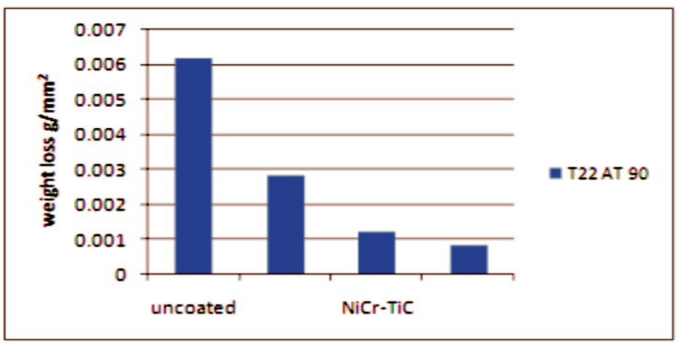

Figure 4: Comparison of weight loss between coated and uncoated T22 steels at 90° Comparison of high temperature erosion at 30° and 90°angle

a) Comparison of weight loss between coated and uncoated T22 at 30° and 90°

So, now by comparing the above graphs it can be concluded that the impingement angle plays a great role in defining the high temperature erosion rate. It has observed that there is higher material loss in both the steels at 90° impingement angle than the 30°impingement angle.

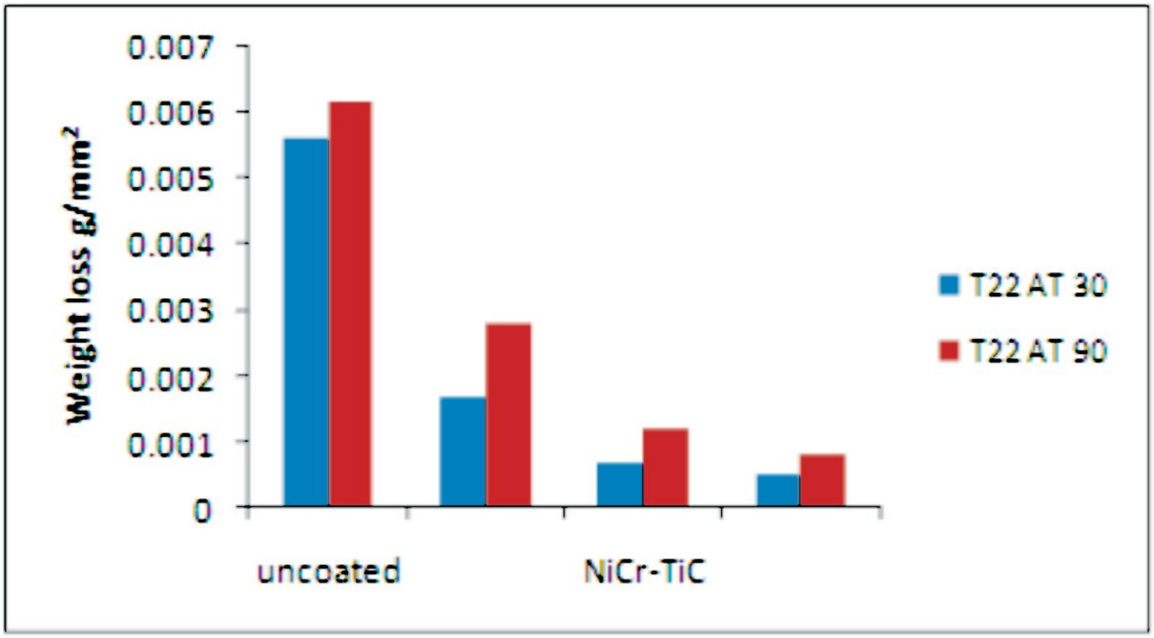

Figure 5: Comparison of weight loss between coated and uncoated T22 steels at 30°and 90°

SEM Analysis Micrographs

SEM micrograph of uncoated T22 steel after high temperature erosion at 90° impingement angle clearly shows the presence of material degradation due to erosion in the form of micro cracks, lip formation and plastic deformation which occurs due to impact of abrasive particles on the surface of the substrate.

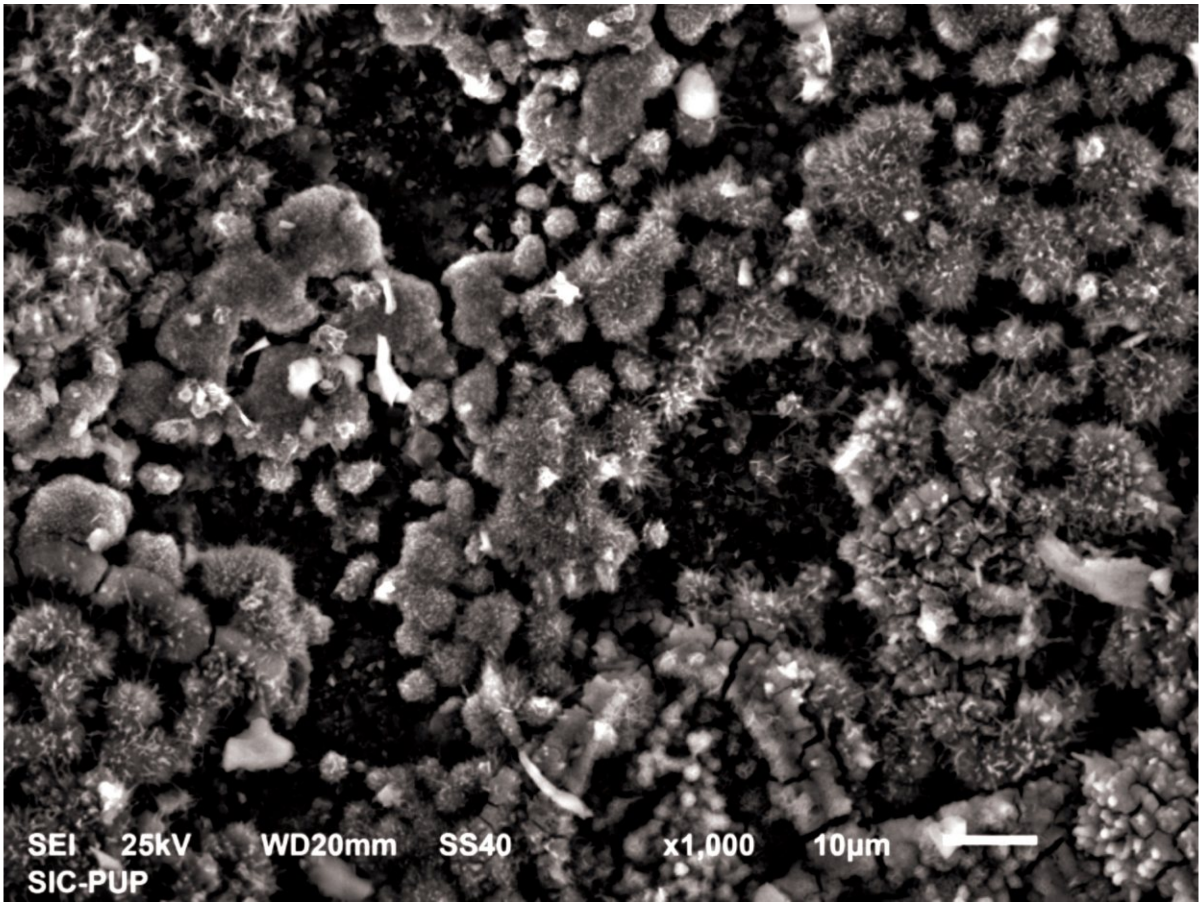

Figure 6: SEM micrograph of uncoated T22 steel after high temperature erosion at 90° impingement angle

SEM micrograph of Ni-20Cr+TiC coated T22 steel after high temperature erosion at 90° impingement angle clearly shows the presence of material degradation due to erosion in the form of crater, lip formation and plastic deformation which occurs due to impact of abrasive particles on the surface of the substrate.

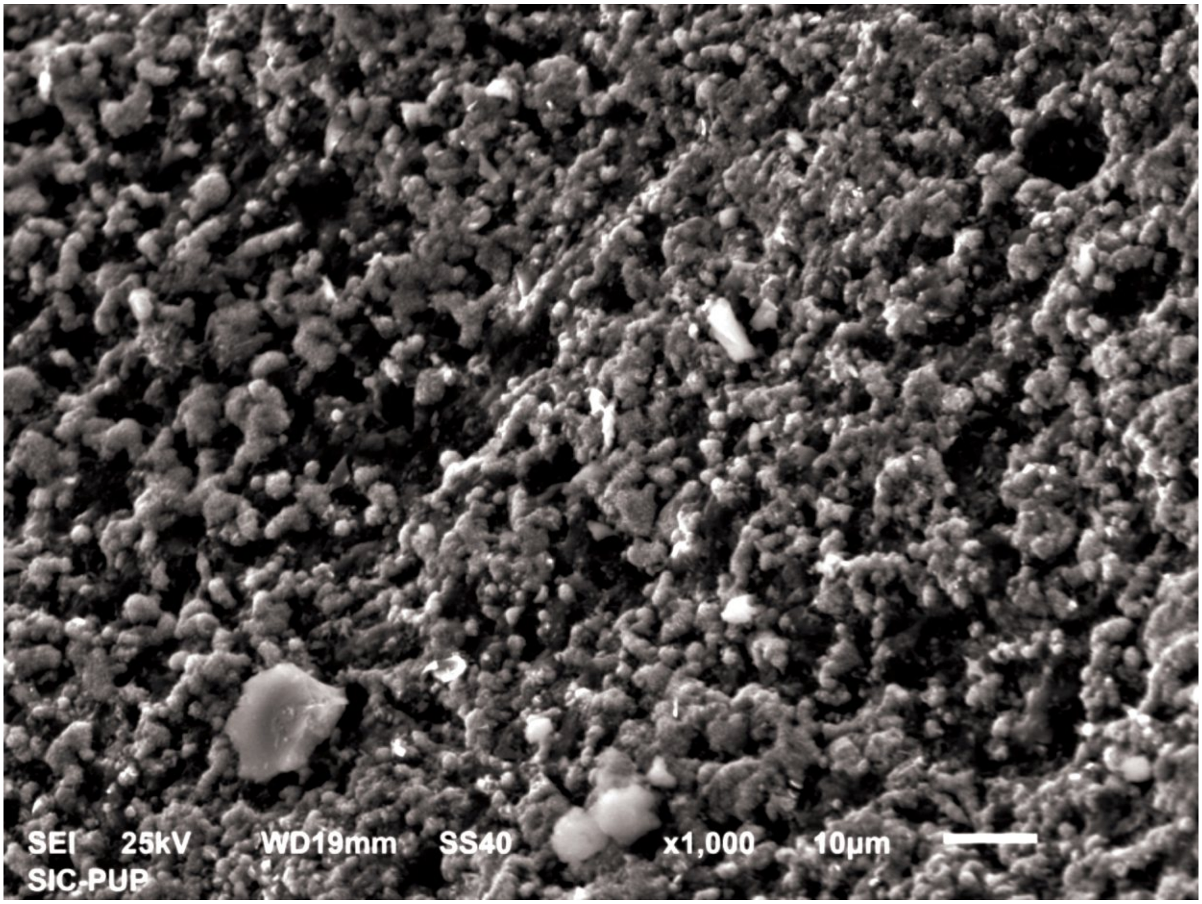

Figure 7: SEM micrograph of Ni-20Cr+TiC coated T22 steel after high temperature erosion at 90° impingement angle

Conclusions

1. Micro hardness was found to increase with the addition of TiC and Re.
2. Experimental results show that there is more weight reduction in the uncoated specimen than the coated specimen. Hence it may be concluded that the cold spray coatings can be used to reduce the erosion rate.
3. The higher material loss during the high temperature erosion testing for the Ni-20Cr coating has been observed. This might be due to roughness of the specimens.
4. Ni-20Cr+TiC+Re coating shows best result for resistance over high temperature erosion than other coatings.
5. Amongst the three coatings studied i.e. Ni-20Cr, Ni-20Cr+TiC, Ni-20Cr+TiC+Re, the Ni-

20Cr+TiC coating was found more erosion resistant at both 30° and 90° impingement angles. This might be due to higher hardness of Ni-20Cr+TiC.

6. It was found that the erosion rate at 90° impingement angle was higher than at 30° impingement angle for all the uncoated and coated cases.
7. Amongst the three coatings studied i.e. Ni-20Cr, Ni-20Cr+TiC, Ni-20Cr+TiC+Re, the Ni-20Cr coating was found least erosion resistant at both 30° and 90° impingement angles.

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Comparison of Brass Holes Finished By Using Different Abrasives By AFM

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Abstract:

Abrasive Flow Machining (AFM) process is a non-traditional finishing process known for high surface finish. Primarily used to finish intricate geometries by extruding abrasive laden medium with special rheological properties. The media is prepared by the combination of a polymer and gel in a definite proportion. A single operation in AFM can perform the operations like radiusing, deburring and polishing simultaneously. The current study compares finishing of holes (in brass specimen HRB 68) by abrasive flow machining using aluminium oxide and silicon carbide as abrasives. The extrusion pressure and number of cycles are varied to get the optimum value of surface finish. The surface finish is analyzed in terms of percent improvement in surface finish (PISF). The extrusion pressure has a significant effect on the PISF. The other parameter of investigation is Material Removal per cycle (MRC). More material is observed to be removed for higher values of pressure.

Keywords: Abrasive Flow Machining (AFM) Percentage Improvement in Surface Finish (PISF), Material Removal per Cycle (MRC), Aluminium Oxide (Al_2O_3), Silicon Carbide (SiC)

INTRODUCTION

Abrasive flow machining process is non-traditional machining process which was originally developed by Extrude Hone Corporation, USA in 1960s. The process uses abrasive laden medium which is forced across the work piece with pressure. It is possible to control the intensity and location of abrasion which differentiates AFM from other finishing processes through fixture design, medium selection and process parameters.

The AFM process has been investigated by several researchers. Fang et al. [1] revealed the fact that work efficiency is considered as most concerned target in abrasive flow machining (AFM). It has been shown that media temperature increases with increasing cycles, which means media viscosity decreases with cycles increasing.

Gorana et al [2] focused on forces acting during material deformation in abrasive flow machining. Jain et al. [3] attempted to analyze the AFM process using finite element method (FEM) for finishing of external surfaces. Rhoades [4-5] [9] experimentally investigated the basic principle of AFM process and identified its control parameters.

Jung et al. [7] analysed the effects of the Abrasive Flow Machining (AFM) process on a direct injection (DI) Diesel engine fuel injector nozzle. **Mali et al [8]** presented the use of artificial neural networks (ANN) for modeling and simulation of response characteristics during AFM process in finishing of Al/SiCp metal matrix composites (MMCs) components. Sankar et al. [10] concluded that various flow and deformation properties of the medium can be investigated by rheological characterization.

Uhlmann et al. [11] concluded that for abrasive flow machining on advanced ceramics a ductile material removal mechanism is achieved by using abrasive diamond grains with average grain size under 44.5µm, whereas a brittle material removal mechanism could be achieved with grain size upon 185µm. Wang et al [12] highlighted on the development of the polymer abrasive gels in AFM process. **Kenda et al [13]** studied the influence of the process parameters on surface integrity, i.e. surface roughness and induced residual stresses. Pengfei et al. [14] **explained about removing the copper stains on the inner wall of steel tubes by AFM.**

Anand et al [15-18] concluded the effect of aluminium oxide and Silicon Carbide abrasives respectively on brass specimen by varying the number of cycles and extrusion pressure. The selected output parameters were MRR and PISF. Uhlmann et al [16] developed a material model for visco elastic abrasive medium in abrasive flow machining. **Kenda et al [17]** studied the influence modelling and energy efficiency of AFM on Tooling Industry Case Study.

MATERIAL AND METHODOLOGY:

The experimentation involved development of the experimental setup, preparation of media and the scheme of experimental work and identifying the important process parameters.

Fig. 1 shows a photographic view of two way abrasive flow machining setup. The three major elements of the process are: the machine, tooling and the abrasive laden polymeric medium.

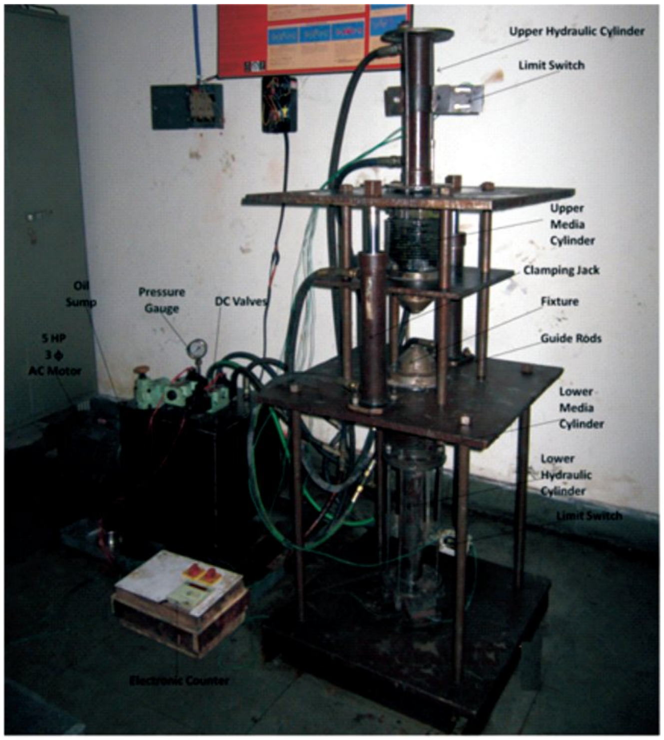


Fig. 1 Abrasive Flow Machining Setup

The tooling confines and directs the abrasive medium flow to the areas where surface improvement is desired. The fixture is used to clamp the work piece and to control the media flow.

To formulate the AFM medium, 70 % by weight the polymer is mixed with 30 % by weight of gel. Further the abrasives 50 % by weight are added, and the mixture is continuously kneaded, till it becomes homogeneous abrasive media. The basic requirements for the media are flowability, flexibility and self deformability [6].

The specimens chosen were of Brass material (HRB 68) of length 25 mm, external diameter 16 mm and inner diameter 8.5 mm.

The response variables chosen for experimentation were:

Percentage improvement in surface finish (PISF) =

(Initial Surface Roughness - Final Surface Roughness) × 100

Initial Surface Roughness

Material removal per cycle (MRC): The stroke length was taken as 210 mm for experimentation.

MRC (mg) = (Initial weight – final weight)

No. of cycles

4

The various independent variables are extrusion pressure and number of finishing cycles. The abrasives selected for comparison were aluminium oxide and silicon carbide.

The finishing characteristics of abrasive media on brass specimens were analyzed by measuring the surface roughness, which was measured at eight points before and after finishing using a Mitutoyo surface roughness tester (SJ-210P) having a least count of 0.001 μm (cut off length = 0.8 mm) and averaged. Therefore finishing characteristics in terms of PISF (Percentage Improvement in Surface Finish) were analyzed. Similarly the work specimen is weighed before and after finishing to record the second response parameter i.e. MRC.

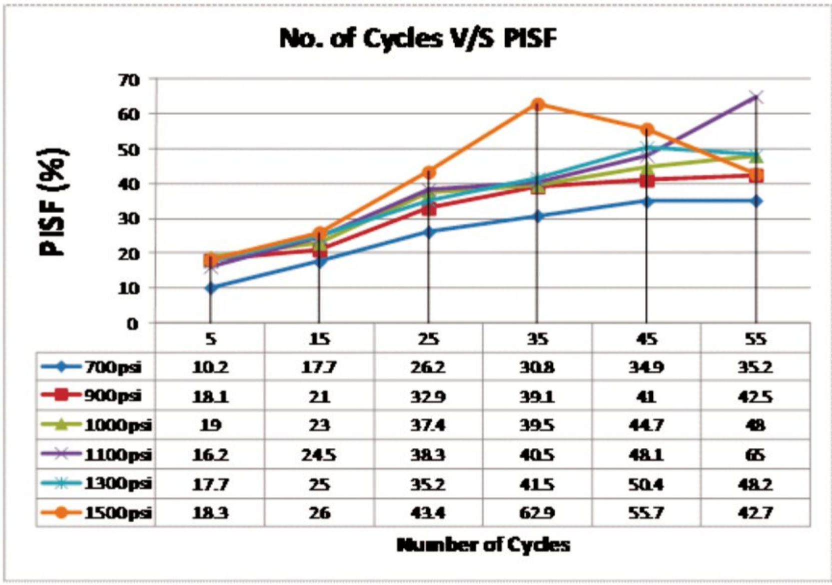
Table 1: Abrasive Flow Machining Constant Parameters

S. No	Parameters	Specification
1.	Type of Abrasives	Aluminium Oxide (Al_2O_3) and Silicon Carbide (SiC)
2.	Abrasive Grain Size (Average)	200 mesh number
3.	Media	Polyborosiloxane + Gel + Abrasives
4.	Polymer to gel ratio	70 % by weight
5.	Abrasive to media concentration	50 % by weight

RESULTS AND DISCUSSIONS:

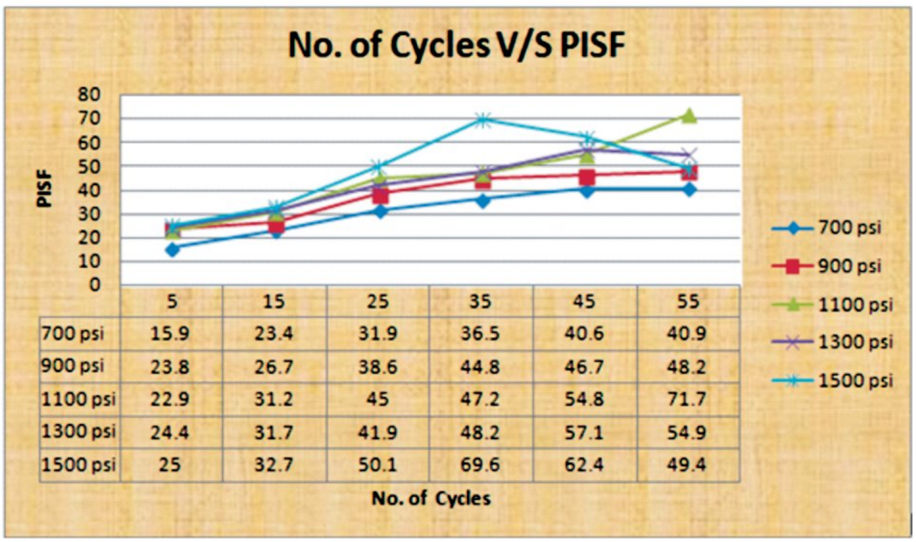
A. Effect on PISF

Graph 1 and 2 show that there is significant effect of pressure and number of cycles on the PISF. For both abrasives it is observed from the graph that up to 1000 psi there is increase in the value of PISF as the numbers of cycles are increased. For pressure above 1000 psi, PISF attains maximum value and then starts decreasing. For higher value of pressure, the number of finishing cycles for attaining highest value of PISF is less as compared to lower values of pressure. The process yields 65 % improvement in surface finish at 1100 psi and 55 number of finishing cycles with Al_2O_3 abrasives. Following the same trend using SiC abrasives 71.7 % improvement in surface finish at 1100 psi and 55 number of finishing cycles is recorded.



	5	15	25	35	45	55
700psi	10.2	17.7	26.2	30.8	34.9	35.2
900psi	18.1	21	32.9	39.1	41	42.5
1000psi	19	23	37.4	39.5	44.7	48
1100psi	16.2	24.5	38.3	40.5	48.1	65
1300psi	17.7	25	35.2	41.5	50.4	48.2
1500psi	18.3	26	43.4	62.9	55.7	42.7

Graph 1 PISF at different values of pressure and cycles using Al_2O_3 abarsives

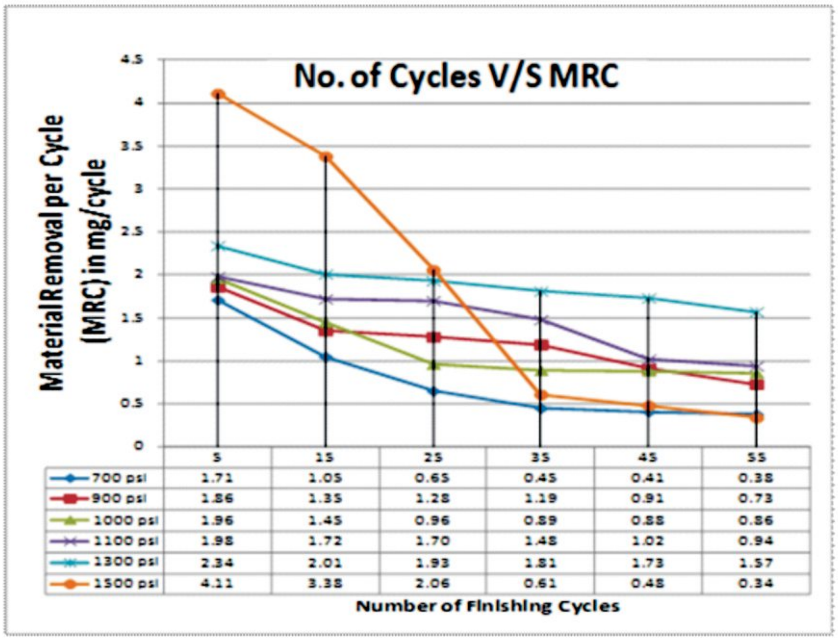


	5	15	25	35	45	55
700 psi	15.9	23.4	31.9	36.5	40.6	40.9
900 psi	23.8	26.7	38.6	44.8	46.7	48.2
1100 psi	22.9	31.2	45	47.2	54.8	71.7
1300 psi	24.4	31.7	41.9	48.2	57.1	54.9
1500 psi	25	32.7	50.1	69.6	62.4	49.4

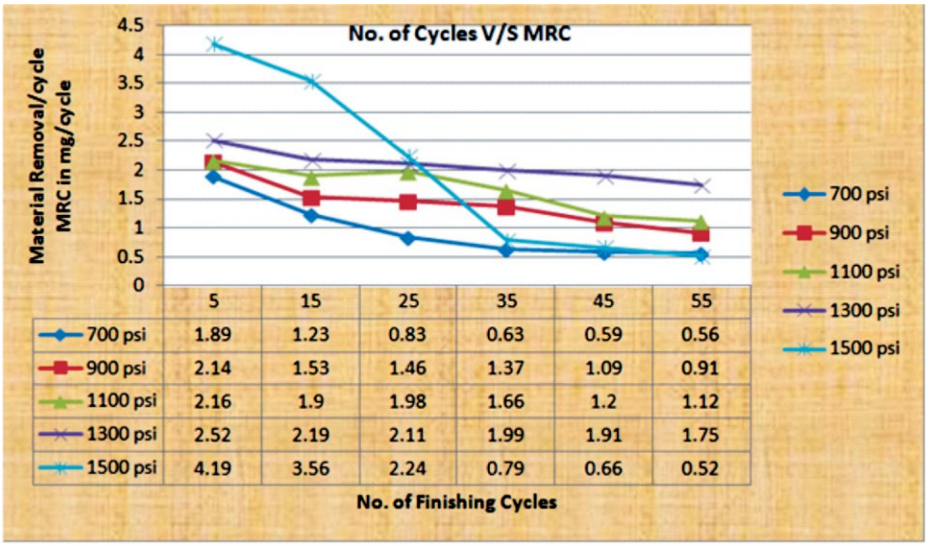
Graph 2 PISF at different values of pressure and cycles using SiC abrasives

A. Effect on MRC

Graph 3 and 4 show the effect of number of cycles and extrusion pressure on the material removal per cycle (MRC) using Al_2O_3 and SiC abrasives respectively. It is observed from the graph that for both the abrasives the material removed per cycle decreased as the number of cycles were increased. This is due to the fact that initially the workpiece have high peaks which are sheared to a smaller value as the number of cycles are increased. Graphs also infer that for higher value of pressure material removed is high.



Graph 3 MRC at different values of pressure and cycles using Al_2O_3 abrasives



	5	15	25	35	45	55
700 psi	1.89	1.23	0.83	0.63	0.59	0.56
900 psi	2.14	1.53	1.46	1.37	1.09	0.91
1100 psi	2.16	1.9	1.98	1.66	1.2	1.12
1300 psi	2.52	2.19	2.11	1.99	1.91	1.75
1500 psi	4.19	3.56	2.24	0.79	0.66	0.52

Graph 4 MRC at different values of pressure and cycles using SiC abrasives

CONCLUSION

The results of this research can be summarized as follows:

1. The process yields best results of PISF = 65 % with Al_2O_3 abrasives and 71.7% with SiC abrasives by using the input parameters as Extrusion Pressure = 1100 psi and Number of Cycles = 55.
2. The R_a value (using Al_2O_3 abrasives) of 0.53 µm (average) and 0.34 µm (individual) is achieved by AFM by using optimum input parameters. The R_a value (using SiC abrasives) of 0.49 µm (average) and 0.29 µm (individual) is achieved by AFM by using optimum input parameters.
3. The extrusion pressure has a predominant effect on the percentage improvement in surface finish. High extrusion pressures are more effective on PISF as compared to low extrusion pressures.
4. More material is removed for higher values of pressure.
5. For higher value of pressure, the number of finishing cycles for attaining highest value of PISF is less as compared to lower values of pressure.
6. Of the two abrasives, SiC fetches better results than Al_2O_3 for Brass Specimen.

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Study of The Surface Quality Produced By Magnetic Abrasive Finishing Process

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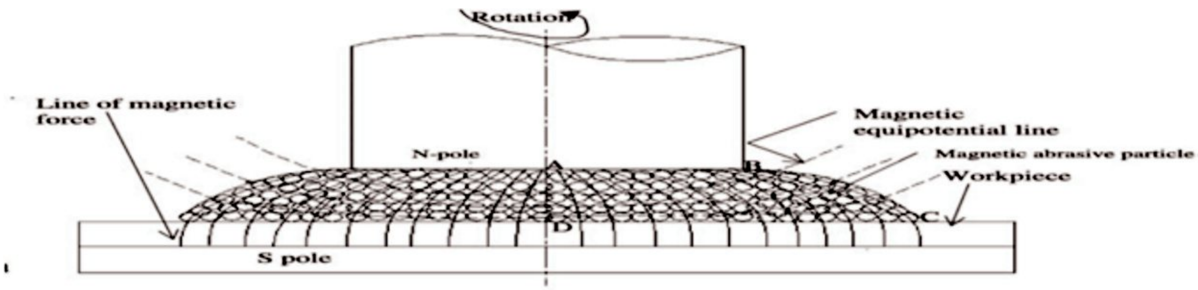
ABSTRACT

Requirement of good surface finish with least surface damage has increased the demand for new advance finishing processes. Traditional methods like grinding, lapping, honing and super finishing are not able to meet the demand of modern engineering components, so new methods are being developed rapidly for such components. Magnetic abrasive finishing is one such advance modern machining process which is getting good attention of researchers. This paper aims to study the effect of different parameters on magnetic abrasive finishing of stainless steel plate. The parameters affecting the surface quality in Magnetic abrasive finishing like machining time, rotational speed of magnetic poles, magnetic flux density and grit size of magnetic abrasive is considered in this study. Percentage improvement in surface finish is calculated to study the effect of process parameters on magnetic abrasive finishing process. Sintered diamond based magnetic abrasive are used in this study. The scanning electron microscopy was also conducted on the work piece surface to understand the surface morphology produced.

Keywords: Magnetic abrasive finishing (MAF), Magnetic abrasive particles (MAP), Sintering, Percentage improvement in surface finish (PISF), Scanning electron microscopy (SEM)

INTRODUCTION

Advancement in technology has lead to development of complex components. Accuracy and minimum tolerance has increased pressure on manufacturing processes [1]. High surface quality with minimum surface defects is a costly and time consuming affair. Traditional methods fail to meet these requirements, so new methods called Non traditional methods are being developed rapidly. Magnetic abrasive finishing is one such modern super finishing non conventional machining method which controls the cutting force with magnetic field [2]. In this technique cutting tool is flexible in nature and is formed by the magnetic abrasive particles [3]. Magnetic abrasive powder is filled in the gap between the workpiece and the magnet. Magnetic abrasive powder aligns along the lines of magnetic field as shown in figure 1.



Source: Jayswal et al. (2005) Figure 1 Magnetic abrasive finishing process

Relative movement between the workpiece and powder produces the cutting force for finishing the workpiece surface [4]. Magnetic abrasive powder can be produced by different techniques like sintering, adhesive based, plasma powder technique, mixing and mechanical alloying method etc [5].

In this study sintered magnetic abrasives are used to study the effect of MAF on the surface quality of stainless steel plate. Stainless steel is widely used these days. Typical applications include Food processing equipment, particularly in beer brewing, milk processing & wine making, Kitchen benches, sinks, troughs, equipment and appliances, Architectural paneling,railings & trim,Chemical containers, including for transport, Heat Exchangers, Woven or welded screens for mining, quarrying & water filtration, Threaded fasteners and Springs etc.[6] Some factors affecting the surface quality in MAF like machining time, rotational speed of magnetic poles, magnetic flux density and grit size of magnetic abrasive is considered in this study[7].

EXPERIMENTAL PROCEDURE

In this section, details of experimental setup, magnetic abrasive used, experimental conditions have been discussed.

Experimental set up

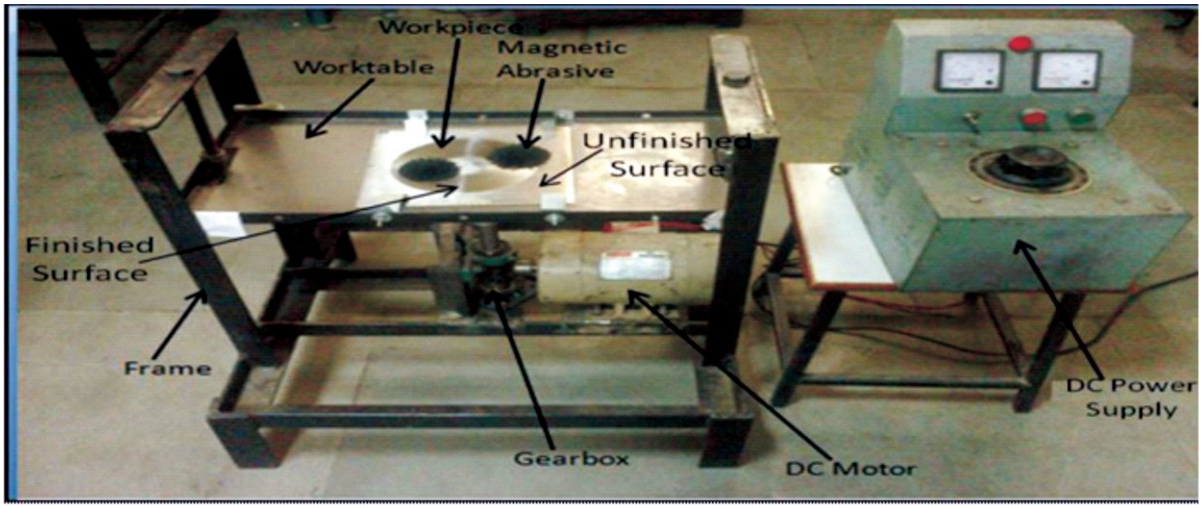


Figure 2 Photographic view of plane finishing set up

Magnetic abrasive finishing set up used in this study is shown in figure 2. The experimental setup for finishing of plane surfaces using Magnetic Abrasive Finishing process consists of 2 permanent magnets mounted on an aluminium disk which act as a carrier and insulator to separate them. This disk is placed below acrylic working table. Magnets are rotated by a D.C motor through a gear arrangement. Work piece is placed over the working table and abrasives are placed upon the work piece. The speed of the magnets is varied by changing the speed of D.C motor.

Magnetic abrasives

Sintered magnetic abrasives are used in this study. The magnetic abrasives are formed by mixing diamond particles (250 mesh size) in different percentage by volume in iron powder(300 mesh size). The mixture was then compressed in the cylindrical die and sintered in a furnace at a temperature of 1100℃ for 2 hrs in the presence of hydrogen gas. After the sintering process, the magnetic abrasives were crushed and separated to different abrasive size using sieve set.The different abrasive sizes used in this study are 45, 60, 100, 163, 250,450 and 600 mesh size. The figure 3 shows photographic view of die used for preparing compacts. The figure 4 shows photographic view of cylindrical compacts after sintering.

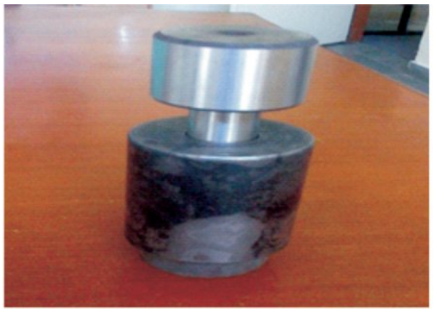


Figure 3 Photographic view of Die

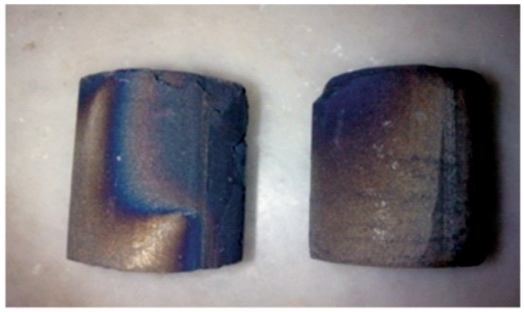


Figure 4 Photographic view of Compacts

Experimental conditions

Since the present operation is finishing operation, so the parameter to study the effect of MAF should show the change in surface roughness. The initial surface roughness of the work specimens was not same for all the workpieces. Therefore, in order to compensate for this variation the percentage improvement in surface finish (PISF) is selected which can be calculated as

$$\text{PISF} = \frac{(\text{Initial surface roughness} - \text{final surface roughness})}{\text{Initial surface roughness}} \text{x} 100$$

Machining time, rotational speed of magnetic poles, magnetic flux density and grit size of magnetic abrasive is considered in this study. Stainless steel plates were prepared for the experimentation by grinding their surface with grinder. Then the initial surface roughness values that are the R_a values of work pieces were measured. The work piece is clamped over the work table above the two poles. The sintered magnetic abrasive powder, which is prepared just before each test by adding the lubricant (5% of wt.) was placed over the stainless steel plate. Experiments were conducted and after cleaning the specimen with ethanol, its surface finished was measured using a Mitutoyo surface roughness tester having a least count of 0.001 μm (cut off length = 0.8mm).

RESULT AND DISCUSSION

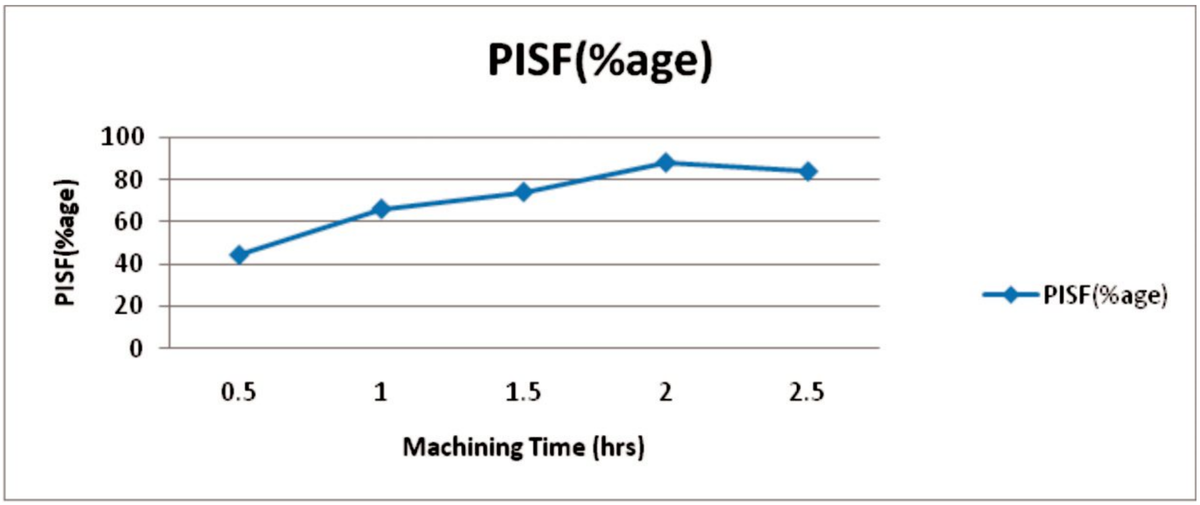
Effect of machining time

This is the time during which MAF is conducted over the workpiece. Table 1 shows the different experimental condition and figure 5 shows that PISF increases for first 2hrs and thereafter decreases slightly. This may be due to the reason that as the finishing operation is done on workpiece it shears off the peaks and lead to improvement in surface finish. But after some time the abrasive particles again starts indenting the smooth surface which leads to decrease in surface finish.

Table 1 Results of Machining Time

Experiment No.	Machining Time(hrs)	Rotational Speed(r.p.m)	Grit Size (μm)	MFD(Gauss)	%age of Magnetic abrasive (%age)	PISF(%age)
1	0.5	250	250	3100	10	44.34
2	1.0	250	250	3100	10	66.28
3	1.5	250	250	3100	10	74.34
4	2.0	250	250	3100	10	88.37
5	2.5	250	250	3100	10	84.12

Figure 5 Effect of Machining Time on PISF



Effect of rotational speed of magnetic poles

The effect of rotational speed of magnetic poles on the surface finish is shown in figure 6. Table 2 shows the experimental conditions. From the table 2 it is seen that increasing the speed above 250 rpm results in decrease in PISF. This may be because at higher rotational speed the flexible tool may start disarranging due to insufficient force or may roll over the workpiece surface without shearing its peaks.

Table 2 Results of Rotational Speed of Magnetic Poles

Experiment No.	Rotational Speed(r.p.m)	Grit Size (µm)	MFD(Gauss)	%age of Magnetic abrasive (%age)	Quantity of Magnetic Abrasives(g)	PISF(%age)
1	150	250	3100	10	20	42.77
2	200	250	3100	10	20	62.26
3	250	250	3100	10	20	88.37
4	300	250	3100	10	20	80.24
5	350	250	3100	10	20	78.46
6	400	250	3100	10	20	64.92
7	450	250	3100	10	20	44.32

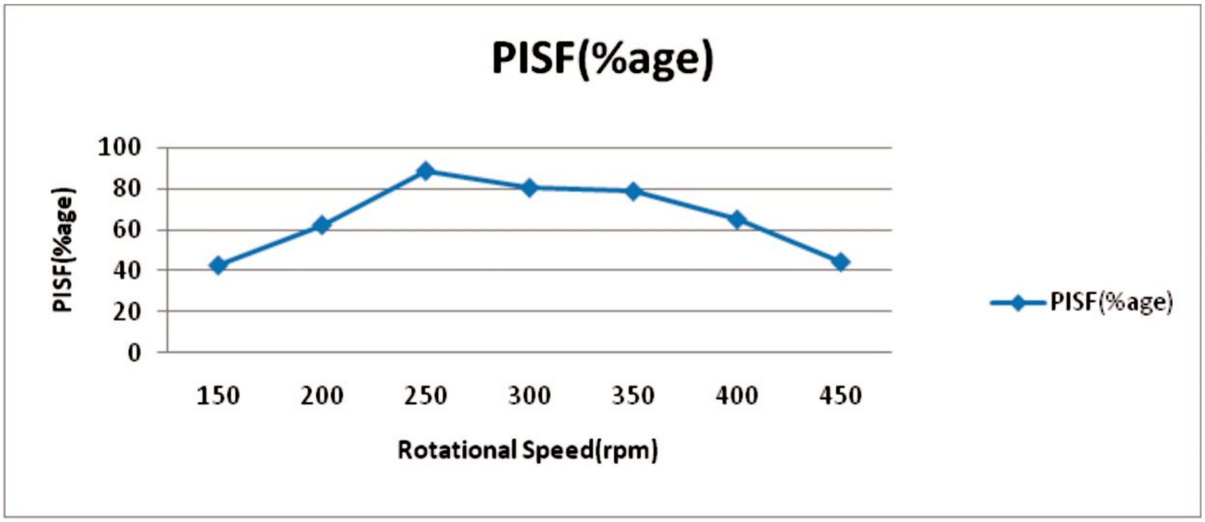


Figure 6 Effect of Rotational Speed of Magnetic Poles on PISF

Effect of magnetic flux density

The variation in the magnetic flux density in the machining gap determines the force acting on the abrasive particle, which generates finishing pressure on the work piece surface during MAF. In present study permanent magnet is used to generate the required magnetic field. The experimental condition and effect of magnetic field on PISF are shown in table 3 and figure 7 respectively. Higher indenting force can be obtained by increasing the magnetic flux density. It is clear from the table 3 that PISF stars decreasing after 3100 Gauss. This may be because at higher value of magnetic flux density the abrasive particles indent deeper into the work piece surface which decreases PISF.

Table 3 Results of Magnetic Flux Density

Experiment No.	MFD(Gauss)	Rotational Speed(r.p.m)	Grit Size (μm)	%age of Magnetic abrasive (%age)	Quantity of Magnetic Abrasives(g)	PISF(%age)
1	2700	250	250	10	20	36.32
2	2800	250	250	10	20	56.27
3	2900	250	250	10	20	64.71
4	3000	250	250	10	20	74.24
5	3100	250	250	10	20	88.37
6	3200	250	250	10	20	71.24
7	3300	250	250	10	20	47.15

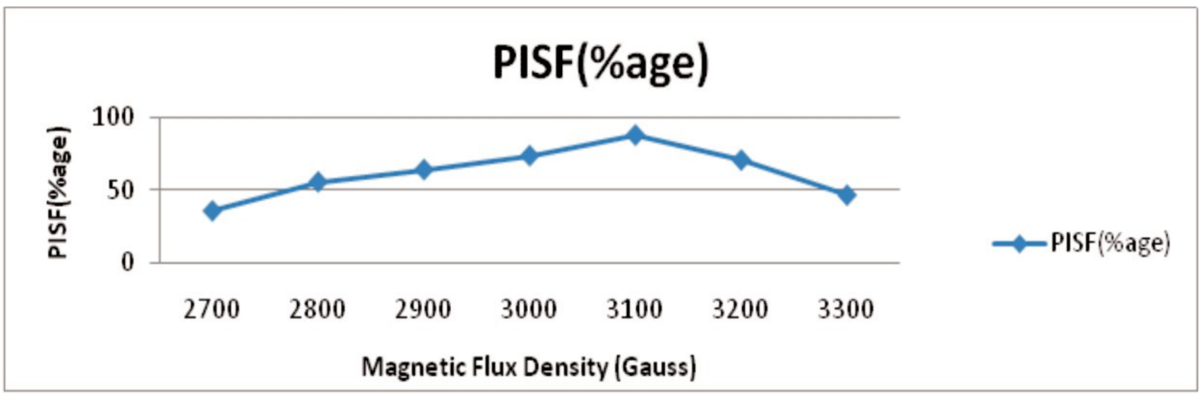


Figure 7 Effect of Magnetic Flux Density on PISF

Effect of size of magnetic abrasives

Figure 8 shows the effect of grit size of magnetic abrasive on PISF. Table 4 shows the experimental condtions. In the present experimentation, the size of Magnetic Abrasives are varied from 45µm–600 µm. PISF increases for grit size up to 250µm and then starts decreasing thereafter which may be due to the reason that bigger abrasive particle causes deep indentation of workpiece surface that results in decrease of PISF.

Table 4 Results of Grit Size of Magnetic Abrasives

Experiment No.	Grit Size of Magnetic Abrasives (µm)	Rotational Speed (r.p.m)	MFD (Gauss)	%age of Magnetic abrasive (%age)	Quantity of Magnetic Abrasives (g)	PISF (%age)
1	45	300	3000	15	20	21.12
2	60	300	3000	15	20	35.24
3	100	300	3000	15	20	64.38
4	163	300	3000	15	20	75.88
5	250	300	3000	15	20	82.58
6	450	300	3000	15	20	79.31
7	600	300	3000	15	20	52.23

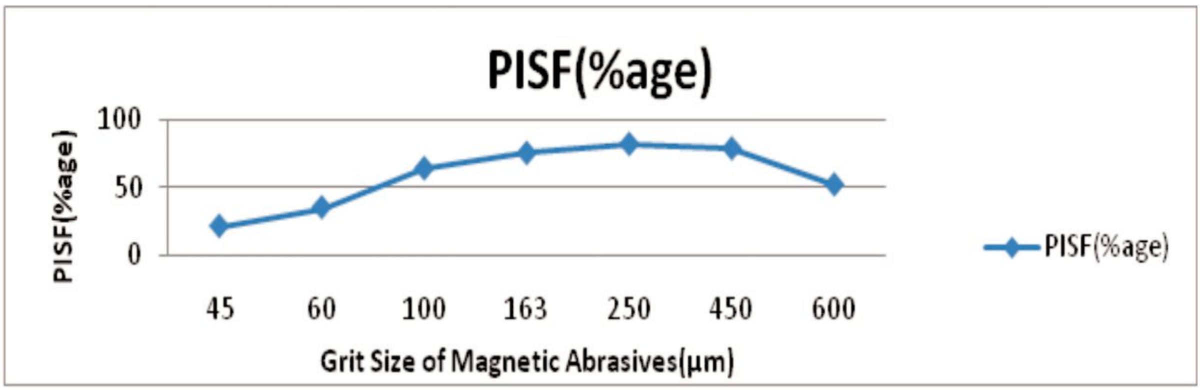
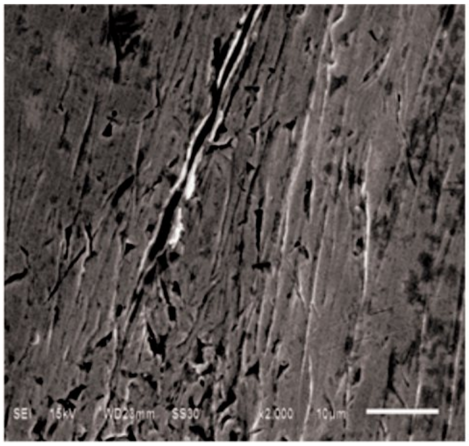


Figure 8 Effect of Grit Size of Abrasives on PISF

SURFACE MORPHOLOGY

Scanning electron microscopy images of samples before and after machining were obtained to get better understanding of the surface profiles generated. Figure 9 and 10 show the SEM images before and after MAF respectively. The observations reveal that the scratches and the grinding marks were removed by magnetic abrasive finishingand most of the peaks have been sheared off to a much smaller height resulting in improved surface finish.



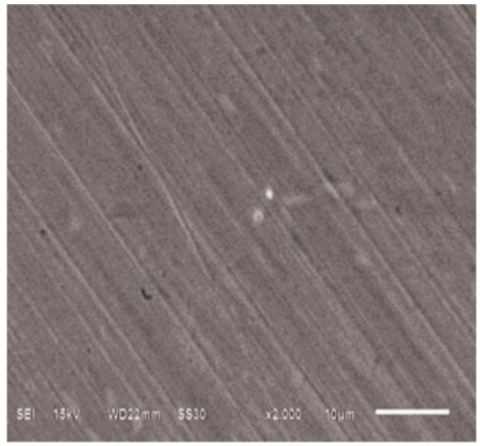


Figure 9 SEM photograph of unfinished surface   Figure 10 SEM photograph of finished surface

CONCLUSIONS

This study showed the feasibility of using Diamond based sintered magnetic abrasive particles for the finishing of SUS 304 stainless steel plates. It is concluded from the results and discussions that Percent improvement in surface finish (PISF) was significantly affected by magnetic flux density, grit size of abrasives, rotational speed of magnetic poles and machining time. The process yield best results at Magnetic flux density = 3100 Gauss, Rotational speed of magnetic poles = 250rpm, Grit size of abrasive particles = 250μm and machining time 2hrs and %age of abrasive particles =10 for Percentage improvement in surface finish.

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Magnesium and its applications in automotive sector: An overview

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ABSTRACT

Recent pressures on the automotive industry to produce light-weight fuel efficient vehicles with lower emissions have led to development of light weight materials. Materials like steel, aluminum, and polymers are already being used by many automobiles industries, but additional 22% to 70% weight reduction could be achieved by use of less denser magnesium and its alloys. At present relatively small quantities of magnesium are in use for automobile parts, which is limited to die castings only. R&D wok is continued to enhance the use of magnesium alloys for some other parts like automotive structural and sheet applications. The current advantages, status of the development of magnesium alloys and applications of Magnesium and its alloys in the automotive sector are discussed in this paper. The study concludes that Magnesium alloys can be good alternative material for production of automotive components to enhance the performance of vehicles.

Keywords: Magnesium, applications, automotive, power train.

INTRODUCTION

Now a day's biggest challenges in transportation industry to reduce fuel consumption and to reduce green house gas emissions. This challenge leads to the development of new structural materials with higher strength to weight ratios. Accordingly, close attention is paid to light metals and alloys such as magnesium, due to their intrinsic characteristics. Magnesium and its alloys are known to be the lightest structural materials today, and have been employed not only for road transportation vehicles but for various types of aero, marine and space research also. The low density of magnesium combined with good machinability, castability, damping capacity and wearing qualities have rendered it eminently suitable for its multifarious applications. Magnesium has a density of 1.74 g/cm^3 which is 35% lighter than aluminium (2.7 g/cm^3) and 78 % lighter than steel (7.86 g/cm^3). As a result, magnesium alloys offer a very high specific strength among conventional engineering alloys (Ye and Lue 2004). The physical properties of Mg, Al and iron as used in transportation sector are indicated in Table 1.

Table 1 Physical properties of Mg, Al, and Fe (Davies, 2003)

S.No.	Property	Magnesium	Aluminium	Iron
1.	Crystal structure	Hcp	FCC	Bcc
2.	Density at 20°C (g/cm^3)	1.74	2.70	7.86
3.	Coefficient of thermal expansion 20–100°C (×106/C)	25.2	23.6	11.7
4.	Elastic modulus [Young's modulus of elasticity] (106 Mpa)	44.126	68.947	206.8
5.	Tensile strength (Mpa)	240 (for AZ91D)	320 (for A380)	350
6.	Melting point (°C)	650	660	1536

Magnesium is the eighth most common element and mostly found in the earth's ocean. it is produced through either the metallothermic reduction of magnesium oxide with silicon or the electrolysis of magnesium chloride melts from seawater. Magnesium alloys are good for engineering applications because they have good strength, ductility and creep properties and excellent castability. On the other hand, magnesium has shortcomings, such as insufficient strength, elongation and heat resistance, and a corrosion propensity. Its corrosion problem has been found to be due to trace content of metals such as iron (Fe), nickel (Ni) and copper (Cu). The problem of corrosion has to be solved if the purity of the Mg is improved. However, its electrochemical potential indicates that magnesium will corrode by contact corrosion whenever it is in contact with any other metal. Therefore, magnesium is generally surface-treated before it is used. Pure magnesium is rarely used in the manufacturing of aerospace and automotive parts due to poor mechanical properties. In order to enhance its mechanical properties, it is generally alloyed with other metals i.e aluminum, zinc, yttrium and zirconium etc. This increases the strength to weight ratio which make them important materials for applications where weight reduction is major concern. Magnesium is strong and light, making it an excellent choice for automobile and aerospace applications such as steering wheels and columns, seat frames, transmission cases, crank case, camshaft sprocket, gearbox housings and aircraft parts (**Blawert et. al., 2004)**. Most of the available magnesium (40 %) is still used for alloying aluminium and only about 34% is directly used for magnesium parts, which can be divided into casting applications (33.5%) and wrought materials

(**Blawert et. al., 2004)**. Developing manufacturing technologies will help to minimize the costs for components and help to increase the area of applications. The average weight of magnesium in European cars is about 2.5 kg and In some of the vehicles the amount of magnesium used was higher e.g. 12 kg, but generally in total it is far less than 1% of the total vehicles weight (**Blawert et. al., 2004)**.

APPLICATIONS OF MAGNESIUM ALLOYS

Automotive producers have always paid attention on application of light weight materials to develop automotive components to improve fuel efficiency and to reduce weight. Global trends force the automotive industry to manufacture lighter, more environmentally friendly, safer and cheaper cars. The automobile body parts broadly categories into three major systems or component i.e the *body*, the *powertrain*, and the *chassis which* are listed in Table 2.

Table 2 Components in the Three Major Auto Systems (Gaines et. al., 1996)

Powertrain	Body	Chassis
engine and accessories engine electricals engine controls engine cooling system transmission or transaxle clutch (if manual) drive line (rear-wheel drive) differential transfer case	unibody and closures glass hardware exterior and interior trim body electricals seats passenger restraints instruments and controls climate control	suspension steering system bumper system brake system subframes fuel storage system chassis electricals exhaust system wheels and tires

Traditionally these parts were made from cast iron and steel, from last few decades many component materials are replaced by replaced by aluminium and magnesium alloys. Volkswagen was the first automotive industry to used magnesium in its Beetle car, which used magnesium upto 22 kg. Porsche first worked with a magnesium engine in 1928. The use of magnesium in cars is increasing day by day from only 3 kg in 2005 to 20kg in 2010. The countries s like Europe, North America, Korea and Japan are actively using magnesium in power trains and interiors parts of luxury cars for significant weight reduction (Kim and Han,2008). The average weight of magnesium in European cars is about 2.5kg and it is predicted that the 300 different magnesium parts used in European cars today. In European cars nearly 85 % steering wheels are made by magnesium alloys i.e Toyota, BMW and VW. Magnesium is used by general motors to produce for instrument panel, transfer cases, steering wheel and side mirror brackets of a GMT800 full size pickup truck. The producer of the Mg alloy component and applications on the car models are given in Table 3.

Table 3 Producers of Mg alloy component and applications on car models (Kulekci, 2008**)**

S. No	Component	Producers and car models
1.	Engine block	BMW: lighter, more powerful and durable six-cylinder inline combustion engine. The world's first engine block made of Noranda's patented alloy AJ62 (Mg-Al-Sr).
2. 3.	Steering wheel frame Seat frame	Ford (Ford Thunderbird, Cougar, Taurus, Sable), Chrysler (Chrysler Plymouth), Toyota, BMW (MINI), Lexus (Lexus LS430). GM (Impact), Mercedes-Benz (Mercedes Roadster 300/400/500 SL), Lexus (Lexus LS430)
4.	Instrument panel	GM, Chrysler (jeep), Ford, Audi (A8), Toyota (Toyota Century)
5. 6.	Wheel rims Cylinder head	Toyota (Toyota 2000GT, Toyota Supra), Alfa Romeo (GTV), Porsche AG (911 Serie) Dodge (Dodge Raw), Honda Motor (City Turbo), Alfa Romeo (GTV), AutoZAZ-Daewoo (Tavria, Slavuta, Daewoo-Sens), Honda, BMW, Ford, Isuzu, Volvo Motors (LCP), Chrysler
7.	Clutch case	AutoZAZ-Daewoo (Tavria, Slavuta, Daewoo-Sens), Volvo Motors (LCP), Alfa Romeo (GTV)
8.	Transmission case	AutoZAZ-Daewoo (Tavria, Slavuta, Daewoo-Sens), Volvo Motors (LCP), Porsche AG (911 Serie), Volkswagen (Volkswagen Passat), Audi (A4,A6), Mercedes-Benz
9.	Lower crankcase	Chrysler (jeep), Alfa Romeo (GTV), GM (Oldsmobile), McLaren Motors (F1-V12)
10.	Cylinder block (without liners and main bearing heads)	GM (Pontiac Gran AM, Corvette)
11.	Intake manifold	GM (V8 North Star motor), Chrysler
12.	Air intake system	BMW (V8 motor)
13.	Steering link bracing	GM (LH Midsize)
14. 15.	Oil pump body Camshaft drive chain case	McLaren Motors (F1-V12) Porsche AG (911 Serie)
16.	Gear controls housing	AutoZAZ-Daewoo(Tavria, Slavuta, Daewoo-Sens)
17.	Brackets for air comfort system compressor, steering booster pump and generator	Chrysler, Volkswagen (Volkswagen Lupo)

Some of the specific automotive components which are produced from magnesium alloys are given in Fig. 1.

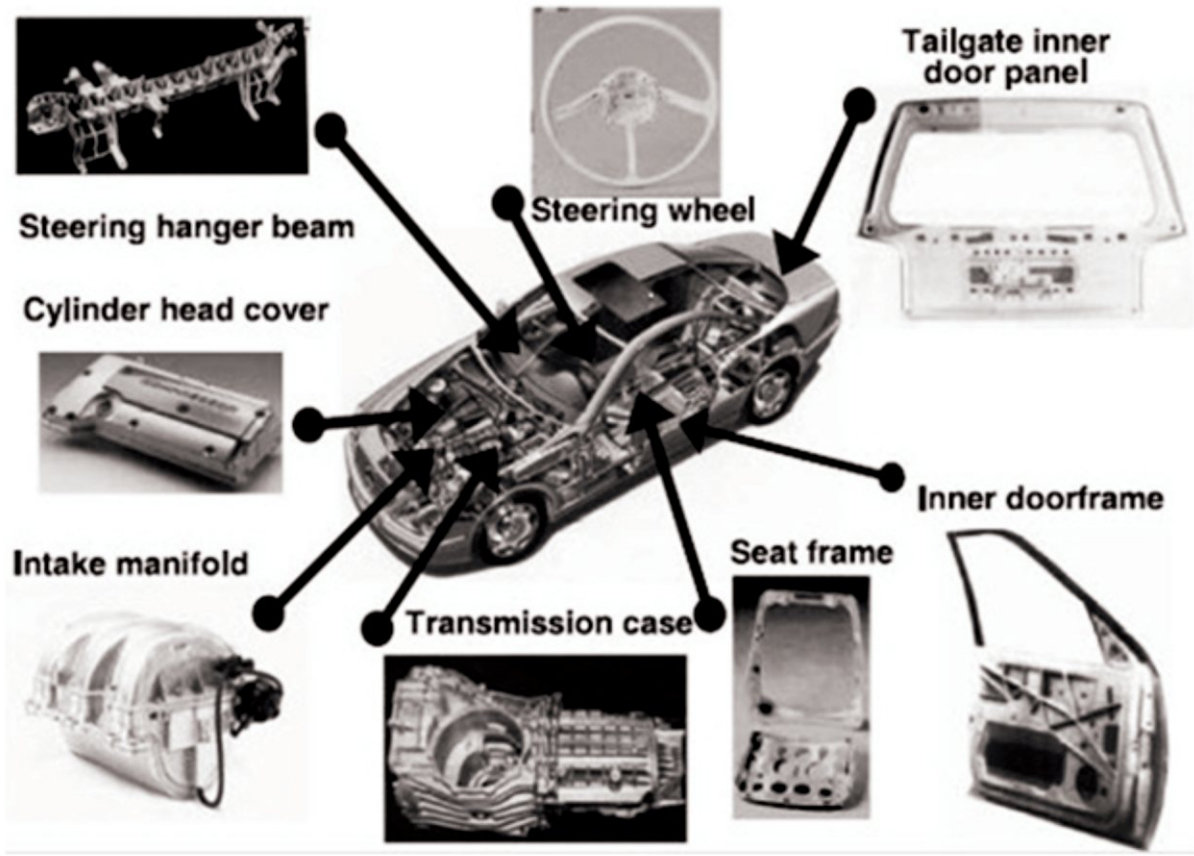

Fig. 1 Examples of automotive components made of Mg alloys

SOME IMPORTANT MAGNESIUM ALLOYS

Pure magnesium is rarely used in the manufacturing of aerospace and automotive parts due to poor mechanical properties. In order to enhance its mechanical properties, it is generally alloyed with other metals i.e aluminum, zinc, yttrium and zirconium etc. (Westengen, 1993). The classification of magnesium alloys adopts the method used by the American Society for Testing and Materials (ASTM). The designation system uses the combination of letters and numbers for identification of the alloys. The first two letters indicate the major alloying elements in the alloy. The letter corresponding to the element shows the quantity of higher element in the alloy system followed by the smaller one, while, if the elemental composition exists in equal quantities, then the alphabetical order is followed. Mg-Al alloys are among the most widely used industrial die casting applications. Such alloys present a good combination of castability, mechanical strength, ductility and excellent corrosion properties. Additions of Al improve mechanical strength and hardness, with the strengthening effect based on a solid-solution formation and an $Mg_{17}Al_{12}$ phase. Mg-Al alloys are often alloyed with Zn, to improve fluidity and room temperature strength by reducing the solid solubility of Al in Mg. recently Mg-Al-RE based variant was developed, which increase the creep properties of Mg alloys. These rare earth alloying elements are added to develop a new alloy designated AE42, which have better mechanical properties then AZ seires alloy.. Magnesium is alloyed to influence its physical and mechanical properties, corrosion behavior for various weight critical applications. The magnesium alloys: broadly classified into two categories: (i) Alloys with 2 to 10% aluminum with additions of zinc and manganese, and (ii) Alloys containing zinc with additions of rare earth (RE) metals, thorium, silver, and zirconium (Aghion et. al.2003, Friedrich, 2001, Garmo et. al. 1997, Huang et. al.2006).

The commonly used magnesium alloys for automobile application are shown in table 4.

Table.4: Commonly used Magnesium alloys and its applications

(Aghion et. al.2003, Friedrich, 2001, Garmo et. al. 1997, Huang et. al.2006)

s.no	Alloy designation	Alloying additives	Basic properties and applications
1.	AZ91	9.0% Al, 0.7%Zn 0.13%Mn	Good castability, good mechanical properties at T<150°C, magnesium die casting alloy.
2.	AZ31	3.0% Al, 1.0Zn, 0.2% Mn	Good extrusion alloy
3.	AM20	Mg-Al system	High ductility, toughness, poor die-castability
4.	AM60	6.0% Al, 0.15%Mn	Greater toughness and ductility than AZ91, slightly lower strength. used for automotive wheels and structural applications
5.	AM 50	Mg-Al system	Good strength, ductility, energy absorption properties and castability
6.	AE42	Mg-4 atomic percent Al-2 atomic percent rare earths	Low castability, good creep behaviour
7.	AE44	Mg-Al-rare earth system	Better creep behaviour and castability than AE42
8.	AJ62	Mg-Al-Sr system	Good thermal and mechanical strength, superior castability, corrosion resistance and creep behaviour

CONCLUSION

Magnesium automotive parts continue to increase due to need for weight reduction and high performance. Greater demand for reduced emissions and better fuel economy in passenger vehicles are the driving forces behind the expanding the use of magnesium. The use of magnesium in automobile industries is increasing day by day due to its low density and high strength to weight ratio. Many automobiles companies throughout the world have started using different magnesium alloys for various parts of automobiles but still use is limited due to cost and manufacturing difficulties. There are various problems to be solved but there is a much bigger potential for magnesium alloys in automotive application than currently used. Magnesium will be good replacement of aluminium and steel if effective and cheaper manufacturing method developed. In essence, the use of magnesium will continue to be developed to address the legislative and environmental pressures on the automotive industry to produce lighter and more fuel efficient vehicles.

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Development, Microstructure Examination and Performance Evaluation of Al_2O_3-Fe Sintered Magnetic Abrasives

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ABSTRACT

Conventional edged tool for machining is uneconomical for harder and difficult to machine materials and also degree of surface finish achieved is poor. In recent years, a great deal of attention in mechanical engineering has been focused on finishing operations. In view of the seriousness of this problem, recently new non-conventional fine machining process i.e. Magnetic Abrasive Machining (MAM) has been developed. However, the major constraint in wide spread adoption of this technology is the exorbitant cost of magnetic abrasive, which acts as a cutting tool in MAM, very few studies have been reported till date on the development of alternative magnetic abrasives. In this paper, to improve the finishing performance, iron (Fe) powder mixed with alumina (Al_20_3) abrasive particles were developed as magnetic abrasives by sintering technique. ***These sintered magnetic abrasives were prepared*** *by mixing of Al_2O_3 abrasive particles of 200 mesh size and iron powder of 300 mesh size, compacting these with universal testing machine (UTM) and then sintered at various temperatures in a sintering machine in inert atmosphere. These compacts were crushed into fine powder and sieved to obtain various sizes of magnetic abrasives. These abrasives were micro-structurally examined. The results indicate that the densification increases and porosity decreases with increase in sintering temperature. Further it was clarified that the developed magnetic abrasives has potential performance as a new magnetic abrasive for fine finishing.*

Key words: Magnetic Abrasive Machining (MAM), Sintering, Universal Testing Machine (UTM)

INTRODUCTION

There has been a rapid growth in the development of harder and difficult to machine metals and alloys during the last two decades. Conventional edged tool machining is uneconomical for such materials and degree of surface finish attainable is poor. In recent years, a great deal of attention in mechanical engineering has been focused on finishing operations aimed at tightening the finishing tolerance of machined components. It is difficult to finish advanced engineering materials with high accuracy, and minimal surface defects such as micro cracks, by conventional grinding and polishing techniques. To minimize the surface damage, gentle flexible finishing conditions are required, namely, a low level of controlled force. Magnetic field assisted manufacturing processes are becoming effective in finishing, cleaning, deburring and burnishing of metal and advanced engineering materials parts . In view of the seriousness of this problem, recently new non-conventional fine machining processes like Magnetic Abrasive Polishing, Magnetic Abrasive Flow Machining (MAFM), Magnetic Float Machining (MFM) and Magnetic Abrasive Machining (MAM) have been developed. Most of the existing studies throw light on the development of process and in the direction of enhancing the capabilities and applications of the process. However, the major constraint in wide spread adoption of this technology is the exorbitant cost of magnetic abrasive, which acts as a cutting tool in MAM, very few studies have been reported till date on the development of alternative magnetic abrasives.

The two types of magnetic abrasives were prepared using this technique by Shinmura et.al. (1990). In one iron particle was varied and in other the diameter of abrasive particle. The influence of the grain diameter of abrasive particle on stock removal was comparatively small while surface roughness was remarkably affected while diameter of iron particle affects both stock removal and surface finish. MAF setup for internal finishing of three kinds of tubing materials (Ly12 aluminium alloy, 316L stainless steel and H62 brass) was designed and developed by Wang et. al. (2005). The effects of different finishing parameters such as polishing speed, magnetic abrasive supply, abrasive material, magnetic abrasive manufacturing processes and particle size were studied. Khairy (2001) prepared magnetic abrasive particles by blending of aluminum oxide(15%) and iron powders(85%) compacting them by a bench press, sintering the mixture in a furnace at 1400° C in inert medium, crushing into small particles and sieving to different ranges of sizes.

Lin et. al. (2007) prepared magnetic abrasives by typically mixing iron powder and aluminum oxide and then compressing into cylindrical shape, these were sintered in vacuum furnace. After process, these cylinders were crushed to produce magnetic abrasives of average size 150 micrometer. These magnetic abrasives were used with ball-shaped magnetic poles having special grooves to form a flexible magnetic brush. Kreman et. al. (1999) developed magnetic abrasives by using the technique in which an adhesive is used to bind magnetic iron powder with abrasive alumina powder. All the components are mixed thoroughly, dried and crushed into small particles of desired size for machining. The spherical iron based magnetic abrasive was developed by Yamaguchi et. al. (2007), which carries aluminum oxide grains on the surface, made by plasma spray. Fox et. al. found that the unbounded magnetic abrasive particles yield higher material removal rate for ceramics. Yin et. al. (2004) finished magnesium, steel and Brass with mixed magnetic abrasives. The volume removal rate of magnesium alloy is more than others. Alumina ceramic tubes were finished using mechanical mixture of iron particles, alumina abrasives and soluble type barrel finishing compound by Yamaguchi et. al. (2004). Jain et. al. (2001) designed and fabricated MAF setup and the performance of setup on nonmagnetic stainless steel were studied with the use of loosely bounded MAP. Singh et al. (2010) used UMA prepared by homogeneous mixing of 25% SiC abrasives (mesh no. 400) and 75% iron particles (mesh no. 300) in 3% oil (SAE30) for finishing of alloy steel tubes. The surface roughness of the workpiece was decreased from 0.58 μm Ra to 0.11μm Ra. Sran et. al. (2012) prepared mechanically alloyed magnetic abrasives for finishing of brass tubes upto nano level. They obtained surface finish of the order of 3 nm. Khangura et. al. (2015) used magnetic abrasive machining technique to remove the recast layer formed by EDM. They observed that the recast layer of around 52 μm has been removed in 40 minutes with nearly 80% improvement in surface finish.

EXPERIMENTAL DETAILS

Experimental Set Up

The schematic view and external photograph of experimental set up i.e. sintering machine is shown in figure **1 and** figure **2 respectively.** Sintering machine is an electric furnace in which specially designed stainless steel tube is used. The specimens are placed in this tube and heated at given temperature ranges for 2 hours. Simultaneously H_2 gas is passed through tube to create inert atmosphere. **The main parts of sintering machine are:**

a) Electric Furnace (Max 1200° C)
b) Thermocouple
c) Stainless Steel (AISI 310S) Tube
d) Power Supply & Control Unit of the Furnace

e) H_2 Gas Cylinder

f) Pressure Regulator & Pressure Gauges

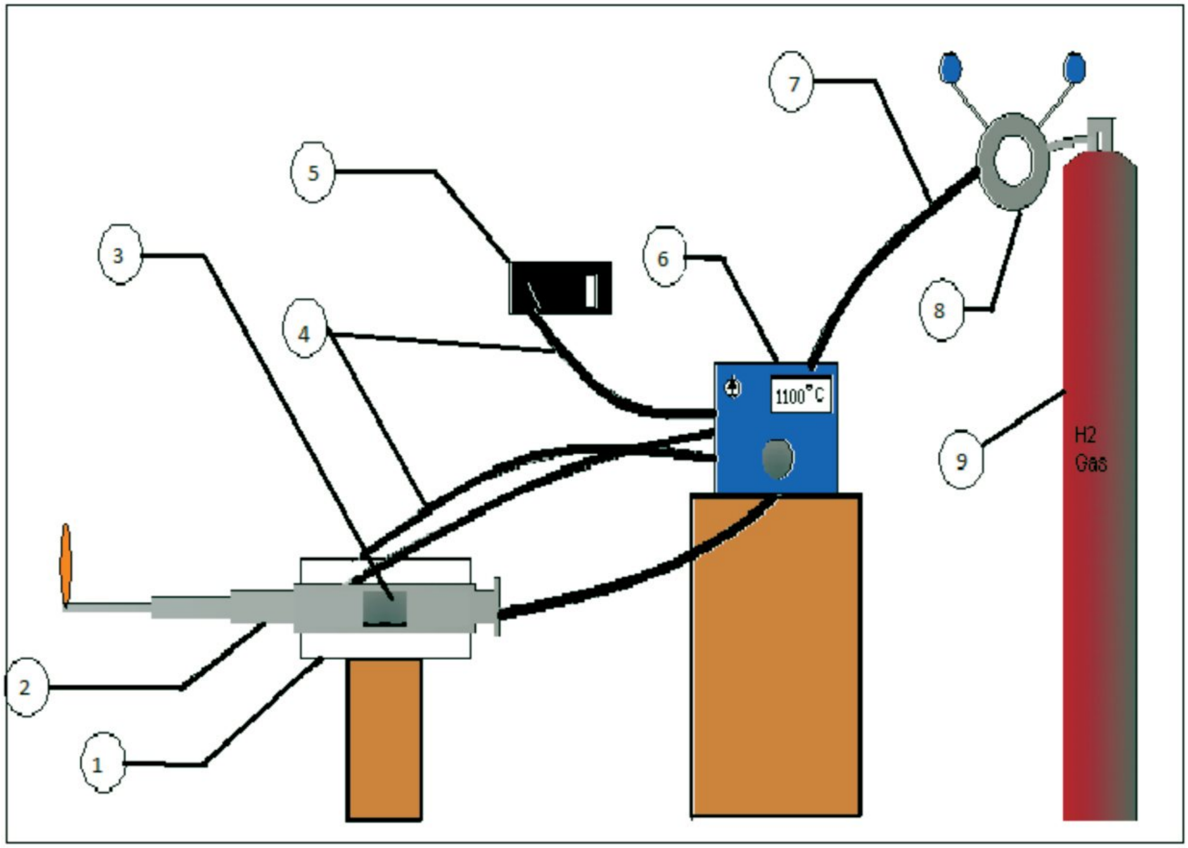


Figure 1. Schematic of sintering machine

1. FURNACE; 2. STAINLESS STEEL (AISI 310) TUBE; 3. SPECIMENS FOR SINTERING; 4.POWER CABLE; 5. MAIN SUPPLY 220V; 6. POWER SUPPLY & CONTROL UNIT OF THE FURNACE; 7. HOSE PIPE FOR H_2 GAS; 8. PRESSURE REGULATOR AND PRESSURE GAUGES; 9. H_2 GAS CYLINDER

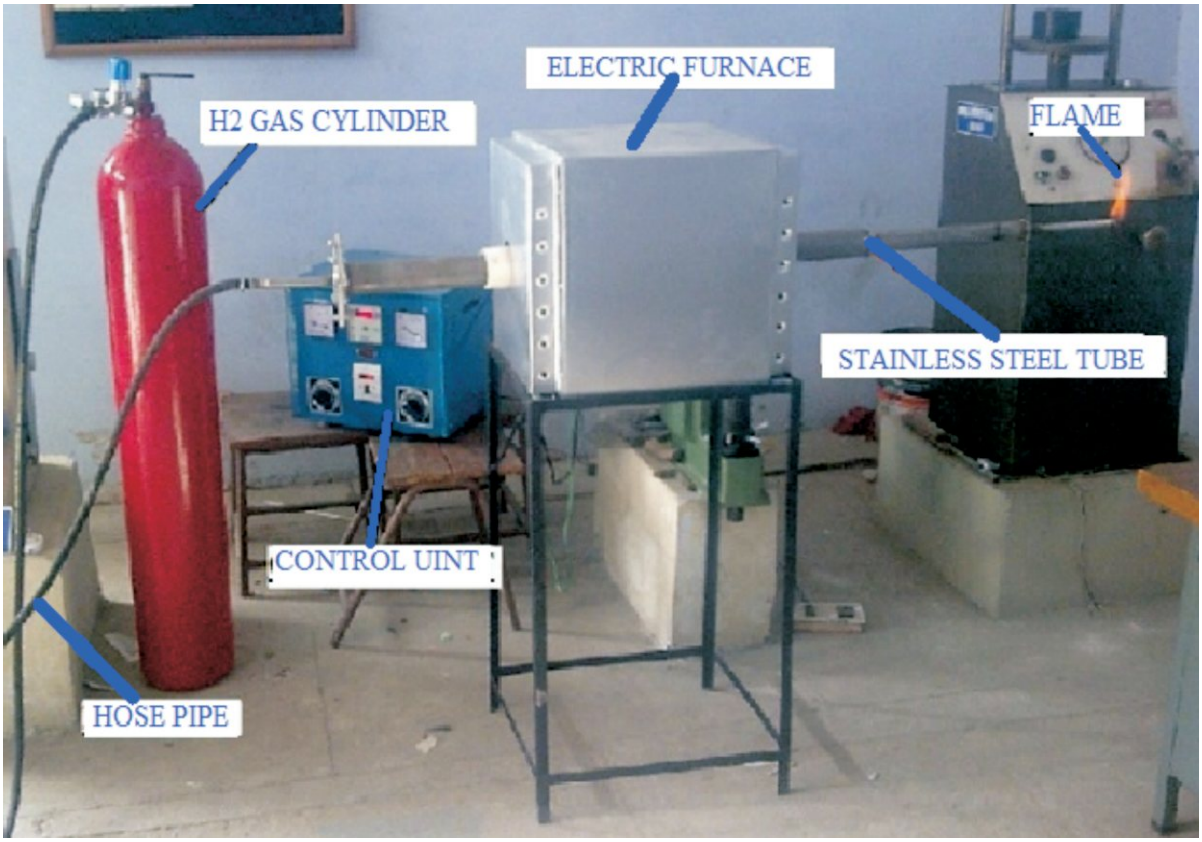


Figure 2. Sintering machine

Development of Sintered Magnetic Abrasives

The following procedure was addpoted for the development of sintered magnetic abrasives:

- Mixing of iron and aluminium oxide powders
- Preparing the compacts of specimens collected
- Sintering of specimens
- Crushing of compacts and sieving

Mixing of iron and aluminium oxide powders

The iron powder and (300 mesh size) and Al_2O_3 powder (200 mesh size) powders were mixed thoroughly in different proportions (by weight) to prepare some specimens. The three proportion used were

90%Fe+10%Al_2O_3, 85%Fe+15%Al_2O_3 and 80%Fe+20%Al_2O_3.

Formation of compacts of specimens collected

Powder metallurgy is a forming and fabrication technique consisting of three major processing stages. First, the primary material is physically powdered, divided into many small individual particles. Next, the powder is injected into a mold or passed through a die to produce a weakly cohesive structure (via cold welding) very near the dimensions of the object ultimately to be manufactured. Pressures of 10-40 tons per square inch are commonly used. Finally, the end part is formed by applying pressure, long setting times (during which self-welding occurs), or any combination thereof. The compacts of different proportions of Fe + Al_2O_3 were prepared in split cylindrical die by applying 10-15 tons of load by using Universal Testing Machine (UTM) in this work. The mixtures that is used here is mixed by the percentage of volume in different proportions.

Sintering of compacts

The compacts were **placed within the stainless steel tube and were heated with the help of an electric furnace** at different temperatures i.e. 900°C, 1000°C, 1100°C. **The furnace raised the temperature of the specimens up to 1100° C and simultaneously the H_2 gas was supplied through hose pipe with suitable pressure that was indicated by the pressure gauges attached on the cylinder containing H_2 gas for two hours.** The pressure was controlled by pressure regulator. At last the furnace was switched off and sintering specimens were cooled at a very slow rate to refine the structure of the specimens. The hydrogen gas helps to produce improved surface crystalline, eliminates scaling, achieves optimum magnetic characteristics, and removes impurities like surface carbon, phosphorous. A nomenclature, e.g. 10AFe900, is given to each specimen. Here A denotes the aluminum oxide, Fe denotes iron, and 900 denotes the sintering temperature. Nine specimens were prepared with different %age of aluminium oxide and temperatures of sintering.

Crushing of compacts and sieving

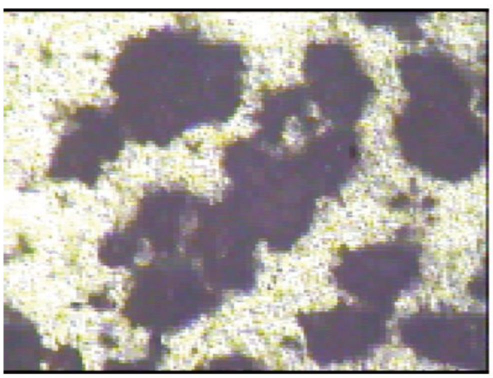
The sintered compacts were crushed mechanically into desired size. The sintered compacts were crushed into powder form. Then powdered abrasives were passed through different sieves to get different abrasive sizes. The obtained abrasive sizes were 85µm, 120µm, 200µm, 300µm, 420µm.

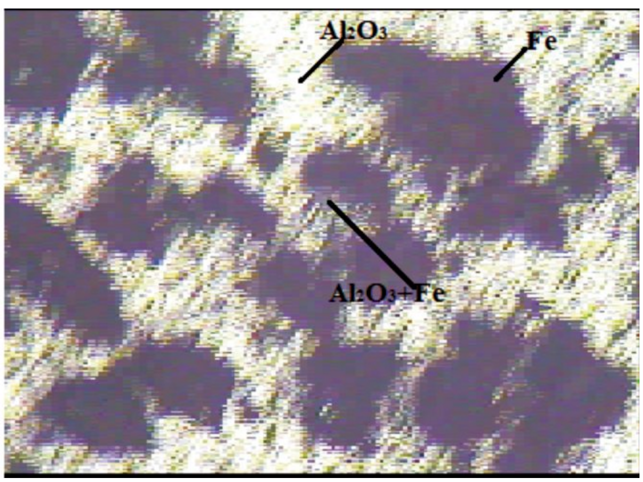
RESULTS AND DISCUSSION

Microstructure Study

To investigate the sintering development of phase and microstructure, micrographs of all the specimens were recorded using metallurgical microscope. In this paper, the microstructures of specimens 10AFe900, 15AFe900, 20AFe900, 10AFe1000, 15AFe1000, 20AFe1000, 10AFe1100, 15AFe1100 and 20AFe1100 were examined. The microstructure photographs of all the specimens' shows three types of grains, white ones are of aluminum oxide, black are of iron and greyish are of iron aluminate, respectively. The nanosize particles of iron aluminate are formed. The iron aluminate formed here is due to reactive sintering between iron and alumina particles. The various particles, i.e. of iron, alumina and iron aluminate, present in the microstructure have been marked on the photographs.

Figure 3 shows the microstructure of specimen 10AFe900, 10AFe1000 and 10AFe1100 respectively. It can be clearly seen that with increase in temperature dense phase formation increases and porosity decreases. The specimen 10AFe1100 is denser in comparison to specimen 10AFe900 and 10AFe1000. Similarly the specimens 15AFe1100 and 20AFe1100 are dense with less porosity as shown in figure 4, figure 5 and figure 6.





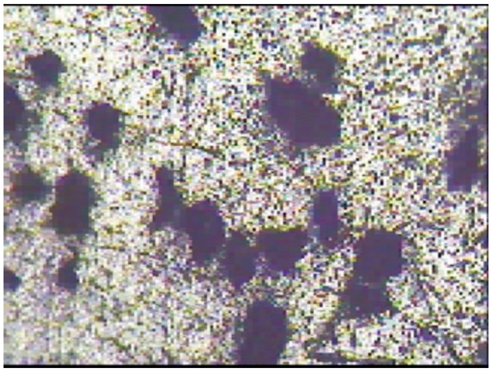
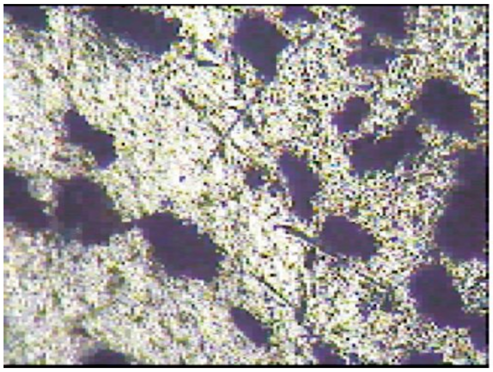


Figure 3. Microstructure photo of (a) 10AFe900 (b) 10AFe1000 and (c) 10AFe1100



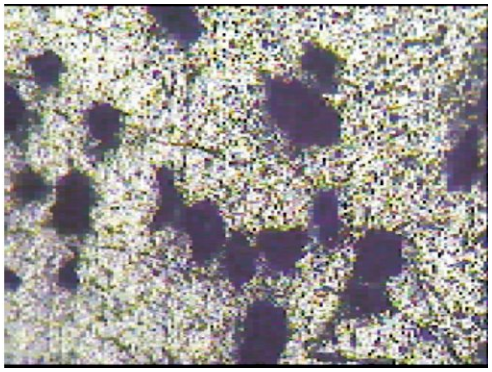


Figure 4. Microstructure photo of (a) 15AFe900 (b) 15AFe1000

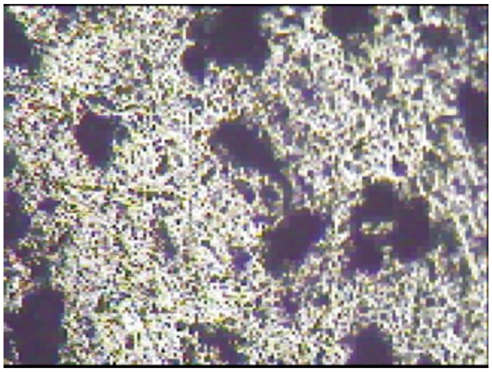


Figure 5. Microstructure photo of 15AFe1100

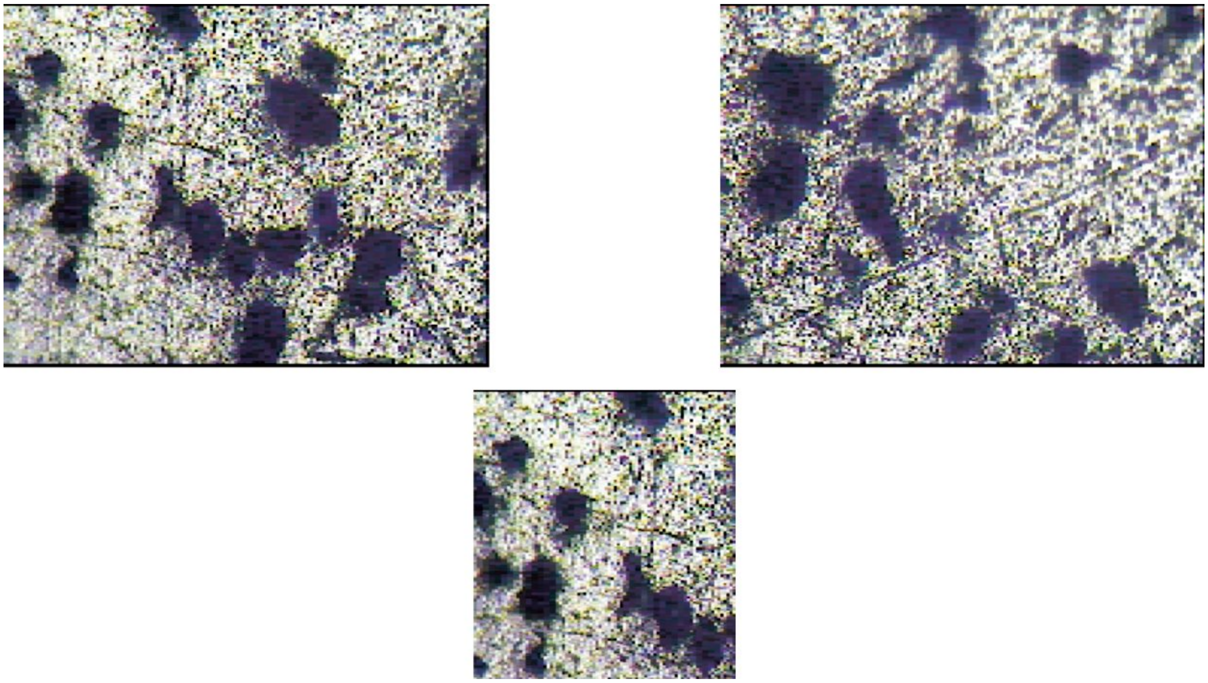


Figure 6. Microstructure photo of (a) 20AFe900 (b) 20AFe1000 and (c) 20AFe1100

Performance Evaluation of Developed Sintered Magnetic Abrasives

The performance of developed sintered magnetic abrasives was evaluated in terms of PISF (Percentage Improvement in Surface Finish). The internal finishing of aluminium pipe was done on magnetic abrasive machining (MAM) set up using these sintered magnetic abrasives. The constant parameters were taken as 0.8 Tesla MFD (Magnetic Flux Density), 900 RPM of speed, 120µm size of abrasives, quantity of abrasives 15 gm and machining time of 45 minutes for evaluation. As it can be clearly seen from the figure 7, that PISF is higher for magnetic abrasive sample 15AFe1100 (15% Al_2O_3, sintering temperature of 1100° C). Therefore the performance of sintered magnetic abrasives improves with increase in sintering temperature.

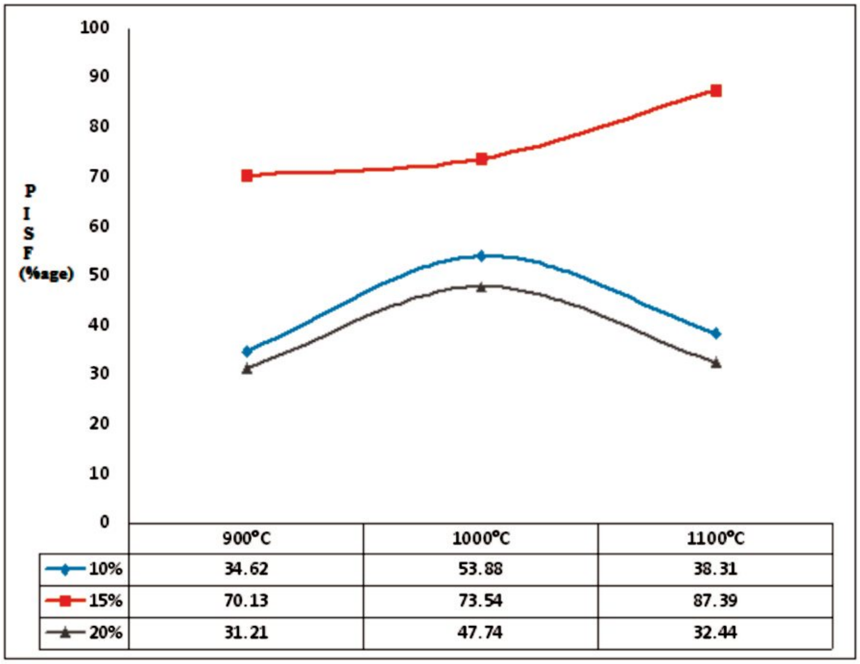


Figure 7. Effect of temperature and %age of Al_2O_3 on PISF

CONCLUSIONS

The conclusions drawn from this research work are summarized as following:

1) The sintering of abrasives results in induced ductility, relieves internal stresses, refines the structure and **increases the bonding strength of Al_2O_3 + Fe abrasive powder**.
2) The dense phase formation increases and porosity decreases with increase in sintering temperature.
3) The developed magnetic abrasives has potential performance as a new magnetic abrasive for fine finishing. The abrasives 15AFe1100 delivered higher improvement in surface finish.

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A Study of Performance of Mechanically Alloyed Magnetic Abrasives on Ceramic Tubes

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ABSTRACT

In modern industries like Ceramic, Cement, Optical Electronics, Medical instruments and Nuclear Reactors there is a great need of parts having super finishing geometries. The Magnetically Assisted Abrasive Finishing (MAAF) processes are emerging as one of the most suitable techniques for obtaining quality finish in which deep cutting marks left by conventional finishing processes like Grinding, Honing, and Lapping etc. In MAAF processes, Ferromagnetic particles are mixed with fine abrasive particles like Al_2O_3*, SIC, CBN and Diamond to form magnetic abrasive particles. In this paper, study of evaluation of performance of magnetic abrasives prepared by a newly developed technique (Mechanical alloying) and a common technique (Annealing).Mechanical alloying and annealing process have been used to prepare magnetic abrasives having 15%* Al_2O_3 *and 85%Fe as constituent powders. An experimental set up was developed for the conduct of experimental work. The experiments were conducted to examine the effect of mesh size, current, quantity and rotational speed of work piece. The amount of lubricant and time has been taken as constant parameters. The performance parameter was taken as percentage improvement in surface finish (PISF).The process yielded best results (maximum surface finish=0.45 µm) at Rotational Speed =800 rpm, current = 3.00 Amp. Mesh Size = 35 and Quantity = 15 gm for PISF of Ceramic tube.*

Keywords*:* Magnetic Abrasives, Mechanical alloying, Annealing, Surface finishing. Etc.

INTRODUCTION

Magnetic Abrasive Finishing (MAF) is one of the promising processes for obtaining high level of finish on metallic and nonmetallic surfaces. Polishing of surfaces like Liquid piping systems, Vacuum tubes, sanitary tubes, High purity gas tubes and Pharmaceutical industries demands high cost. These are not easy to be polished by conventional finishing techniques such as grinding, because of their shapes and the conventional finishing processes apply uncontrolled high pressure on the work piece which may cause micro cracks. Magnetically assisted abrasive finishing is one of the methods which use a controlled magnetic force to finish surfaces. Magnetically assisted Abrasive Finishing has been able to give good surface and edge finishing by help of Flexible Magnetic Abrasive Brush (FMAB) formed in the magnetic field. Under the action of magnetic field the magnetic abrasives gets compressed against the surface to be finished and When rotary motion is given to the work piece the abrasives wear out the work piece material in the form of very small chips.

Principle of magnetic abrasive finishing

The process principle of internal MAF using a work piece rotation system is shown in Fig.1. When current is passed through the coils of the electromagnet, the poles of DC electromagnet generate the magnetic field. The magnetic field attracts the magnetic abrasives to the finishing area in the tube and presses the magnetic abrasive particles against the inner surface of the tube. The magnetic abrasives get conglomerated and form a flexible brush at the finishing area under the influence of magnetic force. When rotary motion is given the work piece, the material is removed from the inner surface of the tube by the magnetic abrasives due to the relative motion. The finishing magnetic abrasive brush is controlled by the magnetic force acting on the magnetic abrasives which in turn is controlled by the current supplied to the electromagnet.

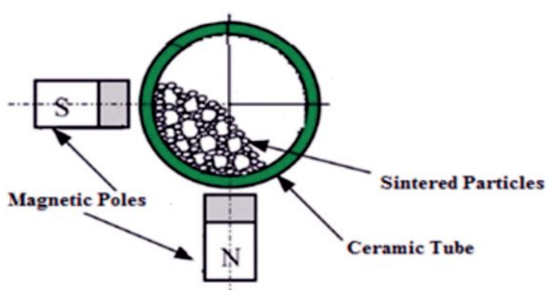

Figure 1. Magnetic Abrasive Finishing Process

REVIEW OF LITERATURE

The existing literature on MAF has been largely focused on three major areas:

1 Development of machines/setups for external/internal/plain finishing with AC and DC electromagnets
2. Process parametric optimization for obtaining best surface finish for metallic and non-materials.
3. Application of magnetic abrasives for developing new hybrid machining/finishing processes.
4. Most of the researchers are used sintered abrasives; few used mechanically alloyed abrasives.

It has been recognized that very few research studies are available in the direction of development and characteristics of magnetic abrasives. A representative brief literature review has been presented here for Highlighting major types of magnetic abrasives employed by various researchers. The sintered magnetic Abrasives have been used by some researchers (Kim 2003, Wang and Dejin 2005, Ching et al. 2007 Kremen et al. (1996) prepared magnetic abrasives by mixing ferromagnetic powder and abrasive power and adhesive. A special type of glue and mixture of ferromagnetic and abrasive particles were mixed in a required proportion. In several studies (Singh et al. 2010, Khairy 2001, Mullik and Pandey 2011), the simple mixture of ferromagnetic and abrasive powder (commonly known as unbounded magnetic abrasive Particles) has been used. An exhaustive review of various available methods of preparing magnetic Abrasives have been presented by Singh et al. (2005). There is a need to evaluate comparative performance of various types of magnetic abrasives. This will help the users to select suitable magnetic abrasive for an Application.

EXPERIMENTAL DESIGN

Preparation of Magnetic Abrasives

In the present work, the magnetic abrasives have been prepared by two techniques. The annealing process is one of the common techniques whereas mechanical alloying has been explored as an alternative technique for preparation of magnetic abrasives. The stepwise procedure for preparing magnetic abrasive is given as follows:

1. Mixing/blending of abrasive (Al_2O_3) Ferromagnetic powder (Fe).
2. Compacting of mixture.
3. Annealing of the compacts.
4. Crushing of compacts

Mechanically alloyed magnetic abrasives

These abrasives are act as a cutting tool in magnetic abrasive finishing process. They consist of ferrous particles and nonferrous abrasives. In this study, the magnetic abrasives are formed by mixing Al2O3 powder (Neutral) (mesh size-200) in two different percentages (i.e. 15% and 20%) by volume in Iron powder (mesh size-300). The mixtures were then compressed into cylindrical mode and annealed in a specially designed furnace at a temperature of 1075°C in the presence of H2 gas. Following the annealing process, the magnetic abrasives were crushed and separated to different sizes using sieving machine. During finishing, Iron particle and Al_2O_3 particle were difficult to separate since they cohered after annealing.

Experimental Setup

Fig. 2 shows photographic view of the experimental setup used for internal MAF. A known quantity of magneticabrasives mixed with required amount of lubricant was packed inside the tube and magnetic field was applied by the electromagnets. Due care was taken that the abrasives should remain in a confined zone on the internal surface of the tube. The magnetic field was generated by two electromagnets, with their poles at 90°apart. The field strength in the working zone may be controlled by the supply current to the electromagnets [Singh Chatwinder, Lakhvir Singh and Sehijpal Singh (2011)]. A set of samples was prepared for carrying out MAF on inner surface of Ceramic tubes for Different mesh sizes of both types of magnetic abrasives. The finishing capability of magnetic abrasives was analyzed by measuring the surface roughness (Ra) on the unfinished and finished inner surface of the tube. The Ra value was measured at four points along the length of tube. The percentage improvement in surface finish over the initial finish of the tube surface (PISF) is taken as performance parameter. For the proposed work, the magnetic abrasive powder will be prepared through homogeneous mixing of magnetic powder (iron powder of 300 mesh size) and Al2O3 powder (200 mesh size) with lubricating oil.

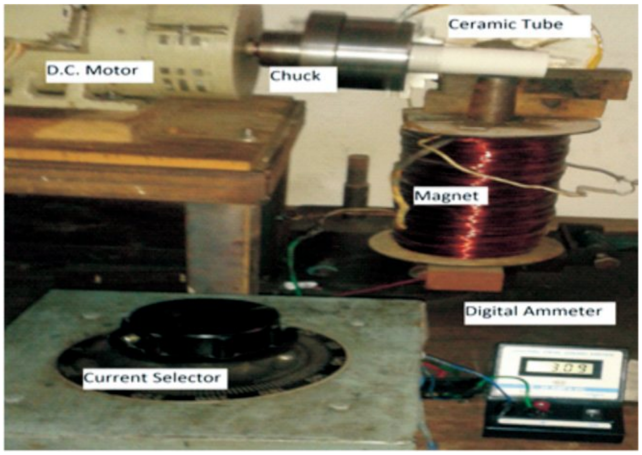

Fig.2 Photographic view of experimental set up.

RESULTS AND DISCUSSIONS

The important input process parameters and their working range have been selected on the basis of capability of the experimental set up developed for the present work. The independent variables of the process were Current, Rotational Speed, Mesh Size and Quantity of Abrasives. The range of input parameters was selected on the basis of preliminary trial experimental results.

Table 1 Input Process Parameters and Their Selected Levels.

Input Process parameter	Lower Level	Upper Level
Current (Amp)	2	4
Rotational Speed(RPM)	600	1000
Mesh Size (μm)	25	85
Quantity (gm.)	5	20

Constant Parameters

Machining Time = 1 Hour

Gap between Pole and work piece = 2mm

Quantity of lubricant= 1 ml for 5 gm. wt. of MAP's

Internal Diameter of work piece = 30 mm

Table 2.Experimental Data of Current, Rotational Speed, Mesh Size and Quantity of Abrasives with Responses PISF

Run	Current(amp)	Speed(RPM)	Mesh Size(μm)	Quantity(gm)	PISF(%age)
1	4	600	35	20	15.39
2	3	800	45	25	23.93
3	2	600	60	20	18.99
4	4	1000	35	20	8.74
5	4	1000	85	10	42.04
6	3	800	45	5	42.39
7	2	1000	60	10	22.01
8	4	1000	60	20	38.3
9	4	600	35	10	41.48
10	2	1000	60	20	35.38
11	2	1000	35	20	9.54
12	5	800	45	15	16.39
13	4	600	60	20	22.21
14	3	800	25	15	18.35
15	3	800	35	15	45.74
16	3	800	45	15	28.41
17	2	1000	35	10	22.67
18	3	800	45	15	20.31
19	2	600	60	10	16.61
20	4	600	60	10	24.12
21	3	1200	45	15	13.8
22	2	600	35	10	37.21
23	3	800	45	15	25.38
24	3	800	45	15	29.31
25	3	400	45	15	12.61
26	3	800	45	15	28.13
27	4	1000	60	10	28.73
28	1	800	45	15	11.19
29	2	600	35	20	15.67
30	3	800	45	15	27.31

RESULTS AND DISCUSSIONS

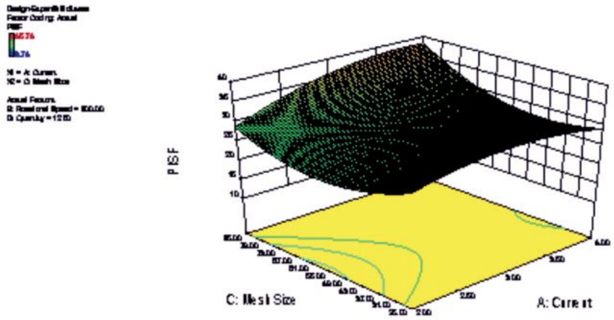

Figure 3:-3D graph plots for the effects of Current and Rotational Speed on PISF

Fig 3 Shows relation between current and mesh size, keeping the value of speed and quantity to a constant level. The combined effect shows that increasing the value of current the PISF first starts increasing and after that starts decreasing in the same manner as it started increasing. Similarly in case of mesh size at 35 mesh size & current 3 amps the PISF increased and then decreased accordingly.

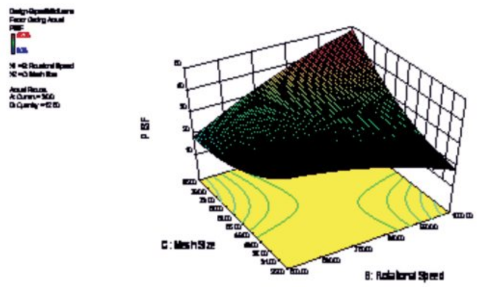

Figure 4:- 3D graph plots for the effects of Mesh size and Rotational Speed on PISF

The Fig. 4 shows the interaction effect of rotational speed & mesh size on PISF. At higher value of mesh size, PISF increases with increase in speed. PISF is maximum at higher level of speed and mesh size

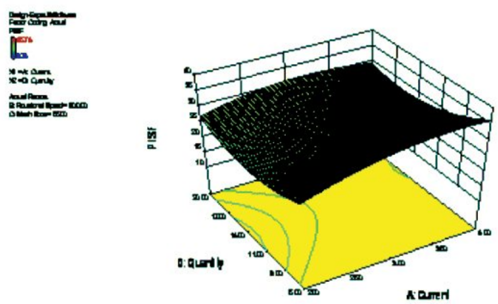

Figure 5:- 3D graph plots for the effects of quantity of abrasives and Current on PISF

Fig 5 shows that at 3amp current and 5gm abrasives the value of PISF is maximum after increasing the value of current and quantity of abrasives the PISF is decreasing, it will again increases with the increase in value of quantity of abrasives and the current..`

CONCLUSIONS

In the present work, Al_2O_3 based mechanically alloyed abrasives have been prepared. The performance of these mechanically alloyed magnetic abrasives has been studied on ceramic tubes. The conclusions drawn from the present research can be summarized as follows:

1.Percent improvement in surface finish (PISF) was significantly affected by current, rotational speed, interaction effect of rotational speed of workpiece & mesh size, interaction effect of rotational speed & quantity of abrasives, interaction quadratic effect of current, rotational speed, quantity of abrasives and mesh size also effects on PISF.

2. The process yielded best results (maximum surface finish=0.45 μm) at Rotational Speed =800 rpm, current = 3.00 Amp. Mesh Size = 35 and Quantity = 15 gm for PISF.

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Optimization of Process parameters of SS416 on Vertical Milling Machine using Grey Relation Analysis

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ABSTRACT

Milling is an extensively employed material removal process for different materials, which is characterized by high material removal rate. It is very important to study the effect of various process parameters on machining characteristics namely Metal removal rate (MRR) and surface roughness (SR). The present paper investigates the effect on MRR and SR by varying various process parameters such as cutting speed, feed rate, depth of cut and cutting oil while machining Stainless steel 416 using solid carbide tool on vertical milling center. The research is seeking to define methods that will allow the selection of optimal parameters for best machining performance. For this purpose, the Taguchi method with the Grey Relational Analysis is applied.

KEY WORDS: CNC, Vertical Milling Centre, Surface Roughness (S.R.), Material Removal Rate (M.R.R.), Optimization, Taguchi Method, Grey Relation Analysis.

INTRODUCTION:

Manufacturing is the fortitude of any industrialized nation. There is numerous process of converting raw materials into useable forms. Milling is also one of the most important methods of converting raw material into final product or, goods. It is the process of removing material by means of a rotating multiple teeth cutter. It is fast and cost-effective method, which manufacture the product at low cost with good surface quality. The surface produced by milling operation may be flat, angular or curved depends upon the product requirement. It can also machine intricate shape and complex geometry. It is necessary to select the appropriate parameters to manufacture the product economically. The present research work revealed the effect of process parameters such as cutting speed, feed rate, depth of cut and cutting fluid on vertical milling machine (VMC). The aim of this study is to optimize the process parameters namely cutting speed, feed rate, depth of cut and cutting fluid to maximize the material removal rate (MRR) and minimize the surface roughness (SR). Three fluids are used in this study, one is the Machine oil and rest two's is the derived from vegetable oil. The vegetable oil is refined vegetable oils (Canola and Sunflower oil) as base oil mixed with a mixture of emulsifiers in different ratio with water for milling of AISI stainless steel 416(SS 416). The two surfactants were added namely 'Tween 80 (10% used) and 'Peg 400' (20% used).The other components may be added to the cutting fluids such as corrosion and rust inhibitors, neutralization agents, lubricating additives like EP (extreme pressure), biocides, fungicides and form inhibitors. The additives concentration used are below 10% w/w [7].Water content in the cutting fluids may be varied depending upon ideal conditions, but the cutting fluid in this study contained 90% water.

In order to understand working and function of VMC and how to perform machining operations on this machine followings terms are important which are given below

Composition of SS416 (in percent)**:**

Carbon 0.150(Max)
Chromium 12.0-14.0
Manganese 1.250 (Max)
Phosphorous 0.060 (Max)
Silicon 1.00 (Max)
Sulphur 0.150 (Max)

RESEARCH METHODOLOGY:

A scientific approach to plan the experiments is necessary for efficient conduct of experiments. By the statistical of experiments the process of planning the experiment is carried out, so that appropriate data will be collected and analyzed by statistical methods resulting in valid and objective conclusions. The methodology followed during this research work is given below:

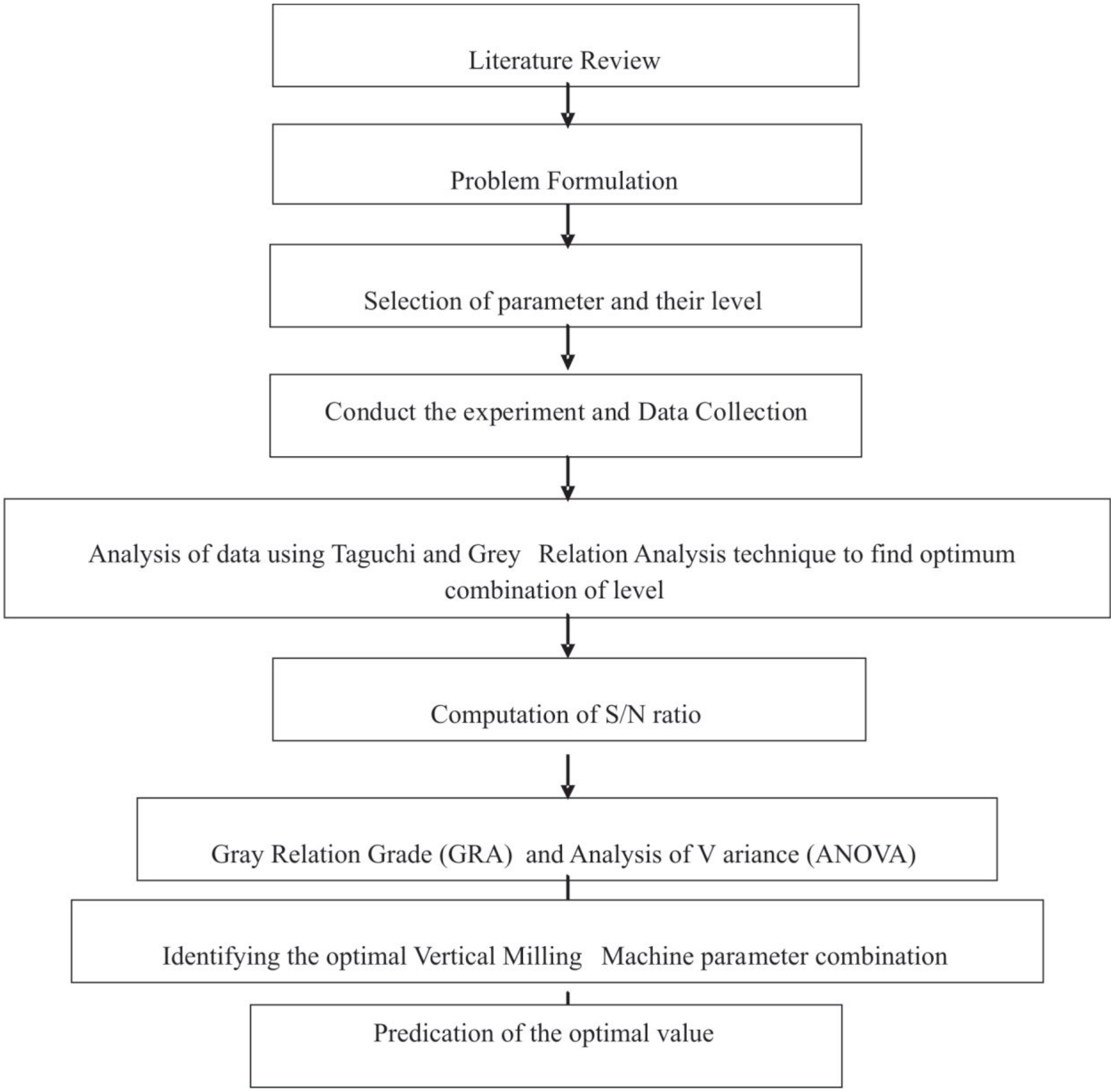


Figure 2: Research Methodology

OPTIMIZATION USING TAGUCHI BASED GREY RELATION METHOD

Taguchi's philosophy developed by Dr. Genichi Taguchi is a powerful tool for the design of high quality manufacturing [12]. This method provides both, an efficient and a systematic approach to optimize design for well balanced experiments to get a sound result [11]. Taguchi's Orthogonal Array (OA) provides a design that has minimum number of experiments runs to get the optimized result. To determine the improved performance of the process parameter this method uses a statistical measure of performance, which increases the quality of characteristics called Signal to Noise (S/N) ratio [12].

The (S/N) ratio performance basically uses three combinations:-

(a) The smaller the better (LB)
(b) Nominal is the best (NB)
(c) Higher the better (HB)

The higher the better performance characteristic was preferred to maximize the M.R.R.

$$L_{ij} = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{y_{ij}^2}$$

The lower the better performance characteristic was preferred to minimize the S.R.

$$\eta_{ij} = 1/n\sum y_{ij}^2$$

Where,

L_{ij}- Loss Function, In which
i^{th} denotes Performance Factor
j^{th} denotes Experiments
y_{ij}- Experiments at the **'k^{th}'** trial and
'n' - Number of trials

The loss function can be further transferred into an **S/N ratio**. To determine the deviation of the performance characteristics from any desired value, the S/N ratio was used in the Taguchi method [14]. The **S/N** ratio '**n_{ij}**' for the '**i^{th}**' performance factor in the '**j^{th}**' experiments can be expressed as:

$$\eta_{ij} = -10\log(L_{ij})$$

The Taguchi method was designed to optimize a single performance characteristic. Optimization of multiple performance characteristics is more complicated than optimization of single performance characteristic [4,6,9,10,13].In this study, the Grey Relation Analysis was employed to determine multiple performance characteristics, which were proposed by **"Deng"**[3]. This theory has been proved a powerful tool for dealing with incomplete, poor and uncertain information. This also provides a solution of complicated interrelationship among multiple performance characteristics [8].In this analysis a Grey Relational Grade is obtained to investigate the multiple performance characteristics. As a result complicated multiple performance characteristics is converted into a single Grey Relational Grade. The study reveals that the Taguchi method with Grey Relation Analysis can greatly simplify the optimization procedure for investigating the optimal milling parameter in Vertical Milling Machine process with multiple performance characteristics [5].

Purpose of study:

1. To analyze the M.R.R. and S.R. for SS 416 using face-milling operation.
2. To analyze the significant parameters for S.R. and M.R.R. for SS 416 using Taguchi with Grey Relational Analysis technique.

Experimental setup: The steps followed during this experiment:

1. To Check and prepare the VMC system ready for performing the machining operation.
2. Prepare circular rod AISI Stainless Steel 416 of size ϕ 45 mm.
3. Measure the initial weight of work-piece by DWM (Digital Weighing Machine).
4. Place the job on VMC.
5. Enter the programme using the selected parameter namely spindle speed, feed rate, depth of cut and cutting oil.
6. To Measure the weight of each machined work-piece again by the DWM.
7. To Measure surface roughness with Surface roughness Tester.

The parameters selected for this experiment, which are spindle speed, feed rate, depth of cut and cutting oil has been tabulated below (Table No.1)

Table No. 1Experimental parameters and their levels

S.No	Spindle Speed(r.p.m)	Feed Rate (mm/rev)	Depth Of Cut (mm)	Cutting Oil
1.	800	200	0.5	Canola
2.	900	225	0.6	Sun flower
3.	1000	250	0.7	Machine oil

The **L9 OA (**Orthogonal array) was used to perform the experiment. There were three trials to optimize the process parameter has been tabulated below (Table No.2)

Table 2: Experimental design

S.No.	Spindle Speed (r.p.m)	Feed Rate(mm/rev)	Depth of Cut(mm)	Cutting Oil
1.	800	200	0.5	Canola
2.	800	225	0.6	Sunflower
3.	800	250	0.7	Machine oil
4.	900	200	0.6	Machine oil
5.	900	225	0.7	Canola
6.	900	250	0.5	Sunflower
7.	1000	200	0.7	Sunflower
8.	1000	225	0.5	Machine oil
9.	1000	250	0.6	Canola

RESULT AND ANALYSIS

Analyze the Result:

To study the effect of output responses on the surface finish and material removal rate using GRA, the data analyzed to better condition of the work. It is necessary which parameter gives better surface finish and higher material removal rate.

The normalized S/N ratio for **S.R. and M.R.R. has been tabulated** below:

Table No. 3: Normalized Signal to Noise ratio

S.No.	Spindle speed(rpm)	Feed Rate (mm/rev)	Depth of cut(mm)	Cutting oil	Normalized S/N ratios	
					MRR	SR
1	800	200	0.5	Canola	0.0000	0.3217
2	800	225	0.6	Sunflower	0.8837	0.9176
3	800	250	0.7	Machine oil	0.6979	1.000
4	900	200	0.6	Machine oil	0.7225	0.2523
5	900	225	0.7	Canola	0.7116	0.6757
6	900	250	0.5	Sunflower	0.6067	0.7560
7	1000	200	0.7	Sunflower	0.5770	0.0000
8	1000	225	0.5	Machine oil	0.1395	0.3561
9	1000	250	0.6	Canola	1.0000	0.4169

The normalized **S/N** ratio for SR and MRR in table 3 is calculated with the help of relation

$$\frac{\text{Yij} - \min(Yij, i = 1,2,3, \ldots, n)}{\max(Yij, i = 1,2,3, \ldots, n) - \min(Yij, i = 1,2,3, \ldots, n)}$$

$$\frac{\max(Yij, i = 1,2,3, \ldots, n) - \text{Yij}}{\max(Yij, i = 1,2,3, \ldots, n) - \min(Yij, i = 1,2,3, \ldots, n)}$$

After calculating the normalized S/N ratio, grey relational coefficient is calculated to express relation between ideal and actual normalized result. Before that the deviation sequence were found. The Deviation sequences for **SR** and **MRR** has been tabulated below (Table No.4)

Table No. 4: The Deviation sequences for SR and **MRR**

S.No	Spindle speed(rpm)	Feed Rate (mm/rev)	Depth of cut(mm)	Cutting oil	Deviation sequence	
					MRR	SR
1	800	200	0.5	Canola	1.0000	0.6783
2	800	225	0.6	Sunflower	0.1163	0.0824
3	800	250	0.7	Machine oil	0.3021	0.0000
4	900	200	0.6	Machine oil	0.2775	0.7477
5	900	225	0.7	Canola	0.2884	0.3243
6	900	250	0.5	Sunflower	0.3933	0.2440
7	1000	200	0.7	Sunflower	0.4230	1.0000
8	1000	225	0.5	Machine oil	0.8605	0.6439
9	1000	250	0.6	Canola	0.0000	0.5831

After calculating deviation sequence, grey relation coefficient in Table No. 5 is calculated with the help of relation.

$$k= \frac{\Delta \min + \zeta \Delta max}{\Delta o + \zeta \Delta max}$$

Here 'ζ' is distinguishing or identified coefficient and ζ= 0.5 is generally used. The calculated Grey Relational Coefficient has been tabulated below (Table No. 5)

Table No. 5: Grey Relational Coefficient

S.No	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	Cutting oil	Grey Relational Coefficient	
					MRR	SR
1	800	200	0.5	Canola	0.3333	0.4243
2	800	225	0.6	Sunflower	0.8112	0.8585
3	800	250	0.7	Machine oil	0.6233	1.0000
4	900	200	0.6	Machine oil	0.6430	0.4007
5	900	225	0.7	Canola	0.6341	0.6065
6	900	250	0.5	Sunflower	0.5597	0.6720
7	1000	200	0.7	Sunflower	0.5417	0.3333
8	1000	225	0.5	Machine oil	0.3675	0.4371
9	1000	250	0.6	Canola	1.0000	0.4616

After this grey relation grade is calculating by averaging the grey relational coefficient corresponding to each performance characteristic has been tabulated below (Table No. 6)

$$\gamma_j = \frac{1}{m}\sum_{k=1}^{n} \omega_i \zeta_{ij}$$

Table No. 6: Grey Relational Grade

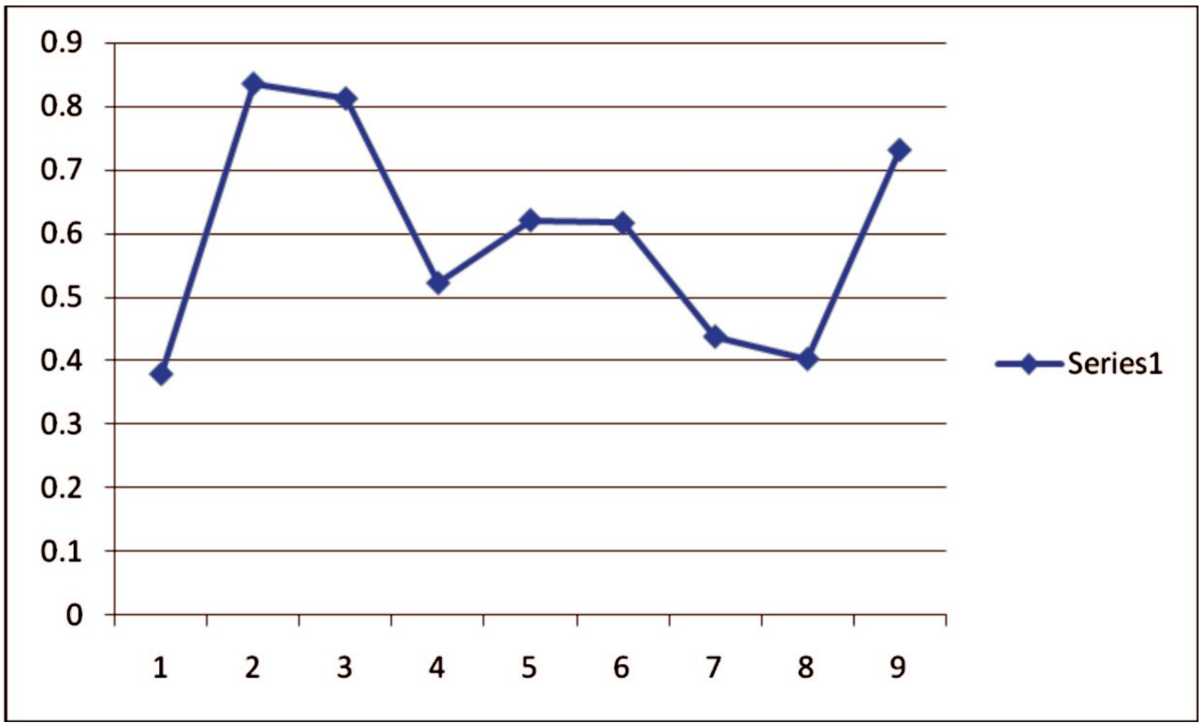
S.No	Spindle speed(rpm)	Feed rate (mm/rev)	Depth of cut(mm)	Cutting oil	Grey relational grade	Rank
1	800	200	0.5	Canola	0.3788	9
2	800	225	0.6	Sunflower	0.8348	1
3	800	250	0.7	Machine oil	0.8116	2
4	900	200	0.6	Machine oil	0.5218	6
5	900	225	0.7	Canola	0.6203	4
6	900	250	0.5	Sunflower	0.6158	5
7	1000	200	0.7	Sunflower	0.4375	7
8	1000	225	0.5	Machine oil	0.4023	8
9	1000	250	0.6	Canola	0.7308	3

Determination of the Optimum Factor Level Combination:

Figure shows the grey relational grade for maximum MRR and minimum SR. Table shows the experimental result for the grey relational grade. The higher value of grey relational grade represents the stronger relational degree between the reference sequence and given sequence. The higher value of grey relational grade means that the corresponding cutting parameter is closer to optimal. From table shows spindle speed of level 1, tool feed of level 2 and depth of cut level 2 and lubricant of level 2 will closer to optimal solution.

Table No. 7: Optimum Factor Level Combination

Parameter	Level 1	Level 2	Level 3	Max-Min	Rank
Spindle speed	0.6750*	0.5859	0.5235	0.1515	3
Tool feed	0.4460	0.6191	0.7194*	0.2734	1
Depth of cut	0.4656	0.6958*	0.6231	0.2302	2
Cutting condition	0.5766	0.6293*	0.5785	0.0527	4



Predicting Optimum Performance at These Levels:

Using the optimal parameters, the Optimum output Characteristics (Surface roughness, Material removal rate) are predicted by

MRR= 0.09193 g/sec.

SR= 2.504 μm

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Comparison Of Al-b_4c Composite With Pure As Cast Aluminium For Wear Behavior

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Abstract

Boron carbide is an extremely hard boron-carbon ceramic material used in numerous industrial applications. As of 2015, boron carbide is the third hardest substance known, after diamond and cubic boron nitride, earning it the nickname "black diamond". Aluminium (Al) alloys are gaining more recognition as a lighter structural material for light weight applications, due to their low density and high stiffness-to-weight ratio. As summarized from the literature Metallic Carbides or Oxides are most commonly used reinforcements in aluminium matrix. Boron Carbide was used in the current research work as reinforcement for Aluminium matrix, mainly because of its high wear resistance and high hardness applications. Al-B_4C Composite was fabricated using cost effective stir casting technique and dry sliding wear testing was performed on a pin on disk type wear testing machine. Optical macrographs and SEM images were taken to study the wear pattern and particle distribution in the cast composite. Results shown that Al-B_4C composite material was found to be % more wear resistant than pure as cast aluminium with uniform particle distribution. So it can be recommended for wear resistance applications and more experiments can be planned to find out the optimum configuration to be used for fabricating Al-B_4C composite materials.

Introduction

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties which are not obtainable with a single constituent material. So, in technical terms, we can define a composite as "a multiphase material from a combination of materials, differing in composition or form, which remain bonded together, but retain their identities and properties, without going into any chemical reactions" [1].

In general composites are broadly classified at two distinct levels. The first level of classification is usually made with respect to the matrix constituent. The major composite classes include organic-matrix composites (OMC's), metal-matrix composites (MMC's), and ceramic-matrix composites (CMC's). The term organic-matrix composite is generally assumed to include two classes of composites: polymer matrix composites (PMC's) and carbon matrix composites (commonly referred to as carbon-carbon composites). The second level of classification refers to the reinforcement form: particulate reinforcements, whiskers, continuous fiber laminated composites, and woven composites (braided and knitted fiber architectures are included in this category) [2].

Composite materials are made from constituents which can be grouped as (i) matrix/binders, (ii) reinforcements and/or (iii) fillers, additives and auxiliary chemicals [1].

Aluminium matrix composites (AMC's) refer to the class of light weight high performance aluminium centric material systems. The reinforcement in AMC's could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions ranging from a few percent to 70%. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route [3].

Aluminum is the most popular matrix for the metal matrix composites (MMC's). The aluminium alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix [4].

Boron carbide is an extremely hard boron-carbon ceramic material used in numerous industrial applications [5]. As of 2015, boron carbide is the third hardest substance known, after diamond and cubic boron nitride, earning it the nickname "black diamond" [6 & 7].

Engineered composite materials must be formed to shape. The reinforcement can be introduced to the matrix before or after the matrix material is placed into the mould cavity. The matrix material experiences a melting event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melting can occur in various ways such as chemical polymerization or solidification from the melted state. A variety of molding methods can be used according to the finish product requirements [8].

Stir casting is the simplest and the most cost effective method of liquid state fabrication. A dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Liquid state composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies [9]. “Figure 1” shows the various parts of a stir casting apparatus, which are: 1-Motor with height adjustment, 2-Heating Furnace, 3-Crucible, 4-Stirring blade [10].

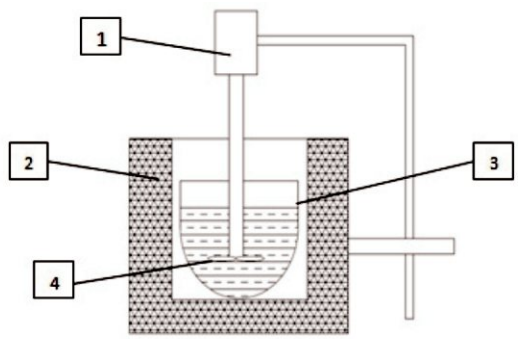

Figure 1: Stir casting set up

Experimental work

The matrix material used in the experimental investigation was 90% commercially pure aluminium bar of 0.5 kg weight and Boron carbide reinforcement size used was 220 mesh. A box type casting furnace with temperature adjustment was used for the experimental work. A stirrer was used separately with the furnace having height adjustment and running at a constant rpm of 200.

Al-B_4C metal matrix composite was prepared using cost effective stir casting technique. For this 500gm of commercially pure aluminum and 220gm(10% by wt.) of reinforcement particles were taken. Commercially pure aluminum was melted in a box type furnace. The melt temperature was raised up to

700 to 800°C. Then the melt was stirred with the help of a mild steel turbine blade stirrer. The stirring was done at an impeller speed of about 200 rpm. The melt temperature was maintained 650 to 700°C during addition of reinforcement particles. The dispersion of reinforcement particles were achieved by the vortex method. The melt with reinforced particulates were poured into the lubricated permanent metallic mold and was allowed to solidify.

Cast aluminium matrix composite with B_4C as particle reinforcement was taken for observing their wear behavior and comparing it with pure as cast aluminium. All the cast samples were finish machined to make pins of 8mm diameter and 40 mm along length. The surface of some of the specimens was prepared to see their microstructure. The wear testing was performed on a pin on disk type wear testing machine. The rpm of the machine was kept constant at 200 and testing was performed for 16 minutes duration with a sliding time of 2 minutes, taking 8 readings of each sample. Testing was done at four different parameters, at two different loads of 30N & 50N and at two different wear track diameters of 100mm and 130mm. SEM images were taken (at 100x and at 1000x) after wear testing for studying the wear behavior of the composite material and for observing the wear patterns.

Results and discussions

The pure aluminium and aluminium based composites were fabricated using stir casting technique by the procedure discussed earlier in experimental work.

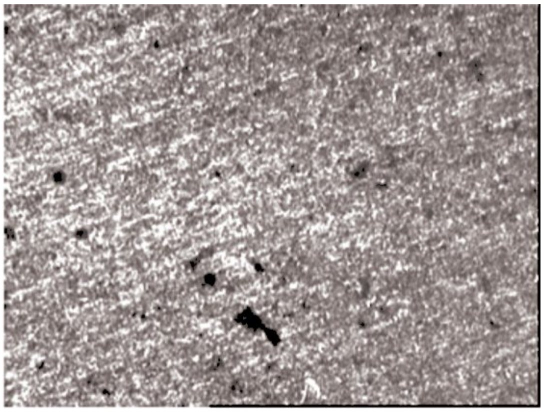

Figure 2: Shows the optical macrographs of Aluminium-Boron carbide composite material

The distribution of the reinforcement particles can be clearly seen in the macrographs of the cast composites material shown in “Figure 2”. The macrographs show almost uniform distribution of reinforcements in the Al-B_4C composite materials. The dark spots indicate the position of reinforcement particles in the aluminium matrix material.

Sliding wear testing was carried out on the prepared specimens from the cast composites using a pin on disk apparatus as per the procedure explained in experimental work section. The wear tests were done for two normal loads of 30N and 50N at a constant time interval of 2 minutes and at two different wear track radius of 100mm and 130mm. The variation of cumulative wear rate (CWR) and weight loss with sliding distance has been discussed in the subsequent paragraphs for the various cases under investigation.

Weight loss data of Al-B_4C composite was plotted against the sliding time to generate the graphs of cumulative wear rate at all the four test conditions and to study the wear trend. The wear rate of Al-B4C composite was very-very less as compared to pure as cast aluminium. It can be seen from “Figure 3” that at the first 8 minutes of testing the wear rate was uniform and then it suddenly increased up to 12th minute of testing then again the wear rate becomes uniform. The same trend of wear rate can be seen in all the four graphs generated at four different test conditions. Weight loss at maximum load conditions are shown by “Figure 6” in which the reduced difference in the weight of the two materials can be clearly seen.

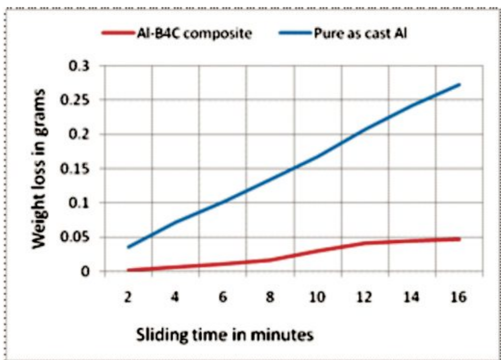

Figure 3: Comparison of wear behavior at a load of 30N & disk diameter of 100mm

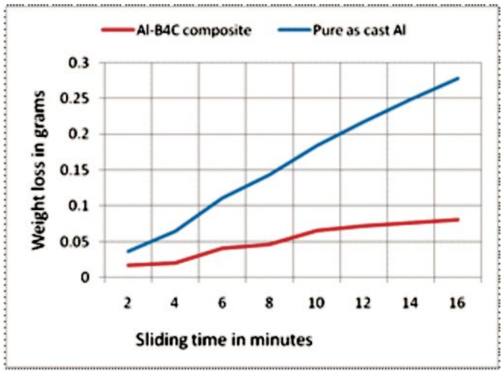

Figure 4: Comparison of wear behavior at a load of 50N & disk diameter of 100mm

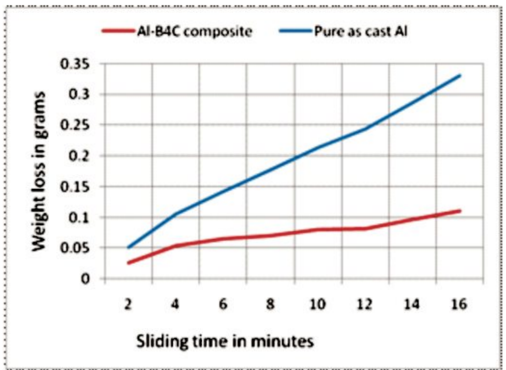

Figure 5: Comparison of wear behavior at a load of 30N & disk diameter of 130mm

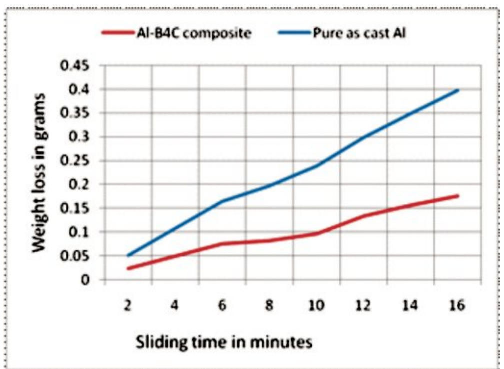

Figure 6: Comparison of wear behavior at a load of 50N & disk diameter of 130mm

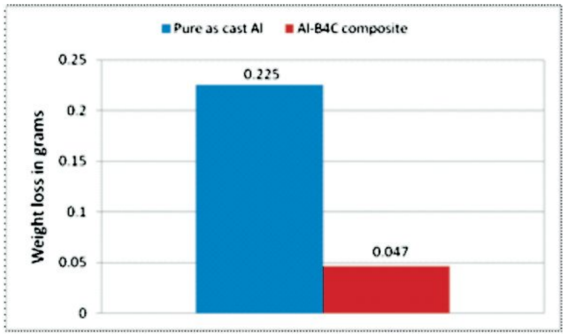

Figure 7: Comparison of total weight loss at a load of 30N & disk diameter of 100mm

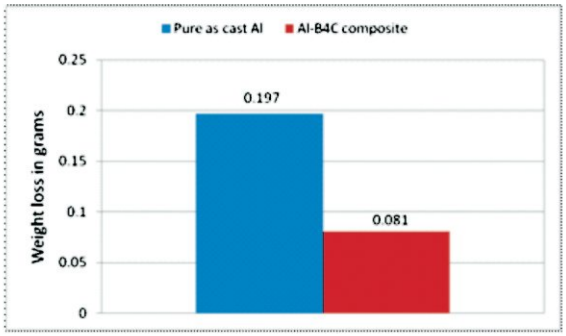

Figure 8: Comparison of total weight loss at a load of 50N & disk diameter of 100mm

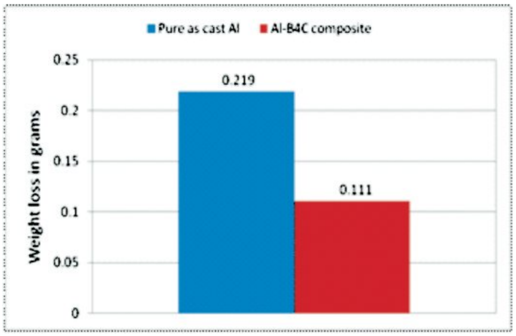

Figure 9: Comparison of total weight loss at a load of 30N & disk diameter of 130mm

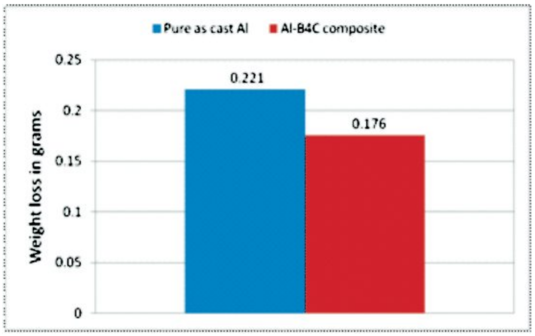

Figure 10: Comparison of total weight loss at a load of 50N & disk diameter of 130mm

To understand the wear mechanisms, the worn surfaces of the specimens corresponding to maximum load conditions i.e. at normal load of 50N and at disk diameter of 130mm, were investigated by SEM. A large number of grooves on the entire surface of the worn specimens can be clearly seen from the SEM images. From "Figure 11 & Figure 12" abrasive wear is evidently clear due to the presence of deep groves in the surface and delamination due to abrasive wear is also present. From the higher resolution image the loose particles causing the surface grooves can be seen clearly. Adhesive wear is also present to a little extent where the two wear patterns are meeting each other.

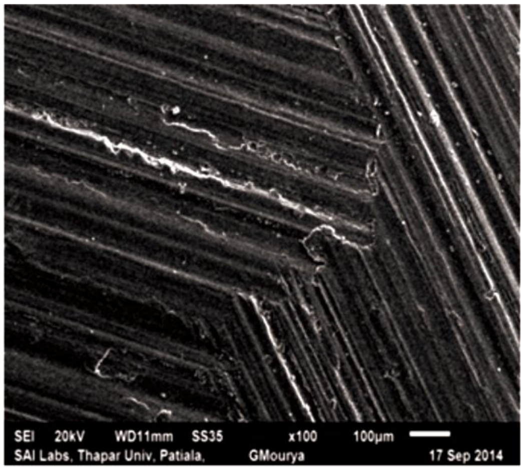

Figure 11: SEM images of Al-B4C composite at a magnification of 100x

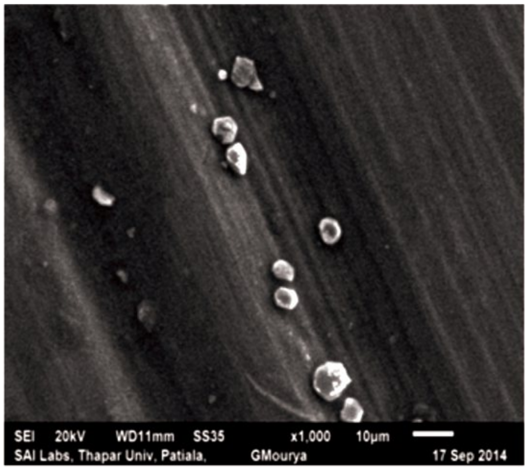

Figure 12: SEM images of Al-B4C composite at a magnification of 1000x

Conclusions

When the diameter of disk was more in contact with pin surface then the wear rate was more and vice-versa. Further with increase in dead weight the wear rate was found to have increased.

The least weight loss was 0.047 grams at disk diameter of 100mm and normal load of 30N and weight loss was found maximum i.e. 0.176 grams at disk diameter of 130mm and normal load of 50N.

At a disc diameter of 100mm and normal load 30N Al-B_4C Composite showed 80% less weight loss than pure as cast aluminium.

At disc diameter of 100mm and normal load Al-B_4C Composite showed 50N 59% less weight loss than pure as cast aluminium.

At disc diameter of 130mm and normal load 30N Al-B_4C Composite showed 49% less weight loss than pure as cast aluminium.

At disc diameter of 130mm and normal load 50N Al-B_4C Composite showed 20 % less weight loss than pure as cast aluminium.

Reinforcement particle distribution was found uniform, as observed from Optical macrographs and SEM images.

Adhesive wear seems more prominent when we look at the SEM images.

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Advances in Manufacturing Techniques (3D printing) - An overview

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ABSTRACT

3D printing or personal fabrication or additive manufacturing, as a newly emergent technology, has now been widely considered as the most significant technological breakthrough of the twenty-first century. This paper is about the advanced manufacturing technique used these days. In this paper I will explain about the history of manufacturing and computer aided designing helping increase manufacturing efficiency. This paper reports on the benefit of 3D printing, role of computer help visualize and create almost impossible designs. 3D printing is far more cost effective. Working principle of 3D manufacturing technique has been illustrated in the paper and various processes of 3D printing like Selective Laser Sintering, Laminated object Manufacturing, Direct Ink Writing and the fields 3D printing is revolutionizing. Applications of 3D printing have been discussed in this paper.

Keywords: Selective laser sintering, laminated object manufacturing, Direct Ink writing

INTRODUCTION

One of the most widely used definitions of advanced manufacturing involves the use of technology to improve products and/or processes, with the relevant technology being described as "advanced," "innovative," or "cutting edge." For example, one organization defines advanced manufacturing as industries that "increasingly integrate new innovative technologies in both products and processes. The rate of technology adoption and the ability to use that technology to remain competitive and add value define the advanced manufacturing sector." Another author defined World Class Foundry (read manufacturing) as:"A World Class Manufacturing (WCM) is one which integrates the latest-gen machinery with (process/ work) systems to facilitate 'manufacturing'- based business development governed around manufactured (Threja and Piyaravat 2006) products only, duly based over a high accent on Product Substitution or New Product Development." 3D technology is emerging by leaps and bounds.It is not generally possible to manufacture that design at home. But now it's is possible with 3D printing technology.

PREVIOUS WORK

Manufacturing activities date back to 5000 to 4000 BC. During the 600 to 800 AD evidences of steel production have been recorded. During the 800 to 1200 AD sand casting of cast iron was carried out. However, if we look at the developments in manufacturing in ancient India, evidences of manufacturing are available, since the year 3000 BC. In 500 AD itself, cast crucible steel was first produced in India. Probably in the year 1750 AD machine tools run by the power of steam engine were developed, that resulted in growth of production and abundant availability of goods. During the years 1920 to 1940 developments in automation, mass production, interchangeable parts, die casting and lost wax methods, for parts required in the engineering took place. While during the period of 1940 to 1960 developments in computer manufacturing ceramic molds, nodular irons, semi conductors and continuous castings dominated the manufacturing activities.

Early, Additive Manufacturing (AM) equipment and materials were developed in the 1980s(Bird 2012). In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two AM fabricating methods of a three-dimensional plastic model with photo-hardening polymer, where the UV exposure area is controlled by a mask pattern or the scanning fiber transmitter(Kodama 1981). Then in 1984, Chuck

Hull of 3D Systems Corporation (Hull 1984) developed a prototype system based on a process known as stereolithography, in which layers are added by curing photopolymers with ultraviolet light lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed,"(Freedman et. al. 2013,1992) but this had been already invented by Kodama. Hull's contribution is the design of the STL (Stereolithography) file format widely accepted by 3D printing software as well as the digital slicing and infill strategies common to many processes today. The term *3D printing* originally referred to a process employing standard and custom inkjet print heads. The technology used by most 3D printers to date—especially hobbyist and consumer-oriented models—is fused deposition modeling, a special application of plastic extrusion.

In general the following developments took place.

Table 1. Manufacturing methods over the time

Time	Description
5000-4000 BC	Wood works, earth wares, stone works, metal works
2500 BC	Wax Sculpture, jewelry , glass beads
600-800 AD	Steel work's evidence recorded
800-1200 AD	Sand casting of cast iron find out
1750 AD 1920-1940	Machine tools used in manufacturing Automation, interchangeable parts, die casting
1940-1960 1960-1990	Development in computer manufacturing, semiconductors NC CNC machines, Robotics, CAD/CAM, Single Crystal Turbine Blade, vacuum casting, large aluminum casting for aircraft structure, 3D printing
1990-Till Date	Nano technology, Micro manufacturing , Hard Manufacturing, Lean Manufacturing

Modules of 3D Printing

Terminology and Methods

AM processes for metal sintering or melting (such as selective laser sintering, direct metal laser sintering, and selective laser melting) usually went by their own individual names in the 1980s and 1990s. At the time, nearly all metalworking was produced by casting, fabrication, stamping, and machining; although plenty of automation was applied to those technologies (such as by robot welding and CNC), the idea of a tool or head moving through a 3D work envelope transforming a mass of raw material into a desired shape layer by layer was associated by most people only with processes that removed metal (rather than adding it), such as CNC milling, CNC EDM, and many others. But AM-type sintering was beginning to challenge that assumption. By the mid 1990s, new techniques for material deposition were developed at

Stanford and Carnegie Mellon University, including microcasting and sprayed materials(Weiss et. al.1992,1997)Sacrificial and support materials had also become more common, enabling new object geometries(Frick).

Working Principle

a) Modeling:-3D printable models may be created with a computer aided design (CAD) package, via a 3D scanner or by a plain digital camera and photogrammetry software. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. 3D scanning is a process of collecting digital data on the shape and appearance of a real object, creating a digital model based on it. Before printing a 3D model from an STL file, it must first be examined for "manifold errors," this step being called the "fixup." Generally STLs that have been produced from a

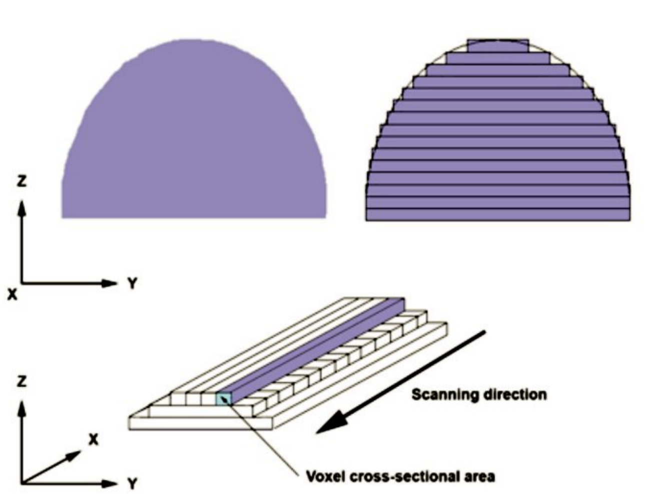

Figure 1. 3D generated CAD model slicing

Examples of these errors are surfaces that do not connect, or gaps in the models. Once that is done, the .STL file needs to be processed by a piece of software called a "slicer," which converts the model into a series of thin layers and produces a G-code file as shown in figure 1 containing instructions tailored to a specific type of 3D printer (FDM printers).

b) Printing: - This G-code file can then be printed with 3D printing client software (which loads the G-code, and uses it to instruct the 3D printer during the 3D printing process).Printer resolution describes layer thickness and X-Y resolution in dots per inch (dpi) or micrometers (µm). Typical layer thickness is around 100 µm (250 DPI), although some machines can print layers as thin as 16 µm (1,600 DPI). X-Y resolution is comparable to that of laser printers. The particles (3D dots) are around 50 to 100 µm (510 to 250 DPI) in diameter.

Construction of a model with contemporary methods can take anywhere from several hours to several days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to a few hours, although it varies widely depending on the type of machine used and the size and number of models being produced simultaneously. Traditional techniques like injection moulding can be less expensive for manufacturing polymer products in high quantities, but additive

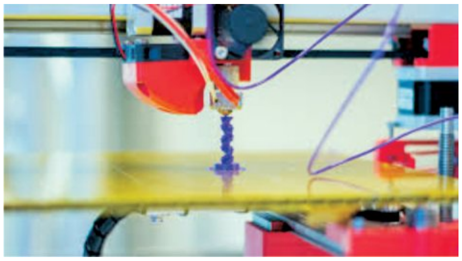

Figure 2. 3D Printing Head

manufacturing can be faster, more flexible and less expensive when producing relatively small quantities of parts. 3D printers give designers and concept development teams the ability to produce parts and concept models using a desktop size printer.

c) Finishing:-Though the printer-produced resolution is sufficient for many applications, printing a slightly oversized version of the desired object in standard resolution, and then removing material(Frick and Lindsey) with a higher-resolution subtractive process can achieve greater precision. Some printable

Figure 3. Sand Blasting a 3D

polymers allow the surface finish to be smoothed and improved using chemical vapour processes. Some additive manufacturing techniques are capable of using multiple materials in the course of constructing parts. These techniques are able to print in multiple colors and color combinations simultaneously, and would not necessarily require painting.

Some printing techniques require internal supports to be built for overhanging features during construction. These supports must be mechanically removed or dissolved upon completion of the print. All of the commercialized metal 3-D printers involve cutting the metal component off of the metal substrate after deposition. A new process for the GMAW 3-D printing allows for substrate surface modifications to remove aluminum or steel (Amberlee et al 2014).

Types of 3D Manufacturing Techniques

Several different 3D printing processes have been invented since the late 1970s. The printers were originally large, expensive, and highly limited in what they could produce. A large number of additive processes are now available. The main differences between processes are in the way layers are deposited to create parts and in the materials that are used. Some methods melt or soften the material to produce the layers.

Each method has its own advantages and drawbacks, which is why some companies offer a choice of powder and polymer for the material used to build the object. Others sometimes use standard, off-the-shelf business paper as the build material to produce a durable prototype. The main considerations in choosing a machine are generally speed, costs of the 3D printer, of the printed prototype, choice and cost of the materials, and color capabilities.Printers that work directly with metals are generally expensive, however, less expensive printers can be used to make a mould, which is then used to make metal parts.

Type	Technologies	Material Used
Extrusion	Fused deposition modeling (FDM) or Fused Filament Fabrication (FFF)	Thermoplastics, eutectic metals, edible materials, Rubbers, Modeling clay, Plasticine, Metal clay (including Precious Metal Clay)
	Robo casting or Direct Ink Writing (DIW)	Ceramic materials, Metal alloy, cermets, metal matrix composite, ceramic matrix composite
Light Polymerized	Stereo lithography (SLA)	Photopolymer
	Digital Light Processing (DLP)	Photopolymer
Powder Bed	Powder bed and inkjet head 3D printing (3DP)	Almost any metal alloy, powdered polymers, Plaster
	Electron-beam melting (EBM) Selective laser melting (SLM) Selective heat sintering (SHS)	Almost any metal alloy including Titanium alloys Titanium alloys, Cobalt Chrome alloys, Stainless Steel, Aluminum Thermoplastic powder
	Selective laser sintering (SLS)	Thermoplastics, metal powders, ceramic powders
	Direct metal laser sintering (DMLS)	Almost any metal alloy
Laminated	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
Wire	Electron beam freeform fabrication (EBF)	Almost any metal alloy

Extrusion

Fused deposition modeling (FDM) was developed by S. Scott Crump in the late 1980s and was

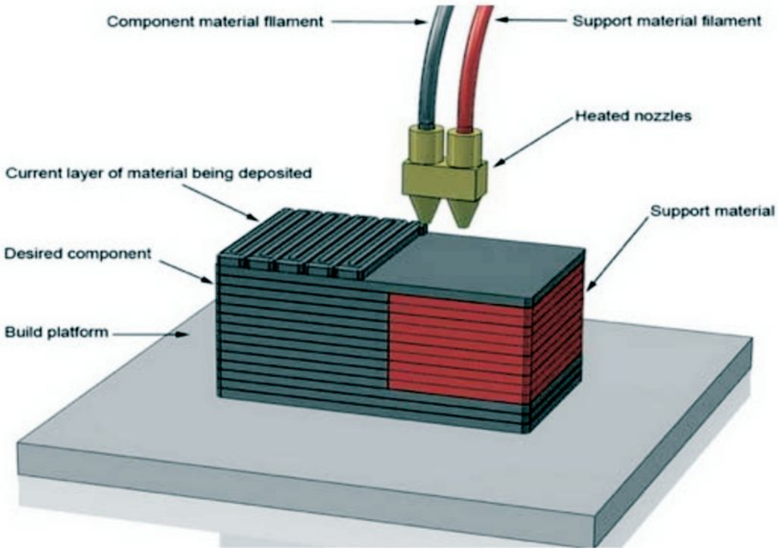

Figure 4. Fused Deposition Modeling

commercialized in 1990 by Stratasys (Hull 1986). After the patent on this technology expired, a large open-source development community developed and both commercial and DIY variants. As a result, the price of this technology has dropped by two orders of magnitude since its creation. In fused deposition modeling the model or part is produced by extruding small beads of material which harden immediately to form layers. A thermoplastic filament or metal wire that is wound on a coil is unreeled to supply material to an extrusion nozzle head (3D printer extruder). The nozzle head heats the material and turns the flow on and off as shown in the figure 4. Typically stepper motors or servo motors are employed to move the extrusion head and adjust the flow. The printer usually has 3 axes of motion. A computer-aided manufacturing (CAM) software package is used to generate the G-Code that is sent to a microcontroller which controls the motors. Extrusion in 3-D printing using material extrusion involves a cold end and a hot end.

Various polymers are used, including acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polylactic acid (PLA), high density polyethylene (HDPE), PC/ABS, polyphenylsulfone (PPSU) and high impact polystyrene (HIPS).

FDM is somewhat restricted in the variation of shapes that may be fabricated. For example, FDM usually cannot produce stalactite-like structures, since they would be unsupported during the build. Otherwise, a thin support must be designed into the structure which can be broken away during finishing. Fused deposition modeling is also referred to as fused filament fabrication (FFF) by companies who do not hold the original patents like Stratasys does.

Light Polymerized (Photopolymerized)

Stereolithography was patented in 1986 by Chuck Hull. Photopolymerization is primarily used in stereolithography (SLA) to produce a solid part from a liquid. This process was a dramatic departure from the "photosculpture" method of François Willème (1830–1905) developed in 1860 and the Photopolymerization of Mitsubishi's Matsubara in 1974.The "photosculpture" method consisted of photographing a subject from a variety of equidistant angles and projecting each photograph onto a screen, where a pantograph was used to trace.

Inkjet printer systems like the *Objet Polyjet* system spray photopolymer materials onto a build tray in ultra-thin layers (between 16 and 30 µm) until the part is completed. Each photopolymer

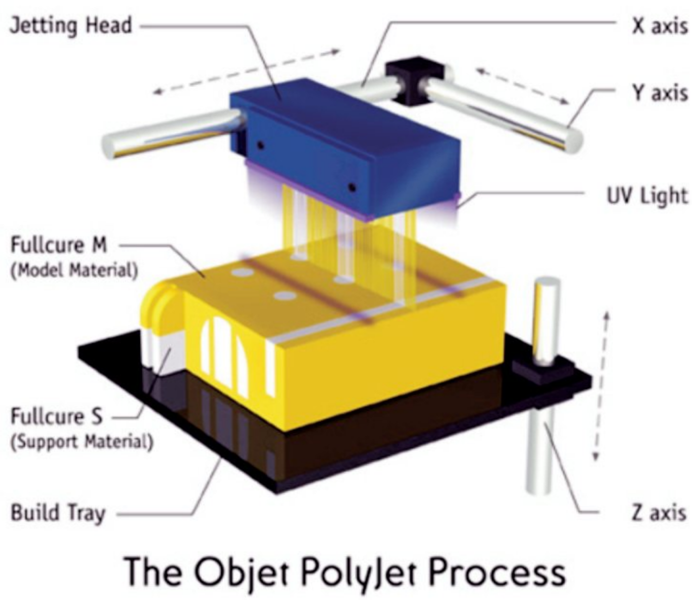

Figure 5.Object Polyjet System

Ultra-small features can be made with the 3D micro-fabrication technique used in multiphoton photopolymerisation. This approach uses a focused laser to trace the desired 3D object into a block of gel. Due to the nonlinear nature of photo excitation, the gel is cured to a solid only in the outline onto modeling clay(Frick 2014). In photo-polymerization, a vat of liquid polymer is exposed to controlled lighting under safelight conditions. The exposed liquid polymer hardens. The build plate then moves down in small increments and the liquid polymer is again exposed to light. The process repeats until the model has been built. The liquid polymer is then drained from the vat, leaving the solid model. The Envision TEC *Perfactory* is an example of a DLP rapid prototyping system.

The places where the laser was focused while the remaining gel is then washed away. Feature sizes of under 100 nm are easily produced, as well as complex structures with moving and interlocked parts.

Powder Bed Manufacturing (Granular Binding)

Another 3D printing approach is the selective fusing of materials in a granular bed. The technique fuses parts of the layer and then moves downward in the working area, adding another layer of granules and repeating the process until the piece has built up. This process uses the unsintered media to support overhangs and thin walls in the part being produced, which reduces the need for temporary auxiliary supports for the piece. A laser is typically used to sinter the media into a solid. Examples include selective laser sintering (SLS) as shown in figure 6, with both metals and polymers and direct metal laser sintering

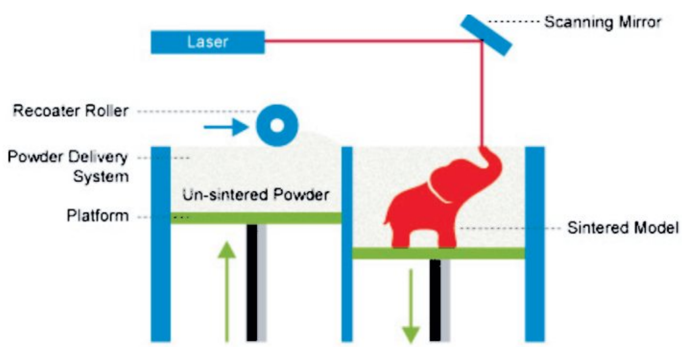

Figure 6.Selective Laser Sintering Or Direct Metal Laser Sintering System

(DMLS) (Deckard 1986).Selective Laser Sintering (SLS) was developed and patented by Dr. Carl Deckard and Dr. Joseph Beaman at the University of Texas at Austin in the mid-1980s, under sponsorship of DARPA.

Selective laser melting (SLM) does not use sintering for the fusion of powder granules but will completely melt the powder using a high-energy laser to create fully dense materials in a layer-wise method that has mechanical properties similar to those of conventional manufactured metals.

Electron beam melting (EBM) is a similar type of additive manufacturing technology for metal parts (e.g. titanium alloys). EBM manufactures parts by melting metal powder layer by layer with an electron beam in a high vacuum. Unlike metal sintering techniques that operate below melting point, EBM parts are void-free.

Another method consists of an inkjet 3D printing system. The printer creates the model one layer at a time by spreading a layer of powder (plaster, or resins) and printing a binder in the cross-section of the part using an inkjet-like process as shown in the figure 7. This is repeated until every layer has been printed.

This technology allows the printing of full color prototypes, overhangs, and elastomer parts.

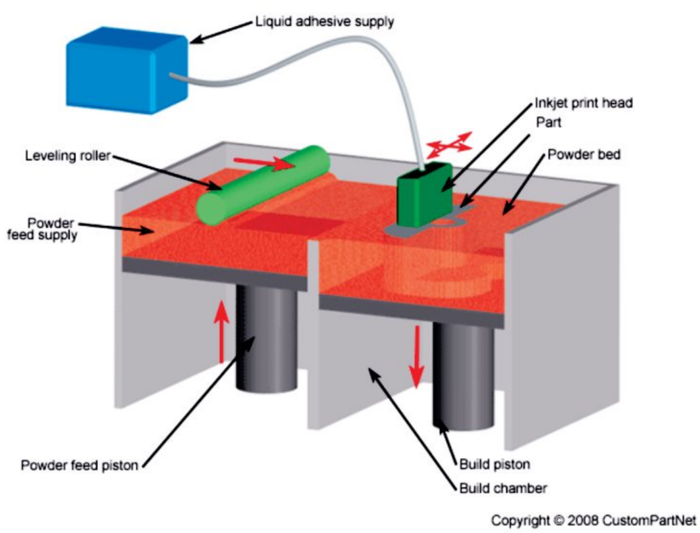

Figure 7. Inkjet 3D Printing System

Lamination

In some printers, paper can be used as the build material, resulting in a lower cost to print. During the 1990s some companies marketed printers that cut cross sections out of special adhesive coated paper

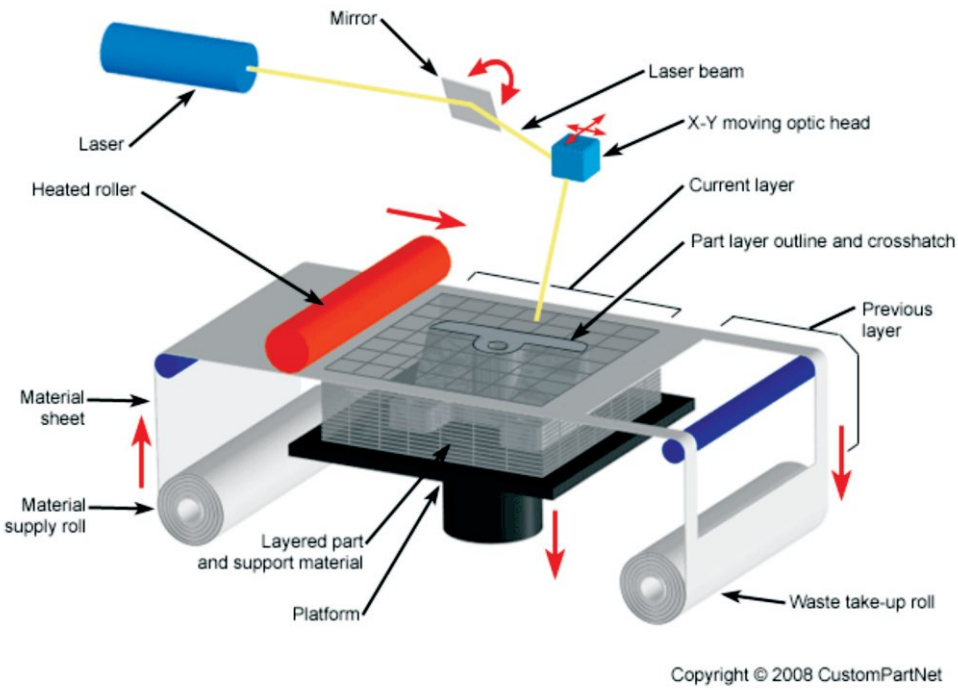

Figure 8. Lamination Process

using a carbon dioxide laser and then laminated them together. In 2005 Mcor Technologies Ltd developed a different process using ordinary sheets of office paper, a tungsten carbide blade to cut the shape, and selective deposition of adhesive and pressure to bond the prototype(Bopp 2010). There are also a number of companies selling printers that print laminated objects using thin plastic and metal sheets.

Metal wire Processes

Laser-based wire feed systems, such as Laser Metal Deposition-wire (LMD-w), feed wire through a nozzle that is melted by a laser using inert gas shielding in either an open environment (gas surrounding the laser), or in a sealed chamber as shown in the figure 9. Electron beam free form fabrication uses an electron beam heat source inside a vacuum chamber.

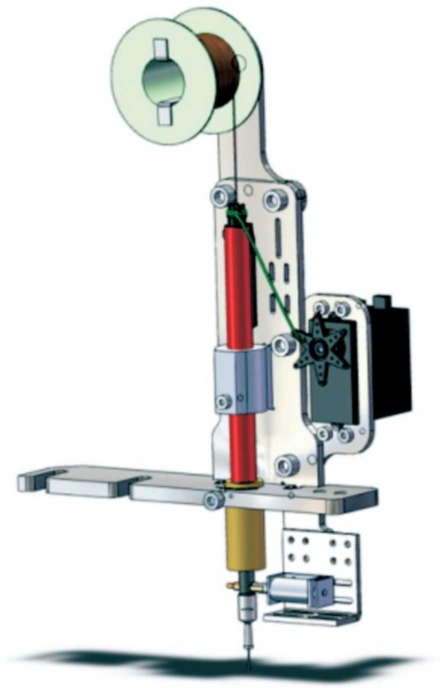

Figure 9. Laser Metal deposition Wire Fabrication

MANUFACTURING APPLICATIONS

Three-dimensional printing makes it as cheap to create single items as it is to produce thousands and thus undermines economies of scale. It may have as profound an impact on the world as the coming of the factory did....Just as nobody could have predicted the impact of the steam engine in 1750—or the printing press in 1450, or the transistor in 1950—it is impossible to foresee the long-term impact of 3D printing. But the technology is coming, and it is likely to disrupt every field it touches(The Economist 2015).

Distributed manufacturing

Additive manufacturing in combination with cloud computing technologies allows decentralized and geographically independent distributed production. Distributed manufacturing as such is carried out by some enterprises; there is also a services like 3D Hubs that put people needing 3D printing in contact with

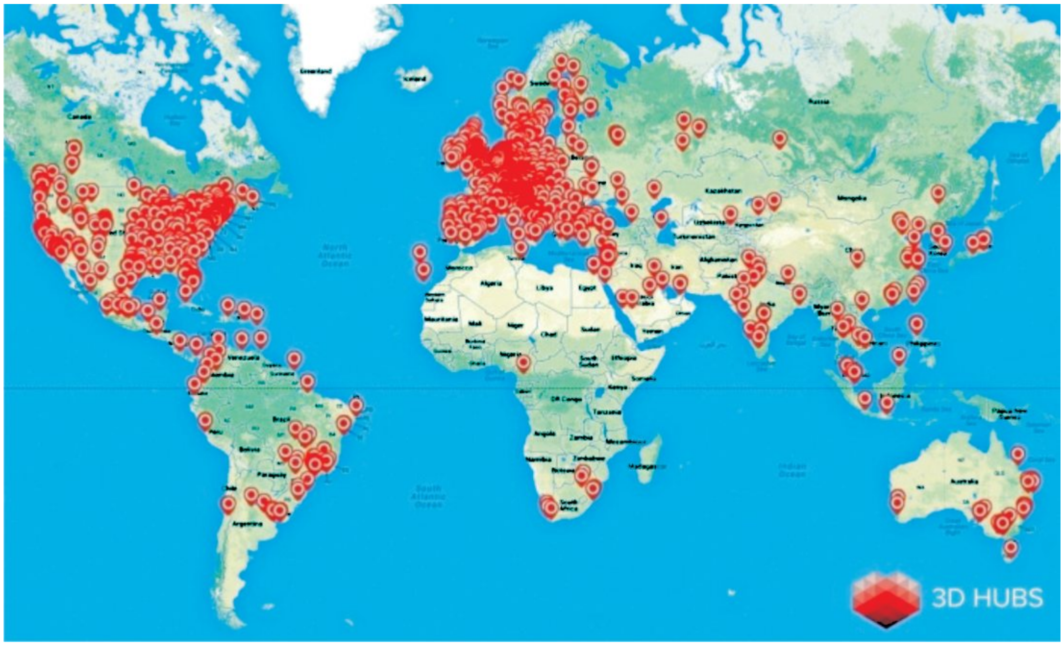

Figure 9. Location of 3D printing Hubs

owners of printers.

Mass customization

Companies have created services where consumers can customize objects using simplified web based customization software, and order the resulting items as 3D printed unique objects. This now allows consumers to create custom cases for their mobile phones. Nokia has released the 3D designs for its case so that owners can customize their own case and have it 3D printed(Wholers 2009).

Rapid manufacturing & Prototyping

Rapid manufacturing is a new method of manufacturing and many of its processes remain unproven. 3D printing is now entering the field of rapid manufacturing and was identified as a "next level" technology by many experts in a 2009 report(Hopkinson 2006).One of the most promising processes looks to be the adaptation of selective laser sintering (SLS), or direct metal laser sintering (DMLS) some of the better-established rapid prototyping methods. As of 2006, however, these techniques were still very much in their infancy, with many obstacles to be overcome before RM could be considered a realistic manufacturing method(Symes et al. 2012).

Medical Applications

Figure 10. Artificial Limb Created with

INDUSTRIAL APPLICATIONS

Vehicle

In early 2014, the Swedish supercar manufacturer, Koenigsegg, announced the One:1, a supercar that utilizes many components that were 3D printed. In the limited run of vehicles Koenigsegg produces, the One:1 has side-mirror internals, air ducts, titanium exhaust components, and even complete turbocharger assemblies that have been 3D printed as part of the manufacturing process(Hays 2014).

Construction

The improvements on accuracy, speed and quality of materials in 3D printing technology have opened new doors for it to move beyond the use of 3-D printing in the modeling process and actually move it to manufacturing strategy. A good example is Dr. Behrokh Khoshnevis' research at the University of Southern California which resulted in a 3D printer that can build a house in 24 hours .The process is called Contour Crafting

Firearms

In 2012, the US-based group Defense Distributed disclosed plans to "[design] a working plastic gun that could be downloaded and reproduced by anybody with a 3D printer.Defense Distributed has also designed a 3D printable AR-15 type rifle lower receiver (capable of lasting more than 650 rounds) and a 30 round M16 magazine The AR-15 has multiple receivers (both an upper and lower receiver), but the legally controlled part is the one that is serialized (the lower, in the AR-15's case).

Space

In September 2014, SpaceX delivered the first zero-gravity 3-D printer to the International Space Station (ISS). On December 19, 2014, NASA emailed CAD drawings for a socket wrench to astronauts aboard the ISS, who then printed the tool using its 3-D printer. Applications for space offer the ability to print parts or tools on-site, as opposed to using rockets to bring along pre-manufactured items for space missions to human colonies on the moon, Mars, or elsewhere(Hays 2014). The European Space Agency plans to deliver its new Portable On-Board 3D Printer (POP3D for short) to the International Space Station by June 2015, making it the second 3D printer in space(Hays 2014).

Education and research

3D printing, and open source RepRap 3D printers in particular, are the latest technology making inroads into the classroom. 3D printing allows students to create prototypes of items without the use of expensive tooling required in subtractive methods. Students design and produce actual models they can hold. The classroom environment allows students to learn and employ new applications for 3D printing. RepRaps, for example, have already been used for an educational mobile robotics platform.

Environmental use

In Bahrain, large-scale 3D printing using a sandstone-like material has been used to create unique coral-shaped structures, which encourage coral polyps to colonize and regenerate damaged reefs. These structures have a much more natural shape than other structures used to create artificial reefs, and, unlike concrete, are neither acid nor alkaline with neutral pH(Chino 2015)

Specialty materials

Consumer grade 3D printing has resulted in new materials that have been developed specifically for 3D printers. For example, filament materials have been developed to imitate wood, in its appearance as well as its texture. Furthermore, new technologies, such as infusing carbon fiber into printable plastics, allowing for a stronger, lighter material. In addition to new structural materials that have been developed due to 3D printing, new technologies have allowed for patterns to be applied directly to 3D printed parts. Iron oxide-free Portland cement powder has been used to create architectural structures up to 9 feet in height (Fixsen 2015).

CONCLUSION

Additive manufacturing, starting with today's infancy period, requires manufacturing firms to be flexible, ever-improving users of all available technologies to remain competitive. Advocates of additive manufacturing also predict that this arc of technological development will counter globalization, as end users will do much of their own manufacturing rather than engage in trade to buy products from other people and corporations. The real integration of the newer additive technologies into commercial production, however, is more a matter of complementing traditional subtractive methods rather than displacing them entirely(Albert 2011). It will allow creators and innovators across the globe to add and capitalize on the entrepreneurial genius that made 3D printing possible to begin with. With power of this caliber, creativity has a strong potential to increase exponentially. Jobs will be created, industries will grow, and investors will profit. You'd be wise to keep your eyes on the 3D printing trend in 2016 — and beyond.

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Performance of Bonded Magnetic Abrasives On Aumina Based Ceramic Tubes

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ABSTRACT

The application of magnetic field in machining processes has played a vital role. Non conventional Machining processes were developed to overcome problems faced in the conventional machining processes and to machine complex shapes with required accuracy and surface qualities. It is understood, that advancing in strength level of the material, needs the cutting tool material sufficiently hard, to machine material like ceramics, metal matrix composite, super alloy and high performance polymer etc. Finishing of internal surface of tubes was tried with etching and laser beaming processes which has been not given very good results. In view of the above, the present research has been under taken to study the internal surface finishing of ceramic tubes using boron carbide based bonded magnetic abrasives and investigate the highest level of PISF and MRR. Microscopic changes in the surface texture resulting from the MAF process. In addition to the surface roughness texture scanning electron microscopy have been carried out to observed wear pattern of finished parts. The maximum percentage improvement in surface finish was obtained around 71.79% and Material Removal Rate = 1.05 mg/min after MAF. These results were obtained at current = 4 Amperes, rotational speed = 800rpm quantity of magnetic abrasives =10gm and machining time = 40 minutes.

KEYWORDS

PISF, MRR, Ceramic Tubes, Bonded Magnetic Abrasives.

INTRODUCTION

In today's advanced engineering industries, the requirements on the components are stringent; for example, extraordinary properties of materials such as high strength, high hardness, resistance to thermal stresses and corrosion resistance. Alumina based ceramic fulfill these requirements. Ceramics have wide range of structural and functional applications. These advanced or technical ceramics are being used for applications such as space shuttle tile, engine components, artificial bones and teeth, computers, cutting tools and other electronic components etc. The difficulty of internal finishing is incredibly tough in the case of high alumina ceramic components**.** Etching processes are commonly used for internal finishing, but they have drawbacks associated with the control of the surface quality and the treatment of chemical waste. Secondly, laser beam machining method involves high temperature for melting and evaporation during machining of ceramics. In this method, MRR is high and surface finish produced is poor. So, magnetic abrasive finishing is the suitable technique to improve the surface finish and control the MRR rate with help of controlling power of electromagnet. Many researchers have tried loosely bonded magnetic abrasive particles but very few tried glued based abrasives. Finishing of ceramic tubes with boron carbide based bonded magnetic abrasives having mesh size of range (85-200µm). Investigating the effect of input process parameters, on the performance characteristics like Percentage Improvement in Surface Finish (PISF) and material removal rate (MRR) using Response Surface Methodology. To develop the empirical relationship between input process parameters and performance parameters, using the regression model. Investigating the interactions between the various input process parameters and their effect on the performance parameters like PISF and MRR. Scanning electron microscopy analysis used for to examine the surface texture of ceramic tubes.

Working Principle of MAF

Magnetic Abrasive Finishing is a nontraditional finishing process developed recently to produce efficiently and economically good quality finish on the flat as well as the internal and external surfaces of the tubes in magnetic or non-magnetic materials. Magnetic Abrasive Finishing (MAF) is the important finishing process by which the material is removed in a way that the surface finishing and deburring is performed with magnetic field in the machining zone. Magnetic abrasives introduced into the pipe are conglomerated at the finishing zone by the magnetic field, generating the finishing force against the inner surface of the tube. In this process, magnetic abrasive particles introduced into the work piece are attracted by the magnetic field and bear on the inner surface of the work piece. These particles join each other along the lines of magnetic force due to dipole–dipole interaction and form a flexible magnetic abrasive brush (FMAB) which pushes against the work piece surface and develops finishing pressure. This finishing pressure originates micro indentations in the work piece surface. The tangential force developed by FMAB is the major cutting force responsible for micro chipping. Fig. 1 shows the working principle of internal magnetic abrasive finishing of inside surface of the tube by using stationary pole system.

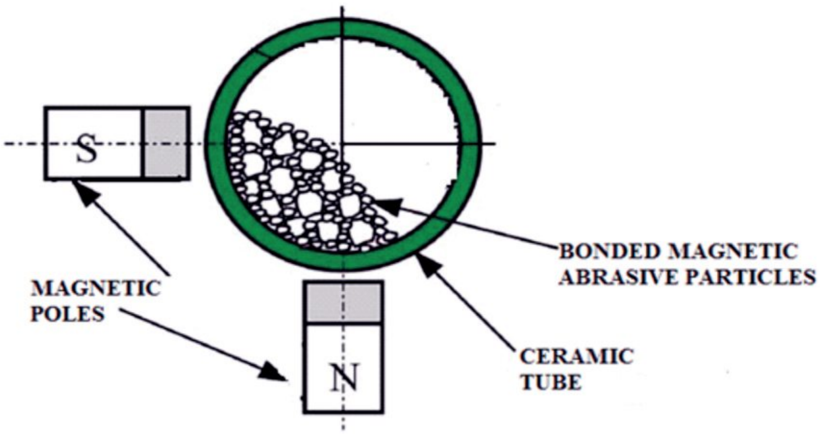


Fig.1 Working Principle of MAF (Inside Finishing of Cylindrical Tube)

Literature

The concept of magnetic abrasive machining/finishing was introduced by Harry P. Coats in 1938. Many countries including USA, England, France, Bulgaria, Germany, China and Japan are involved in continuous research activities on MAF. Jain [1] gives comprehensive overview of various abrasive based NMN processes. Jain also proposed generalized mechanism of material removal for the processes. The MNM processes discussed are AFF, MAF, MRF, MRAFF, Elastic Emission Machining and Magnetic Float Polishing**.** Singh [2] have discussed the major existing technique used to manufacture magnetic abrasives. Those techniques were sintering, adhesive base (glued), plasma based (powder melting/plasma spray), loosely bonded among all those wet abrasive gives better surface finish than dry abrasives. Singhi [3] have studied the finishing characteristic and prepared the bonded (glued) diamond base magnetic abrasives. Performance evaluation was also done using brass as work piece and concluded that PISF is significantly affected by magnetic flux density, grit size, quantity of abrasives and interactions between grit size and quantity of abrasives. Yamaguchi [4] performed experiment on alumina (Al_2O_3) tubes and examined the effects of volume of lubricant, ferrous particle size and abrasive grain size on finishing by using electrolytic iron particles (1.08gm) with diamond as abrasive at 1800min^{-1} with magnetic flux density 0.37T. The experiment showed that the process enables fine surface finishing with minimum effect on residual stress in the target surface.

EXPERIMENTAL PROCEDURE

Specimen preparation and setup development

Ceramic tubes 3 mm thickness and cylindrical length of 100mm respectively was arranged from open market. It consists of Aluminium oxide as major constituent. The tubes are used as work material to finish its internal surface. The view of the work piece is shown by figure 2. The surface roughness and weight of all work pieces was measured with surface roughness tester and weighing balance respectively before and after the experimentation.

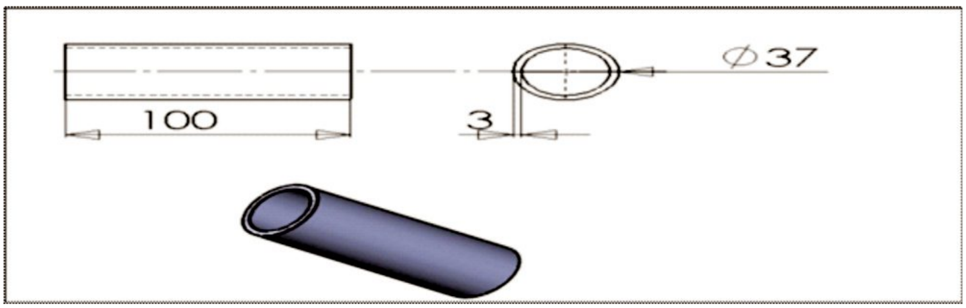
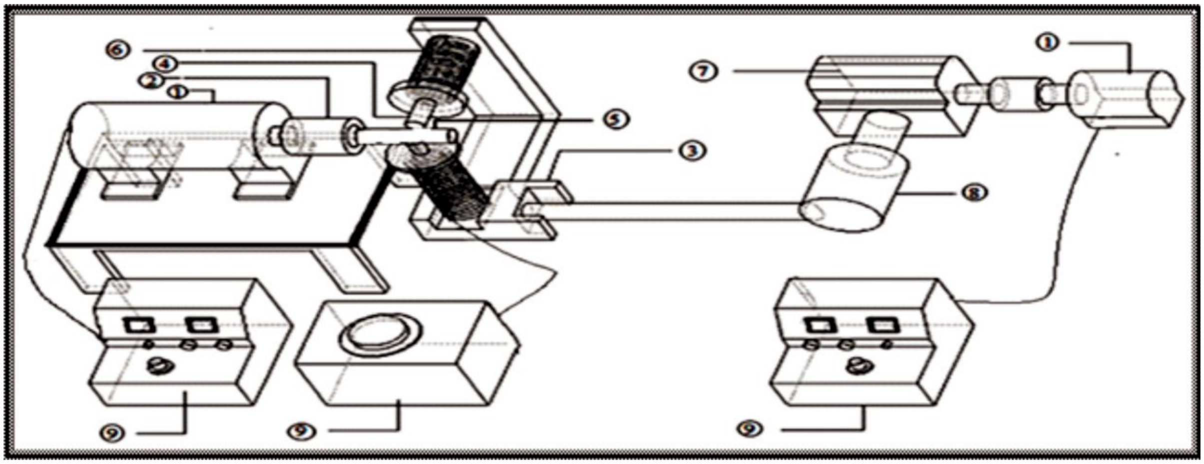


Fig. 2 Size of Ceramic work piece used during experimentation

The schematic view of experimental setup used during experimentation is shown in figure 3. The major components of the experimental setup were electromagnet, control unit, dc motor with chuck; variable dc supply and Boron carbide based bonded (glued) magnetic abrasives of size 65-200 μm.



1. DC Motor 2.Three Jaw Chuck 3.Carriage 4.Magnetic Pole 5.Work Piece 6.Magnetic Coil 7. Gear Box 8.Eccentric 9.Control Units 10.Frame

Fig. 3 Schematic diagram of the experimental setup

The magnetic coil in the experimental setup was installed on the carriage to give manual feed with the help of eccentric driven through crank mechanism, which provides reciprocating motion to magnetic poles with respect to work piece. The coil was wound over a magnetic core and numbers of turns were constant. Magnetic flux density is directly proportional to number of ampere turns. So it is easy to change value of current in electromagnet rather to change the number of turns on the coil. The electromagnet coil was energized using DC power supply. Magnetic field strength in experimentation can be varied with the help of current variance. The energized magnetic coil creates a magnetic field which is confined to the small gap between the magnetic poles. The magnetic field strength depends upon the weight percentage of magnetic particles present in the magnetic abrasive particles. The DC motor was chosen for providing the rotational motion to the work piece. An autotransformer was connected with motor to control its speed. The speed of the motor can be varied by changing the voltage supplied to motor through voltage variance. Size of work piece was taken into consideration while developing the experimental setup, so that, the working gap between work piece and magnetic pole was kept constant. The three jaw chuck was fitted on the DC motor to facilitate the holding of work piece. The number of rpm of the motor was measured with tachometer and controlled by varying the voltage from the voltage variance of control unit. The direction of the DC motor can be got reversed by changing the direction of current.

Experimental Conditions

The factors which control the surface finish and MRR in MAF are current, machining time, size of magnetic abrasives, relative speed of work piece to magnetic pole, quantity of magnetic abrasives, vibrating frequency of the work piece, working gap between work piece and magnetic poles and percentage of iron particles in magnetic abrasives. The effective parameters that influence the PISF and MRR maximum was selected on the basis of trial experiments conducted. The range of the variable process parameters that affects the maximum PISF was selected from literature available and trial experiments. The range of values for different process parameters were given in table 1.

Table 1. Range of Selected Process Parameters

S. No	Parameters	Range
1	Rotational speed of work piece	200-1000 RPM
2	Weight of magnetic abrasives	5-25 gram.
3	Current supplied to electromagnet	1-5 Ampere
4	Machining time	10-50 minutes
5	Working gap between pole and work piece	1 mm
6	Mesh size of magnetic and abrasive particles	65-200 μm
7	Lubricating oil	5% by weight of MA

The four major input process parameters selected were current, rotational speed of work piece, machining time and quantity of abrasive used. These parameter were selected because, they have maximum effect on PISF and MRR. During experimentation the remaining input process parameters such as working gap, abrasive size and volume of lubricant used have least effect on response characteristics.

In experimentation, base design matrix was prepared using design of experiment software. Different set of combinations were designed. These real values are coded according to the values given by Software. Numbers of 30 experiments were conducted, to get, best results from the different combination of process parameters. The PISF and MRR were calculated to using appropriate methods. Also, scanning electron microscopy was conducted to observe surface texture on work pieces before and after the MAF.

RESULTS AND DISCUSSIONS

The various output responses such as percentage improvement in surface finish (PISF) and material removal rate (MRR) was calculated and analyzed. PISF and MRR were used as measure of performance of magnetic abrasive finishing. Analysis of variance (ANOVA) on the raw data was performed to identify the significant parameters and to judge their effect on the performance characteristics. The Scanning Electron Microscopy (SEM) of the magnetic of the magnetic abrasive finished work pieces were taken to provide an in-depth comparison of surface finish before and after the MAF.

The small quantity of abrasive along with high rotational speed will play a dominant role for PISF. Figure 4 gives the relationship between rotational speed (B) and quantity of abrasives (C) on PISF keeping other two parameters constant. At a rotational speed of 200 rpm, it is clear that with the increase of quantity of abrasives, the value of response i.e. PISF first decreases from 20 % to 10%, then at 25 gram it reaches 33%. But when the weight of abrasives is 5 gram and with increase in speed from 200 rpm to 1000 rpm, it shows 4 times increase in PISF. There is decrease in PISF when both speed and quantity is at maximum level i.e. 1000 rpm with 25 gram respectively.

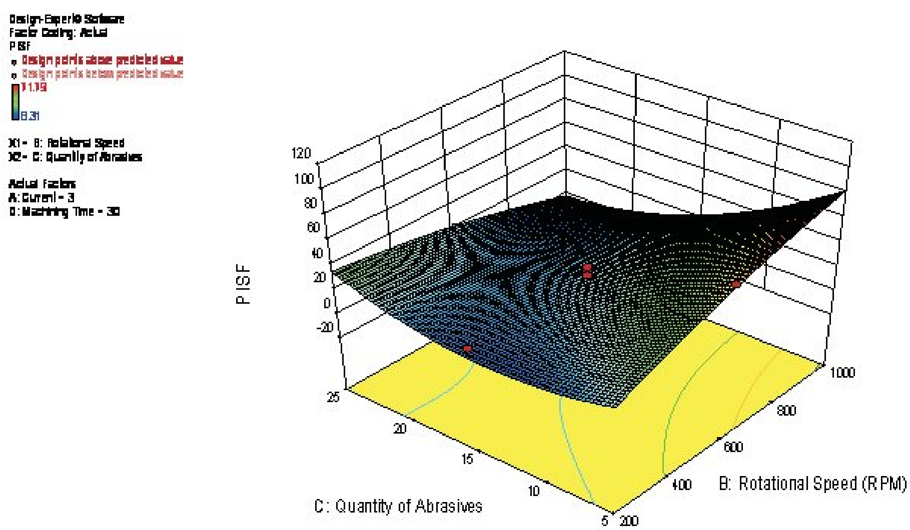


Fig. 4 Effect of rotational speed (B) and quantity of abrasives (C) on PISF

In material removal small quantity of abrasives in combination to high speed gives the maximum MRR. Figure 5 depicts the effect of quantity of abrasives (C) and machining time (D) on material removal rate during experimentation, fixing the value of current and rotational speed constant. Graph shows that at selected quantity of 5 gram and with increase in machining time, gives small improvement (20%) in material removal rate (i.e. 0.75 mg/min to 0.9 mg/min). Similarly, at maximum quantity of abrasives (25 gram) with increase in machining time from 10 minutes to 50 minutes, there is a decrease in the value of MRR by 90% from its initial value i.e. with 25 gram abrasive and 10 minutes of machining time. Moreover, increase in the quantity of abrasives from 5gram to 15 gram, keeping machining time constant (10 minutes), reduces the value of MRR by 50%. Further, increase in the quantity of abrasives (15-25 gram) gives small improvement in MRR 100%.

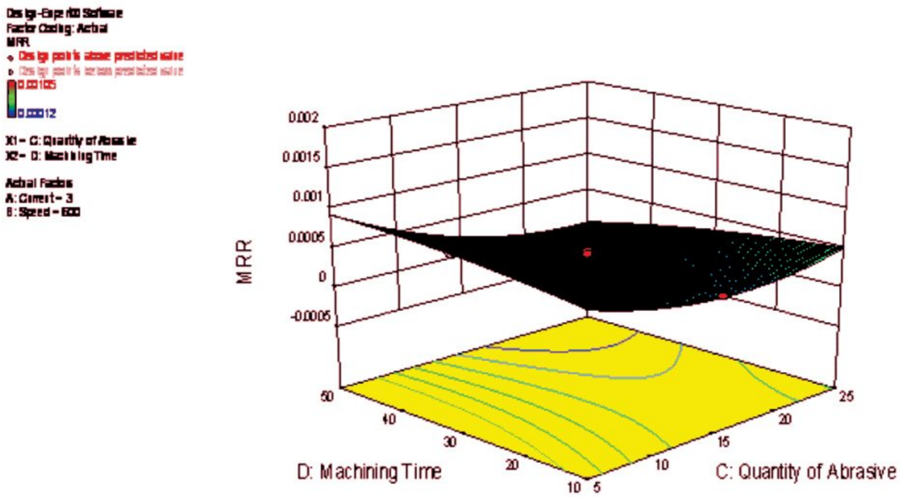


Fig. 5 Effect of Quantity of abrasives (C) and Machining time (D) and on MRR

The surface roughness alone does not reflect the smoothness by magnetic abrasives. Therefore, the scanning electron microscopy examination was performed on the work piece to make in-depth comparison of surface generated before and after MAF. The examination through SEM gives the surface texture improvement with the variation in the process parameters. There is great difference in surface finish after applying MAF. The peaks of irregularities were removed by magnetic abrasive brush. The view of surface texture clearly depicts that surface is significantly improved by great extent. Irregular lines in figure 6 showed large amount of roughness on surface of work piece before MAF. In figure 7 it represent there is some improvement in surface finish, large and deep scratches were removed to great extent by magnetic brush, which is really a difficult task without such process. But surface texture showed in figure 8 gives best result with the influencing process parameters. It showed the surface become smooth and there are few marks remains on surface.

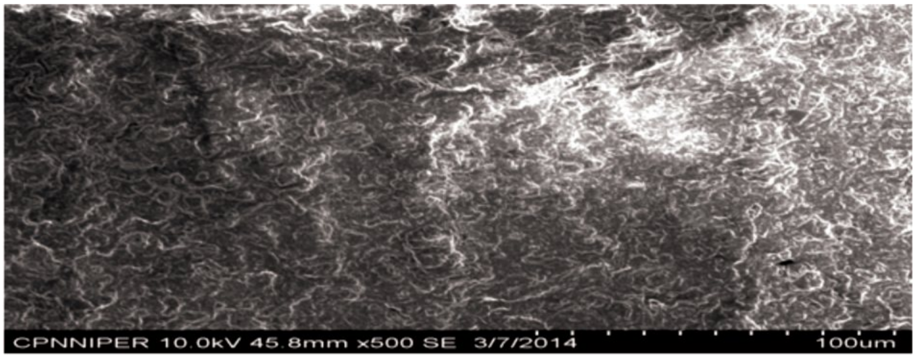


Fig. 6 SEM, micrograph before MAF

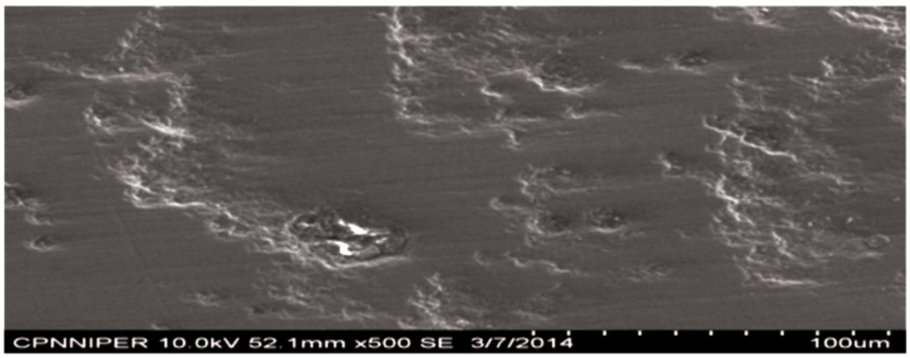


Fig. 7 SEM, micrograph before MAF

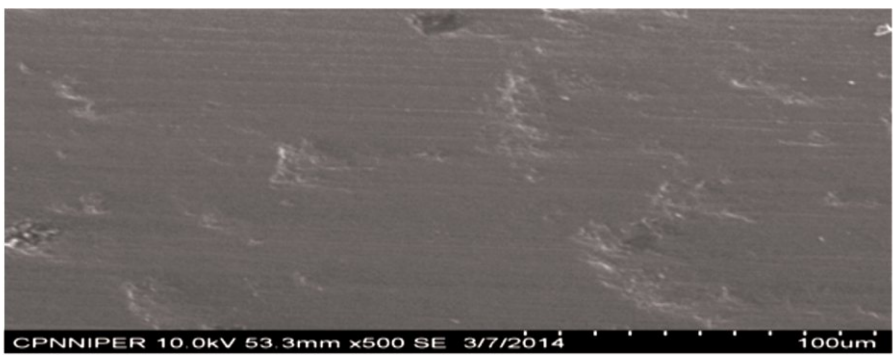


Fig .8 SEM, micrograph before MAF

CONCLUSIONS

Experimental investigations were carried out to optimize the process parameters in internal surface finishing of ceramic tubes using bonded magnetic abrasives. Thirty experiments were carried out at different levels according to the base design matrix using design of experiment software as explained in the methodology. The conclusions drawn from the present work are listed below;

1) The maximum percentage improvement in surface finish (Ra) during experimentation was observed as 71.79% when the current was 4 Amp, rotational speed of work piece was 800 rpm, quantity of magnetic abrasive 10 gram and machining time 40 minutes.
2) The maximum value of MRR was observed as 1.05 mg/min, at the value of current =4 ampere, rotational speed= 800rpm, quantity of abrasives =10 gram and at machining time of 40 minutes.

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Investigation Related To Wear And Erosion Behaviour Of Boiler Steels Using Hvof Spray Coatings

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Abstract

Three coatings namely WC-Co, CrC-NiCr and WC-Co-Cr coating were deposited on ASTM-SA213-T11boiler tube steel by HVOF sprayed thermal spray process is being discussed, under various conditions viz. Wear and High temperature solid particle erosion studies were conducted to investigate the performance of the coating. Wear testing was carried on pin on disc wear test set up by using 2kg load, 800rpmand High temperature erosion tests were carried out in high temperature solid particle erosion test rig by using erodent material alumina of irregular shape of size 50 microns and particle velocity of 32 m/s and discharge rate of 6.4g/min. The erosion resistance and wear resistance was determined from the weight loss results. Each sample for erosion testing completes one cycle at an interval of 3 hours. The results of each sample have been shown with the help of bar graph and line graph. The study has been carried out with impingement angle i.e. 90°. The results of the coated steels have also been compared with the uncoated substrate steel. The samples were characterized by SEM analysis. Coating ofWC-Co-Cr provides best result than all other coatings provided for T11 steel during erosion testing and coating ofCrC-NiCr provides best result during wear testing.

Keywords: Wear; High Temperature Erosion; HVOF Spray; WC-Co, CrC-NiCr, WC-Co-Cr; Boiler Steel.

Introduction

Failure of construction elements in high-temperature applications can be due to interaction of the environment with the material, resulting in solid particle erosion,wear, loss of protection and subsequent accelerated degradation, or to accidental overheating due to poor process control.Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface *[Hawthorne,1999]*.Erosion is defined as the wear caused by hard particles striking a surface, carried by a gas stream, or entrained in a flowing liquid medium *[Hutchings, 1992]*. Solid particle erosion (SPE) is a major issue for the electric power industry, costing an about US$150 million a year in efficiency loss, repair costs *[Stien et al, 1999]*. So material loss due to wear and erosion at high temperatures is a major issue in various high technology industries.Erosion at high temperatures is a major problem in many engineering systems, considering steams and jet turbines, fluidized bed combustion systems and boilers *[Hidalgo, 2001]*.To understand the behavior of boiler steels at high temperature and basically their erosion and wear behavior has become an important area of scientific research.

The selection of material and its preparation are important factors for the efficient functioning of the system components. It is entirely impossible that one material should possess all these properties. Now a days it has become very popular and common to use substrate as base material and to use some protective layer or coating to provide thermal insulation, erosion and wear resistance. Thermal spray coatings are applied to improve the wear characteristics. Different types of thermal spray techniques are applied for coating presently.

From all, HVOF spray technique is used in this work. High-velocity oxy-fuel (HVOF) spraying is a relatively new and rapidly developing thermal spray technology for depositing surface coatings to combat high-temperature corrosion, and is now challenging the vacuum plasma spraying technique (VPS), which is very expensive (capital costs approximately 2 million US$).This is mainly due to the achievement of higher kinetic energy of the particulates and lower melting degrees which enable particle flattening in the plastic state *[Normand et al, 2003]*.Components that are coated by the HVOF method include propellers; pump impellers and casings, valve bodies/trim and pipe systems *[Dallare, 2001]*.Similarly, erosion and corrosion resistant coating materials can be applied to relatively lower cost substrates, to provide a surface that offers better mechanical and chemical properties. Other advantages of these coatings include the ease of application*[Mack et al, 1999]*.The process has been most successful for depositing cermets materials (WC–Co, etc.) and other corrosion-resistant alloys (stainless steels, nickel-based alloys, aluminum etc. *[Mauer et al, 2010]*.Powder particles of the desired coating material are fed axially into a hot gas stream, then into a spray gun, where they are melted and propelled to the surface of work piece to be coated *[Toma et al, 1998]*.

Experimentation

The boiler tube steel, ASTM SA-213 T-11(C 0.15 Mn-0.3-0.6, Si-0.5-1, S-0.03,P-0.03,Cr-1-1.5,Mo-0.44-.65, Fe-Bal) has been used as a main material. This material is used as boiler tube materials in many of the power plant in northern India. The samples were cut to form approximately 20x15x5 mm^3 sized specimens. HVOF spray process was used to apply coatings on the super alloys at Metallizing Equipment, Jodhpur. Standard spray parameters were used for depositing both coatings. The coating parameters adopted are following Parameters/values, Process gas/ Helium, Gun temperature/ 400°C, Gun pressure/ 20.5bars, Process gas flow rate/ $150m^3$/hr, Powder feed rate/ 40g/min, Gas flow rate/ $4m^3$/hr, Carrier gas/ Nitrogen, Coating thickness/ 250µm.

Visual Examination and Weight Change Studies

A visual examination of the specimens was made after each cycle and changes in appearance, color, cracks were noticed.The weight change measurements were taken at the end of each cycle using electronic weight balance machine made of Citizen TOYO HECIO (Class II) to understand the effects of erosion. The weight change per unit area with respect to number of different specimens having different coatingwas plotted using bar graph for erosion and line graph for wear. Comparisons of cumulative weight change gain per unit area of coated/uncoated specimen's at after wear and high temperature erosion were also recorded.

Characterization of Coating

SEM analysis of the wear and hot eroded coated/uncoated specimen was done after completion of one cycle. The specimen were scanned under the microscope and photographed at particular points to identify cracks, change in appearance.

Wear Studies

Wear tests were performed on the pin specimens that had flat surfaces in the contact regions. The pin was held stationery against the counter face of a rotating disc made of En-32 steel at 100 mm track diameter. En-32 steel is a plain carbon steel; case hardened 62 to 65 HRC as provided with the pin-on-disc machine.

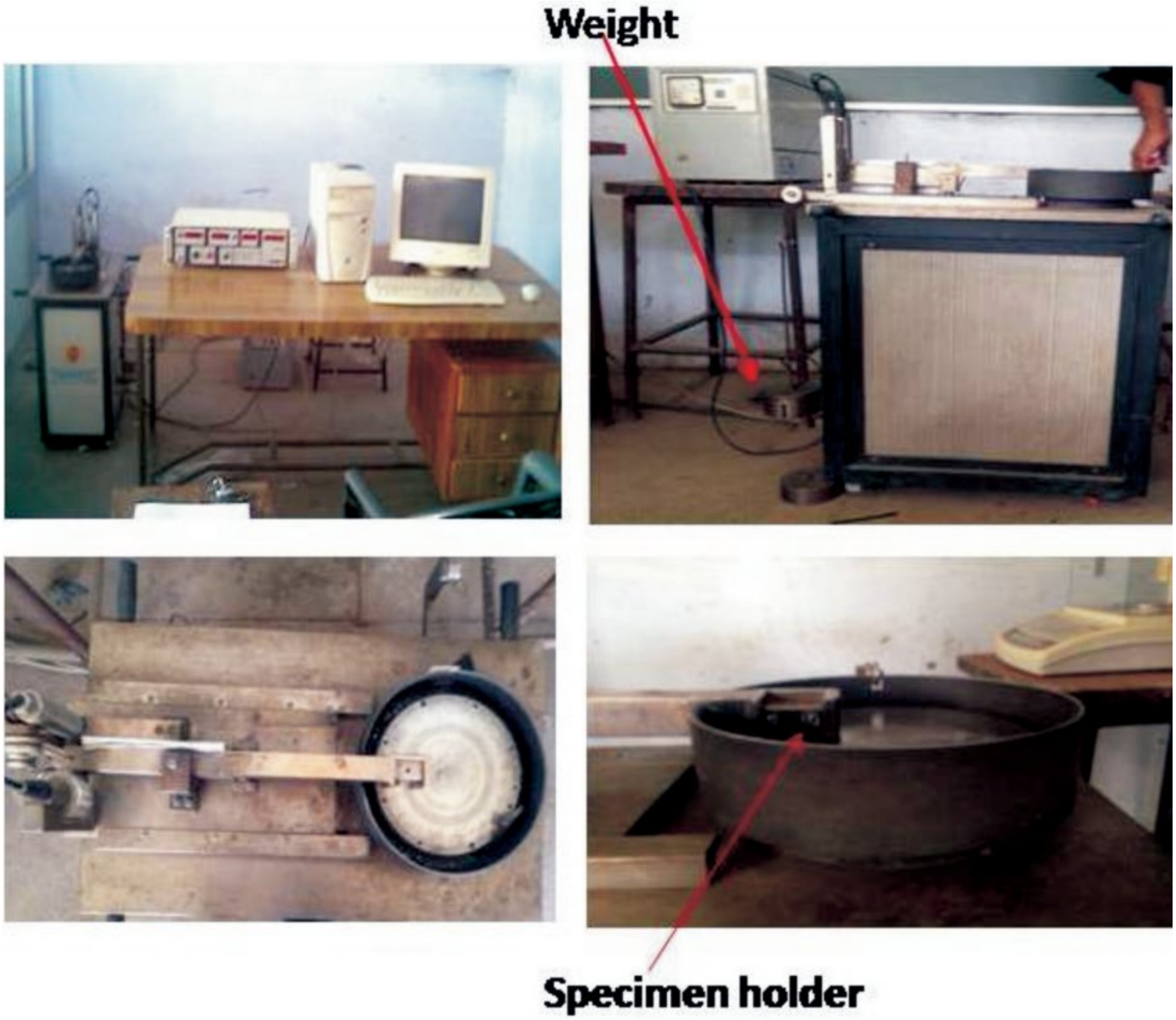

Figure 1: Complete pin on disc wear test set up

High-Temperature Erosion Studies

Erosion testing was carried out using a solid particle erosion test rig TR-471-M10 Air Jet Erosion Tester (Ducom Instruments Private Limited, Bangalore, India) capable of conducting tests at room temperature as well as high temperature. The high temperature erosion testing was performed on uncoated substrate steel and then on coated substrate steel at impingement angles i.e. 90°. The rig consisted of an air compressor, erodent feeding system, mixing chamber, furnace unit, specimen holder, nozzle, erodent collection chamber, pneumatic control box and electrical control box.

Figure 2: High temperature solid particle erosion test rig

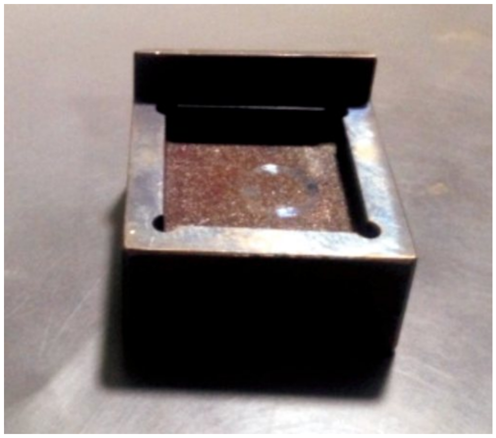

Figure 3: Specimen holder of 90°

The studies were performed for uncoated as well as coated specimens for the purpose of comparison. The erosion test conditions utilized in the present study are listed in Table 1. A standard test procedure was employed for each erosion test. Two temperatures were taken for the test (Table 1), sample temperature 400°C and air/erodent temperature 450°C simulated to service conditions of boiler tubes in which sample temperature and flow gas temperature correspond to the inner and outer temperature of water wall pipes. Erosion resistance was measured using weight loss technique by measuring the weights before and after the test.SEM technique was used to analyze the erosion products.

Table 1: Erosion test conditions

Erodent material	Alumina (Irregular shape)
Erodent Specifications	50 micron Al_2O_3
Particle velocity (m/s)	32m/s
Erodent feed rate (g/min)	6.4 g/min
Impact angle (°)	90
Test temperature	Sample Temperature 400°C and Air Temperature 450°C
Nozzle diameter (mm) Test time (Hrs)	4 3Hours

RESULTS

High temperature erosion at 90° impingement angle

a) Comparison of weight loss between coated and uncoated T11 at 90°

The graph for comparison of the weight loss at 90°for uncoated and coated T11 steels after high temperature erosion at 90° impingement angle has been represented in figure. It can be clearly seen that uncoated T11 steel conceived higher weight loss than the coated T11 steel. This clearly shows that T11 steel having coating WC-Co-Cr was less resistant to erosion rate in comparison to other coatings.

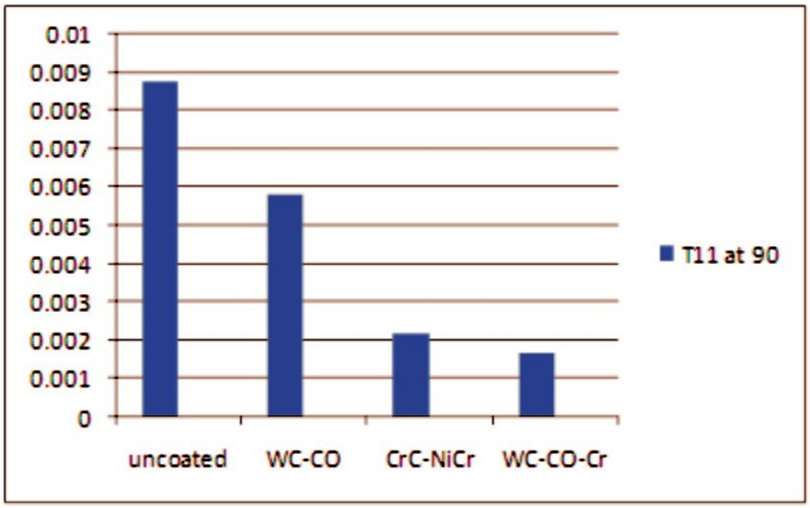

Figure 4: Comparison of weight loss between coated and uncoated T11 steels at 90° Wear using 2kg load and 800 rpm

a) Comparison of weight loss between coated and uncoated T11 at 2kg load and 800 rpm

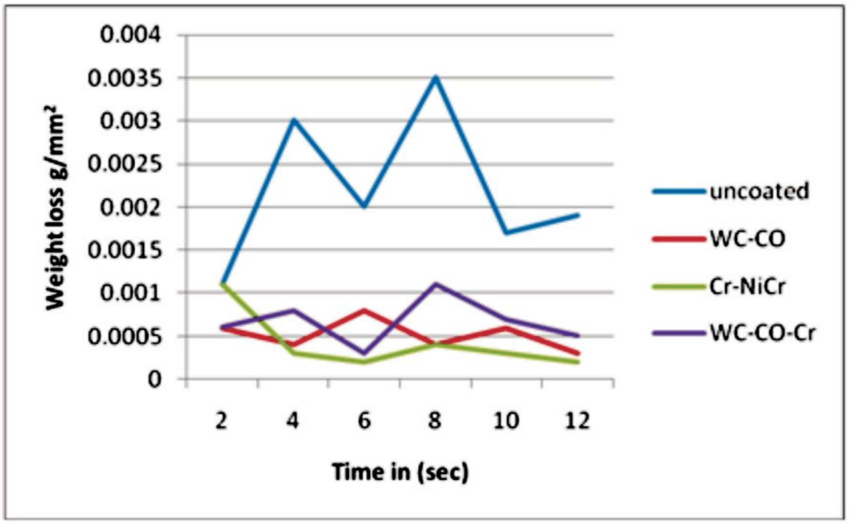

Figure 5: Comparison of weight loss between coated and uncoated T11 steels during wear testing

SEM Analysis Micrographs

SEM micrograph of uncoated T11 steel after high temperature erosion testing at 90° impingement angle clearly shows the presence of material loss in the form of cracks, plastic deformation which occurs due to impact of abrasive particles on the surface of the substrate.

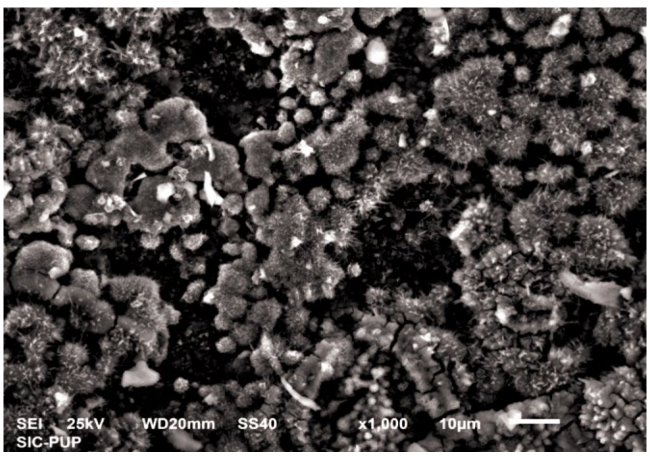

Figure 6: SEM micrograph of uncoated T11 steel after high temperature erosion at 90° impingement angle

SEM micrograph of T11 steel having coating WC-CO after WEAR testing clearly shows the presence of material loss due to wear in the form of grooves, delamination and scratches on the surface of substrate material.

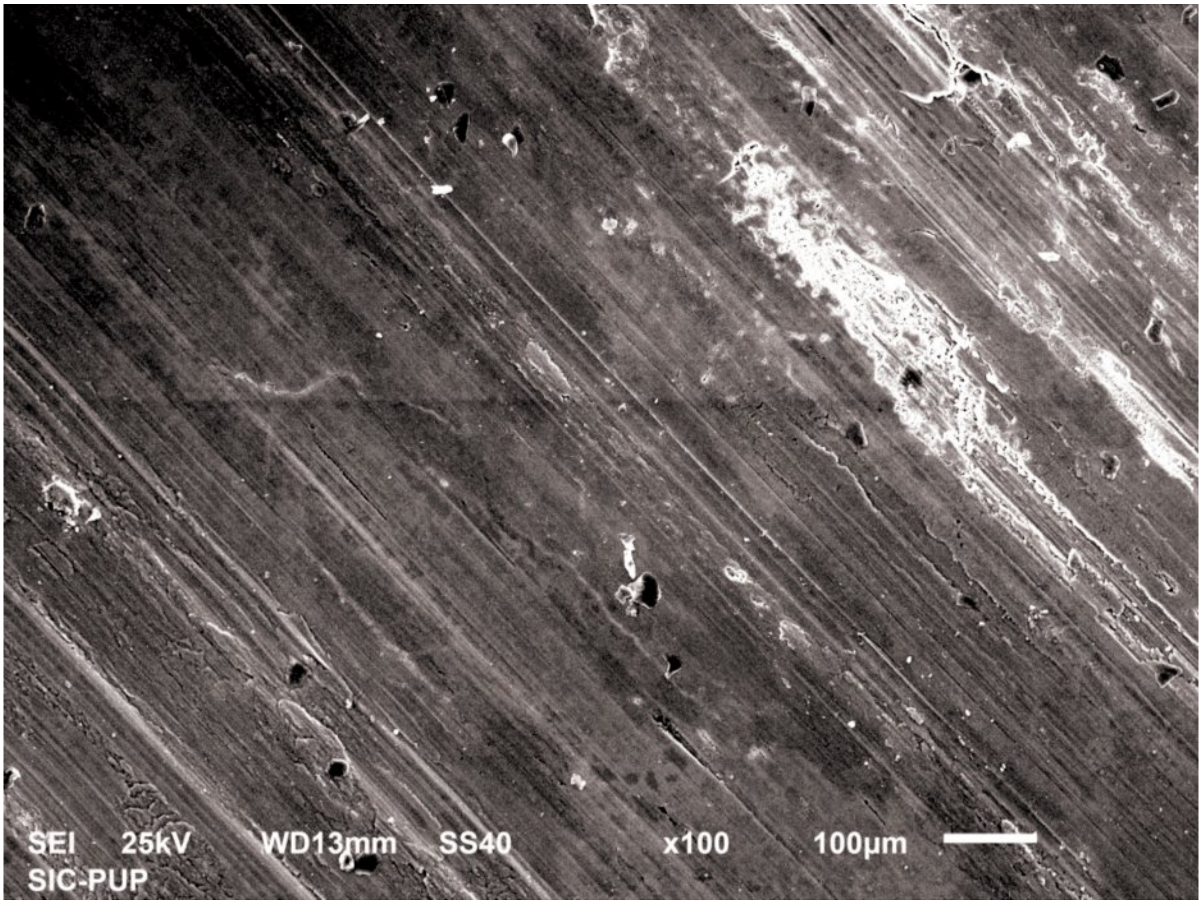

Figure 7: SEM micrograph of T11 steel having coating WC-CO after WEAR testing

Conclusions

1. Experimental results show that there is more weight reduction in the uncoated specimen than the coated specimen. Hence it may be concluded that the HVOF spray coatings can be used to reduce the erosion rate.
2. The higher material loss during the high temperature erosion testing for the WC-CO coating has been observed. This might be due to roughness of the specimens.

3. WC-CO-Cr coating shows best result for resistance over high temperature erosion than other coatings.
4. Among the all three coatings, during wear testing CrC-NiCr coating shows the best result with minimum material loss.
5. Experimental results show that there is more weight reduction in the WC-CO-Cr coating than all other coatings during wear testing.

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Heat Transfer Enhancement And Thermohydraulic Performance Of Artificially Roughened Solar Air Heaters-a Review

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ABSTRACT:

The objective of this paper is to explain the physics of heat transfer enhancement due to modifications in the flow caused by the application of ribs in various configurations on the absorber plate of the solar air heaters and comparison of the thermohydraulic performance of solar air heaters roughened with some best performing rib geometries to evaluate their overall performance. Application of surface roughness in various configurations on the heated surfaces significantly enhances the heat transfer to the flowing fluid with the moderate increase in fluid friction. Effect of ribs,in the form of small cross-section wires fixed on the heated wall of a solar air heater, on the heat transfer and flow friction has been widely studied by researchers in the last 3-4 decades. Since heat transfer enhancement is always at the cost of some increase in fluid friction, so it becomes more logical to study the effect of artificial roughness in the form of some parameter which simultaneously evaluates the gain in thermal energy in the form of heated air vis-à-vis loss of pumping power (electrical energy)to overcome the pressure drop. Thermohydraulic performance parameter is one such parameter, which has been employed by various investigators to compare the effectiveness of roughness geometry in enhancing the performance of solar air heaters.It is imperative to select the roughness pattern and its geometrical parameters, which can maximize the heat transfer with minimum pressure drop.

Key words: Solar air heater, artificial roughness, Nusselt number, friction factor, thermohydraulic performance.

INTRODUCTION

Solar air heaters are one of the simplest applications for the utilization of enormous solar energy available on the surface of planet earth in the form of heat from solar radiations. They are mainly used for space heating in buildings and crop drying in agriculture (Garg and Prakash, 2000). Conventional solar air heater consists of a rectangular duct whose top surface is an absorber plate and air is made to pass through it with the help of a blower. Constant exposure of the absorber plate to the solar radiations raises its temperature. Air passing beneath it at the room temperature comes in contact with it and gets heated up. At steady state in the range of flow Reynolds numbers (3000-15000) commonly encountered in SAH's, turbulent boundary layer becomes fully developed and as a result a laminar sublayer comes up next to the heated absorber plate. As heat transfer through the laminar sublayer is predominantly by conduction only, it reduces the convective heat transfer between the absorber plate and bulk air (Bhatti and Shah, 1987).

Heat transfer enhancement in a solar air heater by interrupting the laminar sub-layer by the application of artificial roughness in the form of ribs on one heated wall is a well-established concept (Prasad and Mullick, 1983; Prasad and Saini, 1988; Momin et. al., 2002;Saini and Saini, 2008;Singh et al., 2011; Patil et al., 2011). Most of the roughness geometries being tested for solar air heaters find their roots in the use of turbulators/vortex generators in other applications requiring faster heat transfer rates e.g. gas turbine blade cooling and industrial heat exchangers.

(J. C. Han et. al., 2004),explained main mechanism of heat transfer from thegas turbine blade surface and reviewed the significant experimental and simulation studies performed in the past. These studies revealed that as coolant passed over a rib oriented at 90° to the flow, the flow near the channel wall separated followed by the reattachment (figure 1.1), this thinner reattached boundary layer resulted in increased heat transfer coefficients in the ribbed channel.

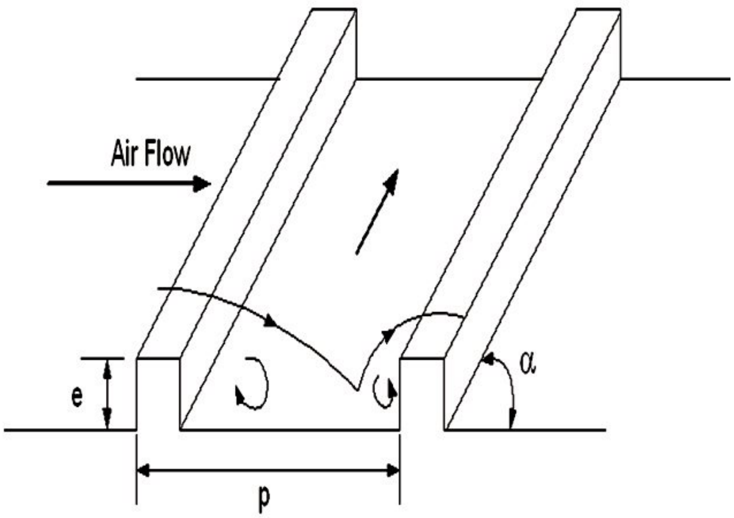


Fig. 1.1 Schematic of flow separation from ribs and secondary flow between angled ribs in a rib-roughened cooling channel (J. C. Han et. al., 2004).

With motivation from the improvement in thermal performance, by the application of artificial roughness in various configurations for gas turbine blade cooling, many researchers(Prasad and Mullick, 1983; Prasad and Saini, 1988; Momin et. al., 2002; Karwa et. al., 2003;Saini and Saini, 2008; Singh et al., 2011; Patil et al., 2011; Kumar et al., 2013) tried different roughness geometries to study their effect on the heat transfer and flow friction characteristics of solar air heaters and reported improvement in thermal performance. They studied the effect of various flow and artificial roughness geometry parameters viz; Reynolds number, relative roughness pitch, relative roughness height, relative inclination of ribs with the main flow direction, relative rib gap position, relative width of the gap, number and relative length of staggered rib pieces on the heat transfer and fluid flow characteristics of the artificial roughness geometry under investigation. Observations from such parametric studies were used to develop the empirical correlations for Nusselt number and friction factor, to evaluate the performance of SAH on the basis of thermal and thermohydraulic efficiencies and thereafter to predict the optimum values of the roughness geometry parameters based upon maximum value of the performance parameter.

HEAT TRANSFER ENHANCEMENT IN RIB ROUGHENED SOLAR AIR HEATERS

It is evident from the forced convection heat transfer studies related to the gas turbine blade cooling that rib roughness and heating was applied to two or more sides of the tested channels of varying aspect ratios and in many studies effect of duct rotation was also studied to simulate the actual working of gas turbines. Reynolds numbers applicable to these applications were generally on the higher side (up to 100000). However, duct geometry and operating parameters applicable to SAHs are different, where rib roughness and heating is applied to only one side of the channel i.e. on the absorber plate and Reynolds numbers are often less than 20,000. So, different operating conditions of solar air heaters necessitate having different experimental set-up to study the effect of similar rib roughness geometries on the enhancement of heat transfer.

EXPERIMENTAL SET-UP OF A SOLAR AIR HEATER

In general the indoor experimental set-up to carry out studies on solar air heaters consists of a wooden duct having aspect ratio in the range of 8-12, which is connected to a centrifugal blower by means of a circular pipe. Duct dimensions and test conditions are kept in accordance with the guidelines suggested in (ASHRAE standard 93-77, 1977). Fig. 2.1 shows the schematic diagram of such type of experimental setup employed for data collection by various researchers(Aharwal et al., 2009; Patil et al., 2011; Shukla et. al., 2014). The duct has mainly three sections: entry, test and exit sections. The upper horizontal wall of test section is replaced by a metallic plate whose top side is painted with black metallic paint, whereas lower side is roughened by gluing small- diameter wires in various patterns, which resembles the absorber plate of an outdoor solar collector. An electric heater is placed over the blackened side of the absorber plate to provide a uniform heat flux. The inlet section of sufficient length is provided to ensure that flow is fully developed before entering the test section while the role of the exit section is to mix the air thoroughly before exiting the duct. The heated air leaving the duct is made to pass through a circular pipe fitted with some mass flow rate measurement device e.g. an orifice meter and a flow control valve to regulate the flow through the system. The other end of circular pipe is connected to the inlet of a centrifugal blower which exhales the air to atmosphere. The duct all along is insulated to minimize the heat loss to the surroundings. The pressure drop across the test section is measured to quantify the fluid friction while the temperatures of absorber plate surface, inlet and exit air are measured to estimate the average heat transfer coefficient over the absorber plate surface.

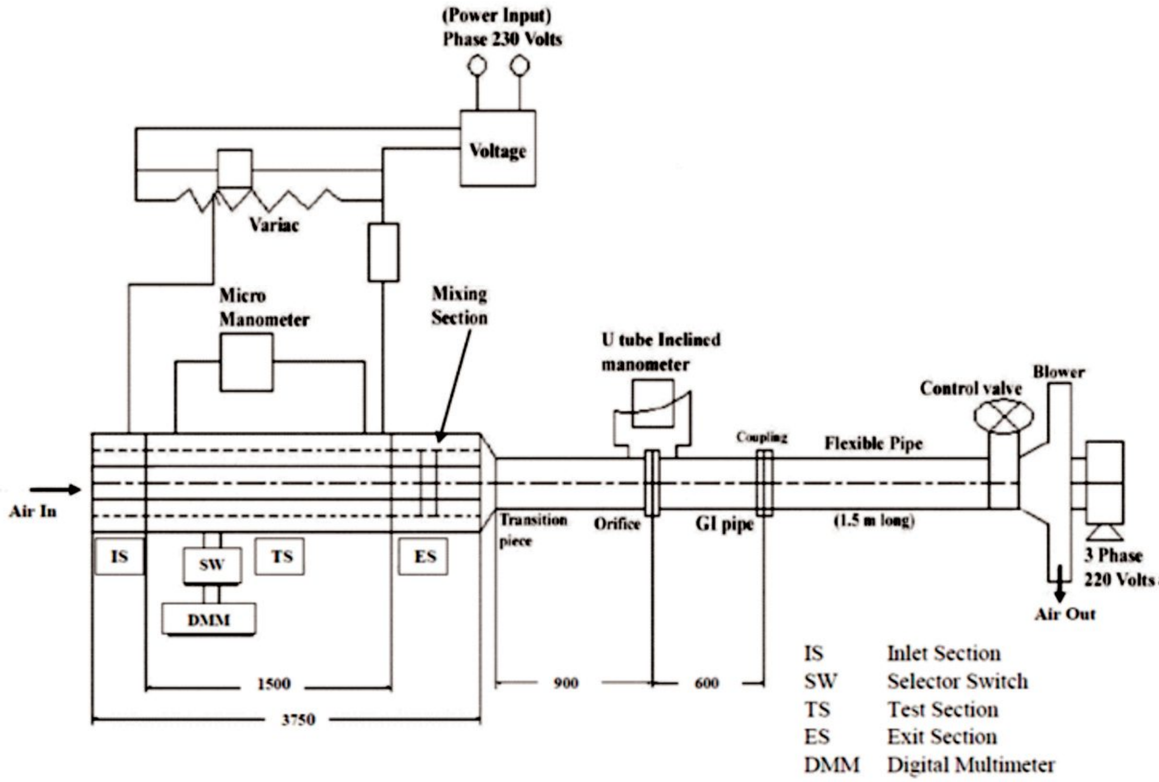


Figure 2.1 Schematic Set-up of SAH testing facility (Shukla et. al., 2014)

CONCEPT OF ARTIFICIAL RIB ROUGHNESS

The basic cause of thermal resistance between absorber plate and air in solar air heater is presence of laminar sub layer. Artificially roughened absorber plate is considered to be a good methodology to break laminar sub layer, in order to reduce thermal resistance and increase heat transfer coefficient. Main phenomena responsible for heat transfer enhancement from heated surfaces in duct flows are: flow separations and reattachments, generation of secondary flows, enhanced turbulence and mixing. Flow separation followed by reattachment tips off the laminar sub layer and increase the rate of heat transfer in the region of reattachment, whereas secondary flows in the lateral direction promote mixing, thereby improving the span wise distribution of heat transfer. The major motivation for the creation of turbulence lies in its capability to enhance the rates of the transport and mixing of matter, momentum and heat in turbulent flows (Pope, 2000). This would ultimately result in enhancing the coefficient of heat transfer between the absorber plate and air flowing beneath it. Simultaneously an increase in friction factor is also noticed in an artificially roughened duct. It is therefore desirable to create turbulence in near vicinity of heat transferring surface i.e. in laminar sub layer only, in order to reduce friction losses.

Meanings of various geometric parameters being studied by various researchers during experimentation are explained as given below:

(a) **Rib cross-section:** Ribs with different cross-sections can be employed for the creation of artificial roughness on the absorber plate. Commonly used rib cross-sections by various investigators are: circular, semi-circular, square, rectangular, trapezoidal, triangular and non-uniform (e.g. hexa blade type).

(b) **Shape of roughness element:** Rib having any cross-section can be applied in any shape, so as to enhance the heat transfer with moderate pressure drop. Most commonly studied shapes in the literature are: transverse, inclined, V-shaped, arc shaped, K-shaped, W-shaped, multiple V-shaped, V with gaps and combination of basic shapes with some staggered rib pieces. ofany special form.

(c) **Rib geometry dimensionless parameters:**In order to optimize the geometry of a particular shaped rib, various geometric parameters are studied in various combinations.

i) **Relative roughness pitch (P/e):** It the ratio ofdistance between two consecutive ribs andheight of the rib.

ii) **Relative roughness height (e/Dh):** It is theratio of rib height to hydraulic diameter of theair passage.

iii) **Angle of attack (α):** Angle of attack is definedas the inclination of rib with direction of airflow in the duct.

iv) **Aspect ratio (AR):** Aspect ratio is defined as theratio of duct width to duct height.

v) **Relative gap width (g/e):** It is ratio of the width of the gap to rib height.

vi) **Relative staggered rib pitch (p/P):** It is defined as the ratio of distance of staggered ribs from the main V-ribs to the distance between two consecutive V-ribs.

vii) **Relative staggered rib size (w/e):** It is defined as the ratio of length of staggered ribs to rib height.

PHYSICS OF HEAT TRANSFER ENHANCEMENT FROM RIB ROUGHENED WALL: It is believed that enhancement in the heat transfer and friction factor in the rib roughened duct are due to alterations in the flow field near the roughened wall. Figure 2.3 below shows the flow patterns over a transverse rib, which results in stationary flow separation vortices upstream as well as downstream the ribs. Heat transfer coefficient is very low in the region covered by stationary vortices. Many researchers in the past have acknowledged the effect of V shaping the rib from the movement of separated flow vortices along the ribs and the presence of counter rotating secondary flow vortices toward the depth of the duct. Figure 2.4 presents conceptual views of the most notable flow characteristics in ribbed channels. As the main stream flow near the wall of the channel passes over the rib, it separates from the wall due to the rib, resulting in relatively low heat transfer downstream of the rib. However, when the main stream flow reattaches to the wall (between two ribs), this isan area of relatively high heat transfer due to impingement of the relatively cool mainstream flow on the surface. Redevelopment of the boundary layer then begins. This pattern of separation, recirculation, and reattachment continues throughout the channel along with the pattern of repeating ribs. In addition, the rib turbulators increase turbulent mixing, which serves to increase the heat transfer from the channel wall.

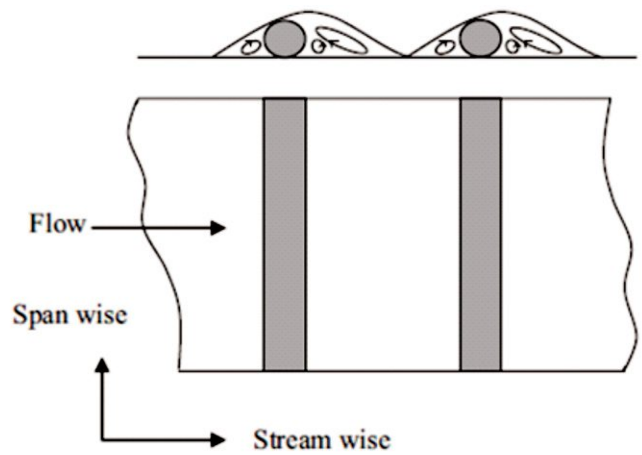


Figure 2.3 Flow patterns over transverse rib roughness (Patil, 2015)

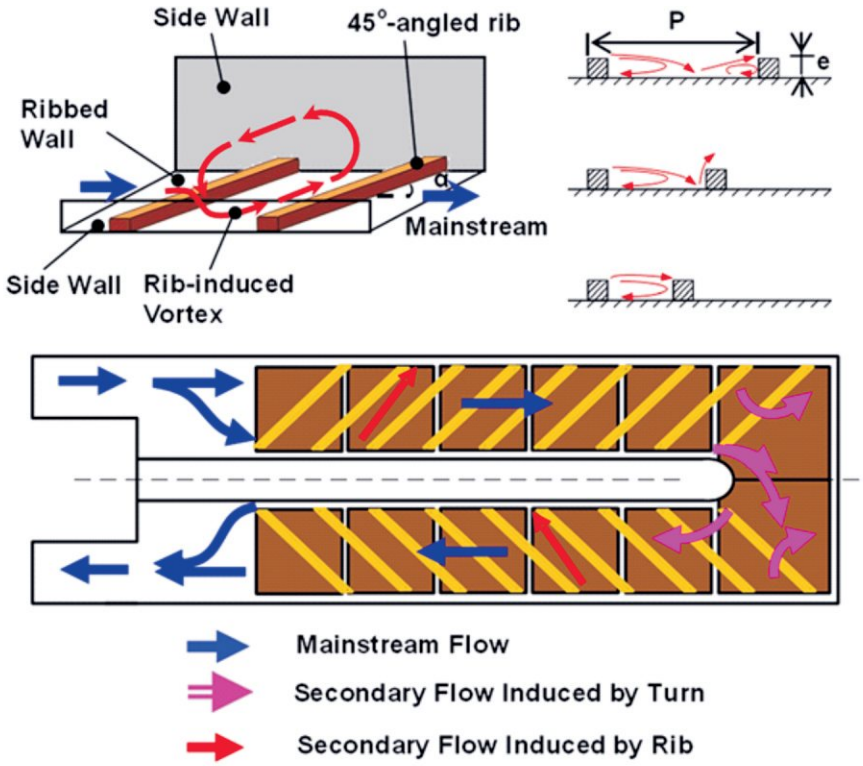


Fig. 2.4 Flow patterns at various locations between the upstream and downstream of V-ribs (Lei et. al., 2012)

The orientation of the rib turbulators has a significant impact onheat transfer by the previous observation that angled ribs yieldhigher heat transfer enhancement than that of orthogonal ribs dueto the additional secondary flow. The fluid near the surface followsthe angle of the rib from one side to the other in the passagecreating a set of counter-rotating vortices, until it impinges on theside wall and returns through central portion of the channel asshown in Fig. 2.4.The ratio of rib pitch (P) to rib height (e) is also important. InFig. 2.4, for the largest P/e ratio case, flow passes the first rib andthen separates, forming a recirculation zone right after the firstrib. It then reattaches the wall between the ribs and new boundarylayer is redeveloped. For the medium P/e ratio case, flow separatesand reattaches after passing the first rib; however, the redevelopmentof the boundary layer is interrupted by the second rib.For the smallest P/e ratio case, flow separates and forms a recirculationzone after passing the first rib; however, it cannot reattachto the wall due to the very small distance between ribs. It can beexpected that heat transfer is also highly affected by these flowpatterns around ribs.

Evolution of rib roughness geometries:

Continuous ribs (Transverse, Inclined, arc and V-shaped)

Initial investigations explored the effect of continuous ribs in various arrangements such as: transverse wires (Prasad and Mullick, 1983; Prasad and Saini, 1988), V-up (Momin et. al., 2002), transverse, inclined, V-up and V-down (Karwa et. al., 2003), arc shaped (Saini and Saini, 2008) and multiple V-rib (Hans et. al., 2010). Application of transverse ribs resulted in the overall improvement of heat transfer, but coefficient of heat transfer was believed to be lowered in the flow separation region behind the ribs, where stationary vortices were present. Use of inclined ribs resulted in the improvement of heat transfer as compared to the transverse ribs. It was opinioned that inclination of the ribs resulted in the generation of secondary flow by the movement of counter-rotating vortices between two consecutive parallel ribs (Taslim et. al., 1996), which swept the floor between two ribs, resulting in the increase of heat transfer from the leading end region; whereas trailing end region witnessed lower heat transfer coefficients due to accumulation of hot fluid. V-shaped ribs were believed to improve the span wise distribution of heat transfer by the doubling the counter-rotating secondary flow regions. Multi V-shaped ribs further improved the performance due to increase in the density of counter-rotating secondary flow vortices.

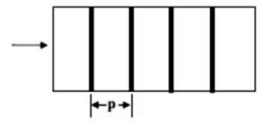
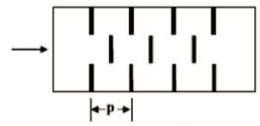
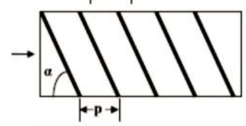
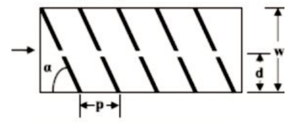
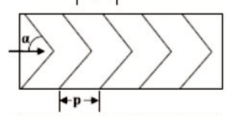
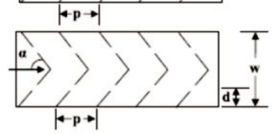
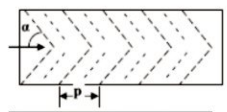
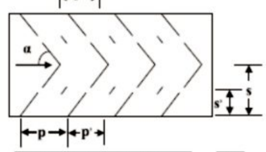
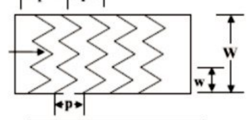
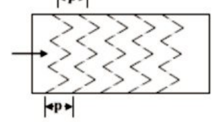
Broken ribs (Transverse, Inclined and V-shaped)

With the endeavor to further enhance the effectiveness of solar air heaters, studies were performed by applying discrete rib roughness in various configurations: staggered discrete V-shaped ribs (Muluwork, 2000), V-up and V-down discrete rib arrangements (Karwa et. al., 2003), transverse broken ribs (Sahu and Bhagoria, 2005). Critical review of the work done using broken ribs reveals that V-down discrete arrangement gives the best heat transfer performance, but at the same time they also resulted in higher friction loss. In order to keep friction loss under control, researchers tried a new type of roughness geometry by introducing a gap in the already well performing inclined or V-rib roughness geometries; viz. inclined rib with gap (Aharwal et. al., 2009), V-rib with gap (Singh et. al., 2011) and multi V-rib with gap (Kumar et. al., 2013). Application of the rib with gaps was stated to improve the heat transfer due to the added advantage of refreshment of the secondary flow through the gap while moving along the inclined ribs and acceleration of the flow while passing through the gap, thereby interrupting the growth of the boundary layer downstream the nearby reattachment zone; on the other hand friction factor was reported to be less than the continuous counterparts of these ribs. Patil et al., 2011, further experimented with a variation of the V-rib with one gap geometry by fixing a staggered rib piece in front of each gap and reported improvement in heat transfer and thermohydraulic performance as compared to the former. Rib roughness patterns of some continuous and discrete geometries along with the range of geometry and flow parameters are shown in the table 3.1.

THERMOHYDRAULIC PERFORMANCE

Study of heat transfer and friction characteristics shows that an enhancement in heat transfer is, in general, accompanied with a friction power penalty due to a corresponding increase in the friction factor. Therefore it is essential to determine the geometry that will result in a maximum enhancement of heat transfer with a minimum friction power penalty. To evaluate the performance of the SAH for equal pumping power for smooth as well as roughened plates, a thermo-hydraulic performance parameter considering both Nusselt number and friction factor enhancements, as defined by (Webb and Eckert, 1972) is used as given in the following equation:

$$\eta = \frac{\left(Nu / Nu_s\right)}{\left(f / f_s\right)^{1/3}}$$

Roughness geometry	Sub category	Investigators	Range of parameters	Typical geometrical illustration
Transverse rib roughness	Continuous	Prasad and Mullick [1] Prasad and Saini [2] Gupta et al. [24] Verma and Prasad [25]	e/D_h: 0.020–0.033 p/e: 10–20 Re:5,000–50,000 e/D_h: 0.018–0.052 Re: 3,000–18,000 e/D_h: 0.01–0.03 p/e: 10–40; e^+: 8–42 Re: 5,000–20,000	
	Broken	Sahu and Bhagoria [28]	p:10–30 mm e: 1.5 mm Re: 3,000–12,000	
Inclined rib roughness	Continuous	Gupta et al. [24]	(e/d): 0.020–0.05 (p/e): 7.5 and 10 α: 30°–90° Re: 3,000–18,000	
	Broken	Aharwal et al. [29]	p/e: 10; e/D_h: 0.0377 W/H: 5.87; α: 60° Re: 3,000–18,000 d/w: 0.167–0.5	
V-rib roughness	Continuous	Momin et al. [26]	e/D_h: 0.02–0.034 p/e: 10; α: 30°–90° Re: 2,500–18,000	
	Broken	Singh et al. [30]	Re: 3,000–15,000 p/e: 4–12 α: 30–75° d/w: 0.2–0.8 g/e: 0.5–2.0 e/D_h: 0.015–0.043	
	Discrete	Muluwork et al. [33]	e/D: 0.02; α: 60° B/S: 3–9 Re: 2,000–15,500	
		Patil et al. [34]	p/e: 10, e/D_h:0.04 α: 60° s'/s:0.2–0.8 p'/p:0.2–0.8 r/e:1–2.5 Re: 3,000–18,000	
Muli V-rib roughness	Continuous	Hans et al. [27]	P/e: 6–12 e/D: 0.019–0.043 α: 30–75° Re: 2,000–20,000 W/w: 1–10	
	Broken	Kumar et al. [31]	W/H: 12; W/w: 6 P/e: 10; e/D_h: 0.043 α: 60°; G_d/L_v: 0.55 g/e:0.5 to 1.5 Re: 2,000–20,000	

A heat transfer enhancement device having a value of thermal as well as hydraulic parameter (η) higher than unity ensures the fruitfulness of using an enhancement device and therefore, this parameter is generally used to compare the performance of different roughness arrangements to decide the best roughness arrangement among all the possible combinations. The values of the thermo-hydraulic parameter determined for some rib geometries viz. Transverse ribs, Angled ribs, broken v-ribs, V-rib with gap, Multi v-riband Multi v-rib with gaphave been compared. It can be seen that the multi v-rib geometry with gap has the best thermo-hydraulic performance among others.

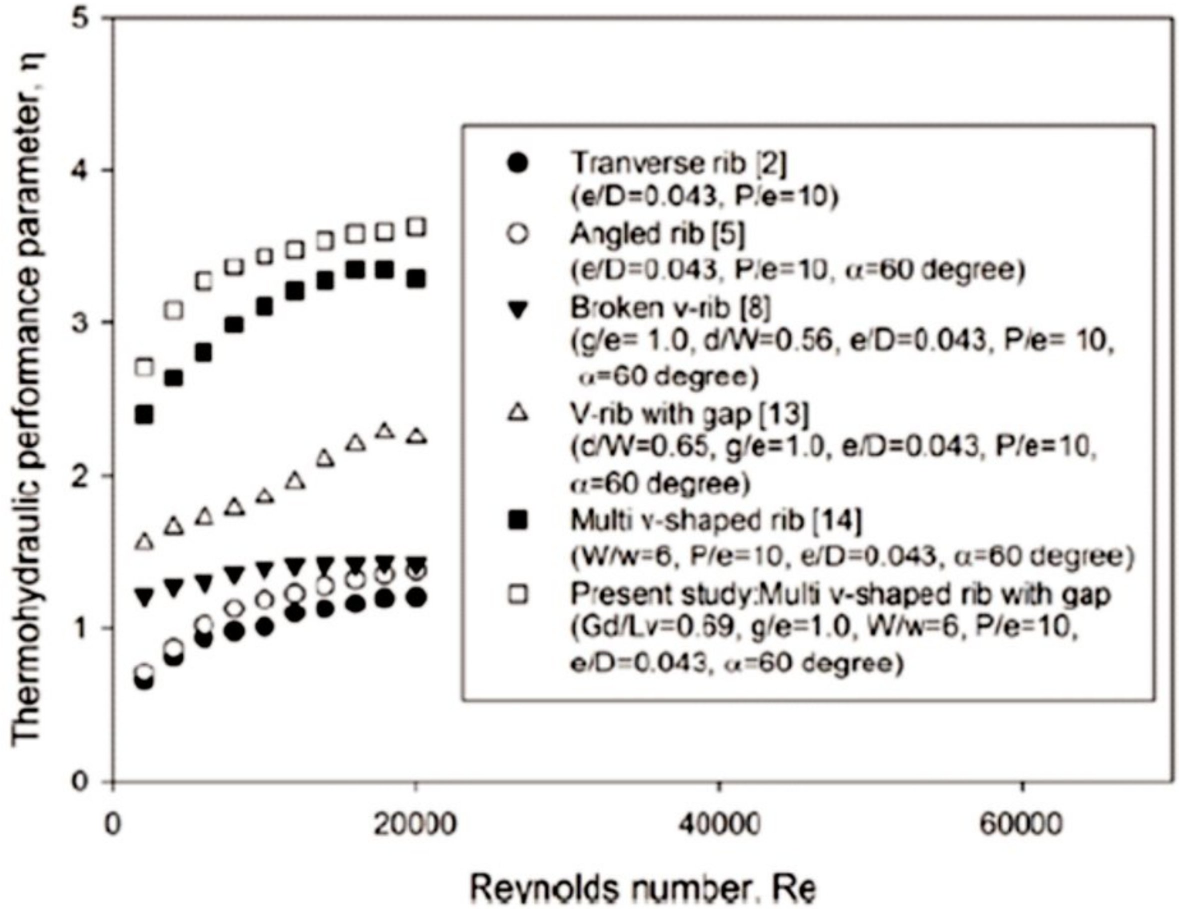


Figure 3.1 Comparison of thermo-hydraulic performance of some rib roughness patterns (Kumar et. al., 2013).

CONCLUSION

Based upon the findings of large number of studies carried out to investigate the effect of artificial roughness on the thermal performance of solar air heaters, is can be concluded that, thermal efficiency of solar air heater can be increased by enhancing the convection coefficient between the absorber plate and the air flowing in the duct. This can be achieved by breaking the laminar sublayer with the help of continuous interruption of flow by fixing some rib roughness on the surface. Various roughness geometries provided shows comparable result in the improvement of heat transfer, for solar air heater. Friction offered to air flow by these roughness geometries, accounted as friction factor, act as a penalty with enhancement of thermal performance of solar air heater using roughened duct. Key findings from the review of the literature can be summarized as given below:

1. Application of rib roughness is an effective method to enhance the heat transfer from the heated surfaces. It can used effectively to increase the thermal performance of a solar air heater.
2. Inclination of the rib with the direction of flow results in higher heat transfer as compared to the application of transverse ribs. This enhancement is due to the development of secondary flows in the span wise direction.
3. V-shaping of the ribs results in further enhancement of heat transfer, due to the generation of double secondary flow vortices per rib. It was found that V-up ribs perform better than V-down ribs in the range of Reynolds numbers applicable to solar air heaters.
4. Cutting of a gap in the continuous rib of any type (transverse, inclined or V-shaped) results in better heat transfer rates as compared to the continuous ribs. This was due to the refreshment of flow while passing through the gaps and generation of additional turbulence on the surface.
5. Multi V-shaped ribs perform better than V-shaped ribs due the generation of additional secondary flow cells. Multi V-shaped with gaps perform again better than their continuous counterparts.
6. Thermohydraulic performance parameter is an effective indicator to analyze the overall performance of a rib taking into account increase in heat transfer and flow friction simultaneously.

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An Experimental Vibration Analysis of whirling of shaft with varying diameters

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Abstract

Vibration is a mechanical phenomenon in which oscillation occurs about equilibrium points. It is a displacement or movement in one direction and then back to again in the opposite direction. For example the musical Instruments that may be plucked. With the passage or Era of time vibration is major issue for the machinery and industries. Everyone knows that the vibration have some merits and demerits. But in modern technology age we cannot minimize whole vibration in the machines as we needed. This paper tries to focus in the analysis of the vibration effect on the whirling shaft while running at the higher speed. The objective of the study is to find the effect of amplitude and natural frequency and forced vibration analysis of the shaft as axial vibration and Lateral whirling vibration on the whirling shaft. Also find some parameters in the system which causes the failure in the system before breakdown, and the effect of the resonance frequency of the shaft. Using the Vibscanner instrument to the study the vibration factors on it.Also with the help of OMNITREND PC software to create the spectrograph of the amplitude and frequency of the system.

Keywords –Whirling shaft, shaft with the different diameters, Vibscanner, accelerometer, amplitude, frequency and vibration factors on the shaft etc.

1. Introduction

Vibration is a mechanical phenomenon in which oscillation occurs about equilibrium points. It may be notices that any motion that repeats itself after an interval of time i.e. known as vibration oscillation. It is a displacement or movement in one direction and then back to again in the opposite direction. For example the musical Instruments that may be plucked. Mostly the energy can be put into the system through an applied force; either can be internal & external. The forces may be instantaneous, impulse & continuous. In the machine this type of energy can be divided from the process. This reduced the machine efficiency & may also result in damage to the machine components or parts.In this time vibration is the major problems for the rotating machineries such as Turbine, Compressor, and Crushers and mostly in the rotating shaft. These problems can be occurs when the rotating speed have corresponding to resonance frequency of the first bending of the shaft. Due to large forces can be induced in the bearing which causes the failure in the shaft. The main focus of the investigation is to study the vibration effect on the rotating shaft using the Vibscanner instrument. The main objective this studies to determine the parameters before the breakdown occurs on the rotating shaft. The main purpose of the analysis is to identify the effect of vibration on the different diameters shaft while running at different parameters. So this analysis can be carried out with the theoretical and experimental procedure.

2. EXPERIMENTAL SETUP AND PROCEDURE

Experimental analysis play most important role in the research work. Experimental approach is being be carried out and justify the theoretical and experimental analysis or by using different techniques. Experimental setup is being be made to measure the natural frequency and amplitude of the different diameter shaft.

2.1 Theoretical and Experimental Model

To study the dynamic Characteristics of the specimens including parameter like natural frequencies and acceleration of the shaft. We can change in their parameters (diameter) for experimental purpose and analysis the changes in their natural frequencies, mode shapes of the desired specimens.

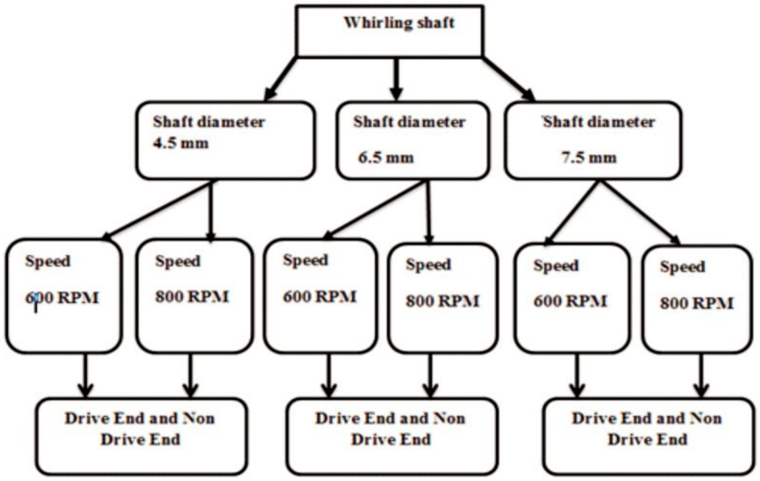

Figure 1: Experimental procedure for the whirling shaft

The whirling shaft can be made with the material of Mild steel (MS) with different diameters (4.5, 6.5, 7.5 mm) in the system. For the analysis of these shaft they can be run at two different RPM that is 600 and 800.The reading can be taken from the different ends of the instruments that is "Drive end and Non-drive end" of the shaft. Now we can also measure the vibration in the shaft at different modes ,these may be "horizontal ,vertical and axial" in the system.

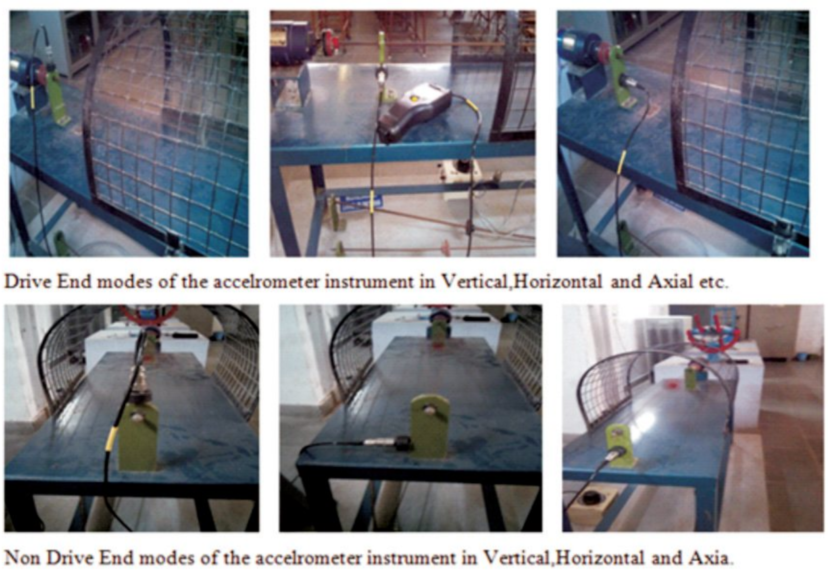

Figure 2: Directions of the Vibscanner (accelerometer) on the whirling shaft instruments

Frequency response functions (FRFs) were obtained using Vibscanner software and were processed using OMNITREND Solutions analysis to identify natural frequencies, damping and the corresponding mode shapes of the shafts.

3. ANALYSIS PROCEDURE AND DISCUSSION

The vibration analysis can be conduct on the test specimen to obtain the dynamic characteristic that may be natural frequency of the whirling shaft. Natural frequency of the shaft can be measured in the first mode only. The dynamic parameters can be measured with the help of accelerometer. The accelerometer is placed at the "drive and non-drive end" of the shaft and connected with the Vibscanner with the help of USB data cable. Accelerometer can be used to measure the vertical, horizontal and axial displacement of the shaft. Now we can study the amplitude and frequency of the shaft with the help of spectrograph.

Study of amplitude of whirling shaft of different diameters in same direction (Drive End):-

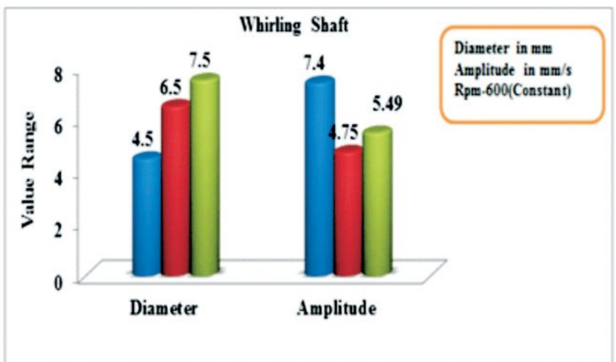

Figure 3: Study of amplitude spectrograph

We can make various graphs for the analysis of the whirling shaft while they can be in the running motion. Also knows the effect on the whirling shaft with different diameters and running at different speed in the system. These types of graphs can be show in the analysis and comparison of the dynamic parameters of the shaft. There will be different amplitude and frequency level graphs made for the study to find the vibration factors on the running condition of the whirling shaft. Now we will show some part of analysis from the various mode of whirling shaft experimental studies at different running speed (600 and 800 rpm), directional ends (drive and non-drive ends) and directions (Horizontal, Vertical and Axial) in the system.

3.1 For the Analysis of DriveEnd of the Whirling Shaft with Varying Speed (600 and 800 rpm):-

3.1.1 For the Drive End of the Shaft with 600 rpm:-

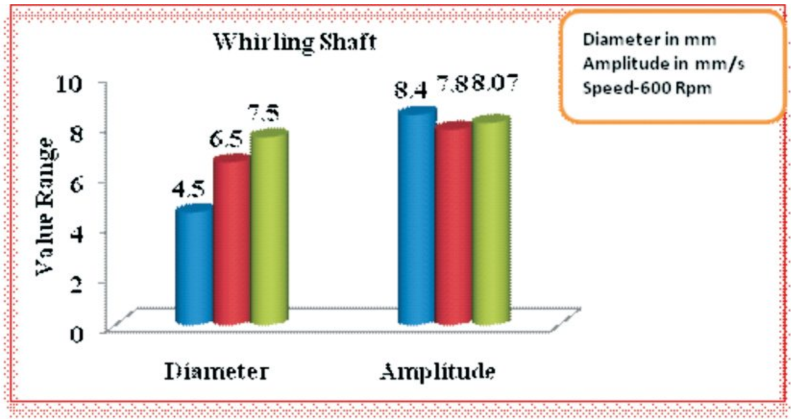

Figure 4: Study the effect of amplitude on the whirling shaft

Table 1: Statically data of whirling shaft with constant speed

Diameter	Amplitude	Rpm	Direction	End
4.5 mm	8.4 mm/s	600	Vertical	Drive End
6.5 mm	7.8 mm/s	600	Vertical	Drive End
7.5 mm	8.07 mm/s	600	Vertical	Drive End

For the study of whirling shaft with varying diameters and speed in the system more fluctuations can be observes in the system while we run the system. More vibration can be induced in the vertical direction of the shaft as be analyze the drive end of the shaft. As we increase the diameter of the shaft there can be slightly increase in amplitude of the shaft. For the vertical direction centrifugal forces can be applied on them to increase the vibration in the shaft while in the running conditions. Mostly from the analysis vertical direction of the drive end have seen more unbalanced in the running system.

3.1.2 for the drive end of the shaft with 800 rpm:-

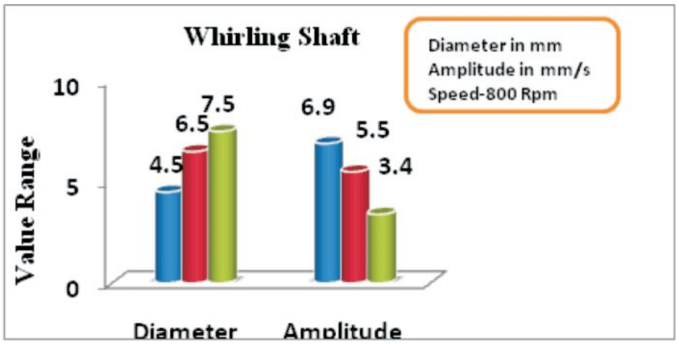

Figure 5: Study the effect of amplitude on the whirling shaft

Table 2: Statically data of whirling shaft with constant speed

Diameter	Amplitude	Rpm	Direction	End
4.5 mm	20.98 mm/s	800	Vertical	Drive End
6.5 mm	34.2 mm/s	800	Vertical	Drive End
7.5 mm	14.98 mm/s	800	Vertical	Drive End

As be increasing the running speed of the shaft at the drive end, there will be suddenly increase in the amplitude of the shaft as be increase the diameter of the shaft. Here more fluctuations can be observes in the vertical directions of the shaft. This can be due to the centrifugal forces can be induced on the metaflex coupling and reduces the running motion of the shaft. As the running motion in the system can abstract there will be more unbalanced forces attach to the shaft to produce more vibration at the particular area of the shaft while running at high speed.

3.2 For the analysis of non-drive end of the whirling Shaft with varying speed (600 and 800 rpm):-

3.2.1for the non-drive end of the shaft with 600 rpm:-

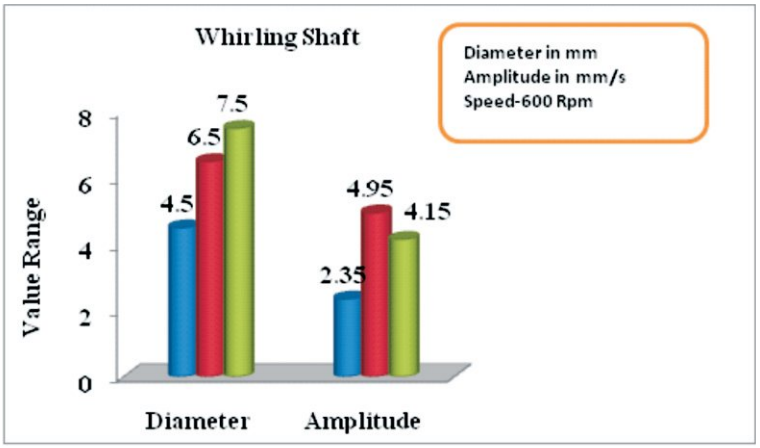

Figure 6: Study the effect of amplitude on the whirling shaft

Table 3: Statically data of whirling shaft with constant speed

Diameter	Amplitude	Rpm	Direction	End
4.5 mm	2.35 mm/s	600	Horizontal	Non-Drive End
6.5 mm	4.95 mm/s	600	Horizontal	Non-Drive End
7.5 mm	4.15 mm/s	600	Horizontal	Non-Drive End

As from the study of the various spectrographs of the whirling shaft in the non-drive end while in the running mode of the system. Now we can see the horizontal direction of the non-drive end has more fluctuates in the system. This can be due to the minimum coupling forces can be attach to these end of the shaft to reduce the shaft motion in the system. If the center of mass attach with the shaft has unbalanced in nature then shaft can also induced the vibrations in the system.

3.2.2 for the non-drive end of the shaft with 800 rpm:-

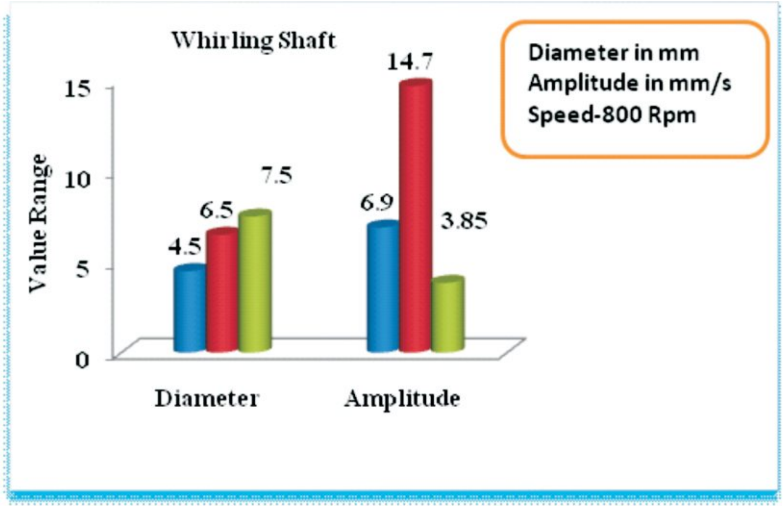

Figure 7: Study the effect of amplitude on the whirling shaft

Table 4: Statically data of whirling shaft with constant speed

Diameter	Amplitude	Rpm	Direction	End
4.5 mm	6.9 mm/s	800	Axial	Non-Drive End
6.5 mm	14.7 mm/s	800	Horizontal	Non-Drive End
7.5 mm	3.85mm/s	800	Horizontal	Non-Drive End

Now at the non-drive end of the shaft, there will be horizontal direction have more unbalanced in nature. This can be due to the coupling forces and eccentricity problems induced in the shaft to reduce the running motion of the shaft. Sometimes they can increase the running speed of the shaft which can induced the whirl in the shaft as be increasing the speed in the system, Here axial direction has also unbalanced in the shaft because of resonate forces can be attack at the system to reduce the stability in the shaft.

CONCLUSION

By the study of various literature reviews it is seen that, compare with previous old systems of vibration analysis of the whirling shaft can be used with the help of Vibscanner. This can be modern technique to check the vibration of the rotating parts of the system while they can be in the running motion. By knowing the amplitude and natural frequency of the shaft to reduce the failure on the rotating shaft before the break down occurs on it. This can be helpful for the rotating parts of various machines or instruments which can be running at very high speed. They can be know the which types of diameters can adjust for the running speed of the shaft.As we analyze the various spectrograph of amplitude of the shaft with changing of parameters in the running condition of the system. So from them some facts can be induced in the study of vibrations which can be very helpful for the rotating parts of machines and other mechanical instruments. These may be giving as below

1.) As we increasing the speed and diameter of the whirling, there will be directly increasing the amplitude of shaft while the system in the running condition.
2.) Whirling shaft can show the maximum amplitude on vertical direction of the drive end, while we run the system with varying speed (600 and800 rpm) in the system.
3.) Whirling shaft have show the maximum amplitude on horizontal direction of the non-drive end, while we run the system with varying speed (600 and800 rpm) in the system.
4.) The maximum amplitude level of the whirling shaft can be induced in the medium diameter (6.5 mm) shaft for both the drive and non-drive end of the shaft.

Future works

After this works on the whirling shaft various paths can be induced for the study to reduce or minimize the vibration and break down in the system. These may be

1. Using the different material (Aluminum, mild steel, Stainless steel, bronze etc.) shaft for the comparison of the whirling shaft with different diameters.
2. Using the Ansys software to determine the static and dynamic load on it and also check the vibration factors on the shaft.
3. Using the Mat lab to create the mode shapes of the whirling shaft while in the running motion.

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Heat Transfer Enhancement From Plate Fin Heat Sink Under Natural And Forced Convection: A Review

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ABSTRACT:

Heat sink is a component designed to lower the temperature of an electronic device by dissipating heat to the surrounding air. Basically, we divide heat sink in two categories: active heat sink and passive heat sinks. Active heat sinks are usually a fan type or some other peltier cooling device. Passive heat sinks are 100% reliable as they have no mechanical device. Geometry of fins plays an important role in the heat transfer from sinks. Researchers have studied the effect of thermodynamic properties like heat input and base to ambient temperature difference. Researchers have also studied the effect of fin height, fin length, fin spacing and fin thickness over convective heat transfer. Some investigators have found the set of correlation between various heat sink parameters .

Keywords: Heat sinks, plate-fins, aspect ratio .

INTRODUCTION

Many engineering operation during their operation generate heat. If the generated heat is not released to the atmosphere, then it may cause rise in temperature of the system component. This may cause overheating problem in the device and leads to the system failure. Using fins is the most inexpensive and common ways to release unwanted heat. Fins are commonly applied for heat management in electrical appliances such as computer power supply. The main objective of the fin is to increase the heat transfer rate from the surface. There are various shapes of the fins such as they come in rectangular, circular, pin fin rectangular, pin fin triangular. But the natural convection heat transfer coefficient is always increased by rectangular fins on horizontal and vertical surfaces. Some researchers used notched fins. The heat transfer rate was more in case of notched fins than unnotched fins.

MATERIALS USED FOR FINS

Generally there are two types of material used for fins aluminum and copper. The thermal conductivity of copper is 385w/mk and that of aluminum is 225w/mk. The melting and boiling point of copper is 1084º and 2595º and that of aluminum 658 º and 2057 º. And basically we use aluminum as fin material because it dissipates heat faster than the copper.

LITERATURE REVIEW

McManus and Starner,1963] used four rectangular fin array keeping base vertical, inclined at 45° and horizontal inter fin separation was 6.35 to 7.95mm with fin heights 6.35,12.70, 25.40 and 38.10mm. Fin length, thickness and width of the base plate was kept constant. From the above observation it has been observed that vertical base orientation gave high heat transfer rate as compared to horizontal.

[Rong Hua, 1997] et al. presented the theoretical information about the optimum spacing of longitudinal fin array in forced convection. In this experiment four different shapes of fins has been used: rectangular, convex parabolic, triangular and concave. From above it has been observed that aspect ratio and spacing was largest for rectangular fins and least for concave parabolic.

Lewandowski and Radziemska, 2001] gave the theoretical solution of natural convective heat transfer from isothermal round plates mounted vertically in unlimited space. A correlation between dimensionless Nusslet number (Nu) and Rayleigh number (Ra) have been given as:

$$Nu = 0.587 * Ra^{1/4} \quad \text{for water}$$
$$Nu = 0.655 * Ra^{1/4} \quad \text{for air}$$

It has been observed that the natural convective heat transfer coefficient was approximately 6% more in case of vertically mounted circular plates than that from vertically mounted rectangular or square plates having height equal to the diameter of circular plate.

[Giri, 2003] et al. gave a mathematical formulation of natural convection heat and mass transfer over a concealed vertical fin array. In experiment the base plate was maintained at temperature below the dew point temperature of the surrounding moist air. It has been concluded that if dry fin analysis used under moisture condensation conditions, then the overall heat transfer will be underestimated about 50%.

[Brauer, 1964] had done his investigation on the total surface area of the finned-tube bundle. It has been concluded that the fin surface area can be augmented by increasing the fin height and the number of fins per meter

[Ingham and Pop, 2001] have presented numerical methods for natural convection over a flat plate kept vertical and having surface temperature oscillation. They obtained numerical results for Grashoff number from 0 to 625 with an iterative approach. Perturbation method was used to validate results for small Grashoff numbers. They constructed an unsteady numerical scheme for larger values of Grashoff numbers. Their results show that unsteady solution approaches steady state for Grashoff number up to 10000.

[Wei, 2002] et al. investigated the natural convection heat transfer coefficient around a uniformly heated thin plate with arbitrary inclination. It has been found that if the angle of inclination is less than 10, then the average Nusslet number cannot be correlated by one equation, but if the angle of inclination is greater than 10, then the average Nusslet number can be correlated. It has been concluded that if the angle of inclination is less than 20 then the local natural heat transfer coefficient was very different for upper and lower heat surfaces.

[Nada, 2006] experimentally determine natural convection heat transfer and fluid flow characteristics in horizontal and vertical narrow fins with high Rayleigh number (Ra) for different fin spacing and length. Author concluded that as the number of fins increases the heat transfer rate increases. It has been observed that Nusslet number and effectiveness increases with increase in fin length. As Rayleigh number increases Nusslet number also increases and for any fin array geometry as Rayleigh number increases, effectiveness reduces for Rayleigh number greater than 10,000.

[Lorenzini, 2006] experimentally analyzed flow field in air over flat metallic hot plate. In this he used a light coil as a partial tracer of air flow field. It has been observed that coil weight has an influence on angular velocity of system but there is no effect of increasing weight of coil on the velocity.

[Axcell and Jouhara, 2009] did an experiment over rectangular fins which is cooled by laminar forced convection. Calculations show variation in heat transfer parameters along axial distance and more particularly rapid changes in heat transfer coefficient and fin efficiency near leading edges of cooling fins. Initially they obtained results for idealized fins which are 100% efficient.

[Farkade and Kharche, 2012] investigated the heat transfer from fin arrays, both analytically and experimentally. It has been concluded that heat transfer rate for notched fins is more than the unnotched fins. It has also been observed that the heat transfer rate purely depends upon the notched area. That is more the notched area more is the heat transfer rate.

[Cakar, 2009] numerically found that for a given fin spacing heat transfer rate increases with increase in fin height. Two sets has been used and numerically found the optimum fin spacing.

[Mehrtash and Tari, 2013] numerically investigated steady state natural convection from heat sinks with parallel arrangement of rectangular cross section plate fins on vertical base. It has been found that convection heat transfer rate stay almost same for small inclination. Aluminum heat sinks of two different lengths have been used. For obtaining natural convection and radiation heat transfer coefficient finite computational fluid dynamics simulation has been used.

[Chao, 2007] et al. used the piezoelectric fan to cool down the plate fin heat sinks. It has been observed that the thermal performance depends upon orientation of the piezoelectric fan. It has also been observed that the thermal performance is best when the piezoelectric fan is in vertical position with tip of the fan blade at the center of heat sink. And if the fan is in horizontal position the performance is best only when fan tip blade at front edge of heat sink.

[Suryavanshi and Sane ,2009] investigated the natural heat transfer through rectangular inverted notched fins and observed that the heat transfer is more where the notched area is large and is less where the area is less.

[Yüncü and Yildiz, 2004] investigated the natural convective heat transfer coefficient on annular fins. 18 sets of annular fin arrays have been used to observe their heat transfer performance. The fin arrays have been heated with different heat inputs and corresponding base and ambient temperature difference have been recorded. It has been concluded that convection heat transfer for the annular fin array depends upon the fin diameter, fin spacing and base to ambient temperature difference.

CONCLUSION

i. From the experimental study it has been found that rectangular plate fin heat sinks are easy to manufacture. It has been experimentally found that heat transfer rate in vertical plane heat sinks is more as compare to the horizontal one.

ii. Heat transfer rate from plate heat sink depends upon the fin geometry as well as base to ambient temperature difference.

iii. Geometry parameters like fin height, fin length, fin spacing plays an important role in heat transfer coefficient. It has been found that with increase in fin height, fin length and increase in base to ambient temperature heat transfer rate increases proportionally.

iv. It has been experimentally found that heat transfer rate in notched fin is more than unnotched fins. In this case, heat transfer rate purely depends upon notched area. That is more the notched area more the heat transfer rate. Also the copper gives more heat transfer rate than aluminum. Simultaneously flow pattern on of air on plate surfaces in various positions has been studied.

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Study Of Mechano-chemical Extraction Of Copper Using Pyrometallurgical And Hydrometallurgical Technaiques For Industrial Applications

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Abstract:

There are various processes to extract aluminium and copper from its ores. But after analyzing various parameters like environment, physical reliability, economic etc, it is observed that the most preferred operation for extraction of aluminium is Bayer's process and for extraction of copper is Pyrometallurgical operations. Based on the analysis, a table has been made reflecting the reasons and the findings to use these operations.

INTRODUCTION

Pyrometallurgyis the branch of extractive metallurgy which includes thermal treatment of minerals, metallurgical ores and concentrated to bring out the physical and chemical transformations in order to extract metal from its ores. Pure metals, intermediate compounds and alloys can be produced using this method. Even the less reactive oxides like Fe, Cu, Zn, Chromium, Tin, Manganese(Industrial Chemistry 2005, Wiley-VCH, Weinheim.) can be extracted. Almost all pyrometallurgical processes require energy to maintain the specified temperatures which is usually given in the form of combustion or electrical heat. In case when there is no external input required and the exothermic reaction alone is sufficient to maintain the temperature, those processes are called autogenous processes. Pyrometallurgical processes are generally classified into below mentioned categories :

1. Calcination
2. Roasting
3. Smelting
4. Refining

Hydrometallurgy is the branch of extractive metallurgy which used aqueous chemistry to derive the precious metal from its ores, concentrates, recycled or residual materials.

Very less reactive metals like gold and silver is extracted using this method. Generally, it is divided into 3 areas :

1. Leaching
2. Solution concentration and purification
3. Metal recovery

Various steps involved in Pyrometallurgical and Hydrometallurgical operations

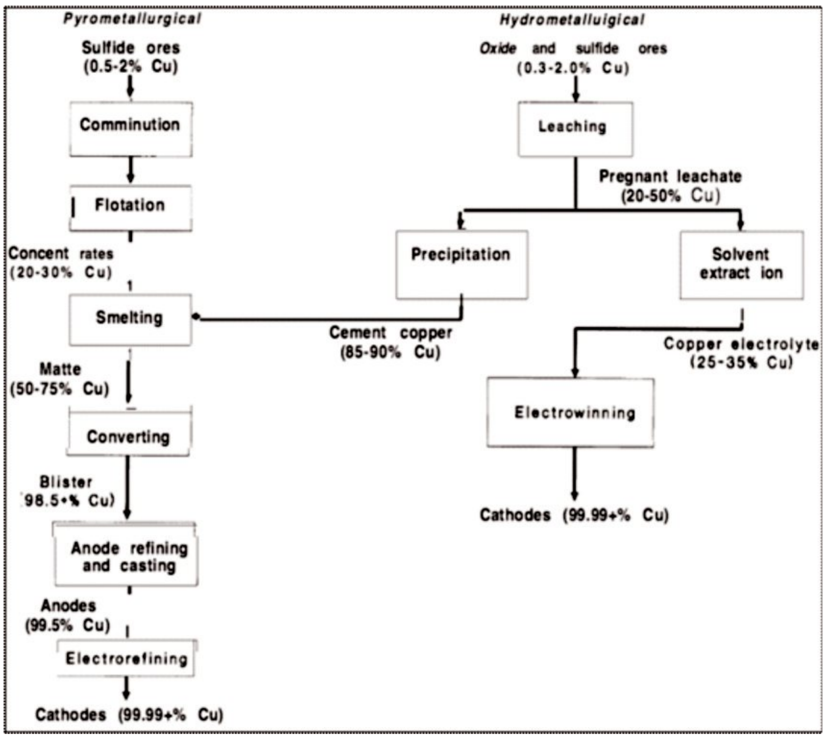

Figure 1: Pyrometallurgical and Hydrometallurgical operations

EXTRACTION OF COPPER USING PYROMETALLURGICAL OPERATIONS

According to International Copper Study Group 79 percent of Copper is extracted by Smelting process, generally used sulphide ores (New Edition of Directory of Copper Mines and Plan).

Process of copper extraction from chalcopyrite ore into pure metal:

Copper ore is concentrated to between 20 and 40% copper in a flotation process and then it is crushed and ground.Using,pyrometallurgical processes copper concentrate is converted 99% pure copper which is suitable for electrochemical refining. These high temperature processes first roast the concentrate, then smelting is done, further oxidising and reducing the molten products to remove sulphur, iron, silicon and oxygen to obtain relatively pure copper.

EXTRACTION OF COPPER USING HYDROMETALLURGICAL OPERATIONS

Oxide ores and low gradesulphides are extracted using this process and it contributes around 21 percent of total primary copper extraction.(International Copper Study Group-New Edition of Directory of Copper Mines and Plan).Oxide ores are first leached by sulfuric acid, using a dump leach process in combination with solvent extraction and electrowinning technology. Commonly sulfuric acid is used as a leach for copper oxide, water can also be used.. Froth flotation is not used to concentrate copper oxide ores in general, as the cost of leaching is cheap when compared to the cost of grinding and flotation. In a way, this means that copper oxides are more economic to process than copper sulfides.

EXTRACTION OF ALUMINIUM

The most common ore for extraction of aluminium is bauxite. Here, I will dicuss some environmental and economical factors related to it. Bauxite is impure aluminium oxide which includes impurities like iron oxides, silicon dioxide, titanium dioxide. The second method is using Hall Heroult process.

Process of Extraction of aluminium from bauxite:

Aluminium is too high in electrochemical series, so it is not possible to extract it using carbon reduction as temperature requirements will be too high to be economic. Instead, it is extracted using electrolysis process.Steps involved :

1. First of all, ore is converted into pure aluminium oxide by Bayers process.
2. Then the ore is electrolyzed in solution in molten cryolite which is another aluminium compound

Bayers Process :Crushed bauxite is treated with moderately concentrated sodium hydroxide solution. The concentration, temperature and pressure set depend on the source of the bauxite and aluminum oxide is present in what form. Temperatures are generally from 140°C to 240°C, pressures can be up to about 35 atmospheres. To keep the water in the sodium hydroxide solution liquidat temperatures above 100°C, high pressures are needed. The higher the temperature, the higher will be the pressure required.

With hot concentrated sodium hydroxide solution, aluminium oxide reacts, it gives a solution of sodium tetrahydroxoaluminate. The impurities in the bauxite remain suspended as solids.

These solids are separated from the sodium tetrahydroxoaluminate solution by filtration. They form something called "red mud" which is just stored in huge lagoons.

Precipitation of aluminium hydroxide:

The sodium tetrahydroxoaluminate solution is cooled, and "seeded" with some previously produced aluminium hydroxide. This provides something for the new aluminium hydroxide to precipitate around.

Formation of pure aluminium oxide

Aluminium oxide (sometimes known as alumina) is produced by heating the aluminium hydroxide to a temperature of about 1100 - 1200°C.

Then using electrolysis, aluminium oxide is converted to aluminium.

Economic considerations

To produce 1 mole of aluminium which only weighs 27 g you need 3 moles of electrons which means there is high cost of electricity involved You need to add a lot of electrons (because of the high charge on the ion) to produce a small mass of aluminium (because of its low relative atomic mass).

Energy and material costs isconstantly replacing the anode material

Environmental problems

Due to mining, processing and transporting the bauxite, there is a great loss to the landscape there

Noise and air pollution (greenhouse effect, acid rain) are also involved in these operations.

Extracting aluminium from the bauxite

Atmospheric and noise pollution from the various stages of extraction.

Pollution caused by power generation (depends on how the electricity is generated.)

Also, there is disposal of red mud into unsightly lagoons.

Table 1.1: Preferred operation for Aluminium and Copper Extraction.

S.No.	Metal	Operation	Temp. requirement	Pollution Type	Advantages	Findings	Ref. No.
1	Al	Hydrometallurgical operations)	Very High temp	Noise and air pollution	No need to use blast furnace	The most preferred operation for extraction of Aluminium is electrolysis process as due to high reactivity of aluminium, very high temperatures are required	[10], [2]
2	Cu	Pyrometallurgical operations	Above 1000°C	Water and air pollution	This Process is fast and By products can be used to fuel other operations	These operations are widely used as same operation can be used to extract copper from its ores for almost all type of ores	[11], [1]

SUMMARY & CONCLUSION

For oxide ores, hyrometallurgical operations are used as they are more cost effective. These operations can treat lower grade ores(even waste dumps) economically, flexibility in scale of operations, simplified material handling and good operational and environmental control.But reaction rates are small, Concentration of reagents are moderate, so we need large volumes of dilute solutions to obtain relatively small output. Also, we are using large volumes of water with lot of plumbing, pipe lines, pumps etc so you need a huge floor space. Clearly there is problem of corrosion. In pyrometallurgical operations, there is problem due to hot gases leaving the furnace and also due to liquid effluents as these cant be discharged into sea or cant be put on the ground, it will affect the livelihood nearby. So depending on our requirements, we can use either technique to extract copper from its ore. In case of aluminium, it is very high in reactivity series so the most preferred operation for this process is electrolysis as very high temperatures can be achieved to separate aluminium from aluminum oxide.

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