The Institution of Engineers (India)

"98 years of relentless journey towards
Engineering Advancement for Nation Building"

ALL INDIA SEMINAR

ON

"MICRO MACHINING"

on

October 25-26, 2018 at Fatehgarh Sahib

Organized by

The Institution of Engineers (India)

Punjab & Chandigarh State Centre
(under the aegis of Mechanical Engineering Division, IEI)

In Association / Collaboratlon with

Baba Banda Singh Bahadur Englneerlng College,
Fatehgarh Sahib, Punjab

Venue :

MECHANICAL ENGINEERING DEPARTMENT SEMINAR HALL

Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab

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The Institution of Engineers (India) or IEI is the largest multidisciplinary professional body that encompasses 15 engineering disciplines and gives engineers a global platform from which to share professional interest. IEI has membership strength of above 0.8 million. Established in 1920, with its headquarter at 8 Gokhale Road, Kolkata-700020, IEI has served the engineering fraternity for over nine decades. In this period of time it has been inextricably linked with the history of modern-day engineering. In 1935, IEI was incorporated by Royal Charter and remains the only professional body in India to be accorded this honour. Today, its quest for professional excellence has given it a place of pride in almost every prestigious and relevant organization across the globe. IEI functions amongst professional engineers, academicians and research workers. It provides a vast array of technical, professional and supporting services to the Government, Industries, Academia and the Engineering fraternity, operating from 121 Centres located across the country. The Institution provides grant-in-aid to its members to conduct research and development on engineering subjects. IEI conducts Section A & B Examinations in different Engineering disciplines, the successful completion of which is recognized as equivalent to Degree in appropriate field of Engineering of recognized Universities of India by the Ministry of Human Resources Development, Government of India. Every year as many as 90000 candidates appear for these exams. For details, please see: www.ieindia.org.

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Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab was established in the year 1993, under the patronage of Shriomani Gurudwara Prabandhak Commitee, Sri Amritsar, with the approval of the Govt, of Punjab. The college was a dream project of Panth Ratan Jathedar Gurcharan Singh Tohra, ex-President of SGPC. The college is approved by the A.I.C.T.E, New Delhi, Ministry of H.R.D, GOI and is affiliated to I.K. Gujral Punjab Technical University, Jalandhar. The college has earned third time accreditation from the NBA and International Accreditation Organization (IAO) for various programmes. BBSBEC has also been accredited by the Institution of Engineers (India). Presently, the college runs six B.Tech Programs and five M.Tech. Programs. It is housed in a sprawling pollution-free campus of 90 acres and is located in the sacred surroundings of historic Gurdwara of Fatehgarh Sahib. The college is named after Baba Banda Singh Bahadur, a great saint and warrior, who conquered the Sirhind fort and laid to rest, the tyranny of the Mughal Empire. It is one of the leading institutions in Engineering & Technology and is the most sought-after for admission by the students. BBSBEC has also made a significant presence in the Techno-Educational field at international level.

ABOUT THE PROGRAMME

The aim of this National seminar is to present current researches being carried out in the areas of Micromachining for scientists, scholars, engineers and students from the universities, technologists, entrepreneurs and policy makers all around the World. Thus, the seminar provides opportunities for the delegates to exchange new ideas and experiences through face to face interactions and to establish research relations. The researchers and engineers coming from academia and industries will be interacted for the advancements of this technical sector and will be able to share best practices and thereby learn to transform their own research findings through step towards 'Make in India' campaign. This seminar will act as a path which leads to search for knowledge. This seminar will focus on Improving researchers retention and success, Enhancing researchers development and learning and Supporting well-being and social inclusivity. The technical seminar is focused on micro machining technologies. Topics of interest include, but are not limited to:

- Micro fabrication technologies
- Micromachining process characterization
- Mechanical based micromachining technology
- Chemical based micromachining
- Thermal erosion based micromachining
- Material related issues in micro manufacturing
- Micro and Nano additive manufacturing technologies
- Renewable Energy, Heat Transfer
- Surface engineering
- On-line monitoring and inspection
- Standardization in micro manufacturing
- Applications of micro and Nano technologies
- Process modelling and simulation
- Advanced Materials, Composite Materials, Smart Materials
- Manufacturing Systems & Design, Lean / Flexible Manufacturing, TQM, Quality
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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 an all India National Seminar on “Micro Machining” on October 25-26, 2018. 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.

Seminar 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.

S.Gobind Singh Longowal

President SGPC & BBSB Education Trust

MESSAGE

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 an all India National Seminar on “Micro Machining” on October 25-26, 2018.

I am certain that this seminar would be a befitting stage for the participants and studentsto 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.Mahinder Singh Ahli

Member-Secretary, BBSB Education Trust

MESSAGE

In pursuance of our mission 'To mould the youth into World-class Technocrats' of tomorrow who would endeavour 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 an all India National Seminar on “Micro Machining” on October 25-26, 2018.

The core purpose of the Seminar 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 Seminar 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.

Major General (Dr.) Gurcharan Singh Lamba, VSM (Retd)
Principal, BBSBEC, Fatehgarh Sahib

MESSAGE

It gives me immense pleasure that Department of Mechanical Engineering of Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib is holding an all India National Seminar on "Micro Machining" on October 25-26, 2018. The seminar will serve as a platform for scholars to meet the technical challenges in the field of Mechanical, Materials, Industrial 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 seminar is heart-warming. The deliberations during seminar 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 seminar.

Dr. Lakhvir Singh

Professor & Head, Department of Mechanical and Industrial Engineering

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Different Types of Advanced Manufacturing Technologies (AMTs) For Production Enhancement in Manufacturing Organizations

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Abstract
Manufacturing organizations contribute significantly towards the fulfilment of major requirements, employment, and economy of the country. Advanced manufacturing technologies (AMTs) reflect the progress made by the humans. The implementation of this technology in the manufacturing organizations has proved to be beneficial in bringing flexibility, improving quality and enhancing the performance. This paper conducts a comprehensive review on classification of AMTs. Literature was reviewed in a way that will assist researchers, academicians, and practitioners to take a closer and thorough look.
Keywords: Advanced manufacturing technologies; AMTs; classification of AMTs

Introduction
Manufacturing organizations contribute considerably towards manufacturing of goods to meet our needs. With globalization they must respond quickly to the market trends, need of the time and threats. They constantly search for solutions where flexibility plays a critical role in this struggle for success. Progress in human society has been accomplished by the making or introduction of new technologies. Last decade has witnessed unmatched changes throughout the world, may it be in terms of availability, quality or range of choices. The major factor that has made it possible is the implementation of AMTs. AMTs have helped in providing tools and techniques required to fulfil the increasing demands of its customers like better quality, accuracy, low cost, fast delivery and range or variety.
AMTs involve the use of computer and consist of a possible group of technologies such as computer aided design (CAD), computer aided manufacturing (CAM), computer numerical control (CNC), computer aided process planning (CAPP) and engineering systems, materials resource management, production planning, scheduling, routing, control and integration, material handling systems such as automated guided vehicles (AGVs), conveyors and robots, etc. AMT is a key contributing factor in improving the productivity, flexibility, product quality and green standards (i.e. clean, sustainability and environmental factors). The advantages of implementation of AMTs are numerous.

Literature review

Advanced manufacturing technology (AMT): The ardour for lower operating costs, flexibility and improved manufacturing efficiency has forced a large number of manufacturing firms to embark on advanced manufacturing technology (AMT).The striking developments in AMT at several organizational levels can be attributed to numerous benefits that improve the competitive position of the adopting companies (Tahriri et al.,2015). AMT impacts not just manufacturing, but also the whole business operations, giving new challenges to a firm's ability to manage both manufacturing and information technologies. AMT refers to manufacturing process technologies that use computers to store and manipulate data (Dangayach and Deshmukh, 2005). AMTs can help firms customize their products and attain economics of scope based on low volume and low cost production (Gunawardana, 2010).

AMTs can produce wide range of varieties at low volumes without added costs (Adler, 1988; Dean and Snell, 1991; 1996; Goldhar and Jelinek, 1985; Gerwin, 1993; Gerwin and Kolodny, 1992; Kaplinsky, 1984; Parthasarthy and Sethi, 1993; Swamidass and Kotha, 1998; Kotha and Swamidass, 2000).

Alcaraz, et al., (2012) in their research enlisted 35 advantages of AMTs out of which the following were found more significant followed by the survey of 60 enterprises.

1. Reduction of the variety of parts
2. Reduction of the variety of products and parts
3. Improve the inventory rotation
4. Reduction of the material handling
5. Reduction of the production lot size
6. Reduction of the number of machinery
7. Process flexibility
8. Machinery flexibility
9. Reduction of the reprocess and waste
10. Reduction of the WIP (Work in progress)
11. Volume flexibility
12. Fast responses to the consumer needs
13. Marketing Reduction of delivery times
14. Time reduction between the order reception and the delivery time
15. Cost reduction of workforce
16. Reduction of the processing time
17. Reduction of the cost of production
18. Reduction of the design time
19. Design quality
20. Time reduction between conceptualization and manufacture of the product
21. Reliability increment
22. Increment in the quality of the product

The benefits also include profitability, strategy and agility, reduction in lead time, increase in machine utilization, reduction in unit and labour costs, product quality improvements and reduced work-in-process inventories (Klocke and Straube, 2004; Milgrom and Roberts, 1990; Mortimer, 1984).

Classification of AMTs

AMTs have been classified into various categories by different authors. A few of them are mentioned here.

AMTs are categorized into Direct AMT, Indirect AMT, and Administrative AMT. Hardware base technologies are termed as Direct AMT. Software-based technologies used for product design and scheduling are termed as Indirect AMT. The administrative AMTs are used for uniting, integrating and simplification of business processes. (Dangayach and Deshmukh, 2005)

- Direct AMT. Technology used on the factory floor to cut, join, reshape, transport, store or modify materials, e.g. CNC, DNC, robotics, FMS, AS/RS, AMHS, AGV, RP, etc.
- Indirect AMT. Technology used to design products and schedule production, e.g. CAD, MRP, SPC, BC, MRP II, etc.
- Administrative AMT. Technology used to give administrative support to the factory and integrate its operations with the rest of the organization, e.g. ERP, ABC, OA, etc.

Alcaraz, et al., (2012) also narrated the classification of AMTs into hard and soft technologies.

The hard technologies include:
1) Robots
2) Computer aided design (CAD)
3) Computer aided manufacturing (CAM)
4) Computer aided engineering (CAE)
5) Computer integrated manufacturing (CIM)
6) Computer numerical control (CNC)
7) Flexible manufacturing systems (FMS's)
8) 3D Digitalization
9) Fast prototypes
10) Local area network (LAN)
11) Wide area network (WAN)
12) Technology information and communication (TIC)
13) Industrial automatization
14) Automated guided vehicle (AGV).
15) Automated inspection (AI)
16) Artificial intelligence in industry
17) Laser technologies to process material and measures
18) Electronic data interchange (EDI)
19) Computer aided process planning (CAPP)
20) Automatic loads and downloads of items
21) Automated tools change
22) Computer aided inspection, test and tracking.
23) Item identification for industrial automated (bar code)
24) Supervisory, control and data acquisition (SCADA)

The soft technologies include:
1) Production system just in time (JIT)
2) Manufacturing resource planning (MRP II)
3) Enterprise resource planning (ERP)
4) Group technology (GT)
5) Manufacturing cells (MCs)
6) Total quality management (TQM)
7) Statistic quality/process control (SQC / SPC)

8) Single minute exchange of die (SMED).
9) Total productive maintenance (TPM)
10) Manufacturing technique: Lean manufacturing.

Uwizeyemungu et al, (2015) classified AMTs into four categories

1) Product Design Technologies (AMT for Innovation)
    a) Computer-aided design and manufacturing (CAD/CAM)
    b) Computer-aided design (CAD)
    c) Computer-aided drawing
    d) Computer-aided manufacturing (CAM)
2) Process Technologies (AMT for Flexibility)
    a) Flexible manufacturing systems (FMS)
    b) Programmable logic controller (PLC)
    c) Automated handling of materials
    d) Computer numerically controlled machines (CNC)
    e) Robotized operations
3) Transactional and Logistic Applications (AMT for logistic and monitoring)
    a) Production inspection and control
    b) Computer-based production scheduling
    c) Computer-aided maintenance
    d) Quality control system
    e) Computer-based inventory management
4) Communication and Integration Applications Systems (AMT for integration)
    a) Enterprise resource planning (ERP)
    b) Material requirement planning (MRP-I)
    c) Manufacturing resource planning (MRP-II)
    d) Electronic data interchange (EDI)
    e) LAN for MRP-II/Plant/Intranet

Guruwardana, (2010) classified the AMTs into following categories:
1. Design and engineering technologies
Computer-aided design (CAD)
Computer-aided process planning (CAPP)
2. Fabricating/machine and assembly technologies
NC/CNC or DNC machines
Materials working laser (MWL)
Pick-and –place robots
Other robots
Intermediate systems
3. Automated material handling technologies
Automatic storage and retrieval systems (AS/RS)
Automated material handling systems (AMHS)
4. Automated inspection and testing systems
Automated Inspection and testing equipment (AITE) Integrated systems

5. Flexible manufacturing technologies
Flexible manufacturing cells/systems (FMC/FMS)
6. Computer-integrated manufacturing systems
Computer-integrated manufacturing (CIM)
7. Logistic related systems
Just-in-time (JIT), Material requirements planning & Manufacturing resources planning (MRPII)

The author also discussed another grouping based on the following categories
(1) AMT related hard ware:
LAN (local area networks), Micros (PC Computers), Graphics hardware: Mainframe Online process instrumentation, Shop floor data capture and WAN (wide area networks)
(2) AMT related Software: CAD/CAM Data base management systems MRPII (Manufacturing Resource planning I and II)
(3) QC software, MRP Expert systems, OPT, MAP.
(4) AMT related plant and equipment:
CNC M/Cs, Automatic testing equipment, Computer-controlled testing equipment, Flexible manufacturing cells, Automatic assembly, Flexible assembly systems, Robots, Laser cutting, Automated warehousing/order picking, AGVs & Laser measuring.

Conclusion

The impact of AMTs implementation in manufacturing organization seems significant from the literature review. The authors have classified the AMTs into numerous categories. No single study can probably attempt to cover all these variables adequately. The benefits of AMTs are justified enough. Hope this review will inspire other researchers to pursue studies aimed at improving the knowledge about AMT adoption and the impact of various variables.

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Investigation on High Temperature Erosion Behavior of HVOF Sprayed Ni-20Cr Coating at Different Impact Angles

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Abstract
According to recent investigation and design ideas high overall performance can be acquired with the alteration of the surface structure by using substrate coating. In this research, Ni20Cr was deposited on SA210 GRADE A1 boiler steel using HVOF thermal spraying technique. The erosion studies were conducted on uncoated as well as coated specimens in coal fired boiler atmosphere using an air jet erosion test rig at two impingement angles of 30° and 90°. The main objective of this research work was to increase the life of boiler tubes by using conventional Ni20Cr coating and to compare the performance of coatings with respect to basic SA210 GRADE A1 grade boiler steel. The Ni20Cr coating had shown minimum erosion rate as compared to uncoated SA210 GRADE A1 boiler steel. Maximum erosion was observed at an angle of 30° as compared to 90° revealing ductile behavior.

Keywords: HVOF thermal spraying technique, Erosion rate.

1. Introduction

Disaster of building elements in high-temperature uses can be because of communication of the environment with the material, resulting in solid particle erosion, wear, corrosion, loss of protection [1,2]. Solid particle erosion is a material degradation tool that met in a lot of engineering systems for example pneumatic bulk transport systems, thermal power plants, aircraft gas turbine engines, coal liquefaction plants and ore or coal slurry pipe lines [3,4]. Coatings offer a way of spreading the boundaries of use of materials at the upper end of their performance abilities, by permitting the mechanical properties of the substrate materials to be preserved while protecting them against wear or erosion [5,6,7]. Thermal spray coatings are applied to improve the erosion resistance characteristics [8,9]. Nickel based alloys hold several striking properties, such as erosion, wear and corrosion resistance in addition to good thermal conductivity. High-velocity oxy-fuel (HVOF) spraying is a fairly new and swiftly developing thermal spray technology for depositing surface coatings to combat high-temperature erosion to produce coatings by means of low porosity, low oxide content, and bond strength than many thermal spray processes [10,11]. NiCr based coatings are applied in conditions when wear resistance shared with hot erosion resistance is required. [12,13]. In this present analysis, Ni20Cr has been HVOF sprayed on SA210 GRADE A1 boiler tube steel.

2. Materials and methods

2.1. Development of coatings

2.1.1. Substrate material

The test material for the current work is SA210 GRADE A1 which is used as boiler tube material. The chemical composition of the material has been explained in Table 1, which presents the composition provided by supplier and the actual composition measured by spectroscopy.

Table 1: Chemical composition of SA 210-A1 boiler steel

Chemical Composition (wt %)	SA 210-A1 Boiler Steel	
	Nominal composition	Actual composition
C	0.20-0.28	0.27
Mn	0.75-0.95	0.93
P	0.03	0.035
S	0.03	0.035
Si	0.05-0.1	0.10
Cr	-	-
Mo	-	-
Fe	Balance	Balance

2.1.2. Coating formulation

The specimens each measuring 20mm x 15mm x 5mm approximately were cut from this material. The specimens were polished down to 180 grit SiC paper finish, and were grit blasted with Al_2O_3 (grit 60) before the deposition of the coatings. Ni20Cr was deposited on SA210 GRADE A1 boiler steel by using HVOF spray process. The HVOF spray coatings were accomplished using commercially available HVOF-spray (HIPOJET- 2100) thermal spray process at Metallizing Equipment Company Private Limited, Jodhpur, India, operating with oxygen and liquid petroleum gas (LPG) as input gases. The substrate steels were cooled by compressed air jets during and after spraying.

2.2. Erosion studies in simulated coal-fired boiler environment

By using a high temperature air-jet erosion test rig, erosion studies were carried out for coated, as well as for uncoated specimens. The two temperatures were used for the test, sample temperature 400°C and air/erodent temperature 900°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 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 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 2. A standard test procedure was employed for each erosion test. In the present study standard alumina 50 micron (supplied with Erosion Test Rig by Ducom Instruments Private Limited, Bangalore, India) was used as erodent.

Table 2: Erosion-Wear Test conditions

Erodent material	Alumina (Irregular shape)
Erodent Specifications	50 micron Al_2O_3
Particle velocity (m/s)	35m/s
Erodent feed rate (g/min)	2 gm/min
Impact angle (°)	30, 90
Nozzle diameter (mm)	4
Test time (Hrs)	3 Hours

3 Experimental Results

3.1 Analysis of eroded surfaces

The erosion loss has been calculated by volume change method. The volume loss occurred after erosion testing was measured. The erosion rate for uncoated and coated SA210 A1 boiler steel at an impact velocity of 35 ms^{-1} and impingement angle of 30° and 90° when substrate temperature was 400°C and surrounding air at 900°C is shown in Table 3 & Fig.1 for 90° and Table 4 & Fig. 2 for 30° impact angle respectively. The volume erosion rate for uncoated SA210 A1, conventional Ni–20Cr are shown in table.

Table 3: Volume Erosion Rate at 90° impact angle (In mm^3/gm)

Volume Erosion Rate at 90 degree impact angle (mm^3/gm x 10^{-3})		
Coating↓	**Substrate →**	Grade A1
Uncoated		2.557
Ni20Cr (Conventional)		0.296

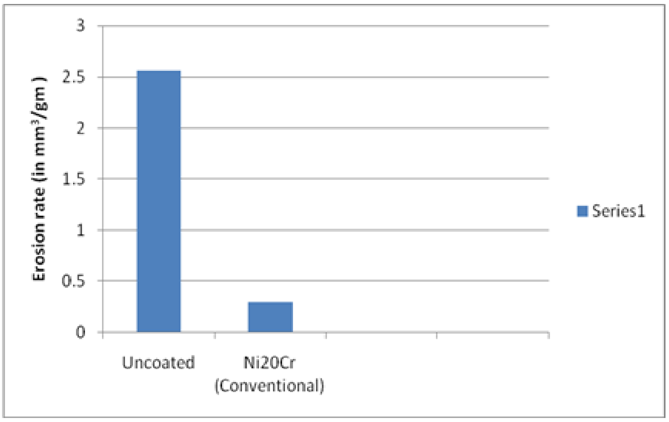

Figure 1: Graph representing Volume Erosion Rate at 90° impact angle (mm^3/gm x 10^{-3})

Table 4: Volume Erosion Rate at 30° impact angle (In mm^3/gm)

Volume Erosion Rate at 30 degree impact angle (mm^3/gm x 10^{-3})		
Coating↓	**Substrate →**	Grade A1
Uncoated		3.120
Ni20Cr (Conventional)		1.898

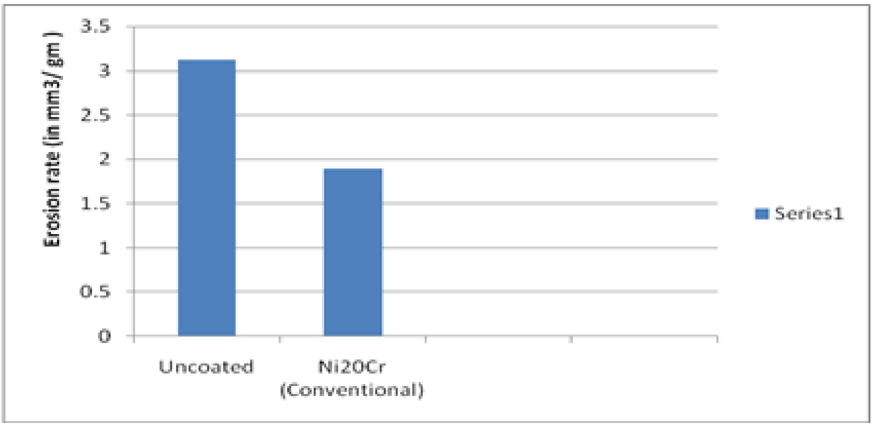

Figure 2: Graph representing Volume Erosion Rate at 30° impact angle (mm^3/gm x 10^{-3})

Conclusions

The following conclusions are made:

1. Ni20Cr was successfully deposited on SA210 A1 grade boiler steel by the HVOF spray technique.
2. The erosion rates for 90° impact angle can be arranged in the following order:
   Uncoated > Conventional Ni20Cr
   The coatings were partially removed by the continuous strikes of the eroding particles on the surface of the coating at 90° impact.
3. At 30° impact, the volume erosion rate can be arranged in the following order:
   Uncoated > Conventional Ni20Cr
   The coatings were removed by the continuous strikes of the eroding particles on the surface of the coating at 30° impact.
4. Maximum erosion was observed at an angle of 30° as compared to 90° revealing ductile behavior.
5. The Ni20Cr coating had shown minimum erosion rate as compared to uncoated SA210 GRADE A1 boiler steel.

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An overview of different techniques for preparing Magnetic Abrasive Particles

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Abstract: Magnetic abrasive finishing is one advanced super finishing process which employs a flexible multipoint cutting tool for finishing. This cutting tool is controlled by the magnetic force. The cutting tool formed of magnetic abrasive particles is the most critical part of the magnetic abrasive finishing process. The magnetic abrasive particles are a kind of composite powder, generally consisting of ferromagnetic matrix phase and hard abrasive grains. However lack of a simple preparation process, low cost and abrasive having long service life are the factors affecting its wide spread use in the industry. These magnetic abrasive particles are prepared by special techniques. This paper highlights major subsisting technologies that are habituated to manufacture magnetic abrasives.

Keywords: Magnetic abrasive finishing; magnetic abrasive particles; Sintering; Plasma spray; Mechanical alloying; elastic magnetic abrasives.

1. Introduction

Magnetic abrasive finishing is one advanced super finishing process which employs a flexible multipoint cutting tool that applies force of very small magnitude. Accordingly fine polishing is achieved without the desideratum for extravagant, rigid, ultra precision; vibration and error free machine tools. The finishing forces are primarily controlled by magnetic flux density, magnetic abrasive particles, polishing conditions and workpiece. Figure 1 shows the Ishikawa cause and effect diagram for magnetic abrasive finishing process. This process is widely used to achieve fine finish on wide range of materials.

This process offers many advantages. The process involves no rigid tool so, lower stresses, no overloading problem, low temperature, no oxide layer formation and negligible surface defects. Process engenders no chemical pollution and doesn't need controlled atmospheres. Cutting tool doesn't require emoluments, reshaping, and dressing and have flexibility of profiling. Process can be applied to cylindrical, plane and intricate shapes of both ferromagnetic and non-ferromagnetic work pieces.

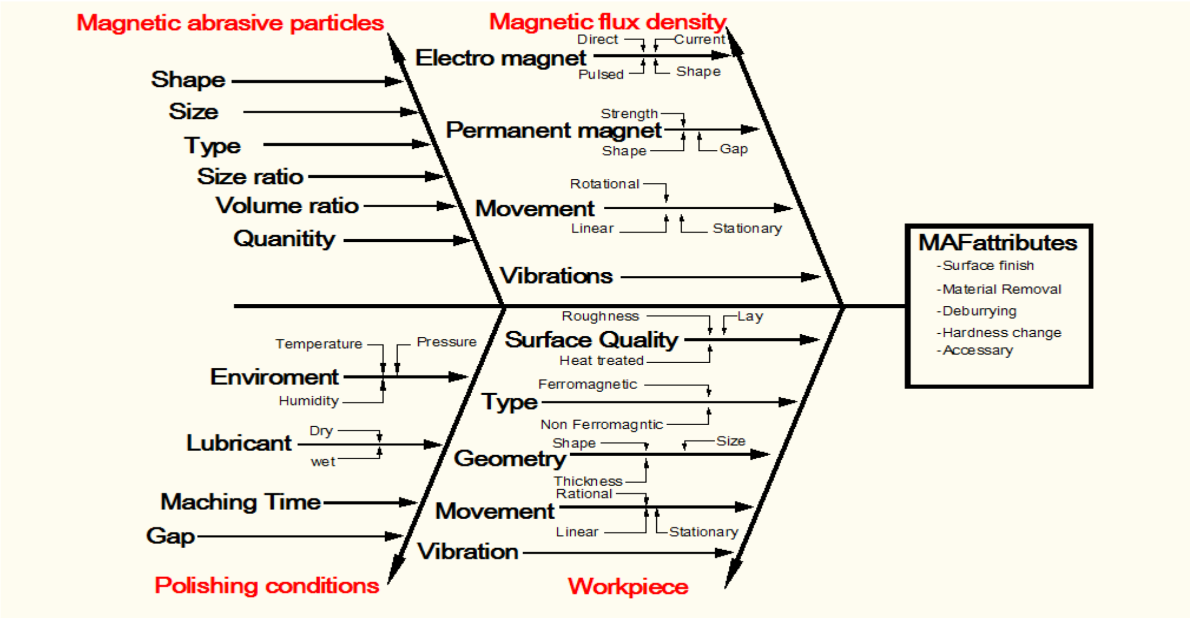

Figure 1 Ishikawa Cause and Effect diagram

The force (typically up to 1 MPa) at which the abrasive grains act on the surface treated promotes formation of an incipient high disperse phase and converts the tensile stresses into compressive [2], amends micro hardness and is able to get high quality of product irrespective of worker's qualification. However, there is problem of difficulty in the making of magnetic abrasive powder and its high cost. There is a need to look into this perspective so that the process can further get flourished. In the following section the techniques used to manufacture magnetic abrasive particles for the finishing process found in literature will be discussed.

2. Techniques to manufacture magnetic abrasives:

Magnetic abrasives play a very vital role on the performance of magnetic abrasive finishing of surfaces. Some of the techniques for manufacturing magnetic abrasive particles for finishing process found in literature are as under:

2.1 Unbonded / Mixed magnetic abrasives: These abrasives are mechanical mixture of abrasive particles and Iron particles. They join each other to form a flexible machining brush. After some time they lose their finishing ability as abrasives are flown away from the working gap.

Singh et al. (2004) conducted the parametric study of magnetic abrasive finishing process of alloy steel using unbounded magnetic abrasives which is mechanical mixture of SIC and Fe particles. They used Taguchi design of experiment and found that for a change in surface roughness, Voltage applied to the electromagnet and working gap are most significant factors followed by grain mesh number and then rotational speed of the magnet.

2.2 Gel based magnetic abrasives: To increase the bonding strength between the abrasive and iron particles gel is used in this technique. It increases the service life and finishing efficiency of abrasives.

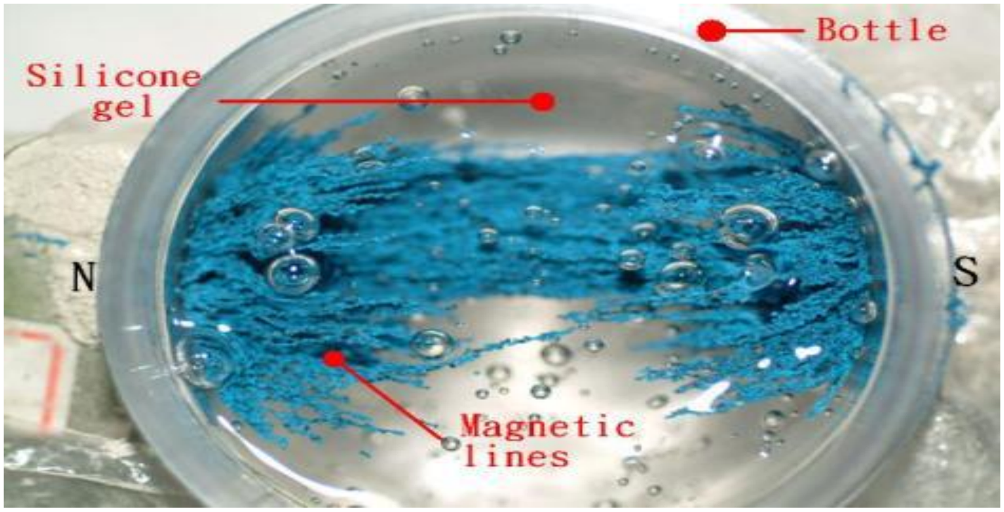

Figure 2 Magnetic gel abrasives in action [4]

Wang and Lee (2009) developed gel based magnetic abrasives by using a mixture of silicone, SiC abrasives and steel grits. The mixture was used for finishing of cylindrical rod of SKD11, HRC60 for 30 minutes. Figure 2 shows the magnetic gel abrasives in action.From their study they claimed that reuse of abrasive media is possible without much influence on recycling efficiency.

2.3 Glued magnetic abrasives particles: Glue epoxy resin is used to bind the abrasive particles with the ferromagnetic particles. The mixture is then allowed to solidify and crushing is done to obtain the magnetic abrasive particles for the finishing process.

Mosina et al. (2011) used a composite magnetic abrasive powder prepared by mechanical mixing of iron and abrasive powder in the presence of surfactants and glue epoxy resin. From their study they claimed that powder of composite composition exhibits polishing and micro cutting properties. They achieved the roughness value of 0.09µm for steel with HRC 45 with the developed magnetic abrasive particles.

2.4 Elastic magnetic abrasive particles: In this technique abrasive particles are embedded into elastomeric medium. The mixed medium in the form of small balls is used for fine finishing of surfaces. The flexible chain of balls forms a flexible brush for finishing. Suraj and Radhakrishnan (2014) used elastomagnetic abrasive balls in which abrasive particles are embedded into elastomeric materials for fine finishing of surfaces. Figure 3 shows the macroscopic image of the developed elastic magnetic abrasive ball.

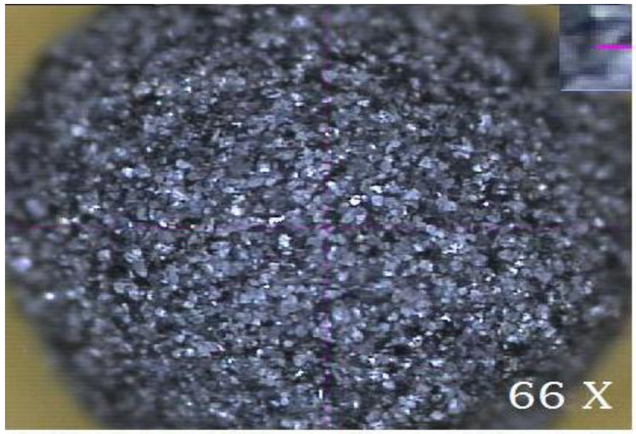

Figure 3 Macroscopic image of Elastomagnetic abrasive ball[6]

2.5 Mechanically alloyed magnetic abrasives: Mechanical alloying is a solid state powder processing technique involving repeated welding, fracturing and rewelding of powder particles in a high energy ball mill. In this process the abrasive particles disperse into/on magnetic particles by repetitive welding without using any binder. Figure 4 shows the schematic of mechanical alloying concept.

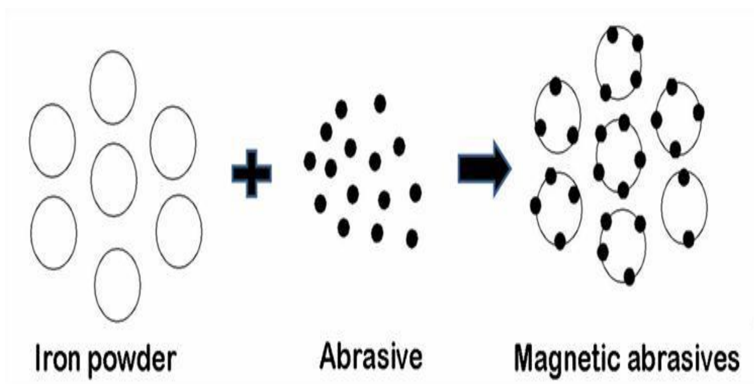

Figure 4 Schematic of Mechanical alloying concept[7]

Patil et al. (2012) proposed a new method to produce magnetic abrasives by attritor ball milling. During this method Silica abrasive particle get adhered to the base metal matrix (Iron) without any bonding material.

2.6 Sintered magnetic abrasives: This technique has been widely used to prepare magnetic abrasive powder. In this technique the magnetic abrasives are prepared under high temperature and pressure conditions in inert medium. The compacts formed are then crushed mechanically to obtain final magnetic abrasive powder. In this method the abrasive particles are bonded firmly with ferromagnetic particles. Figure 5 shows the photographic view of sintered compacts.

Figure 5 Photographic view of sintered compacts [9]

Singh et al. (2011) finished the internal surface of brass tube by magnetic abrasive finishing process using Al_2O_3 based sintered magnetic abrasive. They used RSM method to analyze the effect of parameters like rotational speed, magnetic flux density, grit size of MAP and quantity of abrasive powder on the surface finish of the tube. The surface finish is analyzed in term of PISF. In their experimentation under present parameters they obtained maximum PISF of 98% and minimum surface roughness value of 0.05μm R_a.

2.7 Plasma based magnetic abrasives: Plasma generator is used in this technique to manufacture magnetic abrasive particles. The abrasive particles are embedded on the ferromagnetic particle surface. The powder mixture of abrasive and iron particles is passed through the plasma generator and then cooled rapidly. Figure 6 shows the schematic diagram of Plasma spray system.

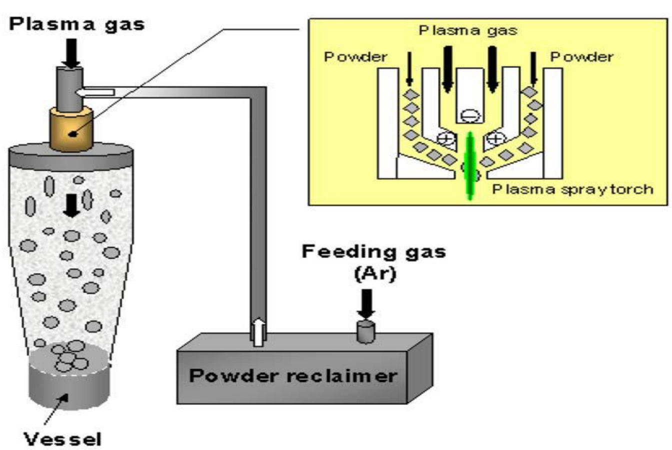

Figure 6 Schematic diagram of Plasma spray system [10]

Yamaguchi and Hanada (2008) proposed a method to make spherical magnetic abrasives for internal finishing of capillary tubes. From their study they concluded that the thermal conditions of the plasma gas have strong influence on the shape of magnetic abrasive particles produced.

2.8 Electroless composite method for magnetic abrasives:

Electroless plating, additionally kenned as chemical or auto-catalytic plating, is a non-galvanic plating method that involves several simultaneous reactions in an aqueous solution, which occur without the utilization of external electrical power.

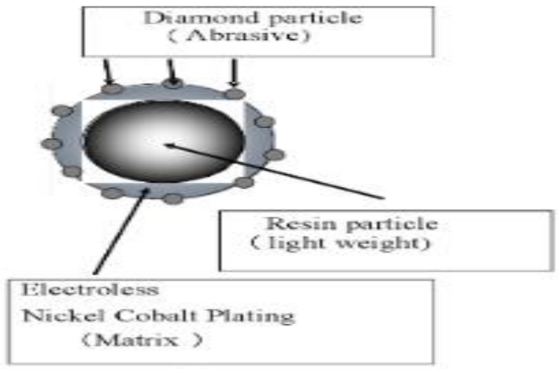

Figure 7 Schematic diagram of new abrasive [11]

Hanzawa et al. (2007) prepared magnetic abrasive particles by a new technique based on the nickel cobalt diamond composite plated plastic balls. They used plastic balls as a support for the growth of magnetic abrasive particles. They claimed that they achieved nano level polishing with the developed magnetic abrasive particles.

2.9 Gas atomization and rapid solidification method for magnetic abrasives: In this technique the raw material is melted and atomized in a specially designed chamber. The tiny droplets were cooled rapidly, solidified and collected in the vessel. Thus spherical composite magnetic abrasive particles are obtained by combining gas atomization and rapid solidification.

Xiang et al. (2011) prepared spherical composite magnetic abrasive particles using ferromagnetic Fe-Si-Al-Ni-Cr alloy as raw material and white alumina micro powder directly through a process that combines gas atomization and rapid solidification. They stated that the developed spherical magnetic abrasive particles posses mechanical and soft magnetic properties, good sphericity, high processing efficiency and longer service life.

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3 Conclusions:

This paper reviews the methods to manufacture the magnetic abrasive particles for fine finishing of surfaces. Following conclusions can be drawn from the study:

1. Production of magnetic abrasives having high service life is difficult, complex and costly.
2. For improving the efficiency of magnetic abrasive finishing process, the magnetic abrasive particles must be renewed in the working gap.

3. Material removal is limited during the finishing process depending upon the type of work piece and type of magnetic abrasive particle used.
4. Simple and cost effective method for producing magnetic abrasive particles is required for wide spread implementation o magnetic abrasive finishing process.

Acknowledgments

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A Brief Review on Various Methods of Hardfacing

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ABSTRACT
Wear is one of the major factors which leads to decrease in life of any machine part. It leads to loss of dimensions and functionality. The machinery used in various industries like coal mining, agriculture, construction, steel industries, and rolling mills is facing severe wear problem. Wear exists in different forms, like abrasion, corrosion, impact, metal to metal, adhesion etc. Researchers are working to reduce the wear either by using new wear resistant material or by improving the wear resistant of existing material by adding different alloying elements, etc. Further various surface engineering techniques can also be applied for enhancing the life of materials. Amongst, various surface techniques hardfacing method is gaining importance in the current scenario. In this paper an endeavor has been made to review some of the hardfacing processes used to improve the wear resistance of the material surface. Studies done by various researchers using hardfacing techniques has also been included in the paper.

1. Introduction

Serviceable engineering components not only rely on their bulk material properties but also on the design and characteristics of their surface. The surface of these components may require treatment, to enhance the surface characteristics. Surface engineering techniques are used to improve the service life of various engineering components. One of surface engineering method for increasing life of material is hardfacing. Hardfacing is also known as “Hard-surfacing” [7]. Hardfacing is a method of repairing or improving or extending the service life of engineering parts economically is to provide excellent wear resistance, increasing hardness and better corrosion resistance. There are some major fields in which used of hardfacing techniques such as agriculture field, coal mining, construction, steel industries and rolling mills. Farmers and equipment operators often complain about the high wear rate of ground tools in some dry land agricultural areas. They are faced several problems recurring labour, downtime and replacement costs of exchanging the worn out ground engaging components. Worn tools are usually less effective in terms of weed control, tillage efficiency also reduced. Metal wear in agriculture is an ancient problem. [1]

2. Types of hardfacing processes

2.1 Thermal Spraying
2.2 Cladding
2.3. Welding

2.1 THERMAL SPRAYING METHODS

2.1.1 Plasma spray coating
2.2.2 High Velocity Oxygen Fuel Coating
2.3.3 Metalizing
2.4.4 Plasma Transferred Arc System

2.5.5 Spray & FUSE hardfacing

2.1.1 Plasma spray coating

A process wherein a High Intensity Arc is thrown across an Electrode and Anode through which is introduced a mixture of gases (Nitrogen & Hydrogen, or Argon & Hydrogen or Helium) causing the gases to ionize, thereby creating ultra high temperatures up to 50,000 °F. Metals, Ceramics or Cermets in powder form are injected into this stream of hot gases and instantly brought up to its molten state. Under high velocity, these molten materials are propelled onto a Substrate causing high integrity coatings with excellent bonding.

2.2.2 High Velocity Oxygen Fuel Coating

The High Velocity Oxygen Fuel (HVOF) process was developed to produce high quality metal, carbide and various specialty coatings. A complete line of powders are available, which are specifically engineered for application with the HVOF System. The commercialization of this coating technology now affords industry the ability to get unique coating properties and extend the range of applications which previously could only be performed by proprietary coating processes.

2.3.3 Metalizing

This equipment is an innovation to the Metalizing Field. A modified basic Solid State 600 Amp. Arc Welder is combined with a specially designed Spray Gun. Two wires are fed simultaneously through the gun at an angle so as to meet as they exit from the gun. The wires are insulated from each other but at the point where the wires exit from the gun, one wire is charged plus and the other minus, causing them to throw a molten arc between each other. Just behind this point we inject high velocity air or inert gas which atomizes the molten arc and propels the atomized particles onto the Substrate. The temperature of the arc is controllable to a maximum of approximately 10,000°F. With this equipment, we can spray any type of metals which have melting points below 10,000°F.

2.4.4 Plasma Transferred Arc System

There is a steadily growing demand from all branches of industry for longer service life for their machinery and for the adaptation of that machinery to meet the specific conditions of their production processes. Part of the response to this demand has been the development of some highly sophisticated surface coating techniques. The most advanced of these are the plasma processes, particularly suitable for very precise anti-wear protection of parts. It has installed a sophisticated Plasma Transferred Arc System (PTA), a high energy, inert gas welding process that produces a very high quality deposit which offers optimal protection with minimal dilution or deformation of the base material.

2.5.5 Spray & FUSE hardfacing

In this process, a Combustion Powder Spray gun is utilized to deposit a wide variety of materials on to a substrate. The powders used for Spray and Fuse Hardfacing are typically compositions of Ni, Cr, Co, Bo, Fe, W and WC in varying blends. After the coating has been sprayed to a pre-determined thickness, an Oxygen-Acetylene torch, or a furnace, is used to hear the part to approximately 2000°F, fusing the coating within itself and to the substrate, thereby achieving a true metallurgical bond. With this process, coating can be applied with hardness up to 80Rc.

2.2 CLADDING

Cladding processes are used to bond bulk materials in foil, sheet or plate form to the substrate to provide triboligical properties. The cladding processes are used either where coatings by thermal spraying and welding cannot be applied or for applications which require surfaces with bulk like properties. Since relatively thick sheets can be readily clad to substrate, increased wear protection may be possible compared to thermal spraying and welding. If coating material is available in sheet form, then cladding maybe cheaper alternative to surface protection. It is difficult to clad parts having complex shapes and extremely large sizes.

2.3 WELDING

Hardfacing by welding processes is a surfacing operation to extend the service life of industrial components, pre-emptively on new components, or as part of a maintenance program. Selection of the most suitable welding process for a given job will depend on a number of factors like: Nature of Work to be Hardfaced, Function of the component, Base metal composition, Size and shape of component, Accessibility of Weld equipment, State of repair of worn components, Number of same or similar items to be hardfaced etc.

2.3.1 Shielded Metal Arc Welding (SMAW)
2.3.2 Gas Metal Arc Welding (GMAW)
2.3.3 Oxy fuel Welding (OFW)
2.3.4 Submerged Arc Welding (SAW)
2.3.5 Flux-cored arc welding (FCAW)

2.3.1 Shielded Metal Arc Welding (SMAW)

Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc welding or informally as stick welding , is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination.

2.3.2 Gas Metal Arc Welding (GMAW)

Gas metal arc welding (GMAW), also known as metal inert gas or MIG welding, is a semi-automatic or automatic process that uses a continuous wire feed as an electrode and an inert or semi-inert gas mixture to protect the weld from contamination. Since the electrode is continuous, welding speeds are greater for GMAW than for SMAW. A related process, flux-cored arc welding (FCAW), uses similar equipment but uses wire consisting of a steel electrode surrounding a powder fill material. This cored wire is more expensive than the standard solid wire and can generate fumes and/or slag, but it permits even higher welding speed and greater metal penetration.

2.3.3 Oxy fuel Welding (OFW)

In oxy-fuel welding, a welding torch is used to weld metals. Welding results when two pieces of metals are heated to a temperature that produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material depends upon the metals to be welded. Oxy-fuel is one of the oldest welding processes, besides forge welding. Still used in industry, in recent decades it has been less widely utilized in industrial applications as other specifically devised technologies have been adopted. It is still widely used for welding pipes and tubes, as well as repair work. It is also frequently well-suited, and favored, for fabricating some types of metal-based artwork.

2.3.4 Submerged Arc Welding (SAW)

It is a common arc welding process. It requires a non-continuously fed consumable solid or tubular (flux cored) electrode. The molten weld and the arc zone are protected from atmospheric contamination by being "submerged" under a blanket of granular fusible flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. When molten, the flux becomes conductive, and provides a current path between the electrode and the work. This thick layer of flux completely covers the molten metal thus preventing spatter and sparks as well as suppressing the intense ultraviolet radiation and fumes that are a part of the shielded metal arc welding (SMAW) process.

2.3.5 Flux-cored arc welding (FCAW)

It is a semi-automatic or automatic arc welding process. FCAW requires a continuously-fed consumable tubular electrode containing a flux and a constant-voltage or, less commonly, a constant-current welding power supply. An externally supplied shielding gas is sometimes used, but often the flux itself is relied upon to generate the necessary protection from the atmosphere, producing both gaseous protection and liquid slag protecting the weld. The process is widely used in construction because of its high welding speed and portability. The process variables are wire feed speed (and current), arc voltage, electrode extension, travel speed and angle, electrode angles & electrode wire type.

3. Literature related to hardfacing alloys and hardfacing techniques

Buchely M F et al. [2005] studied that the process of hardfacing is one of the most useful and economical to improve the performance of engineering components. A study was made to compare the microstructure and abrasion resistance of hardfacing alloys reinforced with primary chromium carbides, complex carbides or tungsten carbides. In this research shielded metal arc welding (SMAW) method used for deposit the hardfacing alloys on to ASTM 36 carbon steel plates. There are used three types of commercial hardfacing electrodes to investigate the effect of microstructure. A wide variety of hardfacing alloys is commercially available for protection against wear. Deposits with a microstructure composed by disperse carbides in austenite matrix are extensively used for abrasion applications. Three different electrodes used for coating material such as H.F-1(Cr-rich) H.F-2(W-rich) H.F-3(Complex-Carbide). The abrasion tests were carried out in a dry sand–rubber wheel abrasion machine according to the procedure A of ASTM G65 standard.

Bayhan [2006] the main aim of this study was to increase the wear resistance by covering the chisel ploughshare produced from low-alloy steel with three different hard facing electrodes.

Abrasive wear of the commercial tillage tool shares can be tested in the soil bin. Comparative wear tests on a regular share and three kinds of hardfacing with electrodes were conducted in the field and laboratory. These three different hardfacing electrodes, which are designated EH-600, EH-350 and EH-14Mn, were used for hardfacing. The wear rate in the laboratory and in field tests was found to be significantly different statistically. As per cost the EH-350 is recommended for hardfacing.

Chatterjee et al. [2006] investigated the weld procedural effects i.e. preheat & without preheat, single & double hard facing layer as well as buffer or without buffer layer. Two commercial & four iron based high Cr high C type hard facing electrodes were deposited on the grey cast iron plate in flat position using MMAW. Buffer layers were employed between substrate & the hardfacing deposits in order to minimize dilution & contraction strain. Maximum bond strength was obtained in specimen deposited with high nickel buffer electrodes & specimen deposited without buffer resulted in minimum bond.

Buchman et al. [2008] in this study the wear test showed that application of an arc-sprayed coating on grey cast iron can provide wear resistance which is comparable to hardfacing by welding. The abrasive wear behavior of hardfaced Fe–Cr–C deposits by SMAW process had been compared with an experimental arc-sprayed Fe–Cr–B coating. The main objective to find the optimal process that performed equally or better than SMAW process. Electric arc spraying is selected for better performance and economically good. The study showed that the arc-sprayed coating exhibited comparable wear resistance to that of the SMAW overlays, although it had higher porosity and its micro hardness was lower than the welded deposit.

M. Kirchgaßner et al. [2008] the main objective of this study was to evaluate the wear behaviour for pure abrasion and for combined wear of iron-based alloys which are typically applied by gas metal arc welding (GMAW). Iron based hardfacing alloys are widely used to protect machinery equipments exposed either to pure abrasion or to a combination of abrasion and impact. The specific wear behaviour of welding alloy under these conditions depends on its chemical composition, the microstructure obtained after welding and finally the welding technology used to apply them respectively the parameters setting which strongly influence, for example, dilution with the base material or formation of metallurgical precipated hard face.

Selvi et al. [2008] studied the influence of C & Cr on wear resistance, hardness and effect on microstructure. The influence of Cr is studied by conducting tests using E410, E430 and modified E430 electrode. The hard facing of valve seat ring used in boiler fed water circuit made of low C steel was done by MMAW process. It was found that C & Cr supports the improvement of wear resistance, hardness & refined microstructure on the weld overlays. The wear rate increases with increase in sliding velocity and applied load. As a result of increase in Cr, the hardness increases due to the formation of Cr carbide at the grain boundaries and there was also a progressive refinement in the grains of the welded layer.

Horvat et al. [2008] presents that the dimensions losses were significantly lower for both types of hard faced plough shares compared to regular shares. As per study of this paper the fuel consumption is low and a higher rate of work in ploughing compared to regular shares. comparison of wear of regular mouldboard plough shares and two plough shares made of different basic materials, steel EN 10027 (HF-1) and EN 50Mn7 (HF-2), hard faced by a combination of two welding processes, namely shielded metal arc welding (SMAW) and high-frequency induction welding (HFIW). Wear was determined by measurements of the changes of dimensions and weight during ploughing of sandy clay soil in Croatia. The dimensions and weight losses were lower for both types of hardfaced plough shares in comparison to regular shares. According to overall results, this combination of two welding processes can be recommended as efficient solution of plough share wear protection.

Pradeep et al. [2010] reviewed few hardfacing processes and materials used to reduce the wear either in the form of using a new wear resistant material. Most worn parts do not fail from a single mode of wear, but from a combination of modes. It was resulted that hard facing is a very suitable process to improve the life of worn out parts. It is also reducing the down time because parts last longer and required some few time to replace it. This process is done on any steel material using wide variety of welding processes.

Yazici et al. [2011] studied that in the field of welding the shielded metal arc welding is suitable for hard facing. Tillage is the agricultural preparation of soil by mechanical agitation. The wear loss were significantly lower of the stamping and heat treatment of the ploughshares compared to the conventionally heat treated ploughshares. The effects of the hot stamping process and different hardfacing techniques, such as shielded metal arc welding (SMAW) and gas metal arc welding (GMAW), on the abrasive wear of ploughshares were investigated under field operational conditions. The wear losses of hot-stamped and hardfaced ploughshares were less significant than those of the conventionally heat-treated ploughshare specimens used under field conditions. According to the results of the overall study, hot stamping and hardfacing by SMAW and GMAW processes can be recommended as efficient solutions for decreasing the wear losses of ploughshares.

Shibe Vineet et al. [2013] examined that the problem of wear resistance of materials can be improved through roughness techniques. It is also observed that most of the worn parts are don't fails from a single mode of wear, but from a combination of modes, such as abrasion and erosion etc. Hardfacing can be done on approximately on any metal using wide variety of welding processes. Different alloy elements can be introduced in the form of consumable to achieve required properties like wear resistance, hardness, porosity and corrosion resistance etc. The success of hardfacing application depends upon the optimized composition of alloying element and welding process used for particular application.

Digambar and Choudhary [2014] concluded that the different hardfacing layers produced by shielded metal arc welding (SMAW) process with a bare electrode coated with fluxes and to which different measures of ferrotitanium (Fe-Ti), ferrovanadium (Fe-Va), ferromolybdenum (Fe-Mo) and grafite had been added showed good resistance to cracking and wear when the amount of above elements are controlled within the range of 8-10%, 12-15%, 10-12% and 2-4% respectively.

Leitner et. al. [2017] investigated metal-cored wire as filler material, the mean volume reduction due to wear significantly reduces by 64 % compared to the mild steel S355 base material performance. The application of the analyzed solid wire once again decreases the wear by 69 % compared to the base material and by 12 % in relation to the metal-cored wire. Hardness measurements basically reveal these tendencies, whereby the solid wire shows a slightly increased hardness condition at the surface compared to the metal-cored wire.

Zhao et. al. [2018] concluded on residual elastic strain, and GND density were analysed from the HR-EBSD and plastic strain distributions were assessed using HR-DIC. They also analyzed that twinning and cross hardening are important strengthening mechanisms in Nitronic 60 (with the lowest galling strength) in the absence of carbide content. In the other alloys, carbides (and silicides in the RR2450) play a significant role in generating higher GND densities and hardening.

CONCLUSION

Hardfacing is a recent procedure, which currently is mainly applied for larger construction parts, in order to extend the lifetime, instead of using massive solution, such as casting. This process is done on any steel material using wide variety of welding processes. It is the best process to reduce the cost of replacement and down time. Different alloy elements can be introduced in the form of consumable to achieve required properties like wear resistance, hardness, porosity and corrosion resistance etc. It was found that C & Cr supports the improvement of wear resistance, hardness & refined microstructure on the weld overlays. Hardfacing by SMAW and GMAW processes can be recommended as efficient solutions for decreasing the wear losses of ploughshares.

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A Study on Tribological Performance of Thermal Spray Coating for Die Steel Applications

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ABSTRACT

In the present investigation, NiCrSiFeBC coating were deposited on H13 die steel with High-Velocity Oxy-fuel (HVOF) thermal spray technique. H13 die steel is mainly used as a tool material in hot forming of high strength steels. The aim of this research work is to study the performance of the selected coating composition. The as-sprayed coatings were characterized using scanning electron microscopy (SEM), Energy Dispersive Spectroscopy (EDS), optical microscopy and X-Ray diffractometry (XRD). The adhesion strength of the developed coatings was also determined. The physical properties like surface roughness, porosity, and microhardness of as-sprayed coatings have also been evaluated. Pin on disc tests was carried out to analyze wear behavior of coatings in comparison with uncoated H13steels. The results have been discussed with respect to the existing literature.

Keywords: *Hot Forming Steels; Coatings; HVOF Spray; Characterization; Wear*

1. Introduction

The forming dies are the most crucial components in every hot forming operation because it usually gives the object its final shape. As the die usually is costly to fabricate it has a key effect on the production costs. A high quality dies with a long lifespan is vital for a successful and cost-effective production [1]. Failure of hot forming dies can be a result of various mechanisms such as wear, plastic deformation, gross cracking, thermal fatigue and mechanical fatigue [2-4]. In hot forming processes such as hot rolling and stamping, medium alloy hot work dies steels such as H11 and H13 are used because of their ability to resist thermal softening along with sufficient strength and toughness to withstand the stresses encountered during hot forming. This steel has chromium as the main alloying element [5].

NiCrBSi coatings have high corrosion resistance, adhesive and abrasive wear resistance at elevated temperatures [6, 13-18]. Chromium and boron additions improve the wear and corrosion resistance and also enhance the mechanical properties such as the hardness of the coatings by supporting the formation of hard carbides, thus increasing the wear resistance of the coatings. Silicon promotes the self-fluxing properties [7, 19 and 20]. Thermally sprayed coatings have been extensively used for modifying the component surface properties in a variety of industrial applications, largely for wear resistance, thermal barrier and corrosive environment [8-11]. High-velocity oxy-fuel (HVOF) thermal spraying has proved to be one of the better methods for deposition of conventional feedstock powders because of higher velocities and lower temperatures experienced by powder particles. Result in less decomposition of carbides during spraying resulting in more wear-resistant coatings, with higher levels of hard carbide particles and less porosity [12].

From the literature, it has been concluded that application and characterization of thermal spray coatings on hot forming die steels had not yet been studied in sufficient detail. The main objective of the current investigation is to analyze experimentally the high-temperature wear behavior of HVOF spray coatings deposited on the die steel.

2. Experimental Procedures

H13 cylindrical pins of 8 mm diameter and 50 mm length have been used as a substrate. Thereafter, NiCrBSi powder with an average particle size of 45±15 μm was chosen. The chemical composition of the coating powder was Ni-71.7, Cr-15.7, Si-4.27, Fe-4.17, B-3.35 and C-0.81. The coating was deposited onto H13 steel substrates with the HVOF spray technique. The coatings were developed at Metallizing Equipment Company Pvt. Ltd., (MECPL) Jodhpur. The substrates were shot blasted prior to spraying to attain proper adhesion between coating and substrate. Coatings of thickness 180-220 µm were obtained. The coatings were deposited by commercial HVOF (HIPOJET-2700) apparatus. The coated specimens were subjected to XRD analysis to identify various phases formed on their surfaces. The XRD analysis of the composite powder and the as-sprayed specimens was performed to identify the various phases present. Expert Hi score Software was used to for identification of various phases and graph were plotted with defined ‘d’ values. Further, the surface morphology of the coating powders and the surface, as well as, cross-sectional morphology along with elemental composition of the as-sprayed coatings was studied with the help of JEOL scanning electron microscope (SEM), JEOL JSM 6610LV; This SEM/EDS and XRD analysis was performed at Indian Institute of Technology, Roorkee (India). The coating bond strength for the compositions of coatings was measured according to the ASTM Standard C-633 on Tensile Bond Strength Testing Machine. Porosity was measured with Image Analyser software Envision 3.0 and the surface roughness was measured by Mitutoyo Surface Roughness Meter. Microhardness of the coatings was measured by microhardness tester (model-WILSON) with digital display. Tribological studies were done on a pin-on-disc tribometer under unidirectional dry sliding conditions according to ASTM wear testing standard G99-04. The pin test specimen was loaded against a rotating 20MnCr5 (hardened up to 60-80 HRC) disc test specimen under the constant load of 25 N sliding speed 0.5 m s^{-1}, sliding distance of 1500 m at room temperature. The total test duration was 50 min. the weight change was considered as the wear weight loss. All tests where repeated and good reproducibility was observed. The morphology and surface topography of test specimens were analyzed by using SEM/EDS technique.

Table 1: Spray parameters as employed during HVOF spraying

Oxygen flow rate (SLPM)	300-350
Fuel (LPG) flow rate (SLPM)	60-80
N_2 flow rate (SLPM)	15-20
Oxygen pressure (kg/cm^2)	9
Fuel pressure (kg/cm^2)	5.6
Powder pressure (kg/cm^2)	3
Spray distance (mm)	250
Flame temperature (ºC)	5000
Particle temperature (ºC)	2200
Particle velocity (m/s)	450-500

3. Results and discussion

3.1 Visual Examination of the Coatings

Macrographs of the uncoated pins (Fig. 1) and as-sprayed samples (Fig. 2) are shown. Coatings are grey in color. The coatings have the smooth surfaces. Further these coatings are found to be free from any visible surface cracks.

3.2 SEM Analysis of Coating Powders

The SEM morphology of the powders is shown in figure 3. It is found from that the particles of NiCrBSi powders have spherical morphology.

Fig. 1 Camera macrographs of steel pins

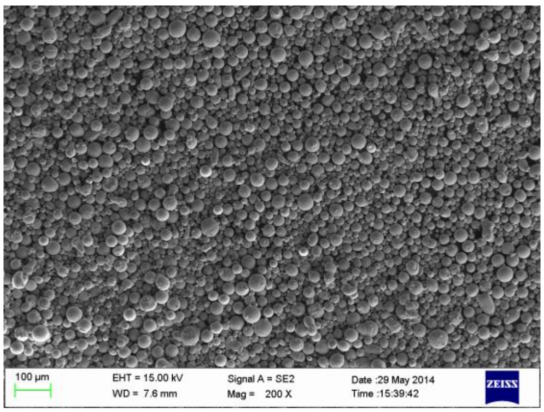
Fig. 2 the camera macrographs of as-sprayed coatings on H13 substrate (a) top surface (b) full sample

3.3 XRD Analysis of Coating Powders

XRD diffractogram for the NiCrBSi powder is shown in Fig. 4 on reduced scales. Very Strong phase indications of Ni and Cr phase were observed, whereas CrB and NiB were revealed as medium intensity phases.

3.4 Evaluation of Coating Bond Strength, Porosity, Surface Roughness and Microhardness

The coating bond strength measurements were done at MECPL, Jodhpur on Tensile Bond Strength Testing Machine with ASTM Standard C-633. The coating bond strength values for the as sprayed specimens were 56.63 MPa. Porosity was found to be 1.48%. The measured values of surface roughness were 6.62 µm. Average micro hardness values for the coating were found out to be 737 Hv.



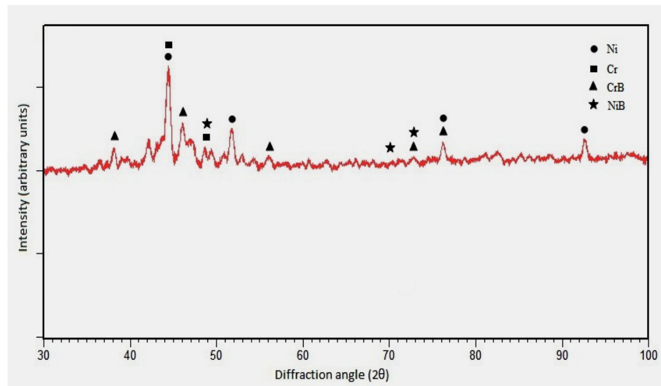


Fig. 3 SEM morphology NiCrBSi powder **Fig.4 X-ray diffraction pattern for NiCrBSi powder**

3.5 Scanning Electron Microscopy /Electron Dispersive Spectroscopy (SEM/EDS) Analysis of As-sprayed Coatings

FE-SEM/EDS morphologies for the HVOF sprayed coating on the tool steels are shown in Fig. 5. The SEM image of NiCrBSi coatings are found to have uniformly distributed splats along with the flattened portions depicting the fully molten areas. The EDS analysis showed the presence of all the elements present in the coating composition. The coatings are found to be free from any cracks. Some pores are visible on the surface.

3.6 XRD Analysis

XRD diffractograms for the surfaces of the HVOF sprayed NiCrBSi coatings are shown in Fig. 6. Ni and Cr_2B were identified as the main phases.

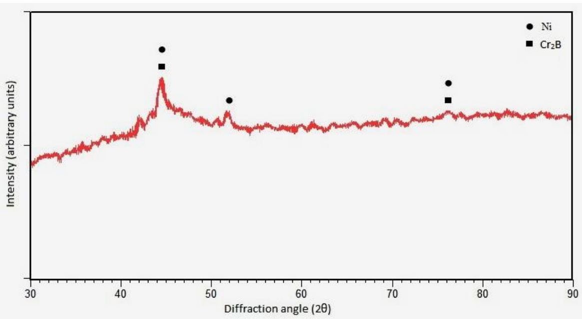


Fig.6 X-ray diffraction pattern for NiCrBSi coating on H13 steel by HVOF spray proces

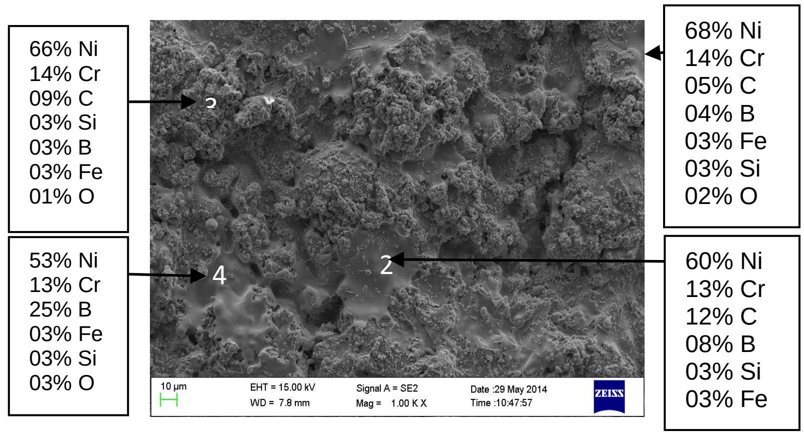


Fig.5 Surface scale morphology and EDS analysis of H13 tool steel with HVOF sprayed NiCrBSi coatings showing elemental composition (%) at selected point.

3.7 Cross-sectional Morphology of As-sprayed Coatings

Cross-sectional morphologies of the HVOF sprayed coated H13 steel is shown in Fig 7. The cross-sectional images of the showed the building of coating thickness due to deposition and resolidification of molten or semi-molten droplets. The required thickness of the coatings was achieved. The coating Substrate interface is free from defects and coatings seem to have good adherence with the substrate**.**

3.8 Visual examination of worn surfaces

The worn surfaces of the uncoated and coated AISI H13 specimens subjected to wear and friction experimentation at room temperature (RT) observed by naked eye are shown in Figure 8. The pictures clearly indicate the presence of shallow sliding marks on the surface on the surafce of coated specimen and Deep plowing grooves are visible on uncoated H13 pin showing that the substrate suffers severe wear.

3.9 Wear and frictional behavior

Figure 9 (a) shows that SEM morphology of the uncoated worn specimen. Severe wear was observed on the uncoated specimen thus contributing to more weight loss. The morphology indicates the presence of many regions of material pull out, delamination and scratch marks. Abrasive wear tracks can also be seen. The higher weight loss of the uncoated specimen was observed. Weight loss of uncoated specimen was 0.058 grams which was about 207 times greater that weight loss of coatings (0.0028 grams). The coated specimen showed the presence of small debris on the worn surface. Light abrasive wear tracks are visible. Formation of abrasive wear mechanism may be attributed to the disc counter body (two-body abrasive wear) or to the debris (three-body abrasive wear) [21]

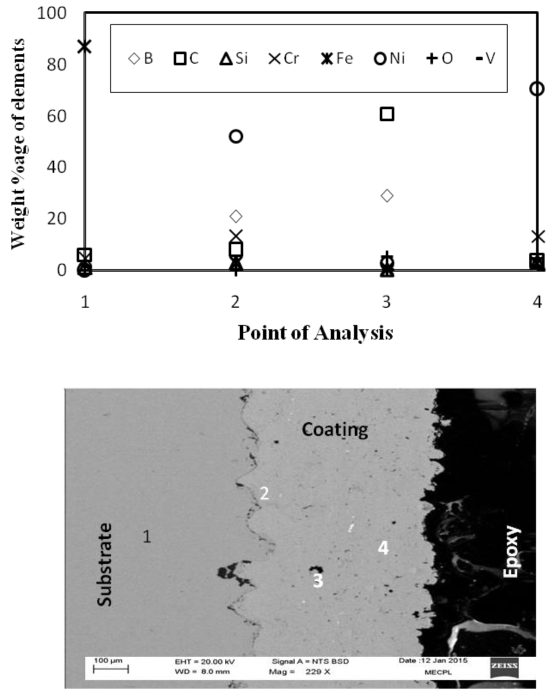


Fig.7 Cross-sectional SEM/EDS morphology of HVOF sprayed NiCrBSi on H13 substrate.

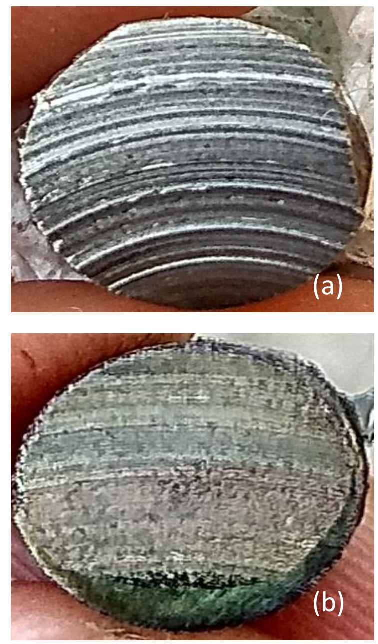


Fig.8 Macrographs of worn surfaces of HVOF sprayed (a) AISI H13 uncoated pin (b) NiCrBSi coatings specimens tested at RT & 25N.

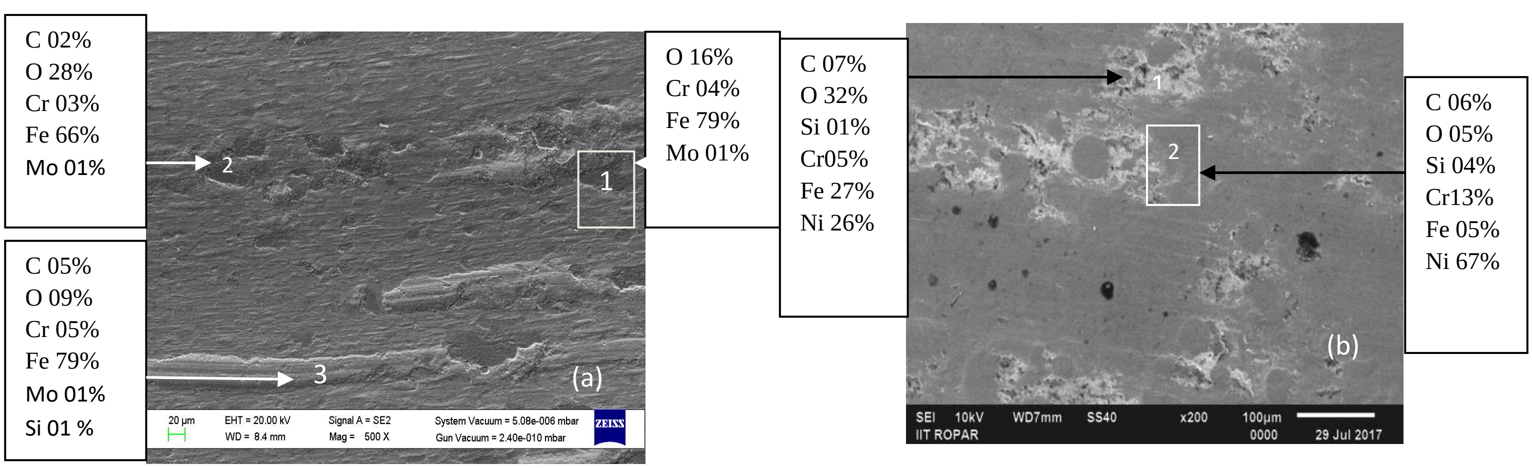


Fig.9 SEM micrographs of worn surfaces of specimens after 50 min run (a) uncoated and (b) HVOF sprayed NiCrBSi coated AISI H13 specimens tested at RT and 25N

Coating is by and large intact to the surface with presence of both coating powders. Lesser weight loss was observed indicating the better wear resistance of coated pin. Figure10 represents the coefficients of friction obtained during the wear test at different conditions for the uncoated and HVOF coated AISI H13 specimens. It was observed that HVOF sprayed coatings exhibit lower value of COF which is due to the high value of surface hardness of coatings. Formation of hard carbide and boride phases were responsible for higher hardness values of coatings.

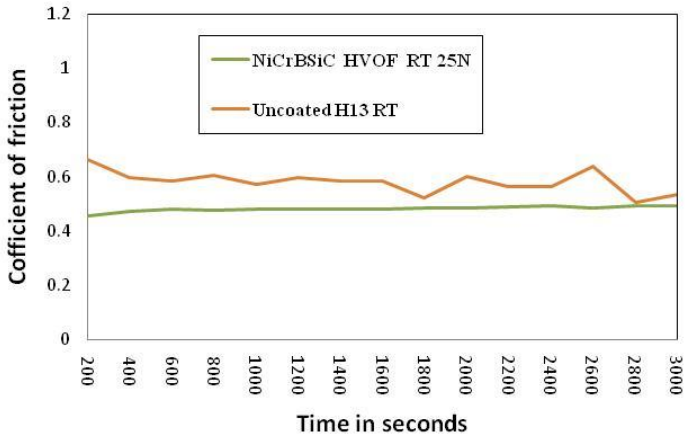


Fig.10 Coefficient of friction of uncoated and NiCrBSi HVOF sprays coated H13 steel pin subjected to wear and friction testing at room temperature and 25N load

4. Conclusions

a) Coatings of thickness ranging from 180-220 µm were obtained successfully using HVOF process.
b) Higher hardness of coatings can be attributed to hard phases formed in coatings and high velocity and impact forces created in HVOF process. This high value indicates a strong mechanical bond between coating and substrate.
c) These coatings exhibit good microstructure, physical and mechanical properties which make them suitable candidate for testing on hot forming applications.
d) Wear results clearly justify application of coating over H13 die steel. Weight loss of coated specimen was 207 times lower than uncoated pin and values of coefficient of friction were also lower.
e) Severe a wear occurred in uncoated H13 pin causing removal of layers of pin material (delamination) however in coated pin mild wear occurred as oxide layers are formed on the surface which aid in wear resistance. Very faint scratch marks are visible on coatings.

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Development and Studies of Friction Stir Processing on Low Carbon Steels

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ABSTRACT

Friction stir processing (FSP) is used for localized modification and control of microstructures in near-surface layers of processed metallic components for specific property enhancement. In the current investigation, FSP was developed on boiler tube material namely SA 210 Grade A1 which is majorly used in steam powered electricity generation plants. FSP was accompanied at rotation speed of 900 rpm with feed rate of 70 mm/min with threefold pass of 100 % overlap. The microstructure, mechanical properties, and high temperature corrosion behavior of the unprocessed and FSPed materials have been evaluated. Friction Stir Processing has revealed to be feasible tool for enhancing the mechanical properties of materials like micro hardness. The main objective of the current investigation is to achieve strengthening of SA210 Grade A1 boiler steel through microstructural refinement by Friction Stir Processing (FSP).

Introduction

Friction stir processing (FSP) is a metalworking technology based on the same basic principles as friction stir welding (FSW). FSW was invented and patented by The Welding Institute in 1991 and is considered an important breakthrough in the field of metal joining technology since it allows welding of alloys that could not be easily welded by conventional fusion methods [1]. It has proven to be an effective treatment to achieve major microstructural refinement, densification and homogeneity at the processed zone, as well as elimination of defects from the manufacturing process. Processed surfaces have shown an improvement of mechanical properties, such as hardness and tensile strength, better fatigue, corrosion and wear resistance [2]. On the other hand, fine microstructures with equiaxed recrystallized grains improve super plasticity behavior [3-5]. Figure 1 shows the schematic representation of Friction stir processing technique. The technique consists of the non-consumable rotating tool divided into a pin and a larger cylindrical body or shoulder which plunges into material until the shoulder presses the workpiece surface. The tool thereby impels the viscoplastic deformation of its surroundings and, when the proper thermo- mechanical conditions (required for good material consolidation) are achieved, the tool initiates its travel movement. Plastic deformation imposed by tool pin and shoulder rotation generates heat which softens the material without reaching its melting point, making it possible to move the pin along the travel direction and the material around the pin [6]. As it travels forward, the work piece material is moved from the front to the back of the pin, where it is forged under shoulder pressure and consolidates into a processed bead [7].

Literature review

Sterling et al [8] used FSP technique to modify the microstructure and mechanical Properties of Fusion Welded 304L stainless Steel. The authors attempted to modify selected regions of materials to enhance specific properties while eliminating fusion welding defects such as porosity, cracking, and the cast microstructure. The cast microstructure and coarse delta-ferrite is replaced with a fine-grained wrought microstructure. FSP eliminated many fusion welding defects while at the same time improving the resulting properties.

Park et al [9] evaluated corrosion properties in friction stir welded 304 stainless steel. The steel is austenitic stainless steel used in heat exchanger and chemical reactors. Steel possess good mechanical properties at elevated temperatures and has excellent corrosion resistance. However, when an austenitic stainless steel is welded, its heat affected zone (HAZ) is often sensitized by formation of intergranular Cr-rich carbides, which deteriorates the corrosion properties of the welded joint. Friction stir welding (FSW), which is a relatively new solid state joining process and has been the focus of constant attention in joining low and high temperature materials, holds promise as an effective method of suppressing development of sensitization in HAZ because it is a low heat input welding process. The result showed that FSW led to low degree of sensitization in Heat affected zone (HAZ).

Aldajah et al [10] applied Friction stir processing (FSP) onto 1080 carbon steel to enhance the near-surface material properties. The process transformed the original pearlite microstructure to martensitic, resulting in significant increase in surface hardness. This surface hardening produced a significant benefit for friction and wear behaviour of the steel as measured by unidirectional sliding ball-on-flat testing. The improvement in tribological performance of 1080 steel by FSP technique is attributed to reduced plasticity of the near-surface material during sliding contact. In present work, FSP of a boiler steel namely ASTM SA210 GRADE A1 will be taken to enhance its surface properties without any pre-treatment.

Experimental Details

Friction Stir Processing The selected steel SA210 Grade A1 (here after denoted as SA 210) in the present study was procured from GNDTPP at Bathinda Punjab (India). The chemical composition of SA 210 base steel reported in Table 1. The as-received boiler steel plates were cut for FSP experimentation testing with defined dimensions 120 mm x 100 mm x 4 mm. FSP was performed on test specimens by fixing them in specially designed fixture using high performance vertical CNC milling machine. Optical microscopy (Leica, DM 4000M, Germany) built-in with Leica Microsystems software used to examine cross-sectional as well as the surface microstructures of the FSPed specimens and base material.The microhardness analysis was performed by means of a Microhardness Tester (Wilson, 402 MVD, and USA) on a load 300 g through dwell period of 10 s. The data was taken at different points equally spaced 50 µm along the nugget region. Parameters followed for processing is defined in table 1

Table 1: Parameters followed for processing

Sample	Rotational Speed (RPM)	Feed Rate (mm/min)	Plunge Depth	Diameter of tool	Passes
SA 210	1400	30	0.5	10	2

Results and Discussion

Microstructure

The SEM image of the FSPed specimen is shown in Figure 1. FSP resulted in a considerable refinement in the microstructure especially inside the nugget zone (NZ). The grain structure is completely refined. The coarse ferrite and pearlite grains were fragmented and refined by the effect of severe plastic deformation, dynamic recrystallization and temperature during FSP. Further, the microstructure reveals the reduction in grain size after the friction stir processing of boiler steel. Initially as observed under the optical microscope by the authors in another study, the microstructure of base steel sheet consisted of coarse ferrite and pearlite grains with the average grain size of 14 µm [11]. Figure 1 shows the morphology of the FSPed sample with average grain size of 7-9 µm. This means that the grain size decreases at least 2 times with the effect of FSP inside the NZ. Haijan et al [12] reported in their work that the size of refined grains in the stir zone of friction stir processed steels is inversely proportional to the heat input of the process . As the tool rotates at high revolutions that are 1400 rpm as in the current investigation, the higher heat input resulted in the decreased grain size. Aldajah et al [10] mentioned in their research work that in the upper stir zone region, the material had been plastically deformed by the friction stir processing tool, and the heat from the process exceeded the austentizing temperature of the base steel resulting in the formation of martensitic phase from the rapid cooling after the FSP tool passes. The results were reported similar to our investigation.

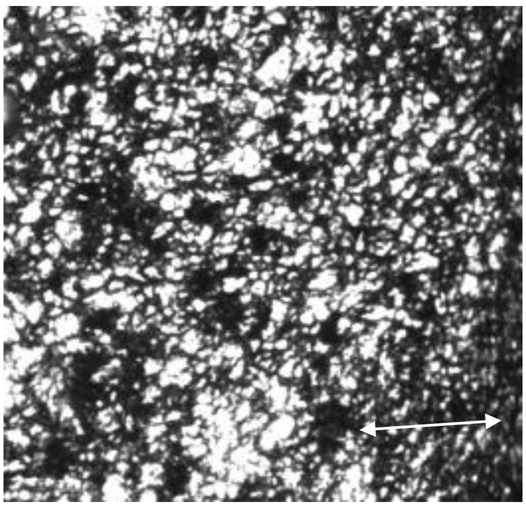

Figure 1: SEM image of the nugget region in the FSPed SA 210 Grade A1 Steel sample

Microhardness

Microhardness of the base steel was evaluated as 180 Hv and that of FSPed specimen as 367 Hv. The results indicate 2 times improvement in the microhardness of the base steel after FSP. Thus, in accordance with the above equation, as the grain diameter/grain size decreases the yield strength and the hardness of the material increases. The refinement of the microstructure may have contributed to the considerable rise in the micro-hardness values. Along with grain size refinement, the presence of sub-micron sized precipitates might have also contributed in increasing the hardness of the steel.

Conclusions

Friction Stir processing resulted in microstructure refinement of the SA 210 grade A1 steel which in turn improved the hardness of the base steel. The microhardness of the FSPed material was found to increase by two times as compared to the base material. The coarse ferrite and pearlite grains were fragmented and refined by the effect of severe plastic deformation, dynamic recrystallization and temperature during FSP with grain size of size of 7-9 µm.

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Solid Particle Erosion study of HVOF Sprayed NiCrFeSiBC-20% Cr3C2 Deposited on Gr A1 Steel

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Abstract
SPE is a wear process where particles strike against surfaces and promote material loss. Erosion results from impact of particulates, such as coal ash, dolomite and unburned carbon particles on the surface of heated boiler tubes. The combustion products of coal contain fly ash particles, which impinge on the boiler tubes and erode them. It is generally believed that the most erosive species in the fly ash are quartz, which is a crystalline form of SiO_2 and mullite. In the present study, solid particle erosion behavior of a boiler steels namely ASTM-SAE210-Grade A1 has been investigated with and without the application of HVOF sprayed composite coatings. Coating composition were used for the HVOF spraying on the given boiler steel, which include 80% NiCrFeSiBC-20% Cr_3C_2. Solid particle erosion behavior of coated steel and uncoated steel have been evaluated using air jet erosion test rig. The deposited coatings were characterized based on microstructure before and after the solid particle erosion tests.

Introduction
The materials used for high temperature applications are subjected to various types of degradation phenomenon such as hot corrosion, erosion-corrosion, overheating, solid particle erosion, wear etc. Solid particle erosion (SPE) is a serious issue in coal-fired thermal power stations, gas turbines, internal combustion engines, fluidized bed combustors, industrial waste incinerators and paper and pulp industries. Solid particle erosion (SPE) is a serious problem for the electric power industry, costing an estimated US$150 million a year in lost efficiency, forced outages, and repair costs,
Stein et al. [1].

Erosion is the second most important cause for boiler tube failure. Das et al. [2] have also reported that 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. This deposited ash is subsequently discharged as slag and clinker during the soot blowing process. The rest of the ash is entertained in the stream of gas leaving the boiler. These ash particles collide with the boiler steel components and cause extensive surface erosion. Such erosion together with the processes of blocking and corrosion shortens the service life of boiler components. However, it is learnt from the literature that further research is still needed to investigate the performance of more coating compositions in some newer environment which may be stimulated in laboratory. It has also been learnt that there is a further need to develop high performance coating composition to be deposited by these processes for various industrial applications especially for power plant boilers. Low carbon steel ASTM-SA210 grade A1 (GrA1) steel is well known candidate for fabricating boiler tubes in steam generating plants. This material is used in some coal fired thermal plants in northern part of India. Although these materials have adequate mechanical strength at elevated temperature, they often lack resistance to erosion and corrosion environments. These components operating at high temperature are often coated .The demand for protective coating has increased recently for almost all types of alloys. The main objective of the current investigation is to develop solid particle erosion resistant thermal spray coating for SA210 GrA1 boiler steel. It has been learnt from the literature. That wear resistance of self fluxing alloys (NiCrFeSiBC) coating can be greatly increased by adding refractory carbides like CrC to metallic matrix. Therefore mechanical mixing of NiCrFeSiBC with Cr3C2 powders was done to obtain suitable composition for solid particle erosion resistance in the current research work .Attempts have been made to study the three composition of selected composite powder. The two powders were mixed in three different ratios of 80% NiCrFeSiBC-20% Cr3C2. Solid particle erosion behavior of coated steel and uncoated steel have been evaluated using air jet erosion test rig. The deposited coatings were characterized based on microstructure before and after the solid particle erosion tests.

Literature Review

Wear is one of the most common problems encountered in industries like thermal power plants, hydropower plants, mining industries, food processing industries etc. in which solid liquid mixture is transported through pumps and pipes .Wear is the loss of material from a component due to a mechanical interaction with another object. Many types of solids, liquids, and even high velocity gases can remove material and change the physical dimensions and functionality of a part. Corrosion and erosion are the main causes of wear. Corrosion is caused by chemical reaction of material with its environment, Kumar [3]. Ramesh et al. [4] investigated the combination of Ni-alloy powder with WC-Co powder on boiler tube steel. The coating was deposited with HVOF spray process. The deposited coating is characterized based on microstructures and physical properties and further evaluated for its performance under solid particle erosion conditions. The boiler steel exhibited lower steady state volume erosion rate in comparison to HVOF sprayed WC-Co/NiCrFeSiB coatings under similar test conditions.WC-Co/NiCrFeSiB coatings showed retention of higher amount of WC in matrix with a minor amount of W2C brittle phase. Decomposition and decarburization of the coating powder was negligible due to higher particle speed and chosen parameters in HVOF spraying. The erosion resistance of WC-Co/NiCrFeSiB coating might be attributed to composite ductile and brittle modes of material removal, although brittle mode is dominant. The morphology of the eroded surface showed craters, groove formation in binder matrix, lips and platelet formation, and carbide particle pull out as the existing erosion mechanism. The higher hardness ratio between silica erodent particle and substrate steel might have caused the penetration of silica particles into the surface which bestowed some shielding effect against impacting particles and indentation induced severe plastic deformation led to lower erosion loss.

Experimental Techniques And Procedures

The boiler steel selected for the study is being used by DBCRTPP, which is basically Fe-based steel with designation as ASTM-SA210 Grade A1 (GrA1) with C-0.27%. Surface porosity measurements for the HVOF sprayed coatings have been made after polishing the specimens.

Image Analyser having software Envision 3.0 was utilized to determine the porosity values. Microhardness in cross-section of the coatings was measured by microhardness tester (model-WILSON) with digital display. An indenting load was 2.45 N i.e. 300 gf was applied on the square pyramidal diamond indenter for penetration and the hardness values were based on the relation (Where F is load in N and d is the mean of the indentation diagonal length in mm). Dwell time for indentation was taken as 10 seconds. Each reported value of the microhardness is a mean of three observations. Coating Bond Strength of Sample SA 210 Gr A1 on Tensile Bond Strength Testing Machine with ASTM Standard C-633 was measured for all three Compositions of coated values was compared with literatures survey. Surface roughness for Sample SA 210 Gr A1 measured by Mitutoyo Surface Roughness Meter before and after coating was measured for coated Compositions of Coatings.

Results and discussion

The microhardness values of the HVOF sprayed coatings on the given boiler steel have been measured. The microhardness profiles along the cross-section of the coating as a function of distance from the coating-substrate interface are plotted. The critical hardness values of the substrate steel were found to 180 Hv. In the case of the HVOF sprayed coatings, the microhardness values for the coated SA210 boiler steel lie in the range of 1120-1290 Hv, with an average value of 1120 Hv for the coating. Porosity measurements were made for the HVOF coating, which are found to be in a range of 2.65-2.81%. Average value for surface roughness of substrate boiler steel after grit blasting and before deposition of coating was measured as 12.5 μm and after coating formulation, the value decreased. The measured values of surface roughness on all the as-sprayed specimens are reported in Table below. The porosity analysis is of prime importance in erosion-oxidation studies. Dense coatings usually provide better corrosion resistance than the porous coatings. The values of porosity for the HVOF sprayed coatings have been measured to be in the range of 1.8-2.8%. In the HVOF spray process, the powder particles are propelled out of the gun nozzle at supersonic velocities towards the substrate. Due to high velocity and high impact of the sprayed powder particles, the coatings produced by the process have very dense structure with very low porosity. The measured values of porosity are in close agreement with the findings of Sidhu et al. [5] and Murthy et al. [6] on studying the behaviour of HVOF spray Cr3C2–NiCr coatings. Hidalgo et al. [15] (2001) reported porosity values as 3.6 % and 2.6 % for plasma sprayed NiCrBSiFe and 35%WC–65%NiCrBSiFe coatings on AISI 304 boiler steel. that the porosity of the composite coatings developed by HVOF spray process on the boiler steel in the present investigation after blending of Cr3C2 in NiCrFeSiBC coating is obviously reduced. Surface roughness is one of the important parameters of the coatings need to be measured for its better performance in several applications. For example, in thermal power plants, the coatings employed on the boiler-tube components are subjected to solid particle erosion and therefore it is essential to ensure the erosion resistance of the coatings with respect to its surface features such as surface roughness and morphology of the grain. It may be mentioned that higher surface roughness of the coated component would result in the higher erosion rate , S. Kamal [7] , 2010. Microhardness is an important property. It is used to characterize the performance of coatings and have strong influences, for example on the coating delamination, erosion-corrosion performance and residual stress state within the coatings

[Richard et al. [8] (1992), Kim et al. [9] (1992), Ahn et al. [10] (1992), Lin et al. [11] (1995)]. According to Tucker [12], (1994), it is the most frequently quoted mechanical property of the coatings. The measured microhardness values of the substrate Grade A-1 boiler steel were in good agreement with those reported by the Vikas [13]. The observed microhardness values of the HVOF sprayed coatings on substrate Grade A-1 boiler steel were identical to the findings of various researchers. The authors suggested that this increased hardness might be partially due to the high speed impact of the coating particles during the HVOF projection and partially due to the work hardening effect of the sandblasting of the substrate prior to the coating process. A similar trend of increased hardness in the austenitic and ferritic steel substrates during the HVOF coating has been discussed by Sundararajan et al. [14] and Hidalgo et al. [15]. Therefore, it can be concluded that the given additions were, in general, useful to enhance the average microhardness of the base NiCrFeSiB coating.

Type of Coating	Coating Bond Strength (in PSI)	Roughness (in µm)	Porosity Range
CC1 [80% (NiCrSiBFeC) +20 %(Cr3C2)]	10437	4.37	2.65-2.81

Conclusions:

- The higher bond strength value was obtained in coating. The measured value was 10437 PSI
- The cross-sectional microhardness of the coatings was found to be variable with the distance from the coating-substrate interface. Coating exhibited an upper limit of 1290 Hv.
- Porosity measurements were made for the HVOF coating, which are found to be in a range of 2.65-2.81%.

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Investigation the Effect of Electrode Bottom Profiles on Machining Characteristics During Machining of Ti6Al4V Alloy by EDM

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ABSTRACT
This paper presents the experimental investigation to determine the parametric setting for the effective and efficient machining of Ti-6Al-4V alloy by EDM process. The metal removal rate and Surface roughness has been measured for each experiment to study the effects of tool profile i.e. Flat, Convex, and Concave shape, peak current, pulse on time and pulse off time on performance during machining. The machining results were obtained by variation of Pulse ON Time ranging from 4 to 6 µs, Pulse OFF Time ranging from 3 to 7 µs, Input Peak Current ranging from 10 to 20 Amp, by changing the tool profile i.e. Flat, Concave and Convex. The optimum combination parameters for machining of Ti-6Al-4V alloy using EDM for higher MRR are Concave shape of tool, 20amp current, 4µs of Pulse on time, 3µs of Pulse off time. The optimum combination parameters for machining of Ti-6Al-4V alloy using EDM for lower surface roughness are Concave shape of tool, 10amp current, 4µs of Pulse on time, 3µs of Pulse off time.
Keywords: EDM, Ti-6Al-4V alloy, electrode bottom profile, MRR, and Surface roughness

1. Introduction

Ti-6Al-4V alloy is classified as difficult-to-machine materials. The conventional processes of machining keeping very low feed to ensure that during machining there are the least structural changes generally do machining of Ti-6Al-4V. Mikesic et al. (2009) presented a novel tooling concept that relates to a set of standard prismatic tools of an oblong section, which incorporate the favorable functional characteristics of both ED-milling and die-sinking technologies. The concepts developed are illustrated through the application of an oblong tool that rotates and translates to machine a sample two-dimensional cavity. Plaza et al. (2014) proposed a new strategy based on the use of helical-shaped electrodes, due to an inefficient removal of debris when increasing hole depth. Main results include 37% reduction in machining times (hole diameter 800 µm) when using electrode helix angle of 45^0 and flute-depth of 50 µm, and an additional 19% with flute-depth of 150 µm. Manohar et al. (2014) understand the effect of the electrode bottom profile and also its extent of influence on machining Inconel alloy. Electrodes having Convex, Concave and Flat profile at their bottom surface were chosen for the experimental study; electrodes were made of copper rod of 12 mm diameter with convex or concave profile at their bottom with three different radii of curvature namely, 6, 8 or10 mm. Vijay and Sajeevan (2015) optimized the process parameters in Die-Sinking EDM on Titanium Alloy Grad-V (Ti6Al4V). The microcracks on the machined surface and the formation of recast layer were observed in the SEM micrograph. Saravanan et al. (2017) optimized parameters namely diameter of wire, on/off pulse time, current, tension in wire for minimizing surface roughness (SR) & for maximizing MRR (metal removal rate) during machining by wire electrical discharge (WEDM) process of Titanium Grade 2 (Ti Gr 2) alloys. The optimized process parameters were experimentally observed to yield high quality of surface finish, increased corner accuracy & high rate of material removal. Arikatla et al. (2017) optimize the process parameters during machining of titanium (Ti-6Al-4V) alloy by WEDM using response surface methodology (RSM). The experimental results reveal that the kerf width increases as the pulse on time, input power, server voltage and wire tension increases and the MRR increases as the pulse on time and input power increases. Vijay and Rohit (2017) optimized the process parameters of die-sinking EDM by using full factorial technique for machining titanium grade – V alloy. It was found that peak current and gap voltage are the main control parameters for increasing material removal rate.

2. Experimental Work

Electrical discharge machining is to be used for the experimental investigation. Ti-6Al-4V alloy will to be used as work piece materials. Following are the various parameters of EDM, which are the considered for analyzing the machining of performance criteria e.g. electrode wear rate, material removal rate, and surface structure. Experiments will be conduct based on Taguchi's method with four factors at three levels each. The levels of parameters will be decided through detailed study of literature review, and by performing the pilot experimentation. The values take by factor are termed to be levels. The factors will be study and their levels chosen are detailed in the Table1.

Table1: EDM Parameters and Their Levels

S.No	Input Parameters	Units	Levels		
			1	2	3
1	Tool Profile		Flat	Concave	Convex
2	Peak Current	Amp	5	10	15
3	Pulse On-Time	μs	5	10	15
4	Pulse Off-Time	μs	4	9	14

Fig 1: Machining of Ti-6Al-4V alloy by EDM

3. Results and Discussions

After all the experimentations and measurements, it is required to study the effect of different machining parameters of EDM for machining of Ti6Al4V. The metal removal rate and Surface roughness has been measured for each experiment to study the effects of tool profile i.e. Flat, Convex, and Concave shape, peak current, pulse on time and pulse off time on performance during machining.

The effects of process parameters i.e. tool profile i.e. flat; convex, and concave shape, peak current, pulse on time and pulse off time on material removal rate, and surface roughness on EDM has been analyzed for exploring the research finding for the better combination of parameters and control over machining of Ti-6Al-4V alloy.

Table 2 Experimental result for MRR, and SR

S.No	Tool Profile	Current (Amp)	Pulse On Time (µs)	Pulse On Time (µs)	MRR (mg/min)	SR (Ra)
1	1	1	1	1	0.136	1.32
2	1	2	2	2	0.185	1.91
3	1	3	3	3	0.215	2.52
4	2	1	2	3	0.412	1.34
5	2	2	3	1	0.427	1.62
6	2	3	1	2	0.429	1.93
7	3	1	3	2	0.252	1.56
8	3	2	1	3	0.261	1.73
9	3	3	2	1	0.283	1.98

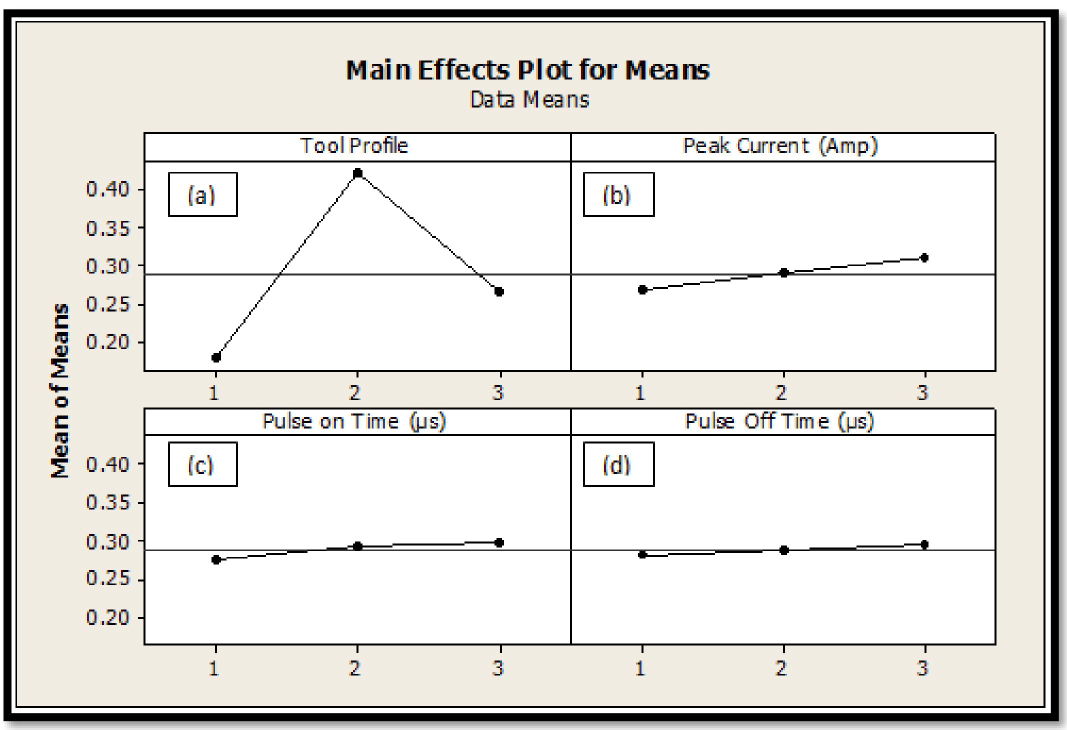

Fig 2: Shows the effect of various parameters on Mean of Means of MRR

Fig. 2(a) shows the effect of various parameters on Mean of Means of MRR. Graph plotted by utilizing the MRR results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 5 to 15, variation of Pulse On-time 5 to 15µs and Pulse Off-time

4 to 14 µs. It is clear that there is increase in MRR with the change of Tool Profile from level 1 to level 2 i.e. flat to concave profile and then decreases from level 2 to level 3 i.e. concave to convex profile. Fig. 2(b) shows the effect of various parameters on Mean of Means of MRR. It is clear that there is increase in MRR with the increase in Peak Current from level 1 to level 2 i.e. 5 to 10 and then increases further from level 2 to level 3 i.e. 10 to 15 with decrease in Peak Current. Fig. 2(c) shows the effect of various parameters on Mean of Means of MRR. It is clear that there is increase in MRR with the increase in Pulse On-time from level 1 to level 2 i.e. 5 to 10 µs and then increases again from level2 to level3 i.e. 10 to 15 µs. Fig. 2(d) shows the effect of various parameters on Mean of Means of MRR. It is clear that MRR increases with the increase in Pulse Off-time from level 1 to level 2 i.e. 4 to 9µs and then increases further from level 2 to level 3 i.e. 9 to 14µs.

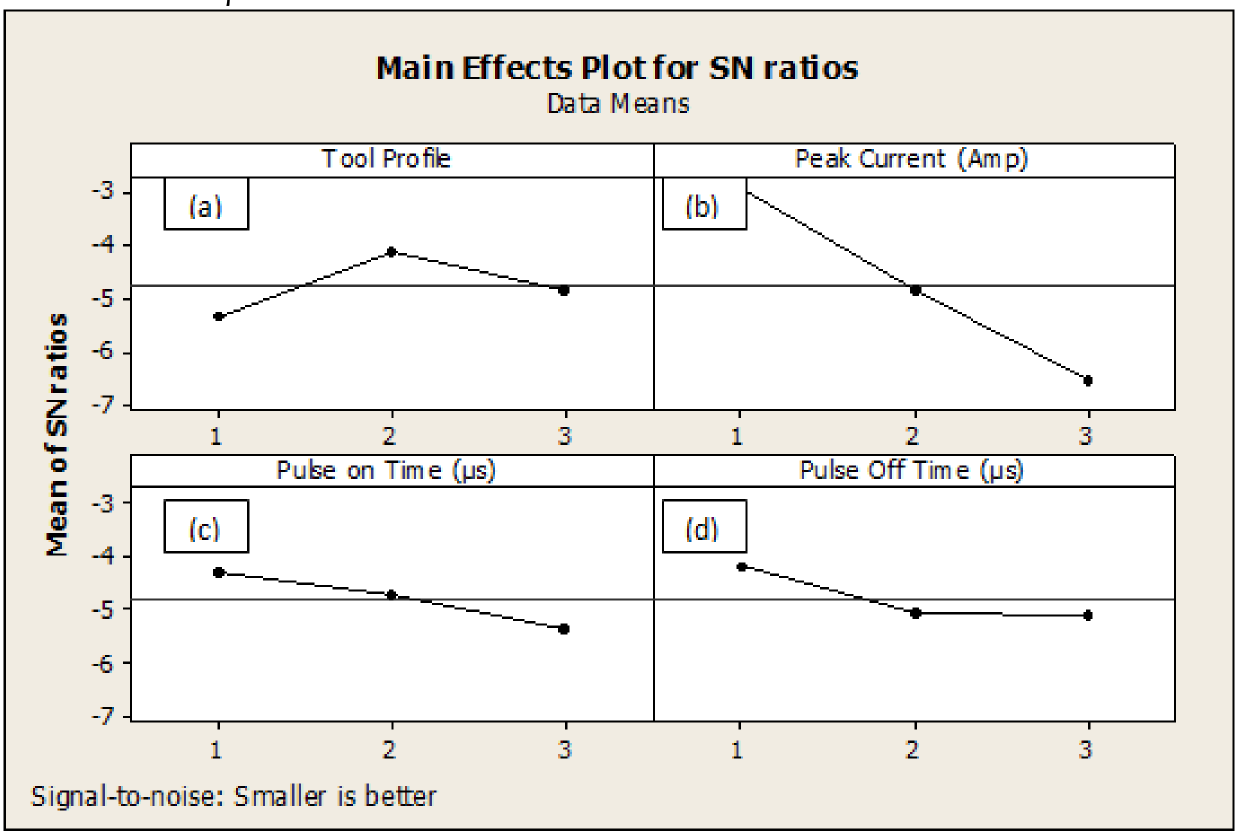

Fig 3: Mean of SN ratio of graph for Surface Roughness (Ra)

Figure 3 (a) shows the effect of variation of Tool Profile on Mean of SN Ratios of Surface Roughness (Ra). Graph plotted by utilizing the Surface Roughness (Ra) results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 5 to 15, variation of Pulse On-time 5 to 15µs and Pulse Off-time 4 to 14 µs. It is clear that there is increase in Surface Roughness (Ra) with the change of Tool Profile from level 1 to level 2 i.e. flat to concave profile and then decreases from level 2 to level 3 i.e. concave to convex profile. Figure 3 (b) shows the effect of variation of Peak Current on Mean of SN Ratios of Surface Roughness (Ra). It is clear that there is decrease in Surface Roughness (Ra) with the increase in Peak Current from level 1 to level 2 i.e. 10 to 15 and then decreases further from level 2 to level 3 i.e. 15 to 20 with decrease in Peak Current. Figure 3 (c) shows the effect of variation of Pulse

On-time on Mean of SN Ratios of Surface Roughness (Ra). It is clear that there is decrease in Surface Roughness (Ra) with the increase in Pulse On-time from level 1 to level 2 i.e. 4 to 6 µs and then decreases constantly from level 2 to level 3 i.e. 6 to 8 µs. Figure 3 (d) shows the effect of variation of Pulse Off-time on Mean of SN Ratios of Surface Roughness (Ra). It is clear that Surface Roughness (Ra) decreases with the increase in Pulse Off-time from level 1 to level 2 i.e. 3 to 5µs and then decreases minutely from level 2 to level 3 i.e. 5 to 7µs.

4. Conclusions for Material Removal Rate

1. It is noted that the maximum mean of material removal rate (MRR) is 0.429 mg/hr which is at 15 amp current, 5µs of Pulse on time, 10 µs of Pulse off time, for concave shape of tool.
2. The optimum combination parameters for machining of Ti-6Al-4V alloy using EDM for higher MRR are Concave shape of tool, 15 amp current, 15 µs of Pulse on time, 14 µs of Pulse off time.
3. It is noted that the minimum mean of Surface roughness (SR) is 1.32 Ra, which is at 5 amp current, 5 µs of Pulse on time, 4 µs of Pulse off time, for flat shape of tool.
4. The optimum combination parameters for machining of Ti6Al4V alloy using EDM for lower surface roughness are Concave shape of tool, 5 amp current, 5 µs of Pulse on time, 4µs of Pulse off time.

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Surface Modification of Austenitic Stainless Steel (Ss-304) through Microwave Heating Route

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ABSTRACT

The present work focuses on the development of metal matrix composite cladding on an austenitic stainless steel substrate through microwave heating route. In the interest of discovery more practicality of the microwave heating process, (EWAC (Ni-based) + 30% Cr_3C_2 powder) composites claddings have been developed on austenitic stainless steel (SS-304) substrate through microwave hybrid heating. The domestic multimode microwave oven working at 2.45 GHz and 900 W was used to develop the composite clads. The so developed clads were characterized by scanning electron microscope (SEM), X-ray diffraction (XRD), Vicker's micro hardness measurement and flexural strength testing. Further tribological wear behaviour of the developed clads was analyzed using pin-on-disk type tribometer. The SEM analysis reveals that the clad of 0.6mm thickness were developed with significantly less porosity (0.95%). Clads were metallurgically bonded with substrate material by partial dilution of elements from substrates to clad regions. The Vicker's microhardness of Ni+ 30% Cr_3C_2 powder was observed to be 455 ± 55 HV respectively. The cumulative weight loss for microwave processed clads were significantly lower than that of SS-304 substrate.

1. INTRODUCTION

A process in which electromagnetic wave is aided for fusion of a material with some diverse metallurgical properties onto a substrate; so as to attain a strong metallurgical bonding is called Microwave cladding. Properties of the clad material have to be maintained, so that a delicately small layer of the substrate could melt, hence very less dilution of added clad powder material into the substrate. This microwave heating mechanism offers various advantages in excess of conventional heating because of the following reasons: The direct absorption of microwaves inside materials allows volumetric heating which produces better diffusion rates, lower processing times and reduced power consumptions. These features of higher diffusion rates and higher heating rates allowed enhancement in mechanical and physical properties of the microwave treated components owing to which the development of defects is lower. These characteristics of higher heating rates and diffusion rates permitted enhancement in mechanical as well asphysical properties of the microwave treated components to decline the defect formation[1]. The universal improvements taking place in the field of microwave processing of materials and their related industrial uses [2]. The core focused aim of developing innovative processing and manufacturing technologies were to decrease manufacture or developed costs, handling times and to improve manufactured product properties [3]. The developed processing techniques should be usually acceptable for all types of materials including alloys, ceramics, fibre reinforced plastics and metal matrix composites. Microwave materials processing was developing as a new processing technology which was applicable to a wide range of materials system including processing of FRP, MMC, ceramics, metals, material joining, alloys, powder metallurgy, coatings and claddings. Microwave processing of materials offers good mechanical properties with reduced defects and economical advantage in terms of time and power savings[4]. Compared the abrasive and erosive wear behavior of micrometric and nanometricwc-12co microwave clads. It was observed that nano metric clad exhibits a cluster of nano-carbides whereas micrometric exhibits skeleton structure of carbides reinforced in a metallic matrix. The abrasive wear was evaluated on a dry sand rubber apparatus. In this study silica sand is used as abradant [5-7]. The SEM morphology of silica sand shows the presence of sharp edge particles. The total cycle time of abrasion for each sample is 40 minutes where weight is calculated after every 5 minutes. The result shows that cumulative weight loss was less in case of nanometric clads. Air jet erosion test rig was used to determine the erosion wear behavior of both clad. The SEM analysis shows that at low impact angles micro-cutting is responsible for removal of material but at high impact angle it was plastic deformation which results in high wear rate [8-11].

2. MATERIAL AND METHODS

2.1 Substrate Material

Austenitic stainless steel (SS-304) was used in the present investigation as the substrate material. The SS-304 material has been extensively deployed in the area of food processing equipment, heat exchangers and chemical tanks etc. SS-304 substrate exhibits good corrosion resistance properties. The chemical composition of SS-304 was evaluated using a spectrometer and was reported in Table 1.

Table 1: Substrate Chemical composition (wt. %)

Material	Elements								
	Cr	Ni	W	C	Si	Fe	Co	Mn	Others
SS-304	8-10.5	18-20	-	0.08	1	Bal		2	-

2.2 Raw clad powder

Ni based EWAC powder

EWAC (Ni-based powder) powder was procured from L& T India. The average particle size of the nickel-based powder was 40μm. Ni-based powder exhibits good corrosion resistance and wears resistance properties. The morphology of Ni based powder as shown in Fig.1 shows the spherical shape of Ni powder particles. The chemical composition of EWAC powder is shown in Table. XRD spectrum (Fig.2) reveals the presence of enriched Ni elements with small traces of Cr, Si.

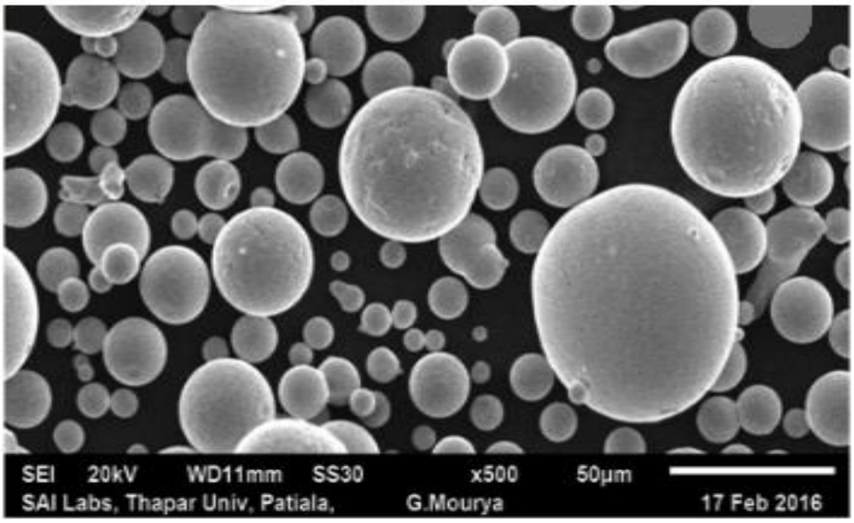

Figure 1. SEM image showing typical morphology of Ni-based EWAC powder.

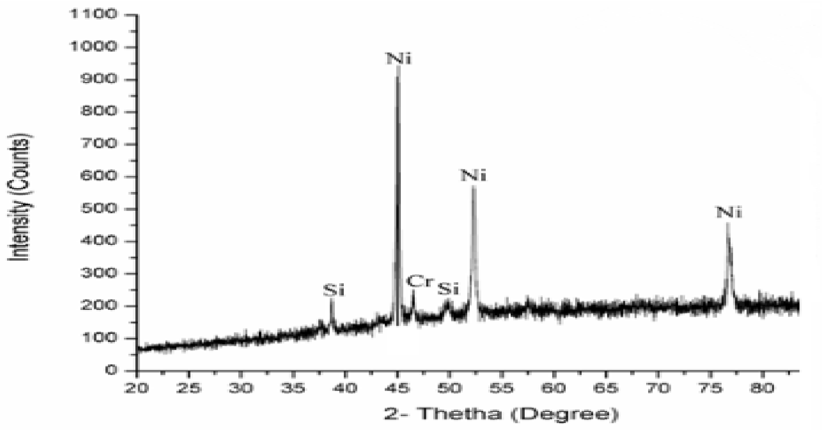

Figure 2. XRD image Ni-based EWAC powder.

2.3 Cr_3C_2 powder:

Chromium carbide Cr_3C_2 powder is a wear resistant material having a melting point of 1811° C. The average particle size of theCr_3C_2 powder was 40µm. SEM images (Fig.3) shows the sharp edge morphology of Cr_3C_2 particles.

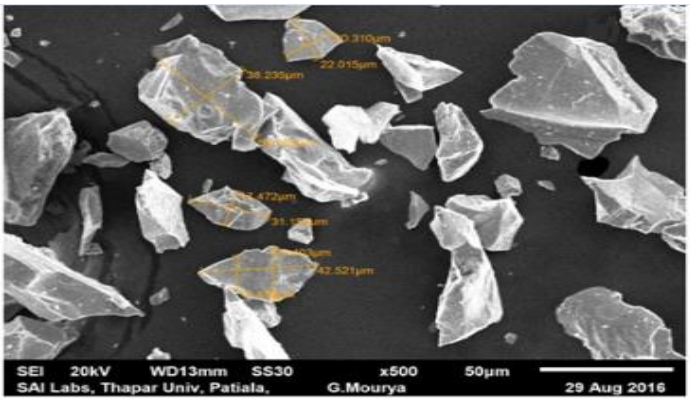

Figure 2. SEM image showing typical morphology of Chromium Carbides powder.

2.4 Microstructural analysis of Ni-based + 30% Cr_3C_2 composite clad

The typical back-scattered electronic (BSE) image of a transverse section of Ni-based + 30% Cr_3C_2 composite clad sample (Fig.4.1 (a)) shows the clad of approximate thickness 600 µm. A wavy interface can be clearly seen between clad layer and substrate region. It can be observed from Fig.4. (a) that the hard carbide (Cr_3C_2) phases are uniformly dispersed in the form of cellular-like structure in the Ni matrix. The clad section is shown in Fig.4. (b) is an enlarged view, which shows that the clad is free from any type of solidification cracks.

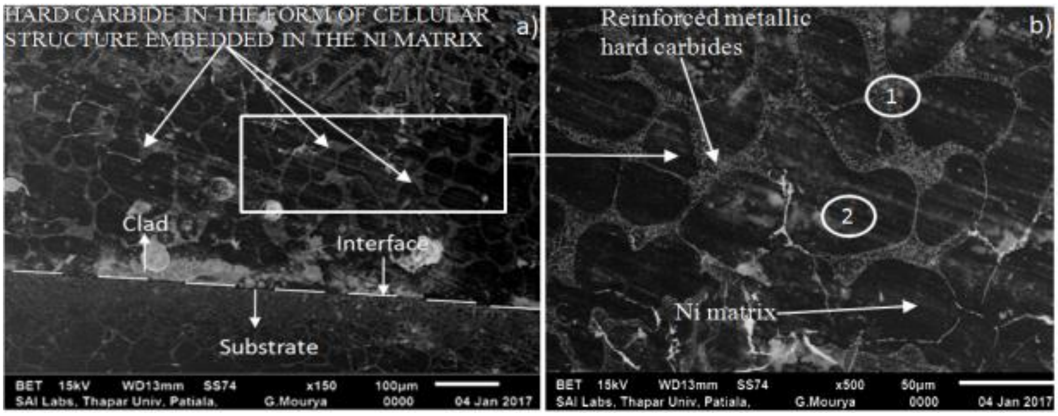

Figure 4. SEM images showing (a) microstructure of a transverse section of cladding; (b) enlarged view of the enclosed clad region.

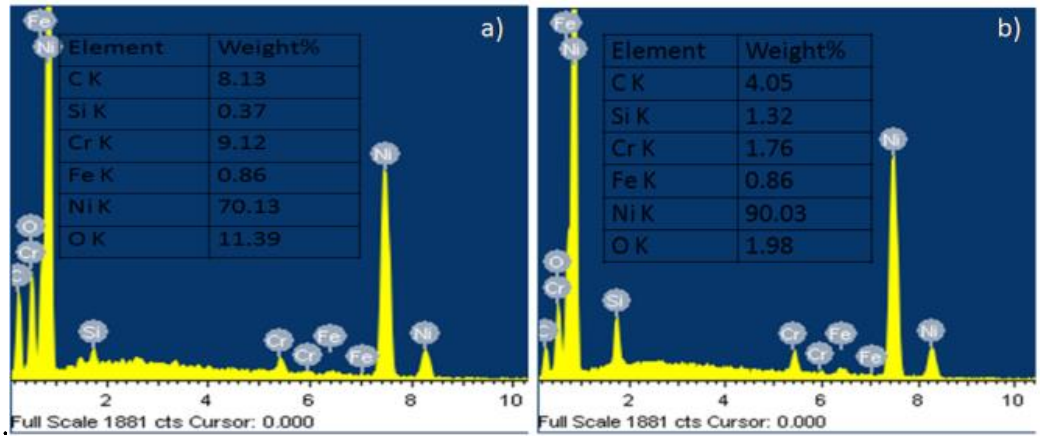

Figure 5. EDS analysis (a-b) at point 1 and point 2.

EDS analysis Fig.5 (a-b) confirmed the presence of hard carbides phases at location 1 and 2 (Ref. Fig.4 (b)). It was also confirmed from the EDS analysis that the matrix mainly composed of Ni, Si, C, while Cellular likes structure composed of C, Cr, Ni and O.

3. PHASE ANALYSIS OF NI-BASED + 30% CR_3C_2 CLADS

The XRD pattern of the composite clad confirmed that $FeNi_3$, NiSi, Cr_3Ni_2 and chromium carbide (Cr_3C_2) were present in the composite clad. During microwave heating, the formation of NiSi occurred due to the reaction between Ni and Si which are the elements of raw powder. The presence of Cr_3Ni_2 and $FeNi_3$ phases might be due to the dilution of chromium and iron elements from the substrate to clad, which is the evidence of metallurgical bonding of substrate with cladding. Fig.6 shows the XRD spectra of the microwave processed Ni-based + 30% Cr_3C_2 clads.

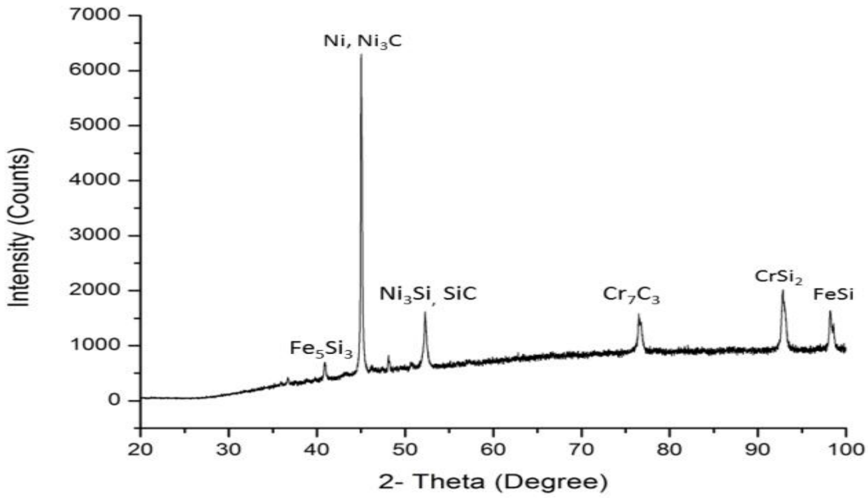

Figure 6. XRD analysis of microwave processed composite clad.

3.1 Micro-hardness study of Ni-based +30% Cr_3C_2 clads

The wear characteristics of the microwave clad layer influences by its micro-hardness. The uniformly distributed carbides in the clad region contribute to the increase in wear resistance and hardness. The micro-hardness of the microwave processed clad was calculated using Vicker's micro-hardness tester. The micro-hardness values were detected to be non-uniform through the thickness of clad, it could be attributed to the fact that, indentations were taken on hard carbides phase as well as tougher Ni matrix phase. The average Vicker's micro-hardness of the clad was found to be 450 ± 55 HV.

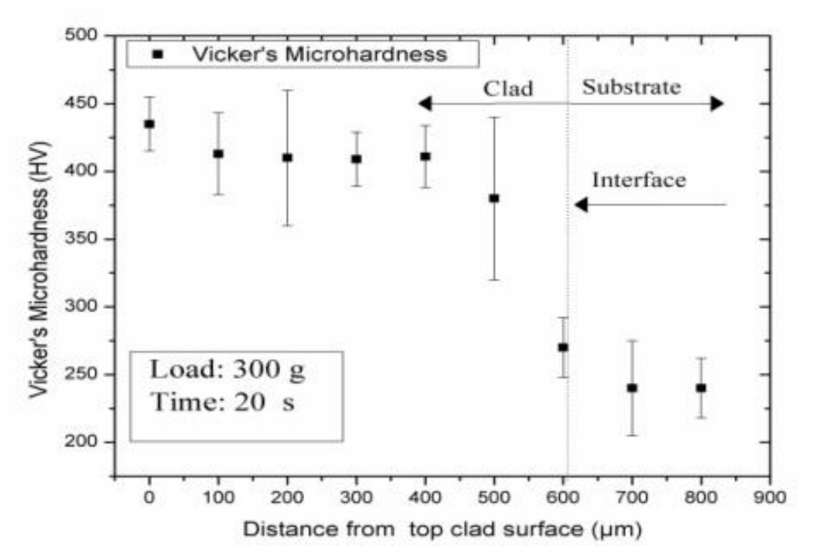

Figure 7. Micro-hardness analysis of developed clad at various locations.

3.2 Dry sliding wear study

The dry sliding wear test of Ni-based + 30% Cr_3C_2 composite clads was carried out using alumina disc as a counter surface under the defined set of parameters. The cumulative weight loss (mg) diagrams for clad as well as an SS-304 substrate under different conditions of loads and sliding velocities are shown in Fig.8 (a-f).

It was observed from Fig.4.5 (a, c, e) that cumulative weight loss for clad samples was significantly less than that of SS-304 substrate samples (Fig.8 (b, d, and f)).

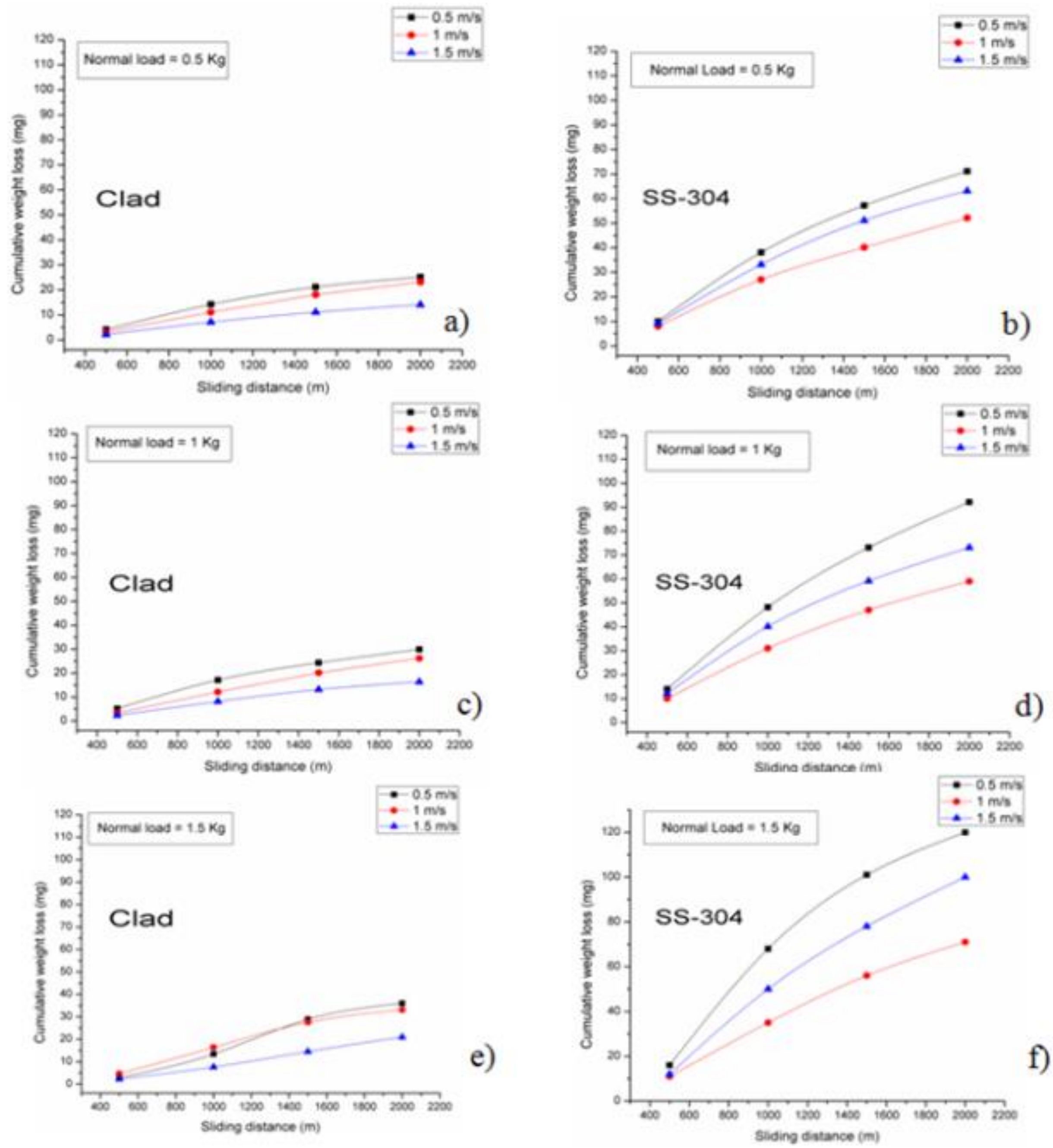

Figure 8. Weight loss (mg) diagrams under different conditions of loads and sliding velocities

The wear rate characteristics of SS-304 substrate and microwave clad under 1.5 Kg normal loads are shown in Fig.9(a, b), which revealed that wear rate for both clad and the substratewas higher for initial 1500 m of sliding distance (run in wear conditions) due to the presence of rough surface asperities. These rough surface asperities get removed during run-in wear phase and beyond 1500 m of sliding distance, due to smoothening of wear track, the wear rate gets lowered down and resulted in the steady wear zone. The dry sliding wear behavior study was carried out systematically and effect of sliding distance, sliding velocity and normal load on cumulative weight loss has been analyzed.

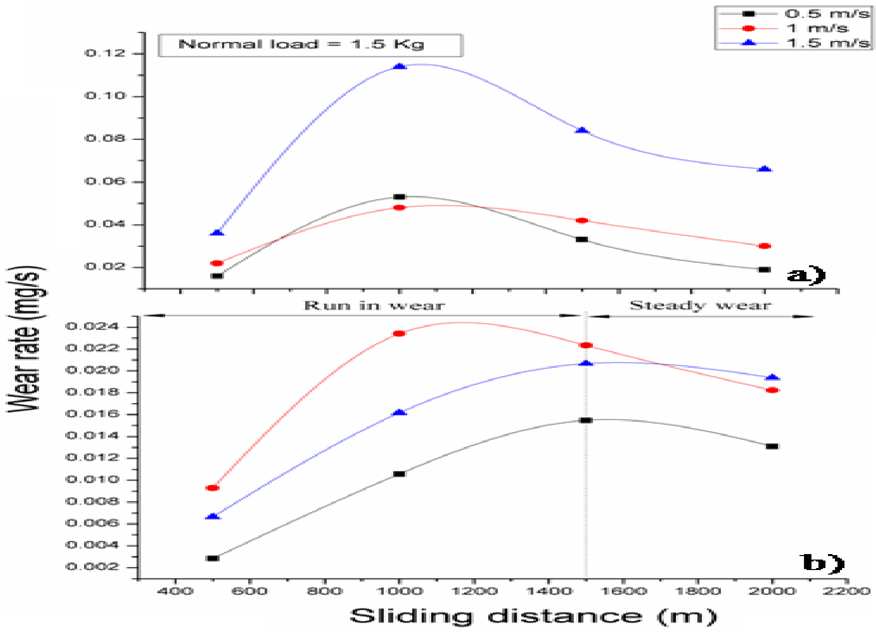

Figure 9. Wear Rate and Sliding distance on 2000 m.

3.3 Effect of sliding velocity

It was observed in Fig. 8 (a, c, e) that the cumulative weight loss of microwave clad samples decreases with increase in sliding velocity under given a set of loads. At a lower sliding velocity of 0.5 m/s and 1 m/s more cumulative weight loss is more than at 1.5 m/s sliding velocity. It could be attributed to the fact that at lower sliding velocity there is more contact time between the sliding surfaces and more heat is generated, which causes the loss in binding strength of the carbides embedded in the Ni matrix and hence more material loss occurs. However, at higher sliding velocity a uniform tribo-oxide film formation occur which offers resistance to the wear. Cumulative weight loss for SS-304 substrate sample at different sliding velocity is given in Fig.8 (b, d, and f) which reveals that the weight loss trend was linear at all sliding velocity and at moderate sliding velocity of 1 m/s weight loss was lower. As the micro-hardness of SS-304 substrate is almost 2.5 times less than microwave processed Ni-based + 30% Cr_3C_2 clad, so more plastic deformation and lower thermal stability occur in case of SS-304 substrate, which causes the micro-weldments and partial melting of the sliding surfaces. At 0.5 Kg load and 0.5 m/s of sliding velocity the weight loss for cladding at the end of 500 m of sliding distance were recorded as 11 mg which is 3 times less than the weight loss for SS-304 substrate (32 mg) under similar conditions. In case of SS-304 substrate, a very thin and non-uniform tribo film was formed at 1 m/s of sliding velocity, which results in lower weight loss. Overall results indicated that the weight loss for SS-304 substrate samples was significantly higher than that of microwave clad samples for all velocity conditions.

3.4 Effect of normal load

With increase in normal load, the weight loss for both substrate and clad samples increases (Fig.8 (a-f)). It was observed that at moderate sliding velocity of 1 m/s the weight loss was 19 mg at 0.5 Kg load, 25 mg at 1 Kg load and 31 mg for 1.5 Kg load. Hence cumulative weight loss increases by ~ 63% by increasing normal load from 0.5 Kg to 1.5 Kg. Further, at lower velocity 0.5 m/s and normal load 1.5 Kg, the weight loss was 37 mg, while at higher sliding velocity and at load 1.5 kg weight loss was 17 mg, hence weight loss at higher sliding velocity and at higher load was significantly less than at lower sliding velocity and higher load. It is mainly due to the formation of atribo-oxide film at higher load and higher velocity and rupturing of tribo-film at lower sliding velocity. In case of theSS-304 substrate, the weight loss at a lower velocity and the higher load was significantly higher than that at lower load. This is again due to the rupturing of tribo-film at a lower velocity and higher load.

3.5 Effect of sliding distance

In case of microwave clad samples and SS-304 substrate samples, for initial 1000 m distance, the weight loss was higher due to the presence of uneven ridges on the surface and high initial friction between the mating surfaces. Steep slopes can be clearly seen between 500-1000 m of sliding distances. At the end of 1000 m of sliding distance, the semi-steadywear state occurred due to the removal of uneven ridges from the surface and the cumulative weight loss slopes start fattening up. After 1500 m of sliding distance wear loss is less due to the attainment of steady state condition due to the formation of smooth wear track.

Overall results showed that the weight loss in case of SS-304 substrate was significantly higher than that of microwave processed composite clad. The maximum weight loss in case of microwave processed clad was 37 mg at 0.5 m/s and 1.5 Kg, while in case of SS-304 substrate it was 110 mg. which shows that the wear resistance of SS-304 substrate was enhanced by 3 times by developing microwave composite cladding of Ni-based + 30% Cr_3C_2 as shown in Fig.10.

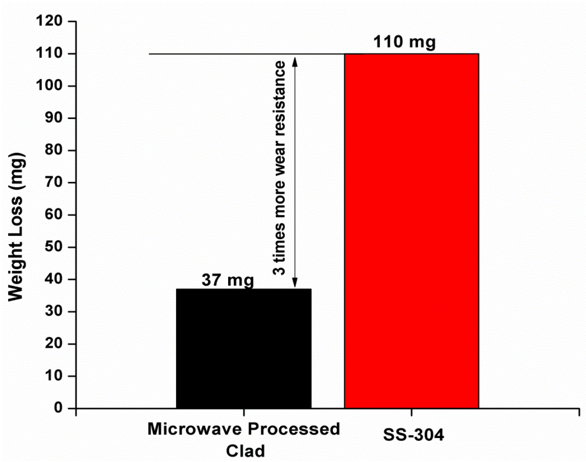

Figure 10. Wear resistance in Clad and Substrate

4. ANALYSIS OF WORN SURFACES

The worn surfaces of Ni-based + 30% Cr_3C_2 clad and SS-304 substrate was examined using SEM. The wear of clad samples mainly happens because of smearing of tribo-film and debonding of particles (Fig.11 (a-c)). It was observed from cumulative weight loss diagrams that at lower sliding velocity and higher normal load, the weight loss from the clad surface was more. This is due to the fact that at the lower sliding velocity the contact time period between the sliding surfaces is more, so more frictional forces causes more heat generation at the contact surfaces. This generated heat causes the softening of Ni matrix and debonding of materials particles from the clad surface as shown in Fig.4.8 (a). Also at lower sliding velocity and higher load formation of craters occur. At higher sliding velocity 1.5 m/s, the formation of tribo oxide layer occurs (Fig.11 (c)) which prevents the loss of material during sliding of surfaces. However, this tribo-film cannot sustain for a longer time and gets smeared off during long sliding distance. At higher sliding velocity (1.5 m/s)

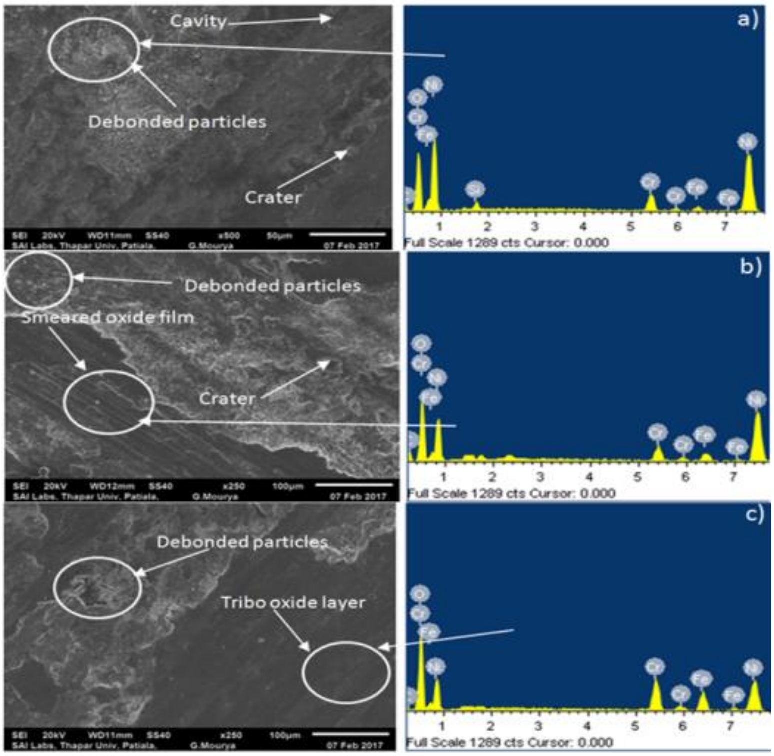

Figure 11. SEM images showing worn surface and EDS Analysis

The interaction time between sliding surfaces is very less (almost 1/3rd of 0.5 m/s), so less wear loss at higher sliding velocity. In case of SS-304 substrate, abrasion, adhesion and plastic deformation were mainly responsible for wear (Fig.12 (a-c)). Due to strong adhesion between SS-304 and alumina counter disc surfaces the wear mechanism would change from two bodies to three bodies contact with wear debris remaining between the mating surfaces. The wear debris collected from pin-on-disc sliding wear tests was also analyzed through SEM/EDS.

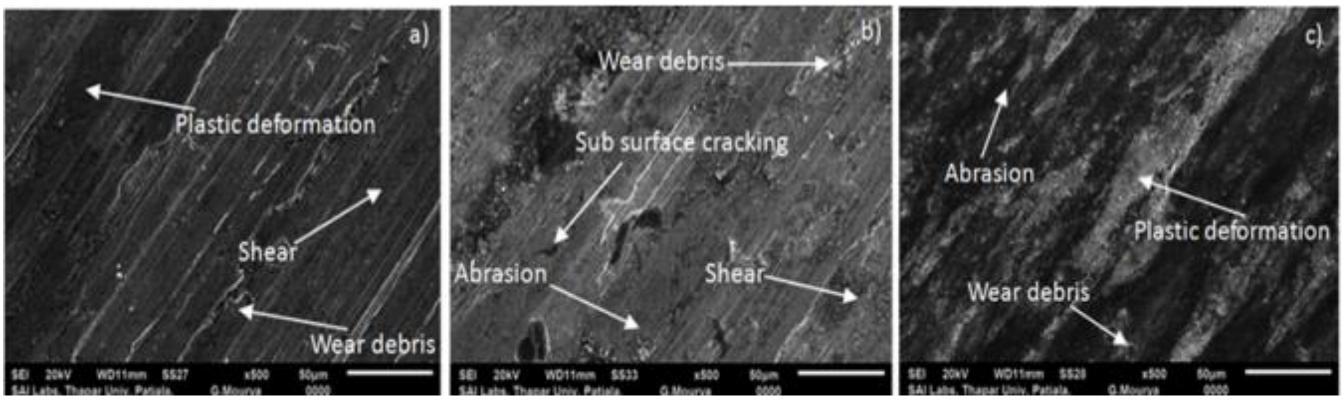

Figure 12. SEM images showing abrasion, adhesion and plastic deformation

It was observed that wear debris was diverse in shape, size and morphology (Fig.13 (a)). It was also observed in EDS analysis (Fig. 13 (b)) that wear debris was developed in Ni, Fe,O and Cr with small traces of Si, Al. The presence of Al indicates that small amount of material was also removed from the Al_2O_3 counter disc during sliding.

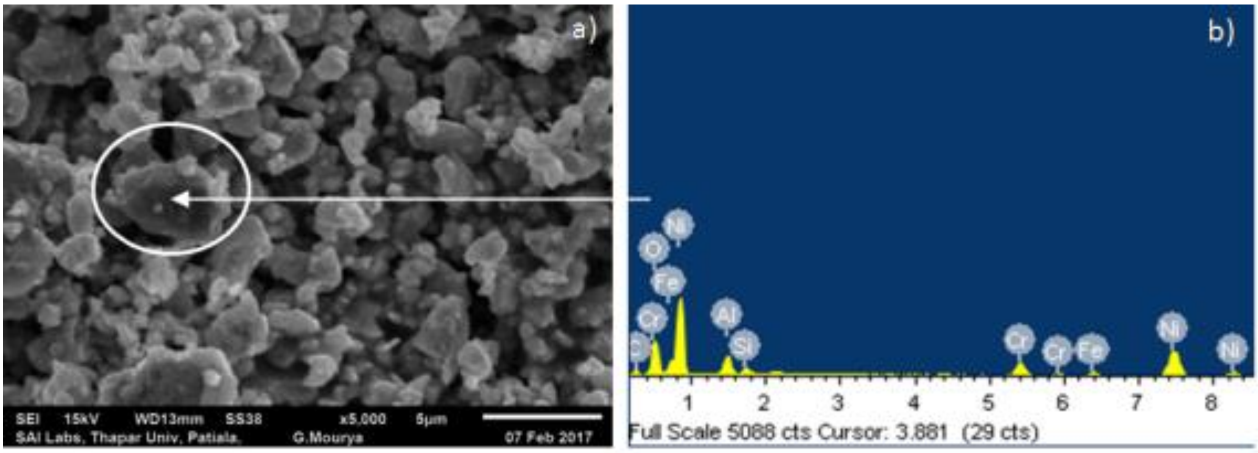

Figure 13. SEM and EDS Analysis of Wear debris.

4.1 Flexural testing results:

The flexural strength of the developed clads was determined with an objective of evaluating interfacial strength between the cladding and the substrate. Three-point bend test on a UTM was performed with a crosshead speed of 1mm/min. Resulting load-displacement characteristics curves obtained are shown in the Fig.14 The average value of the maximum load, displacement and calculated flexural strength are presented in the table. The deformed samples with fractured clad during the flexural test were shown in the Fig.15.

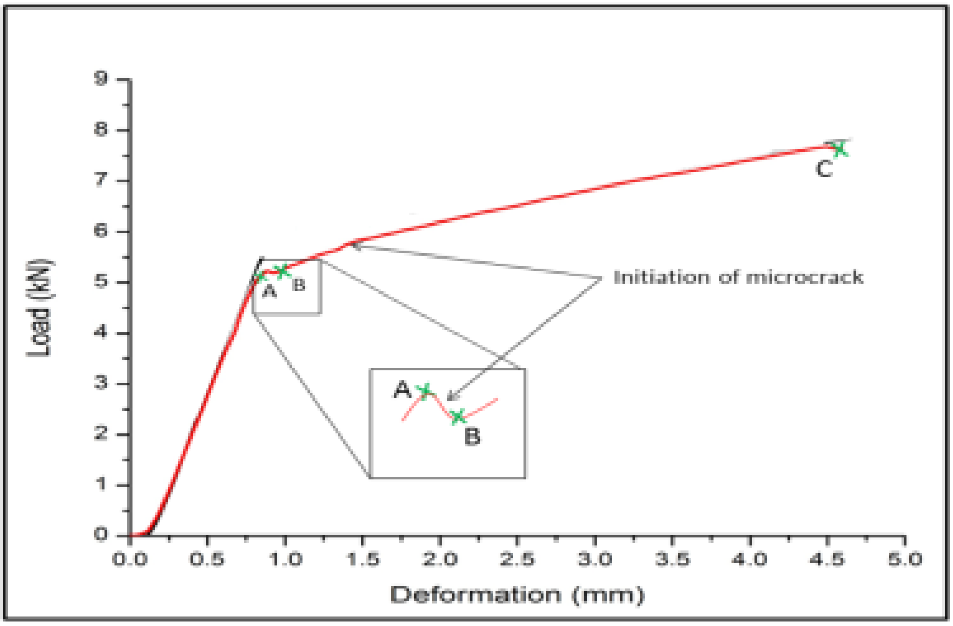

Figure 14. Resulting load-displacement characteristics curve

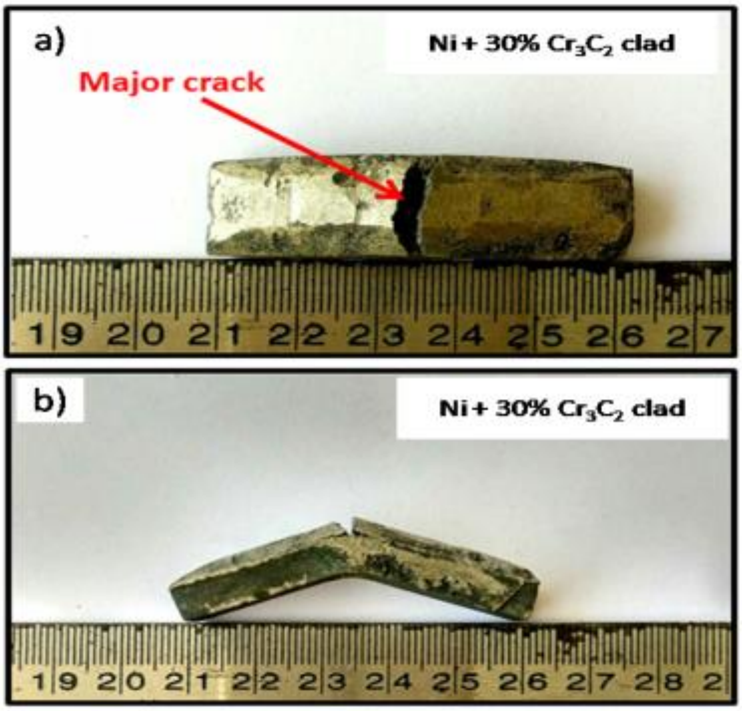

Figure 15. Fractured specimens after flexural strength test
(a) top view of Ni+30% Cr_3C_2 clad, (b) side view of Ni+ 30% Cr_3C_2 clad.

Table 2. Flexural strengths of Ni+30% Cr_3C_2 microwave clad

Microwave Cladding	**Maximum displacement (mm)**	**Maximum load (kN)**	**Maximum flexural strength (MPa)**
Ni + 30% Cr_3C_2Clad	4.1 ± 0.4	7.6 ± 0.2	791

5. CONCLUSION

The Ni + 30% Cr_3C_2 based composite clads on the SS-304 substrate were developed using microwave heating a 2.45 GHz and 900W. The so developed clads were characterized through various relevant techniques and the conclusions drawn from the characterization results are explained as follow.

- Clads of Ni + 30% $Cr_3C_2$with a thickness of ~ 0.8 mm on SS-304 was successfully developed.
- Clads are free from any type visible solidification cracks.
- Partial diffusion of elements from the substrate region to clad region and vice versa leads to metallurgical bonding between substrate and clad bead.
- XRD of Ni + 30% Cr_3C_2clad confirms the presence of hard phases such as FeSi, Fe_5Si_3, Ni_3Si, Ni_3C and $CrSi_2$. The presence of Ni_3C should definitely increase the wear resistance properties of the clad as it possess good wear resistance properties.
- Formation of hard phases as confirmed by XRD enhanced the microhardness of the clad. The microhardness of Ni + 30% Cr_3C_2clad was 2 times higher than that of the substrate material.
- The average flexural strength of Ni + 30% Cr_3C_2clad was 7.9kN.
- The Ni + 30% Cr_3C_2 clad exhibited 3 times higher wear resistance as compared to SS-304 substrate.

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Failure of the Gear of Work Roll-End of Drive Spindle in Cold Rolling Mill: A Case Study

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Abstract
Spectacular advancements in technology, expeditious knowledge explosion, the amazing pace of production and multidimensional dissemination of knowledge in all fields, growth of industries, all these developments have significantly affected engineering field. While opening up new vistas of overcoming the hurdles in the way of speedy production the study has been conducted on M/s Bhushan Power and Steel Ltd, Chandigarh. In this project the gear of the workroll end side of hub of a spindle in a cold rolling mill has been analyzed. It was found that there is frequent failure of the gear of workroll-end of drive spindle and it was causing huge losses to the company in terms of downtime. Hence to save the gear from failure and to enhance its life there is a requirement to set the load below this particular level.

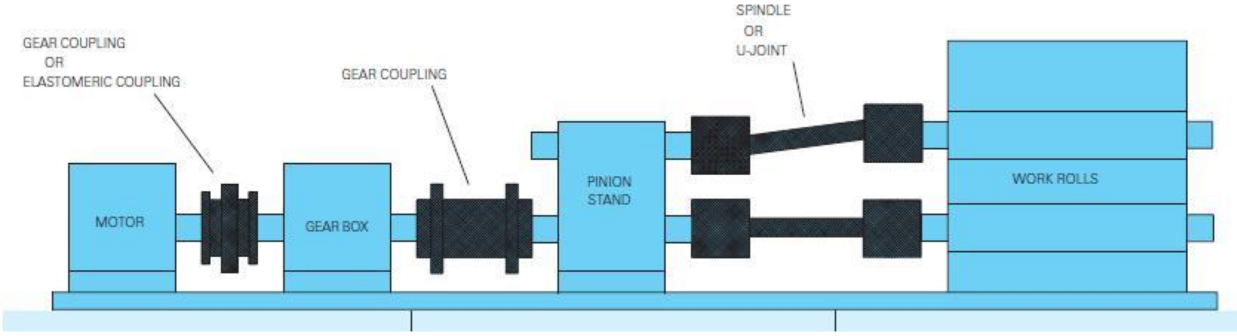
Key words: *Mill, drive, roll-end, cold rolling*

1. Introduction

The Cold Rolling Mills are designed and built in complete lines for the production and further processing of cold-rolled stainless steel, carbon steel, and non-ferrous metals. This line consists of equipment for cold-rolling, surface treatment, strip coating and finishing, stamping, deep drawing and acid regeneration.

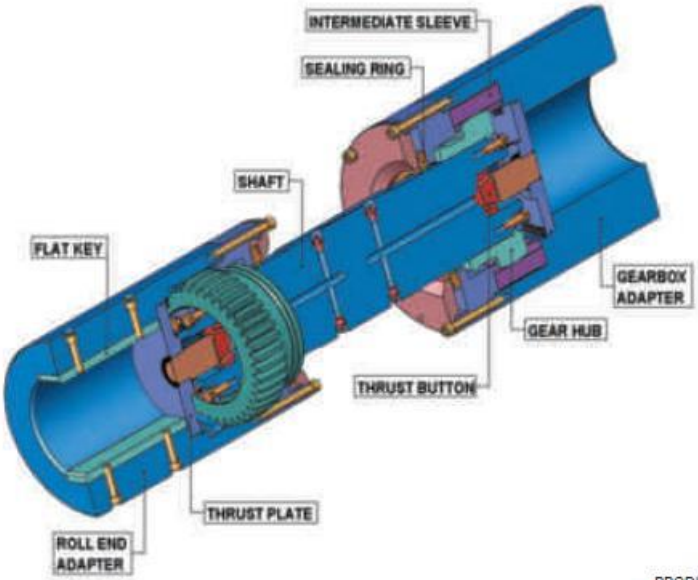
The major parts in the Cold Rolling mill are couplings that connect the drives and the rolls which are often taken for granted. However, market demand for greater productivity and improved quality of rolled products, has driven the design and manufacture of equipment to accommodate high operating speeds, torques and misalignments with minimum maintenance. Gear spindles are specially designed for those applications where driving and driven components are necessarily misaligned and where service dictates a changeable amount of misalignment. More common application of gear spindles is for ferrous and non-ferrous rolling mills drive, where technology is in continuous development to achieve a higher product quality with lower and maintenance costs. Gear spindles are critical components of the drive train and for this reason and to meet the demands of the most up-date mill equipment, these are designed to ensure performances in terms of operating efficiency, and less and easier maintenance.

According to a study of frequent failures occurring in M/s Bhushan Power and Steel Ltd, Chandigarh, it was realized that there is frequent failure of the gear of workroll-end of drive spindle and it was causing huge losses to the company in terms of downtime. It has been decided to study the current design for its failure analysis



Block Diagram of Cold Rolling Mill

Spindles and gear hub



Sectional View of the spindle

2. Brief survey of previous work

Companies in the industrialized nations mostly achieve an increase of their productivity by raising the energy input in their production plants, i.e. increasing production speed and rate. The continuous optimization of productivity is especially important in primary industry, for instance the mining and metallurgical industry, as developing countries or those on the threshold of becoming industrialized nations have an advantage due to their potential of human and raw material resources. The increase of the power density within a production process generally implies higher standards in terms of maintenance and process control, to avoid losses in product quality and machine availability. This requires the extensive use of data acquisition, diagnostic engineering and control tools, i.e. condition monitoring. Also reduce downtime to increase the efficiency of the mills.

3. Problem Formulation

A gear coupling is one of the simplest and most common mechanism used for transmission, but at the same time, it is also one of the most difficult to design and optimize. Some of the important parameters that affect its successful operation include:

1) Tooth design
2) Material
3) Lubrication

The main concept of the gear tooth design is optimization of the tooth geometry to obtain a higher percent of teeth in contact at the coupling operation conditions. In order to perform this optimization, is very important to understand the variables that affect the actual percent of teeth in contact:

4. Tooth Design

The tooth design is mainly dependent upon:

4.1. Misalignment Angle

Theoretically, there are only two teeth in contact when misalignment is present and no load is applied. There must be a load applied to obtain contact of more than two teeth. The degree of misalignment partly determines the number of teeth in contact for a given amount of torque. The lower the angle, the more teeth in contact and greater the torque capacity.

4.2 Tooth Loading

There are three basic loading conditions which can contribute to tooth failure:

- Compressive stress
- Bending stress
- Contact pressure/sliding velocity component

All of these variables and different variables must be considered in the design of a gear spindle. Any Engineering Department designs the spindles according to the misalignment angle and each type of tooth loading and misalignment angle, selecting the right material and heat treatment with the right design of the tooth, to suit our application based on years of experience in spindle design.

4.3 Flank curvature

This is the main contributor besides the misalignment angle in determining the gap between each tooth set. An optimized flank curvature will produce minimal gaps between each tooth set while maintaining an acceptable compressive stress. Proper flank crowning reduces contact stress, prevents tooth end bending and increases the contact area by moving the load closer to the centre of the tooth.

4.4. Materials

Materials used in the production of gear spindle components, include a proper combination of steel and heat treatment, depending on the stressing level and the required operating life. The best heat treatment for a coupling gear tooth gives the correct combination of core hardness versus case depth and hardness is used. For maximum strength and durability, it’s desirable to harden selected outer surfaces of spindles parts while leaving the inner cores ductile for shock resistance. Several heat treatment methods are available for case hardening the gear tooth components including nitriding, induction hardening and carburizing. The selections of a proper combination of steel and heat treatment, depending on the stressing level and the required operating life, are:

- NA Heat treated nitride alloy steel. This is for medium torque, high angle and high speed applications. Nitriding is also preferred for high temperature and high speeds applications where it is more durable than other forms of hardening.

- NHA Heat treated nitride alloy high strength steel. For medium to high torques.
- CHA Heat treated and carburized alloy high-strength steel. The carburizing process imparts a hard, deep case over a ductile and shock resistant core to resist wear and abrasion. Mainly used in high torque applications.

Materials used in the production of spindle gear elements, include both medium carbon and forged alloy steels. The material and heat treatment combinations commonly used for spindles applications. A vital aspect having a direct affect on spindles life and performances, is the provision of quality seals for efficient retention of the gear lubricant for exclusion of external contaminates. Modern Rolling mills and revamping of old mills, require or are implementing new developments as: new machine design concepts, better metallurgical practices, as well as the application of process control and automation. Consequently, mechanical components including gear spindles are becoming a critical component of the drive train. To be able to transmit large torques at large misalignment, spindle gear couplings use fewer teeth than conventional gear couplings, high-strength alloyed steels, and surface hardening: either nitriding or carburizing. This is the case, for instance, in cold rolling mills. Each mill spindle is custom designed for a particular application. Torque amplification factors (TAF) are also considered when designing the spindle and all the effort is done at design stage to decrease the stresses on the gear mesh. The gear tooth profile is specially designed to optimize the load capability for each single application.

Objective

The modified and efficient gear type spindle will require less maintenance and will be much more economical than the existing ones. Gear spindles provide constant angular velocity at misalignment angles, which ensures even transmission of power. This results in uniform sizes and improved surface quality of rolled products. In addition, the dynamic balance characteristics of gear type flexible spindles will minimize vibration, thus will increase the operating life of bearings, gears, and other components of the drive train. To accommodate load and no load misalignment with minimum backlash it is proposed to crown the flanks and the tips of the hub teeth. Teeth are also designed to allow higher no load angle to easy roll change. Spindles with fully crowned gear teeth offer operational benefits of maximum load carrying capacity with minimum size, maximum reliability and long life. Strip quality and thickness control will also be influenced by the performance of the drive spindles.

5. Conclusions

Firstly, check all the parameters or designed parameters for attain the maximum life span. Calculate the maximum and minimum RPM of the motor and after that check the shaft separation and then we have to calculate the number of teeth and type of profile of the gear. Then applied the radial and axial load on the shaft and gear check the resistance power of the shaft and gear. Find out the minimum stress point with respect to all the parameters and then fix the design of the gear hub with help of design software.

- Speed of the motor
- Roll separation
- Roll diameter
- Number of teeth
- Data of the existing design
- Design in software
- Load applied with analysis
- Outcome with stresses

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Effects of process parameters on Dimensional Deviation in WEDM for Mg Alloy (AZ91C) for Intricate Shape Cutting

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Abstract

In this paper, the special effects of various process parameters of WEDM like pulse on time (T_{ON}), pulse off time (T_{OFF}), Servo voltage (S_V), wire feed (W_F) and wire tension (W_T) have been examined to disclose their impact on material removal rate Mg Alloy AZ91C using one variable at a time approach. The optimal set of process parameters has also been predicted to maximize the material removal rate. The experimental studies were performed on ELECKTRA WEDM (ELPLUS 15) WEDM machine. The Dimensional deviation (DD) directly increases with increase in pulse on time (T_{ON}) and wire tension (W_T) while remains constant with increase in pulse off time (TOFF) and servo voltage (SV). Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of intricate shape cutting of the parts which have varying hardness, complex shapes and sharp edges that are very difficult to be machined by the traditional machining processes.

Keywords: WEDM, $T_{ON,}$ $T_{OFF,}$ DD, $W_{T,}$ $W_{F,}$ $S_{V.}$

Introduction

Wire EDM was introduced in the late 1960s', and has revolutionized the tool & die, mold, and metal working industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer. It can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the work piece, so there is no physical pressure imparted on the work piece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the work piece. The accuracy, surface finish and time required to complete a job is extremely predictable, making it much easier to quote, WEDM leaves a totally random pattern on the surface as compared to tooling marks left by milling cutters and grinding wheels. The WEDM process leaves no residual burrs on the work piece, which reduces or eliminates the need for subsequent finishing operations. Wire EDM also gives designers more freedom in designing dies, and more control of manufacturing management, since the machining is completed automatically. Parts that have complex geometry and tolerances don't require relying on different skill levels or multiple equipment. Substantial increases in productivity are achieved since the machining is Unattended and allowing operators to do work in other areas. Most machines run overnight in a "lights-out" environment. Long jobs are cut overnight, or over the weekend, while shorter Jobs are scheduled during the day. Most work pieces come off the machine as a finished part, without the need for secondary operations.

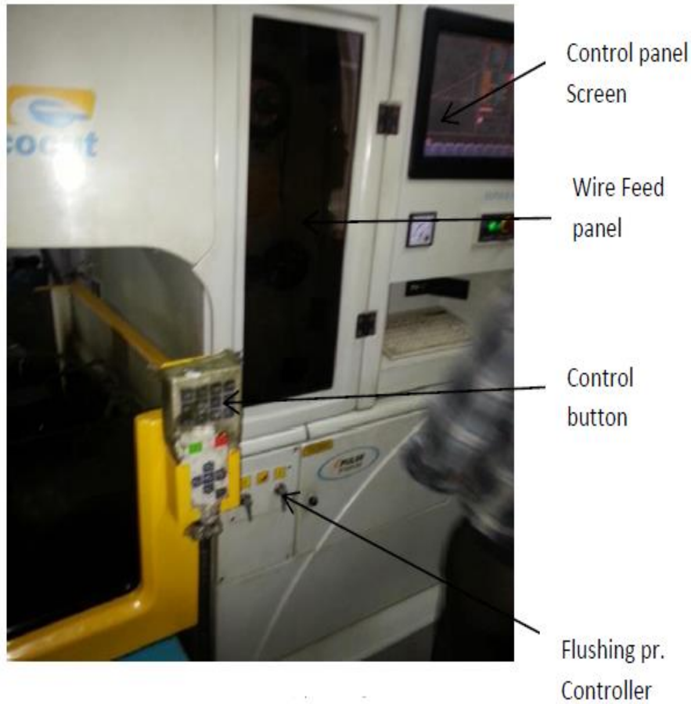

Figure 1: View of ELEKTRA WEDM MACHINE

Principle of WEDM Process

The Spark Produce in a wire EDM is same as that of the vertical EDM process. In wire EDM, the conductive materials are machined with a series of electrical discharges (sparks) that are produced between a perfectly vertical positioned moving wire electrode and the work piece. The work piece is clamped on main work table (X-Y), an auxiliary table (U-V) and wire driving mechanism. The Main Table can move in X-Y direction. The table is powered by DC servo motor. The wire is supported under tension between a pair of wire guide located at the opposite of the work piece. The lower wire guide is stationary whereas the upper wire guide, supported by the U-V table. The wire can be transversely displaced along U-V axis with respect to lower wire guide. High frequency pulses of alternating or direct current is discharged from the wire to the work piece with a very small spark gap through an insulated dielectric fluid (water). Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required. The heat of each electrical spark, estimated at around 8000°C to 11,000°C, erodes away a tiny bit of material that is vaporized and melted from the work piece also some of the wire material is also eroded away (Kalpakjain, 2000). These particles are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the work piece. Without this cooling, thermal expansion of the part would affect size and positional accuracy. The ON and OFF time of the spark that is repeated over and over removes material, not just the flow of electric current. It is very important that the water must not ionize during the machine operation. Therefor to prevent the ionization of the water an ion exchange resin is used in the dielectric distribution system to maintain the conductivity of the water. Ho et al. (2004) reviewed the vast area of research work carried out from the spin-off from the EDM process to the development of the WEDM. It reported on the WEDM research involving the optimization of the process parameters surveying the influence of the various factors affecting the machining performance and productivity. The paper also highlighted the Adaptive monitoring and control of the process investigating the feasibility of the different control strategies of obtaining the optimal machining conditions. Hewidy et al. (2005) developed a mathematical model for correlating a various EDM machining parameters such as pulse on time, pulse off time, wire feed , wire tension. The experiment was conducted based on the response surface methodology. Lahane et al. (2012) proposed the multi response optimization of wire edm process using weighted principal component analysis. Author stated that the WPC method along with taguchi method reduces the uncertainty and complexity of engineer judgment associated with taguchi method and shows significantly better overall machining quality. Number of research has been carried out in the past for the optimization of the WEDM input parameters using the different techniques of optimization. The significant effect of the input parameters on the response has also been evaluated using ANOVA table by many researchers.

Experimental Methodology

The experiment was performed on the ELECKTRA WEDM (ELPLUS 15) machine. Various input parameters i.e. Pulse

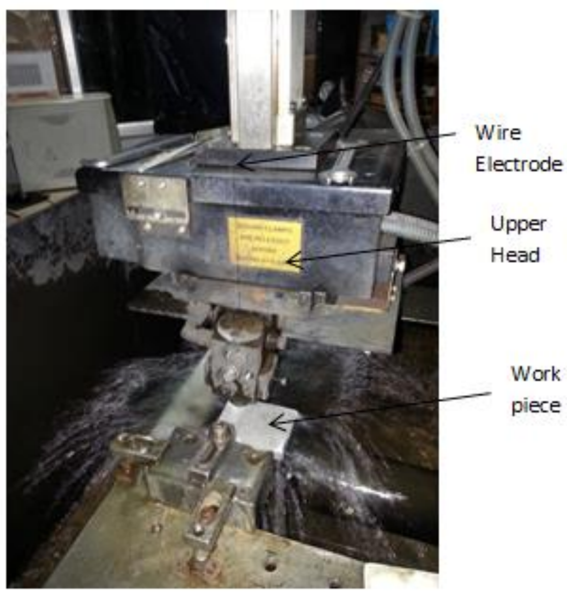

Figure 2: Specimen hold for WEDM Machining

on, Pulse off, Wire tension, wire feed rate, servo voltage and there effect on the output response variables were studied by keeping time factor constant. The magnesium alloy grade of AZ91C rectangular piece of 700 mm X 500 mm X 50 mm of size has been used as a work piece material for the present experiment. Magnesium alloy is the low specific weight material with excellent machining ability and good cycle potential. They are not used frequently because of the high cost of the parent material, coupled with partial absence of recycling possibility. The chemical composition of the material is obtained by chemical test (Wet) in accordance with ASTM E35-88(1993) (Table 1). The AZ91C Mg alloy rectangular piece of 70 mm X 60 mm X 6 mm is mounted on the ELECKTRA WEDM (ELPLUS 15) machine for cutting specimen of 20 mm X 10 mm X 5 mm of size.

Table 1: - The Chemical composition of Mg. Alloy

Mg. Alloy AZ91C	Chemical						
	%age of Ingredients by weight						
	Al	Zn	Si	Cu	Ni	Mn	Mg
	8.92	0.53	0.23	0.06	0.009	0.28	Rem

Measurement of the Response variable

The length of the specimen is measured with the help of digital vernier caliper having a least count of 0.02mm and the deviation of the measured dimension is calculated in terms of the percentage using the following expression.

$$\frac{\text{Actual dimensions} - \text{Measured dimensions}}{\text{Actual dimensions}} \times 100$$

The Setup used of measuring the dimension is shown in the figure 3.

Figure3: Vernier caliper with least count 0.02

Observations

Number of experiment has been performed to identify the effect of different parameters on the output parameters i.e. dimensional deviation. In the first of experiment Pulse on time (T_{on}) is varied. The pulse on time ranges from 106 µs to 112 µs increment in steps of 1 µs. The values of the other parameters were given as T_{off} = 50 µs, current = 2 ampere, W_F = 8 m/min; W_T = 8 kgf, S_V = 20 volt, S_F = 2050 unit. The experimentally observed data for the response characteristics for different values of pulse on time is given in Table 2.

Table 2: Percentage of DD with T_{on} value

S.no	T_{on} (µs)	Dimension Deviation(%age)
1	106	0.40
2	107	0.00
3	108	0.25
4	109	0.30

5	110	0.70
6	111	0.65
7	112	0.60

In the next set of experiment the pulse off time (T_{off}) was varied from 48 µs to 30 µs with a decrement of 3 µs. The values of the other parameters are kept constant and their values are given as T_{on} = 109 µs; I_P = 2 ampere, W_F = 10 m/min, W_T = 8 kgf, SV = 50 Volt, S_F = 2050 unit. The experimentally observed data for the performance parameters for a given value of pulse off time is given in Table 3.

Table 3: Percentage of DD with Toff value

S.no	T_{0ff} (µs)	% Dimension Deviation
1	48	0.70
2	45	0.55
3	42	0.20
4	39	0.35
5	36	0.50
6	33	0.20
7	30	0.05

In the third set of experiment effect of servo voltage was studied. The Servo voltage was varied from 35 volt to 60 volt in the increments of 5 volt. The values of the other parameters were kept constant and their values are given as T_{on} = 109 µs; T_{off} = 36 µs, W_F = 10 m/min, I_P = 2 ampere, W_T = 8 unit; SF = 2150. The experimentally observed data for the performance measures for different values of S_V is given in Table 4.

Table 4: Percentage of DD with S_v value

S.no	Servo Voltage	%age Deviation
1	35	0.55
2	40	0.15
3	45	0.25
4	50	0.25
5	55	0.15
6	60	0.20

In the next set of experiment the effect of wire feed rate was studied. The wire feed ranges from 2 m/min to 12 m/min in the steps of 2 m/min. The values of the other parameters were kept constant and their values are given as Ton = 109 unit; T_{off} = 36 unit; I_P = 2 ampere; S_V = 50 volt; W_T = 8 unit; SF = 2150 unit. The experimentally observed data for the performance measures for different values of wire feed is given in Table 5. The effect of the chance error has been neglected during the set of experiment.

Table 5: Percentage of DD with W_f value

S.no	Wire Feed	%age Deviation
1	2	0.30
2	4	0.70
3	6	0.65
4	8	0.90
5	10	0.50
6	12	0.85

In the last set of experiment the effect of the wire tension was studied. The experimentally observed data for the performance measures for different values of wire tension is given in Table 6.

Table 6: Percentage of DD with W_T value

S.No	Wire tension	%age deviation
1	420	0.40
2	540	0.25
3	660	0.30
4	780	0.35
5	900	0.50
6	1020	0.40
7	1140	0.50

Result and Analysis

The experiments are based on one factor experiment strategy. In this only one input parameter was varied however keeping all others input parameters at constant values. During this experimental procedure, different sets of experiments were

performed for different input parameters. After analyzing the results of the experiments performed, various facts derived into light. The effect of pulse on time (T_{ON}) on the output parameter is shown in Figure 4.

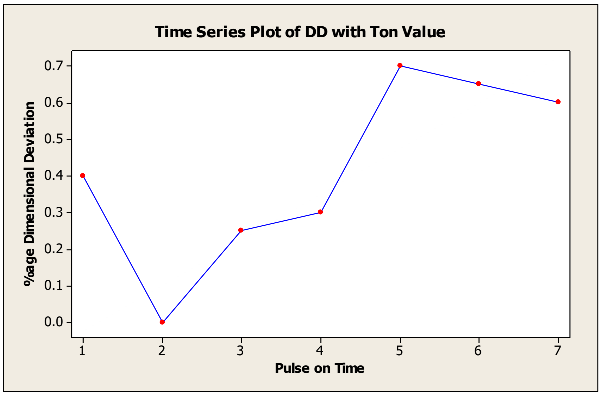

Figure 4: Effect of the pulse on Time of DD

The dimensional deviation shows an irregular pattern. It decreases first with pulse on time initially for few machine units of pulse on time and then settles into an increasing pattern with increase in pulse on time. For the second set of experiment the effect of decrease in pulse off time (T_{off}) on DD is shown in figure 5.

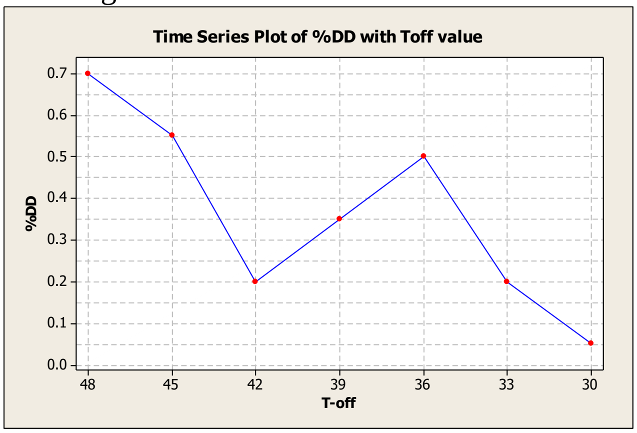

Figure 5 : Effect of the pulse off Time on % DD

The dimensional deviation though shows an irregular pattern.

For the Third set of experiment the effect of increase in servo voltage (S_v) on DD is shown in figure 6. The dimensional deviation is decreased initially with increase in servo voltage then remains constant.

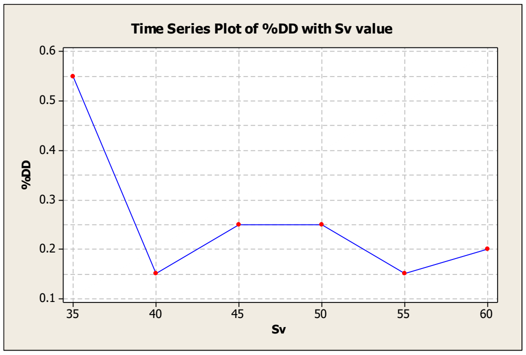

Figure 6: Effect of the servo voltage on Time on % DD

In the next set of experiment, the effect of wire feed rate (W_f) on the DD was studied in figure 7.

Figure 7: Effect of the wire feed rate on Time on % DD

The dimensional deviation first decrease drastically with wire feed and then increases further with increase in wire feed.

In the last set of experiment the effect of wire tension (W_T) was evaluated on DD. The figure 8 shows the effect of wire tension varied and there effect on DD. The DD remains in irregular character with increase in the wire tension.

Figure 8 : Effect of the Wire tension on % DD

Conclusions

The following conclusions are drawn on experimental study.

1. The parameter pulse on time increases the dimension deviation during intricate cutting of the specimen.
2. The increase in pulse off time shows a irregular pattern of dimension deviation in cutting specimen.
3. With decrease in servo voltage the dimensional deviation first decrease drastically with wire feed and then increases further with increase in wire feed.

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A review and analysis on new Practice in Maintenance Engineering: CMMS

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Abstract

The role of information technology is vital for plant maintenance optimization because it relies on the ability of the plant personnel to bring all data together in a coherent fashion for optimum analysis and decision-making. Computerized maintenance management systems (CMMSs) is a very helpful tool necessary for obtaining information from raw data and support the decision-making process. The computer program simplifies and reduces the time of data capture compared to the currently used paper-based reporting system. Special attention is given to Computerized Maintenance Management Systems (CMMSs), how this particular strategy was successfully implemented in a medium sized manufacturing company. The implemented CMMS aims to reduce total downtime and frequency of failures of the machines by improving the efficiency and effectiveness of the maintenance.

Keywords- Computerized Maintenance Management Systems (CMMSs), Maintenance Management Information Systems, Preventive Maintenance

1. Introduction

In order to stay competitive, it is necessary for companies to continuously increase the effectiveness and efficiency of their production processes. Production strategies such as Just in Time (JIT) and Lean Production demand high availability of production equipment in order to meet customer satisfaction. Therefore, maintenance has gained in importance as a support function for ensuring equipment availability, quality products, on-time deliveries, and plant safety. Maintenance though is a costly support function. It has been reported that as much as maximum of the total production cost can be spent on maintenance. Further, as much as one third of the cost of maintenance is incurred unnecessarily due to bad planning, overtime cost, limited or misused preventive maintenance. Within any organization where manufacture is the primary activity, it is crucial that procedures exist for equipment maintenance. Not only does equipment maintenance need to be planned for, the possibility and probability of breakdowns and disruption to operations must also be considered when planning and scheduling production. This paper examines the basis of various maintenance management strategies used to date in international manufacturing. These strategies assist the maintenance function and enable the process of maintenance to be optimized. Special attention is given to Computerized Maintenance Management Systems (CMMSs), how this particular strategy was successfully implemented in a medium sized manufacturing company.

2. Types of maintenance

Maintenance can be defined as a set of actions which are carried out to replace, repair and service an identifiable set of manufacturing components, so that the plant continuous to operate at a specified level of availability for a specified time. The main objective of Maintenance is to maximize the availability of machinery and equipments for production. Preserve the values of the plant, machinery or equipment by minimizing wear and deterioration. Accomplish the above goals most economically on a long term basis. By systematic maintenance it is possible to achieve substantial savings in money, material and manpower as every effort is directed towards avoiding disastrous failures.

2.1. Breakdown Maintenance

It implies that repairs are made after the equipment is failed and cannot perform its normal function anymore. It is a maintenance task performed to identify, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to an operational condition within the tolerances or limits established for in-service operations.

2.2. Scheduled Maintenance

It is any variety of scheduled maintenance to an object or item of equipment. Specifically, Planned Maintenance is a scheduled service visit carried out by a competent and suitable agent, to ensure that an item of equipment is operating correctly and to therefore avoid any unscheduled breakdown and downtime.

2.3. Preventive Maintenance

Its principle is "Prevention is better than cure and it has the following meanings. It provides them periodic/scheduled inspections and minor repairs to reduce the danger of unanticipated breakdowns. The care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection and correction of incipient failures either before they occur or before they develop into major defects. Maintenance including tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring. Wild (1995) draws the familiar total cost curve as in Figure 2.1, which shows that increased effort in preventative maintenance should reduce the cost of repair. If it were possible to define both of these curves, then it would be a simple task to determine the minimum cost maintenance policy. However, it is not as clear-cut as this and therefore maintenance policy is much more difficult to formulate

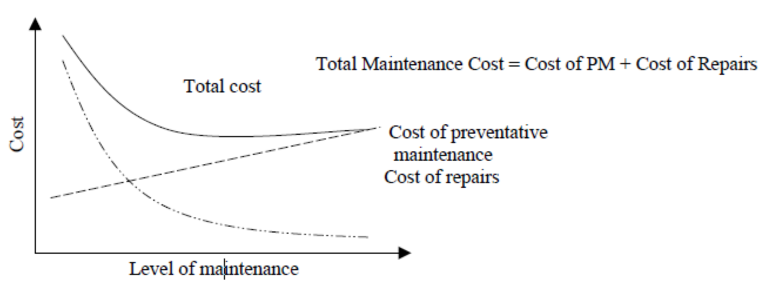


Figure 2.1 Maintenance Costs (Source: Wild, 1995)

The overall objective is to minimize the total cost of maintenance by minimizing one or both of the costs that contribute to it. Reducing the cost of preventative maintenance (PM) by minimizing the level of PM carried out in the manufacturing facility can increase downtime due to breakdowns and consequently necessitate the need for more repairs. On the other hand, increasing the level of PM to too high a level will introduce unnecessary extra maintenance cost without necessarily minimizing the risk of breakdown. The overall objective is to obtain an optimum level of preventative maintenance so as to reduce total maintenance cost. Achieving this optimum delivers other benefits such as increased morale, reduction in random breakdowns, improved quality of product, increased equipment availability, reduced delivery times and of course increases in profitability.

2.4. Condition-based Maintenance

Condition based Maintenance shortly called CBM, It is maintenance when need originate. This maintenance is executed after one or more condition indicators shows that equipment is going to cease functioning or that equipment performance become worse. This idea is applicable to critical machinery that incorporate active redundancy and fault reporting. It is also good for non-mission critical systems that lack redundancy and fault reporting. Condition-based maintenance was initiated to try to maintain the correct equipment at the correct time. CBM is based on using actual time data during process occurs to prioritize and effective use of maintenance resources Corrective Maintenance

2.5. Corrective Maintenance

It implies that repairs are made after the equipment is failed and cannot perform its normal function anymore. It is a maintenance task performed to identify, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to an operational condition within the tolerances or limits established for in-service operations.

3. New Practice in Maintenance Engineering

3.1. Computerized Maintenance Management system (CMMS)

Computerized Maintenance Management Systems (CMMS) are increasingly being used to manage and control plant and equipment maintenance in modern manufacturing and construction services industries. This view of the selection and implementation process can assist those who are considering CMMS for the first time, to decide their requirements. A number of years ago, the principles of CMMS were applied to hospital equipment maintenance, where critical breakdowns could lead to the development of life threatening situations. In recent years private companies have come to recognize the value of these systems as a maintenance performance and improvement tool. The advent of the PC during the last few years has further boosted their popularity. As more and more maintenance personnel become computer literate they are regarded as an increasingly attractive option. Companies are also investing in CMMS because they are generally designed to support the document control requirements of ISO 9002.Some of the standard functions available from a CMMS are discussed later in this document and those who have had no previous exposure to CMMS will find this useful. However, in essence, a CMMS may be used to

- Control the company's list of maintainable assets through an asset register.
- Control accounting of assets, purchase price, depreciation rates, etc.
- Schedule planned preventive maintenance routines.
- Control preventive maintenance procedures and documentation.
- Control the issue and documentation of planned and unplanned maintenance work.
- Organize the maintenance personnel database including shift work schedules.
- Schedule calibration for gauges and instruments.
- Control portable appliance testing. Assist in maintenance project management.
- Provide maintenance budgeting and costing statistics.
- Control maintenance inventory (store's management, requisition and purchasing).
- Process condition monitoring inputs

Computerized Maintenance Management system is relatively new type of maintenance it is making use of computer for rapidly and effectively controlling, planning and organizing various jobs for systematic plant maintenance. Computer aided maintenance planning & Computer aided maintenance planning control are the two major components of the computerized Management System(CMMS)

3.1.1. Computer Aided Maintenance Planning (CAMP)

This maintenance planning is based on gathering of large data or information and then subsequently to pull out job plans. Drawing out a plan does not involve any complex mathematical data but it is hugeness of data, which makes the manual work difficult in practically. One has referred to maintenance standards, the detail of history file and list of defect reports simultaneously to make a plan. Accessing many files and go through large data. As long as there is no need of new methods thinking, better to this difficulty of maintenance is computerization of all process. This is the basic method of CAMP

The second type of difficulty is the maintenance personnel who makes the plan faces is in record keeping. Manually writing down is very difficult task and it is creating data for the computer, but keeping safe the data and updating it more is lacking in variety job. Computers can effectively solve this problem. Thirdly preparing plans every time manually can be replaced by high speed printers of the computer system. If data is finalized planning and scheduling can be down without human effort. The main advantages of CAMP over manual system are:

- Timely detailed planning & scheduling.
- Maintaining minute details of equipment history.
- Accurate analysis of performance of equipment and easy managerial monitoring.

3.1.2. Computer Aided Maintenance Control (CAMC)

When the large quantity of data related with maintenance is entered into the computer and is control with the help of computer for getting various types of output, and then it is called Computer Aided Maintenance Control. In this all maintenance activities (maintenance schedules, Maintenance policies, maintenance standards, maintenance inventory &maintenance cost) are controlled by computers.

In today's age of industrialization, there are various types of industries such as: process industries, manufacturing industries, transportation, utilities etc. Though various types of industries may need little different maintenance system, all use of large amount of Men, Machine and Material and to manage this suitable 'Management' technique is needed for efficient and beneficial operations. Any good maintenance system may be adopted but, for more complex and bigger size of organizations, manual collection and analysis of following information and records for affecting ideal maintenance systems becomes extremely difficult and time consuming.

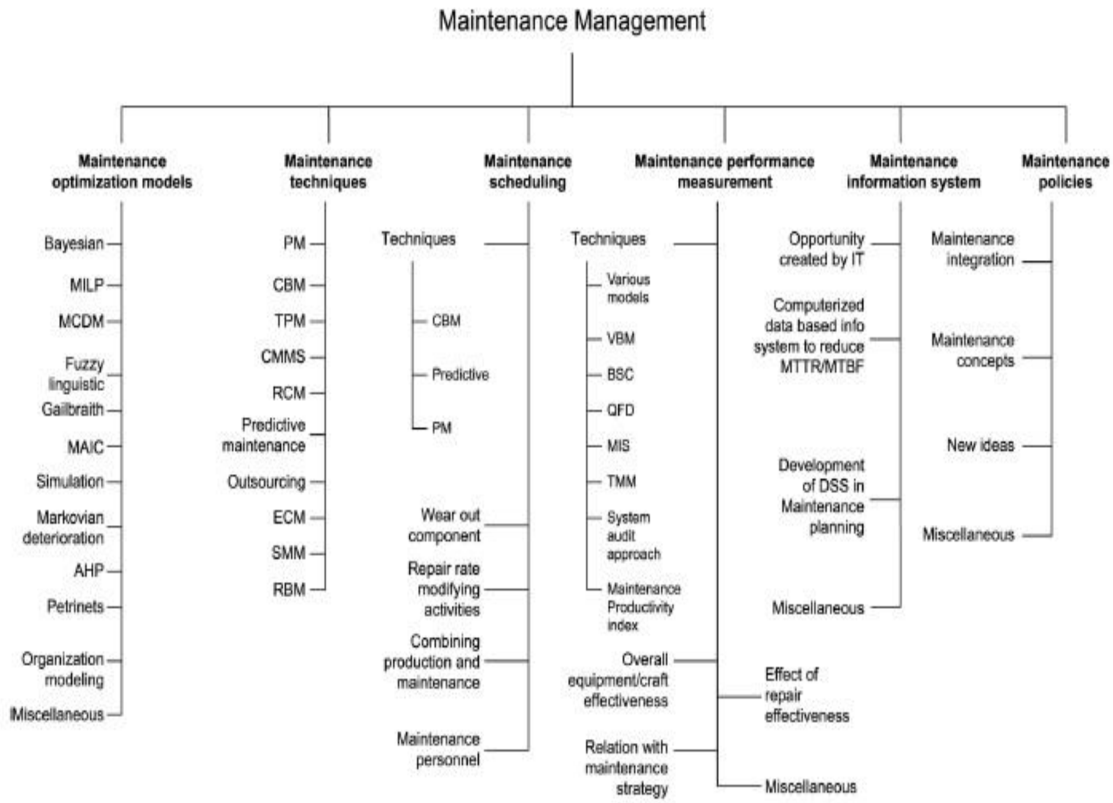
- Planning and scheduling of various tasks / action well in advance
- Correlating causes and defects and jobs done earlier etc.
- Correct and undistorted communication of equipment health, fault list and other information.
- Accurate and timely generation of information like jobs done, resources used, special problems faced, jobs not done etc.
- Some of main problems in achieving above mentioned features are the huge volume of data, monotonous type of job in data recording and storing manually, human error during repetition of manual work, difficulties in communication of information in different departments (like various concerned shop floors, store and purchase department, account department etc.).

Computerization of maintenance management system (CMMS) is the only answer for above mentioned problems. Huge amount of data is completely no difficulty for modern computers. The huge numbers of manual entries can be removed and total data can be stored centrally and safety taking a small space in a computer. The total data can be also be copied quickly and stores separately on hard disc so that, in case the data in computer gets accidentally removed or affected by virus, it can again be copied easily. Retrieval of any part of saved data does not consume any time. The only answer for problems like shortage of any employees, piracy of any work by various agencies and interdepartmental and intra department communication is computerization.

4. Literature Review

The aim of the literature review was to identify various researchers have said on computerized maintenance management system .A lot of research work has been done on different systems of maintenance planning and scheduling including 'Computerized Maintenance Management System 'taking the case studies of different industries. A few research activities reviewed in this field are as follows.

Chapman (1993) has stated that CMMS software was first introduced around 1976 .Now days it is extensively used by manufacturing industries around the world. Maintenance optimization is largely facilitated when industries choose a World Class Maintenance/ Manufacturing (WCM) management policy in joining with CMMS implementation. There may be many factors, which determine management on installing CMMS software and using it within the plants.



Notes: MILP: Mixed Integer Linear Programming; MCDM: Multiple Criteria Decision Making; MAIC: Materially per Apparecchiature de Impiariti Chemiei; AHP: Analytic Hierarchy Process; PM: Preventive Maintenance; CBM: Condition Based Maintenance; TPM: Total Productive Maintenance; CMMS: Computerized Maintenance Management Systems; RCM: Reliability Centered Maintenance; ECM: Effectiveness Centered Maintenance; SMM: Strategic Maintenance Management; RBM: Risk Based Maintenance; VBM: Vibration Based Maintenance; BSC: Balanced Score Card; MTTR: Mean Time to Repair; MTBF: Mean Time Between Failure; QFD: Quality Function Deployment; MIS: Maintenance Information Systems; TMM: Total Maintenance Management; DSS: Decision Support Systems; ECM: Electronic Counter Measures

Figure 3.1 Maintenance management classification tree showing various sub areas (Source: Garg et al,2006)

Corder (1993) has given an insight into the outlook of current plant maintenance practices. Maintenance management is very broad indeed, since almost all present engineering, accounting and management methods have importance to the subject". In order to make better the standard of maintenance and improving the efficiency of work expectations are being enforced on the maintenance employees in order to make better the standard of maintenance and improving the efficiency of work and in mean time reducing the maintenance operating costs.

Wireman (1994) has viewed that if Computer Maintenance Management Systems are to be properly examined it is essential to have an insight of the primary maintenance functions including: plant maintenance service and inspections, equipment installation, maintenance storekeeping. Author has gone on to outline the objectives of CMMS incorporating: improved maintenance costs, reduced equipment breakdown as a result of scheduled preventative maintenance, improved equipment availability, capacity to store and retrieve historical records to guide in the future planning and estimating budget of maintenance, to generate various maintenance reports quickly. Most of the computerized maintenance management systems have four sub features or components catering for:

- Maintenance order planning and scheduling.
- Inventory Control.
- Preventative/Predictive maintenance.
- Maintenance reports.

According to Wireman (1994) a team should head the recruitment process with employees from various department in industry for data processing. The aim of these committees includes:

- Record keeping units and paper work flow.
- Planning goals of the system in the areas of: Maintenance order processing, Spare stores, preventative maintenance, cost controls and maintenance reports.
- Understanding the classifications of computer systems that are needed.
- Understanding the vendor extension that meet the objectives
- Evaluation of systems and errors.

Trunk (1997) has described the following reasons for choosing CMMS software:

- Consumers insisted compliance with ISO 9000;
- Insurance industries insisted to know expenditure and condition of material handling equipments and assets.

Lamendola (1998) stressed the need to exclude non-value added activities especially with respect to computation of work within maintenance. He states that "this philosophy has long been the essence of Computerised Maintenance Management Systems." Travis and Casinger (1997) have marked the outline of other problems joined with modern maintenance management. In the paper they emphasize the top five problems encountered by maintenance employees and suggest that CMMS is the solution to these issues. The issues and solutions are mentioned below:

- Little or less support from management to implement world class maintenance practices, CMMS reports can draw attention the levels of downtime and reduce costs;
- Inventory problems, the need to reduce spare parts and still have parts on hand.
- Control of spares stock is part of most of the current CMMS packages
- The problems associated with maintenance staff excelling at some jobs and unskilled in other craft areas. CMMS allows managers to review this information, what work has been done and by who over a period and assign work appropriately in a variety of craft areas in the future.

Mweta and Mjema (2003) have revealed that application of CMMS is to monitor the maintenance tasks, Control material management, control of inventory spares, and interval inspection. It makes possible the maintenance staff to pull the defect records of all the equipments. It helps in retain all things up and continuously as without expensive as much extent possible where downtime is show directly in product costs. CMMS has very powerful tool include accounting, scheduling and predictive functions. Computer can also be used to find out the most effecting the cost of preventive maintenance interval the aim of the study is to claim quantitatively the effect of introducing PC in the maintenance department with regard to the reduce of operation cost, improving the products quality and productivity.

Fernandez et al. (2003) have investigated with the implementation of the computerized maintenance management systems can make simple and automate processes as a method to improve efficiency. (CMMSs). Recently it is helpful tool essential for finding information from raw data and help the decision-making process. CMMS will boost as the maintenance function moves from a reactive to a proactive culture. The implemented CMMS objective is to reduce total downtime and frequency of defects of the equipments by improving the efficiency and effectiveness of the maintenance schedule. The computer program make easier and reduces the effort to collecting the data as compared to the currently used computer-based reporting system. It also improves the maintenance planner's decision analysis function and support.

Gabbar et al. (2003) have given in sight of scope of computer-aided RCM-based CMMS solution to overcome some of the highlighted maintenance problems in old maintenance practices. The integration between RCM and CMMS can help in achieving that, as it will dynamically define the suitable and optimized maintenance strategy along with the required parameters for each detailed maintenance task. The developed activity and function models are useful to understand such solution and to analyze other plants with minor modifications saving analysis time.

Prendergas et al. (2004) have examined with CMMS implementation in active process prevent the expenditure of spares, reduce downtime, increased equipment availability and reliability, reducing lead times, increased confidence, proper scheduling of maintenance and more efficient of maintenance orders schedules. Facts of these helpful factors were supported by various key performance indicators, which were evaluated. These conclude of reduced maintenance expenditure in the inventory or spares, Sizeable increases in productivity could be seen in the department, where maintenance activity was very essential for production on due to the peak levels of hydraulic, pneumatic and electrical technologies being used there. Various costs such as Spares inventory costs, labor costs, equipment downtime costs, shutdown costs with CMMS implementation can also evaluated in the form of a revert of investment analysis.

Garg and Deshmukh (2006) stated that Computerized maintenance management systems (CMMS) provide capabilities to store retrieve and analyze huge amount of information. In this they defined, it might be expected that maintenance personnel would be the primary users of CMMS, an opportunity exists for a more broad use of CMMS by production personnel. Increased use of analysis and coordination capabilities and greater use of CMMS by personnel outside the maintenance function has the potential to improve maintenance responsiveness and equipment condition.RCM integration with CMMS has potential to be utilized in automated environment.

Sohrabi et al (2007) have proposed the requirement of maintenance in businesses, participate a vital role in backing up any knowing business and operation policies. It is need to increase the availability of equipment and systems. Maintenance includes the repair, replacement, and maintenance of machine in order to avoid unexpected failure during use. The aim of any Plant maintenance program is to reduce of the total expense of repair and inspection and equipment downtime. Maintenance operations have been expressed as a necessary cost that belongs to the operating budget. But since, organizational sources are restricted, prioritizing equipments for assigning resources is essential.

Khamba and Ahuja (2007) have outlined the importance of maintenance function as an important factor for reaching core competition in the manufacturing industry. It therefore becomes relevant for the prosperous industry to integrate maintenance and make better originates into their manufacturing policy for understanding of organizational objectives. Impressive Total Productive Maintenance implementation software can focus on addressing the maintenance problems in the organization, with a vision to make the best of equipment performance. It can be concluded that top management leadership, effective organization structure, adaptation of effective conventional maintenance are best procedures for the organization to compete efficiently in the dynamic condition.

Olsson et al. (2009) reported that successful implementation of Computerized Maintenance Management System in any industry required heavy support of management and also there need to get commitment from the employees involved in whole process to get right return on investment. The investment in modern software for maintenance management is an expensive project especially when one considers the money invested in purchasing, installing and software license costs. If particular organization considers the time and effort that needs to be provided in end user software training, building up the structure of the system and data or information gathering, then the running cost increase more than initial set up cost. Using standards to secure proper understanding and proper structures gives the platform for a more effective use of system.

Duran (2011) suggested that computerized maintenance management systems (CMMS) have become very common in now day's organization. The author proposed the methodology for choosing CMMS software. It reduced maintenance costs, increased production rate with proper utilization of resources. When purchasing a system, one that suits the specific needs and objectives of the company's maintenance operations should be preferred. Using CMMS is a highly relevant solution in a production environment where the number of critical equipment is high or where the need for maintenance resources management is significant.

Utne et al. (2012) presented the implementation of Computerized Maintenance Management System (CMMS) for measuring maintenance performance in the industry. The various indicators like volume, quality and utilization have been identified. Indicators measured the quality of work order, amount of maintenance work done in the system and calculated the performance. These indicators gave information about installed and executed planned maintenance work done during shut down. With CMMS using in industry the data quality in the system improved which benefited maintenance planning and scheduling, and effective utilization of unforeseen shutdowns lead to decrease the inventory cost in process plant.

Ramachandra et al. (2012) suggested that maintenance management system was one of solution to provide accurate and timely information to maintenance staff. CMMS could easily generate reports which help in day to day decision making in long term planning. It reduced down time, maintenance cost, inventory costs and increased productivity. Management system offered the capability to handle large quantity of data, maintained accurate records, updated them instantly with most recent information and did accurate calculating for more rapidly than human brain. Maintenance management should be effective so that there should not be any loss of production because of maintenance.

Aniki and Akinlabi (2013) proposed an effective maintenance method by considering the implementation of the Computerized Maintenance Management System (CMMS) in manufacturing industry. With effective usage of CMMS in industry reduced financial losses for repairs and saved production downtime. In this paper author suggested that appropriate maintenance of plant equipment and machinery reduced tendencies of injuries to personnel in working area, Effective work order planning and scheduling can extend the life cycle of plant and machinery in manufacturing industry. And in this paper steps to make effective job planning in particular manufacturing industry also highlighted.

5. Conclusion

One of the driving forces behind maintenance in manufacturing firms is the continuous improvement in technological development. The computer aided maintenance management information system has been developed keeping in mind the user requirement as the primary concern. This information system is designated to assist management in monitoring and controlling maintenance activities. The result of this information system is

- Proper recording of data/information.
- Generate a report which helps in day to day decision making and in long term planning.
- Reduction in down time.
- Reduction in maintenance cost.
- Increased productivity.
- Reduced inventory costs.
- Less paper work and fast access of information.

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Enhancing manufacturing Performance through lean practice from Supplier Perspective: An evidence from smaller enterprise in Northern India

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Purpose: The purpose of this paper is to uncover the significance of adopting Lean manufacturing practice in smaller enterprise dealing in manufacturing of rubber machinery located in Northern India.

Design Methodology/Approach: In this investigation a survey of the industry and interaction with people of the higher officials and on ground floor was carried on the shop floor. To tackle with supplier issues, SWOT analysis and previous records of the suppliers looked into. Then it was decided to implement the Supplier Management which is integral part of Lean Tools

Findings: Continuous scepticism about Lean practices on the shop floor was discovered there. Although the enterprise is in business for nearly four decades, the problem of coping with market pressure orders still prevalent there. A SWOT analysis of the enterprise carried out, then on the basis of that one, present scenario of the adopted practices depicted. This investigation led towards the certain areas where the enhancement can be done very straightforwardly. From there the issues concerned with the supplier noticed and examined. With the help of stakeholders majority of them were eradicated.

Research Limitations: The focus of the work was limited to certain area and selected variables were limited.

Practical Implications: Lean practices can be extended to other areas in the organisation.

Originality/Value: This is one of kind of the research where the enhancement of the firm in shorter period was noticed in span of five to sixth months.

Keywords: Lean Manufacturing, Smaller enterprises, Performance, Supplier Management

1. INTRODUCTION:

Rising Inputs, market volatility, delivery on time are the certain factors on the manufacturers mind for the enhancement and be in competition for survival in this era. Above consequences led towards a single solution for the all these complications, Lean Manufacturing is the only best answer for this. It's a set of practices that focuses for the enhancement of the organisation either in the form of waste eradication or cost cutting according to the need of the situation available there in the organisation. Lean manufacturing is a set of practices which targets to eradicate the waste from the system and improve the flow in the system. (Saini and Singh, 2015).

2. LITERATURE REVIEW:

Remarkable performance recorded for the four companies that embraced Lean after Liberalization (Pannizollo et al., 2012). Productivity enhanced after the adoption of lean practices in a spring manufacturing company (Mathur et al., 2013). JIT delivery was found to be crucial factor for the productivity improvement in case of bicycle industry (Singh et al., 2018). The bondation of TQM with TPM was investigated for enhancement in the production of the firms (Singh and Ahuja, 2014). Apart from automotive sectors and manufacturing ones, Lean was successfully implemented in finish furniture and boating sectors in Finland (Doroto Rymaszewska,, 2014)

3. PROBLEM FORMULATION: Quick response to new demands and competing in this era is the need of the hour for manufacturing industries. Simply, the goal is to enhance the performance by adopting newer methods, realizing organizational potential and embracing new market limitations. The possibility of rising to the occasion is only through adoption of Lean manufacturing practices. In context of Indian manufacturing industries, Large and medium enterprises have successfully reaped the benefits with lean practices. But scepticism about its applicability in smaller enterprise is factor to be looked at. Apart from budget constraint, smaller firms are under the pressure of rising imports in Indian region. The present study is focused on the smaller enterprise dealing in the manufacturing of rubber machinery located in northern India. The following objectives of the study are as follows:

- Existing practices inside the organisation
- To draw the Lean radar
- SWOT analysis of the organisation(for looking inside practices going within industry)
- Implementation of supplier management inside the organisation

4. METHODOLOGY

The organisation is a small scale enterprise named as XYZ LTD. located in Northern India dealing with manufacturing of rubber processing machinery with turnover less than 50 crores. This organisation is in business for almost thirty five years. After that the current practices of the organisation was explored and from there scepticism about working culture in the firm started to be vanished. The production is in batch order and it's directly with customer demand. The cost of the product of the cost is so high so it can't be made to stock. Around 60-70% of the parts of the machinery are through delivery by the suppliers as per orders. The quality of the raw material is tested on the machine by spark test and chip formation. Production process is done on Lathe and shaper machines.

The production undergoes various works under the dynamic leadership of production supervisor who is in service there for more than three decades. The firm is fully aware of its capabilities and its presence in the market. **The organisation believes in policy of "Customer is king"**. Although it's hard to find any quality certifications in the organisation, but firm believe on its bonded customers for no. of years. The rejection rate of the firm is less than 4-5%, but the responsibility of failure analysis is strongly present there. Looking at the no. of the constraints inside the organisation, it was decided to develop a SWOT analysis. Looking at the competitive market, some improvement areas still prevails there for futuristic growth.

After the survey inside the organisation for the existent practices going on, it was decided to looking into the lagging factors where the enhancement in shorter period is possible. Looking at all possibilities and other constraints inside the organisation the practice of supplier management was chosen off randomly. Then after that the previous track record, delivery, bonding and reliability of the supplier is recorded there for a year. From that crucial analysis the factor of multiple suppliers and risks associated with them cropped up. Then organisation decided to go for multiple suppliers with on time deliveries in peak season for improving productivity. This issue was also made aware to the shop floor workers through shorter training period for 10-15 days.

Table 1: Representation of Lean practices and their scores

Lean parameters(Saini and Singh, 2018)	**Score(Likert scale 1-5)**
5S	2
JIT delivery	3
Kaizen	2
TPM	1
PM	2
Kanban	1
Takt time	2
Supplier management	3
Training and Teamwork	2
Statiscal Process control	1
Quality control	2
Single minute exchange of dies	1

Table 2: Depiction of Demand rate and Takt time for particular period

Month/year	**Demand**	**Production rate**	**Takt time**	**Remarks for supplier**
Jan 2018	4	4 machines	Equals the rate of production	Old supplier track record examined
February 2018	4	4 machines	Equals	Supplier Relations looked
March 2018	5	4 machines	Lagged in absence of forecasting and supplier's reliability	Bonding, Reliability factor tested
April 2018	4	4 machines	Equals	New Supplier added for
May 2018	5	4 machines	Multiple supplier added	Location and delivery rate increased
June 2018	4	5 Machines	Forecasting and supplier relations enhanced	Increase production

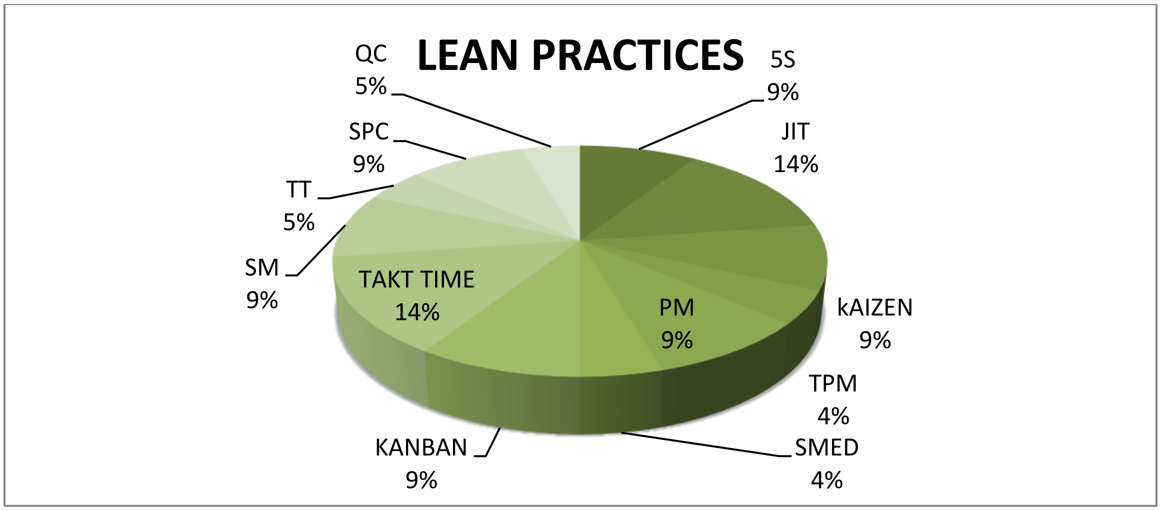

Fig. 1. Lean Practices in dispersed manner

Table 2. SWOT ANALYSIS:

STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Vision	Quality certification	Market survey	Presence of competitors
Old employees	Functional standardization	Competitive cost	Existence of Chinese products
Bonding with customers	Age of employees	Rewards and Recognition	Up gradation of technology with time
Market Image	Skilled professionals		
Focus on improvement areas	Absence of Training programs		
Multitasking employees	Accuracy		
	Waste recognition		
	Absence of statiscal tools		
	Customer satisfaction rate		
	Process improvements		
	Supplier relations		

RESULTS AND DISCUSSIONS:

Numerous articles, case studies reported in the journals for the benefits obtained at the level of lean implementation in the industries. Lean manufacturing practices is the optimal solution for the firms who are in search of performance enhancement methods apart from giving them competitive edge. Although from the array of Lean tools, viability for implementation of all tools is out of reach for the smaller business, but providing them Lean strategy according to the nature of the product, type of production order and volume is the need of the hour (Saini and Singh, 2015). Looking inside the organisation for existing practices, various issues related with suppliers cropped out. Then the previous track record of supplier reliability, bonding, risks associated and on time deliveries analysed. The product nature was 60-70% dependent upon the supplier for on time delivery.

CONCLUSIONS:

This is a study of its first kind where the performance of organisation improved with the application of supplier management. Supplier management is part from the set of lean practices where the hidden waste from the system is invisible. The existing practices inside the organisation were looked for tracing out the roots of the waste and lagging factors of the organisation. From the previous demand rate at the same period, it was decided for improving the flow and increases the production rate forecasted. The production rate from the 4 machines increased to 5 machines at the same time interval with the implementation of supplier practices. It was convincing for the stakeholders of the organisation looking for increasing market share and hiking the image of the organisation in the market.

Suggestions for further research:

Another lean practice like kaizen, TPM can be used for cost reduction and enhancement in the organisation.

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Analysis of Wire Electrode Wear Ratio in WEDM of Al-MMC

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Abstract

In this study, investigation on wire wear ratio (WWR) during wire-cut electric discharge machining (WEDM) of Al-metal matrix composite is carried out. WWR prediction model in terms of process parameters has been developed using response surface methodology based Box–Behnken's design.An attempt has been made to obtain the quality of machining through identify the optimum machining conditions for minimum WWR. The variation of surface roughness height (R_a) and spark gap width have also been investigated in relation to the WWR. The surface morphology of selected wire electrode surfaces havealso been studied through scanning electron microscope. The test results indicate that that the high value of WWR has been accompanied with poor surface quality and inaccuracy of machined components.

Keywords: wire-cut electric discharge machining, wire electrode wear ratio, metal matrix composites, scanning electron micrographs, analysis of variance, response surface methodology

1. Introduction

Recently metal matrix composites (MMCs) are replacing the monolithic materials because of their excellent mechanical properties particularly in terms of its wear, strength, and stiffness. These materials have gained importance in various fields like automobile, defense, aerospace, and sports [1]. However, the presence of hard reinforced SiC particles in MMCs makes it difficult to machine using conventional machining methods due to its abrasive nature [2]. Wire-cut electric discharge machining (WEDM) is a well known non-conventional machining process, can be effectively used for machining of MMCs. It is considered as an effective and economical tool for the machining of MMCs [3]. In the WEDM process, a traveling wire electrode is used to cut complex contour in the required workpiece. The wire is wound and kept in constant tension. The wire feed system consists of a large spool of wire and rollers which direct the wire through the machine.

From the available published research work on WEDM, it is identified that major work was focused on improving the output response variables such as cutting speed, the surface roughness (R_a) and kerf width for machining of MMCs on WEDM. However, the analysis of wire electrode wear ratio (WWR) is very much important especially for effective machining of MMCs. Tosun and Cogun [4] examined the effect of process parameters on WWR in WEDM of AISI-4140 steel and modeled statistically by using regression analysis techniques. Authorsconcluded that the high WWR is always accompanied with high material removal rate and high surface roughness heights (R_a) values. Yan et al. [5] studied the effect of percentage of reinforcing particle on wire electrode wear during machining of Al_2O_3p/6061Al composite. Author's claimed that the increase in percentage of reinforcing Al_2O_3 particles in MMCs produces deeper and wider craters on wire electrode surface thereby frequently wire breakage occurs during machining. Patil et. al. [6] investigated the effect of type of wire electrode material and %vol. the fraction of reinforcement on output responses during WEDM of A359/SiC-MMC. In their study, they found that the use of coated wire electrode as compared to brass wire improved the cutting speed and kerf width but loosen the machined surface quality.

Pramanik and Basak [7] explored the effect of reinforced particle size (0.7, 3 and 13 µm) on the degradation of wire in WEDM of MMCs. Authors reported that the diameter of the electrode wire was decreased nonlinearly with the increase of reinforced particles size after machining.

From the review of literature and detail experiments in machining of Al/SiC$_p$-MMC, it was realized that there are possibilities of improvement in performance of the WEDM process by minimizing the wire electrode wear through optimization of process parameters. Because of many parameters and stochastic nature of the WEDM process, achieving the minimum WWR is a challenge. An effective way to solve this problem is to develop a relationship between the WWR and process parameters that can help to select the setting of parameters in advance for effective machining of MMCs. Keeping in view; experimentally acquired results are utilized to develop a mathematical relation for WWR. The level of significance of process parameters has been determined using analysis of variance method. In addition to this, a variation of important response variables such as surface roughness height, R_a and spark gap width have also been investigated in relation to the WWR. The surface morphology of selected wire electrode surfaces has been studied through scanning electron microscope.

2. Experimental details

The experiments have been carried out on a four-axis Electronica Sprintcut CNC-wire cut EDM machine tool. The brass wire of 250 µm diameter was used as wire electrode. The machined workpiece dimension was 5mm x 5mm x 15mm. Based on a review of literature and pilot experiments, variables such as pulse on-time (T_{on}), pulse off-time (T_{off}), spark gap voltage (SV), peak current (Ip), wire feed rate (WF) and wire tension (WT) were considered for experimental investigation. The Al/SiC$_p$-MMC used as workpiece material. Table.1 represents the chemical composition of Al/SiC$_p$-MMC workpiece used for the experimental investigation. The WWR is considered as output response characteristics. The WWR is calculated based on loss of wire weight after machining divided by the weight of fresh wire before machining. For each trial 15m length of wear out wire is weighted and loss of weight was calculated.The initial and final weights of the wire electrode are measured on Citizen Model (CX120) digital weighing machine having a resolution of 0.1mg.

For the design of experiments, six factor-3-level Box-Behnken design (BBD) of RSM has been employed for setting the parameters during machining of MMC. The BBD is very efficient in RSM for fitting the second order model with a smallest possible number of experiments [8]. Table.2 represents the setting of six process parameter with their levels, units, and notations as considered for experimentation.

3. **Results**

The 54 experimental are carried out at different combinations of input parameters as per BBD. Minitab-16 software is utilized for analysis.

3.1 Regression modeling for electrode wire wear ratio

Considering 6 variables and based on the experimental data acquired from 54 experiments, the regression model for WWR is developed. The developed quadratic regression model for WWR to correlate the wire wears with various predominant WEDM process parameters as follows,

$$WWR = 0.059145 + 0.021910 * Ton - 0.011408 * Toff - 0.008203 * SV + 0.010011 * Ip - 0.002317 * WT - 0.005132 * WF + 0.0034 * SV^2 + 0.003644 * Ip^2 + 0.005313 * WT^2 - 0.008001 * (Ton * SV) + 0.004286 * (Ton * Ip) - 0.003807 * (Ton * WF) + 0.004495 * (SV * Ip) \quad \text{(Eq.1)}$$

The developed regression model can be effectively utilized to predict of WWR in advance without experimentation under various parameter settings.

3.2 Analysis of variance and model fitness test

The analysis of variance (ANOVA) has been done to check the adequacy of the model and to determine the level of significance of process parameters on WWR. Table.3 represents the ANOVA for the reduced quadratic model for WWR. The linked P value of the model is less than 0.05 (i.e. α=0.05 or 95% confidence) indicating that developed model is significant. The calculated P-value for lack of fit (0.122) is found to be insignificant, as it is desired. From Table.3, it is clear that all considered variables affect directly or indirectly by means of interactions, the WWR indices. The coefficient of determination (R^2) is a measure of goodness of fit, which is defined as the ratio of explained variation to total variation. Residual plot (Fig.1-a) for WWR confirm that there is no severe departure from normality. The residuals do not show any noticeable pattern and are distributed in both positive and negative directions. This implies that the model is adequate and hence can be used to navigate the design space.

3.3 Optimization of machining conditions

Minitab-16 software has been used to obtain the optimal parametric combination for minimum WWR using desirability function approach. The optimal solution for minimum WWR is reported in Table.4. A set of three experiments were carried out with randomly selected process parameters to verify the prediction ability of the developed WWR model. Table.5 represents the validity test results, predicted values based on developed model and percentage of error. The percentage error between the experimental and the predicted values of WWR is found to be very less which clearly demonstrates the accuracy of the developed model.

4. **Discussion**

4.1 Main and interaction effects of WEDM parameters on WWR

Fig.1 shows the parametric effects and residuals plot for WWR. From Fig.1 (b), it is observed that the WWR increases almost linearly from 0.042 to 0.086 with an increase in pulse on-time from 0.6µs to 1.2µs. The WWR also increases and seems to vary from 0.055mm to 0.076mm with an increase in peak current (Fig.1(c)). Fig.2 shows the SEM images of fresh wire electrode surface and wear out wire electrode surfaces obtained during experiments before and after WEDM of Al/SiC_p-MMC. From SEM images, it is identified that the erosion craters and indents are formed on the wire electrode surface. The erosion craters become wider and deeper on wire electrode surface with an increase of pulse on time and peak current. As results of this, the tensile strength of electrode wire decreases which results into wire breakage. The experimental results explained through SEM images are also in agreement with the experimental measured value of WWR.

The effect of pulse off-time on WWR is shown in Fig.1(d). As a general trend, an increase in pulse off-time reduces WWR. A higher value of pulse off-time leads to low pulse frequency as a result WWR reduces. Insufficient pulse off-time does not allow efficient flushing, and so, it may cause arcing, which deteriorate the surface quality of machined surface and also enhanced WWR. From Fig.1 (e)) it is clear that increasing wire feed

Table 1 Composition of Al/SiCp-MMC used for experiment

Type of MMC	Type of reinforced particle	% SiC	% Cu	% Mg	% Si	% Fe	% Mn	% Ti	Rem -aining
Discontinues MMC	SiC (APS:37μm)	10	0.02	0.62	0.49	0.32	0.12	0.01	Al

Table 2 WEDM process parameters with their levels

S. No.	Machine parameter	Notation	Units	Level		
				-1	0	1
1	Pulse on time	T_{on}	μs	0.6	0.9	1.2
2	Pulse off time	T_{off}	μs	16	22	28
3	Spark gap set voltage	SV	V	20	30	40
4	Peak current	Ip	A	120	150	180
5	Wire tension	WT	g	850	1000	1200
6	Wire feed	WF	m/min	6	8	10

Table 3 ANOVA for quadratic model of wire wear ratio

Source	Sum of Squares	DF	Mean Square	F value	Prob > F	R-square
Model	0.020908	13	0.001608	53.70	0.000	R^2= 0.94 Adj R^2=0.92 Pred R^2=0.89
T_{on}	0.011521	1	0.011521	384.66	0.000	
T_{off}	0.003123	1	0.003123	104.28	0.000	
SV	0.001615	1	0.001615	53.92	0.000	
Ip	0.002405	1	0.002405	80.31	0.000	
WT	0.000099	1	0.000129	4.30	0.045	
WF	0.000632	1	0.000632	21.10	0.000	
SV^2	0.000036	1	0.000139	4.63	0.037	
Ip^2	0.000071	1	0.000159	5.32	0.026	
WT^2	0.000322	1	0.000322	10.74	0.002	
T_{on} .SV	0.000512	1	0.000512	17.10	0.000	
T_{on} . Ip	0.000294	1	0.000294	9.81	0.003	
T_{on} . WF	0.000116	1	0.000116	3.87	0.056	
SV * Ip	0.000162	1	0.000162	5.40	0.025	
Residual	0.001198	40	0.000030			
Lack of Fit	0.001141	35	0.000033	2.84	0.122	
Pure Error	0.000057	5	0.000011			

Table 4 Optimization results through desirability functions approach

Sol. no.	Machine input parameters						Response Variable	Composite desirability
	T_{on} (μs)	T_{off} (μs)	SV (V)	Ip (A)	WT (g)	WF (m/min)	WWR	
1	0.6	28	36	120	1062	10	0.0205	0.99

Table 5 Confirmation experiments and results

Sol no.	Machine input parameters						Experimental WWR	Predicted WWR	Prediction Error (%)
	T_{on} (μs)	T_{off} (μs)	SV (V)	Ip (A)	WT (g)	WF (m/min)			
1.	0.6	28	40	120	1000	10	0.023	0.0211	8.26
2.	1.2	22	30	180	850	8	0.111	0.1126	1.44
3.	0.9	16	20	150	1200	6	0.095	0.0903	4.94

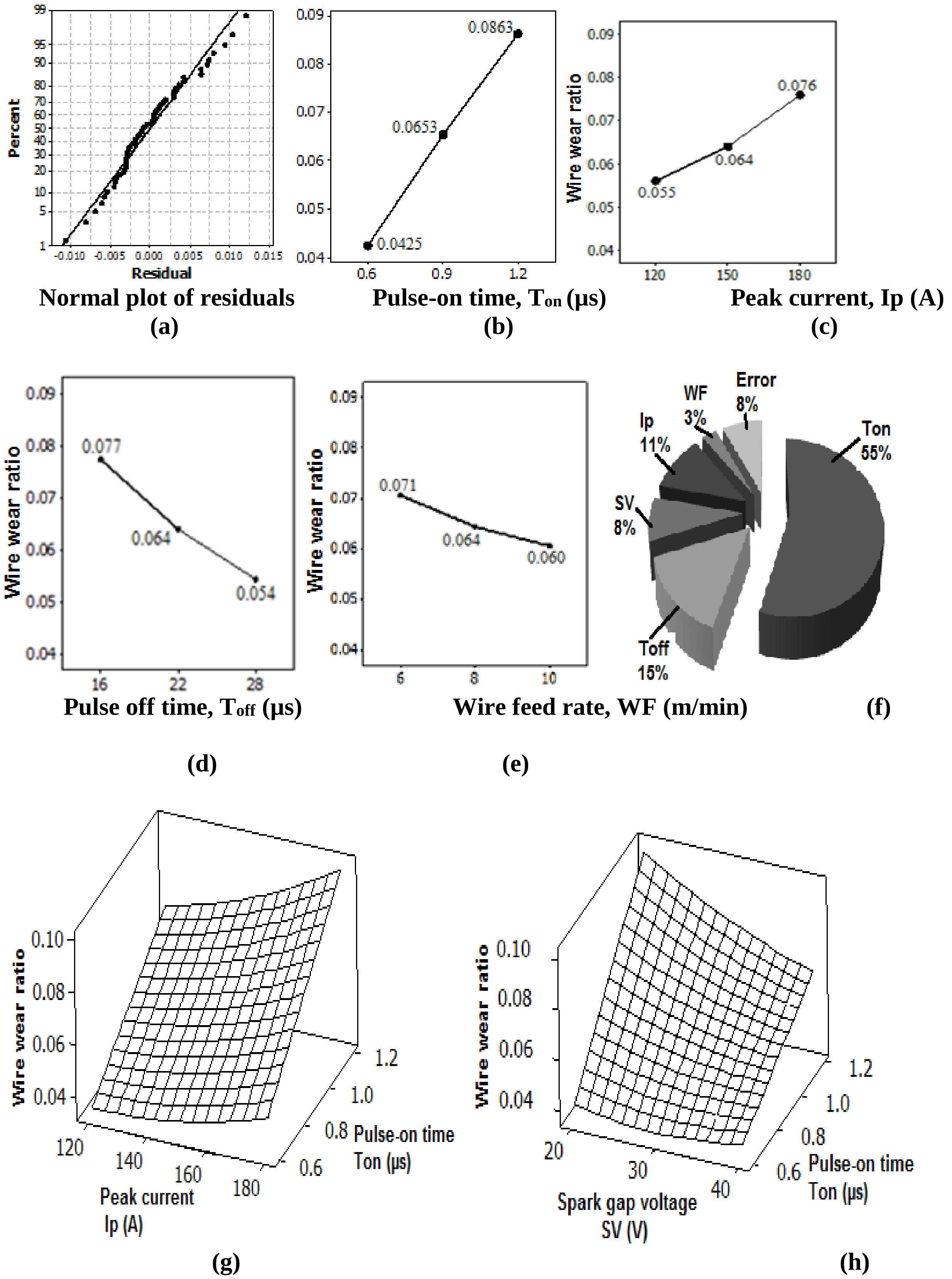


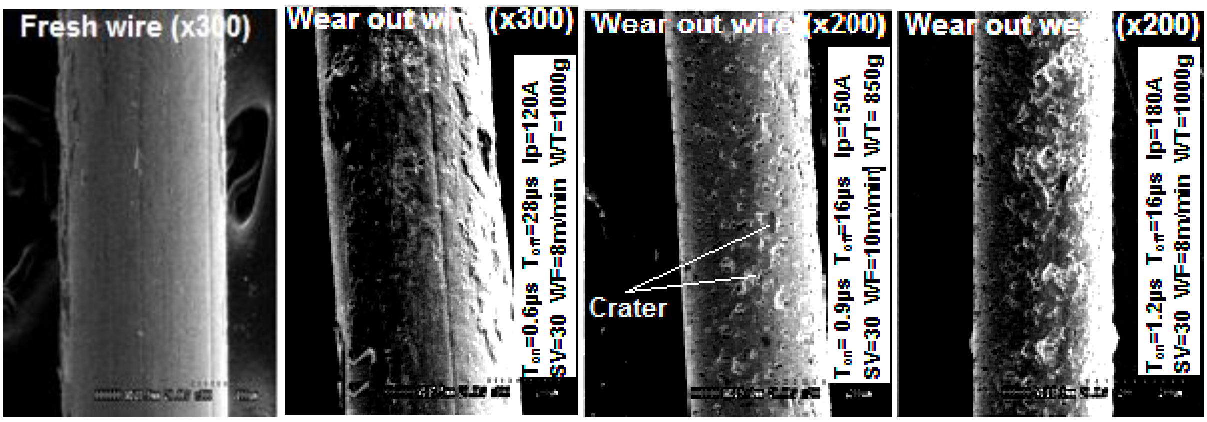
Fig. 1 Direct, interaction and residuals plot for wire electrode wear ratio; (a) Residuals plot, (b-e) Main effects of process parameters, (f) Contribution of significant parameters, (g-h) Interaction Plots

rate decreases WWR. Again the increasing of wire speed enables the brass wire to bear lesser spark energy per unit time which results as lesser no. of craters on the wire surface per unit length and hence lessen WWR. It is found that increasing spark gap voltage decreases the WWR. This may be due to the fact that at a higher value of spark gap voltage, the gap between the workpiece and wire electrode widens hence eroded lesser volume of material from wire surface thereby reduces WWR. The percentage of contribution of significant parameters is shown in Fig.1 (f). Pulse on-time is the major parameters affecting the WWR (55%). The percentage contribution of pulse off-time, peak current and spark gap voltage on WWR are 15%, 11%, and 8% respectively.

Fig. 1(g) shows the interaction plot for WWR in relation to parameters spark gap voltage and pulse on-time. From Fig.1 (g), it is clear that WWR increases with increase in pulse on-time for all values of peak current. The minimum WWR can be achieved at the lowest values of pulse on-time (0.6 µs) and peak current (120A). Fig.1(h) depicts that the WWR decreases with increase in spark gap voltage and at the highest value of pulse on-time (1.2 µs) considered for experiments but reasonably constant at the lowest value of pulse on-time (0.6 µs) which indicated a significant interaction between spark gap voltage and pulse on-time.

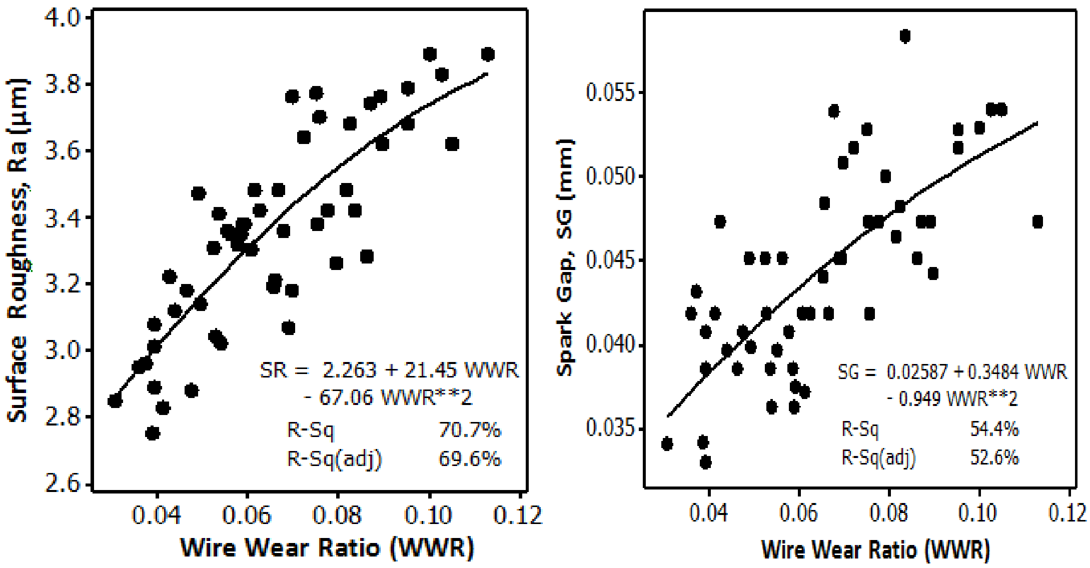
4.2 Relation of WWR with surface roughness and spark gap

Fig.3 shows the variation in surface roughness height (R_a) and spark gap width (mm) in relation to the WWR. Each dot in Fig.3 represents the value of WWR for each and individual experimental run corresponding to surface roughness height (R_a) and spark gap width. It is clear that that the high value of WWR has been accompanied with high surface roughness height (R_a) and a high value of spark gap width. Spark gap width signifies the degree of precision and determines the accuracy of the machined components. It can be noticedthat although the new wire is continuously exposed in the machining zone still wire electrode wear during machining is an issue to be addressed because it affects surface quality and accuracy of the machined components.



a) Fresh wire electrode **b) WWR = 0.031** **c) WWR = 0.820** **d) WWR =0.100**

Fig.2 SEM images of wire electrode surface after machining of Al/SiC$_P$-MMC for different cutting conditions



(a) **(b)**

Fig.3 Fitted line plot of a) Surface roughness (R_a) versus WWR b) Spark gap width versus WWR

5. Conclusions

The experimental study has led to the following conclusions.

1. The results clearly reveal thattheWWR increases with increase in pulse on-time and peak current. Again WWR decreases with increase in pulse off-time and spark gap voltage.
2. Percentage contribution of pulse on-time on WWR has been found to be 55%, which clearly indicates that pulse on time is the most significant parameter affecting the WWR. The parameters peak current (contribution of 15%), spark gap voltage and wire feed rate (contribution of 11%) are the significant parameters for WWR.
3. The developed regression model for WWR can be used for effective machining of Al/SiC$_p$-MMC by proper selection of process parameters in advance. The validity test results also proved that the developed model for WWR is bear a good agreement with experimental results.
4. The most optimal results for WWR was found when machining operation was carried out at 0.6µs pulse on time, 19µs pulse off-time, 120A peak current, 40V spark gap voltage, 1200g wire tension and 8m/min wire feed.
5. It has been established experimentally that the high value of WWR accompanied with high surface roughness height (Ra) and a high value of spark gap width. Hence, the surface quality and accuracy of machined components can be improved by reducing the WWR during machining.

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Electrical Discharge Machining: A Study on Recent Areas of Research

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Abstract:

Electrical discharge machining (EDM) is one of the oldest non-conventional machining processes. EDM process works on the principle of occurrence of thermoelectric energy between the work piece and an electrode. A pulse discharge occurs in a small gap between the work piece and the electrode and removes the unwanted material from the parent metal through melting and vaporising. EDM can be used for improving finishing of automotive industry components, surgical components and dies and moulds. This paper reviews the research in electrical discharge machining and research trends in EDM on ultrasonic vibration, dry EDM machining, EDM in water.

Keywords: EDM, thermoelectric energy, ultrasonic vibration

Introduction:

Electrical discharge machining is the thermal erosion process in which metal is removed by series of recurring electrical discharges between a cutting tool acts as an electrode and a conductive work piece, in the presence of dielectric fluid. Heat from the discharge vaporizes minute particles of work piece material, which are then washed from the gap by the continuously flushing dielectric fluid. There are various types of products which can be produced by using EDM, such as dies and moulds. Today, many parts used in the aerospace and automotive industries and in the final processes of surgical can be finished by the EDM processes.

This technique has been developed in the late 1940s where the process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses, chatter and vibration problems during machining. Materials of any hardness can be cut as long as the material can conduct electricity. EDM technique the working principle of EDM process is based on the thermoelectric energy. This energy is created between a work piece and an electrode submerged in a dielectric fluid with the passage of electric current. The work piece and the electrode are separated by a specific small gap called spark gap. Pulsed arc discharges occur in this gap filled with an insulating medium, preferably a dielectric liquid like hydrocarbon oil or de-ionized (de-mineralized) water. Schumacher described the technique of material erosion employed in EDM as still arguable .This is because ignition of electrical discharges in a dirty, liquid filled gap, when applying EDM, is mostly interpreted as ion action identical as found by physical research of discharges in air or in vacuum as well as with investigations on the breakthrough strength of insulating hydrocarbon liquids have developed in many areas.

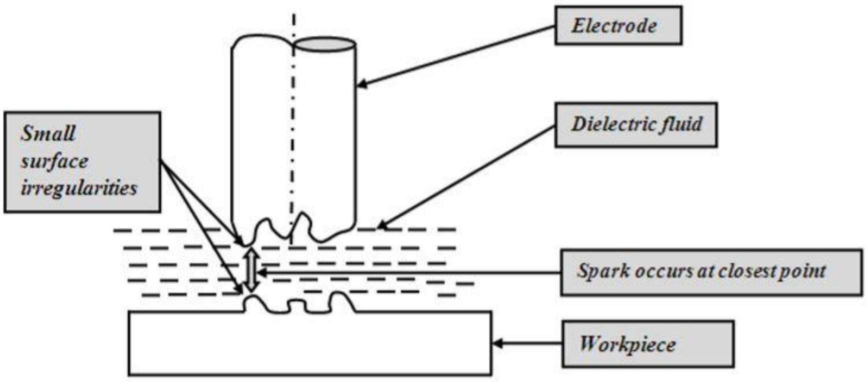

Figure 1: Working principle of EDM

Literature Survey:

In EDM processes, which was first discovered in the late 1940s [1], the electrical energy is applied to the machining gap to produce periodic discharges. Recently, EDM is used widespread in industry because it has a good accuracy and precision. One of the advantages of EDM is that the machining processes are independent on the hardness of work piece materials. Thus, all materials can be machined as long as they are conductors such as: metals, metallic alloys, graphite, or even some ceramic materials [2]. Since the process will machine all materials that are electrically conductive, then extremely hard metal could be machined by material which has lower hardness, such as brass and copper [3].

However, EDM has many drawbacks. The accuracy of the work piece produced by EDM is affected by tool electrode wear and it will make the shape compensation become difficult. It is also very difficult to fully determine the effect of process parameters such as charge voltage and capacitance because of the stochastic thermal nature of the EDM process [4].

Other drawbacks are adhesion, short circuiting and cavitation which occur frequently, making the discharge pulse unstable and machining time become excessively long. Adhesion occurs when the melted component of the work piece becomes attached to the tool electrode, causing the discharge pulse to become unstable as a result of short-circuiting between the work piece and tool electrode, and inhibiting the insulation recovery of the EDM machine. The monitoring system is necessary to observe these phenomena. Pham *et al*.[5], have described the problematic area in EDM processes, which are handling, electrode and work piece preparation, machining processes, and measurement.

The present paper presents the recent trends in the EDM processes in regard to overcome these problems.

A. EDM using Ultrasonic Vibrations:

In EDM, ultrasonic vibrations of the electrode can improve the process. Firstly, the high frequency pumping action of the vibrating surface of the electrode accelerates the slurry circulation, giving smaller machining times (up to 5 times less for finishing operations). Secondly, the great pressure variations in the gap lead to more efficient discharges, which remove more melted metal from every crater. The affected layer is reduced, thermal residual stresses are modified, less micro-cracks are observed (and they are smaller): fatigue resistance is increased, by ratio up to 6 times. Effects on other parameters are also observed (relative wear, surface roughness, hardness). Ogawa et al proved that the depth of microholes by EDM with ultrasonic vibration becomes as about two times as that without ultrasonic vibration and machining rate increased.What seems the more important is the ability of working without instability, particularly when the gap is narrow. In 1995 [6]Zhixin et al has developed an ultrasonic vibration pulse electro-discharge machining (UVPEDM) technique to produce holes in engineering ceramics material. They have confirmed by experiment that this new technique is effective in obtaining a high material removal rate (MRR).

B. Dry EDM Machining

Dry EDM is a 'green' environment friendly EDM technique in which instead of mineral oil based liquid dielectric, gas at high pressure is used as the dielectric medium. Some added advantages are lower tool wear, lower residual thermal stresses and higher precision. However, the major roadblocks in its commercialization have been the low material removal rate (MRR) and poor process stability. In dry EDM, tool electrode is formed to be thin walled pipe. High-pressure gas or air is supplied through the pipe. The role of the gas is to remove the debris from the gap and to cool the inter electrode gap shows the principle of dry EDM. The technique was developed to decrease the pollution caused by the use of liquid dielectric which leads to production of vapour during machining and the cost to manage the waste.

Reasons prompting dry EDM Research:

Dry EDM is a completely 'green' machining process (in terms of health, safety & environmental reasons)

Factors favouring dry EDM:

- No fire hazard
- No toxic fumes generated
- No need for special treatment for disposal of waste, filter cartridges, etc.
- Higher Precision
- Very low tool wear
- Thinner white layer and lower residual stresses
- Narrower discharge gap length
- No electrolytic corrosion of w/p (as compared to water based dielectrics)

Major disadvantages:

- Low material removal rate (MRR)
- Poor process stability

C. EDM with powder additives:

Fine abrasive powder is mixed into the dielectric fluid. The hybrid material removal process is called powder mixed EDM (PMEDM) where it works steadily at low pulse energy [7] and it significantly affects the performance of EDM process. Electrically conductive powder reduces the insulating strength of the dielectric fluid and increase the spark gap between the tool and the work piece. EDM process becomes more stable and improves machining efficiency, MRR and SQ. However, most studies were conducted to evaluate the surface finish since the process can provide mirror surface finish which is a challenging issue in EDM. The characteristics of the powder such as the size, type and concentration influence the dielectric performance [8].

D. EDM in Water:

Water as dielectric is an alternative to hydrocarbon oil. The approach is taken to promote a better health and safe environment while working with EDM. This is because hydrocarbon oil such as kerosene will decompose and release harmful vapour (CO and CH4). Research over the last 25 years has involved the use of pure water and water with additives.

Pure Water:
The first paper about the usage of water as dielectric was published by Jeswani in 1981. He compared the performances of kerosene and distilled water over the pulse energy range 72–288 mJ. Machining in distilled water resulted in a higher MRR and a lower wear ratio than in kerosene when a high pulse energy range was used [9]. With distilled water, the machining accuracy was poor but the surface finish was better. The best machining rates have been achieved with the tap water and machining in water has the possibility of achieving zero electrode wear when using copper tools with negative polarities.

Water with Additives:
Koenig and Joerres reported that a highly concentrated aqueous glycerine solution has an advantage as compared to hydrocarbon dielectrics when working with long pulse durations and high pulse duty factors and discharge currents, i.e. in the roughing range with high open-circuit voltages and positive polarity tool electrode. Some researchers have studied the feasibility of adding organic compound such as ethylene glycol, polyethylene glycol 200, polyethylene glycol 400, polyethylene glycol 600, dextrose and sucrose to improve the performance of demonized water. The surface of titanium has been modified after EDM using dielectric of urea solution in water. The nitrogen element decomposed from the dielectric that contained urea, migrated to the work piece forming a TiN hard layer which resulting in good wear resistance of the machined surface after EDM.

Conclusion:

Micromachining is facing new challenges with the constantly growing demand for smaller, more accurate structures in new, emerging materials. Electro discharge machining has the potential to fulfil those needs in hard to machine materials. The application of hybrid processes to enhance stability by influencing the flushing and discharge gap state has shown great potential in the machining of conducting materials. Thus all EDM machining trends using ultrasonic vibrations, water, Dry EDM, with powder additives shows great potential and help increasing the precision, accuracy and efficiency of the EDM process.

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Design and Modeling of Tuned Mass Damper System of Machine Platform for Attenuating Vibration

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Abstract

The design and modeling of the machine platform based on spring damper system is presented in this paper. The proposed design is used to reduce vibration of the machine platform. The modeling of the system is done by using Bondgraph approach. The expressions for the optimum spring and damping constant of the tuned mass damper system is generated. Also the equation of the motion of the quarter system is developed. The validation of the proposed tuned system in terms of frequency response, dynamic response and power spectrum is done.

Keywords: - Tuned mass damper, machine platform, vibration, bond graph

1. Introduction

Vibration control of vehicle suspension systems has been a very active subject of research, since it can provide a very good performance for drivers and passengers [1-2]. It reduces the motion and acceleration of the sprung mass in the system [3]. A study on vibration-based diagnostic platform to systematically monitor and diagnose of rotary machine faults is presented in [4]. An analytical study of the kinematics and dynamics of Stewart platform-based machine tool structures is presented [5]. The application of electrorheological fluids to machine tool elements is proposed [6]. The dynamic characteristics of machine tool table systems with linear motion rolling element bearings are improved by using an ERF film damper. In this paper the design and modeling of the machine platform based on spring damper system is done using bond graph approach. The double mass spring damper system is considered in this work. The objective of the tuned mass spring damper system is to reduce the effect of the vertical tool force on the job or work piece by damping the force by the machine platform. Also the equation of motion of the system is developed and used to generate the optimum value of the damper and spring constant. The performance validation of the proposed tuned system is done in terms of frequency response, dynamic response and power spectrum.

The paper is organized as follow: In section 2, the design of the machine platform based on the double spring damper system is describe. The bond graph model of the quarter system is developed in the section 3. Also the motion of equation is presented. In section 4, the results related to the frequency response, dynamic response and power spectrum are shown. The section 5 concludes the summary of the paper.

2. Design of the Machine Platform

In this section, the design of the machine platform based on the double spring damper system is proposed. Figure 1 shows the schematic diagram of the proposed system.

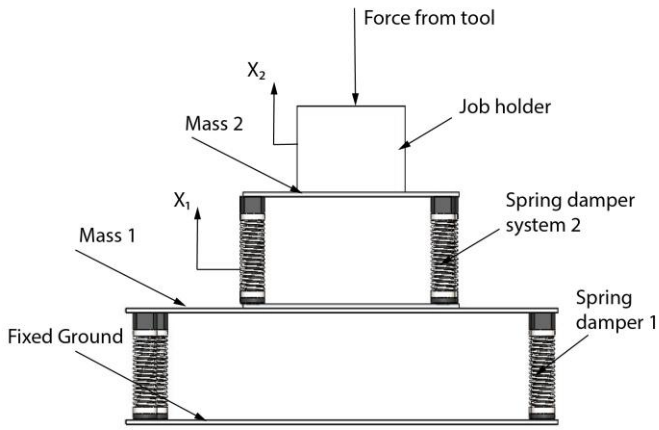

Fig. 1 Schematic diagram of the machine platform

The lower plate with mass (m_1) and spring damper 1 (sd_1) is connected to the fixed ground. Also the upper plate with mass (m_2) is connected to the lower plate with spring damper 2 (sd_2). The job holder or vertical chuck is placed on the top of the upper plate. The force from the tool is considered as external force act on the job holder or job. The X_1 and X_2 are the displacement due to vibration. The objective of the proposed design of the mass spring damper system is to reduce the vibration in the machine platform during machining operation.

3. Modeling of the Tuned Mass Spring Damper System

The bond graph approach is used for modeling the machine platform based on the tuned mass spring damper system. Figure 2 shows the schematic diagram of the quarter model of the proposed system.

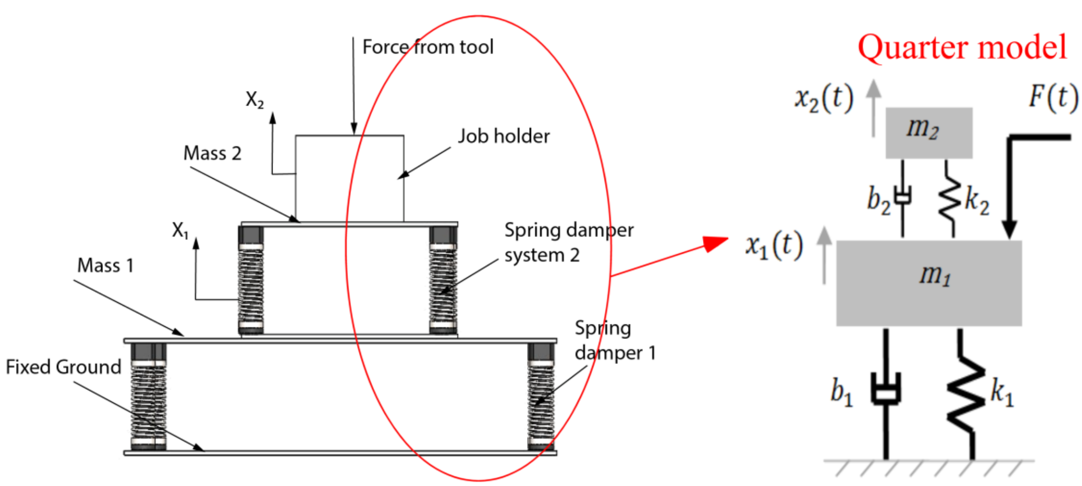

Fig. 2 Schematic diagram of the quarter model of the double spring damper system

3.1 Bond graph model

The bond graph model of the double mass damper spring system is shown in Fig. 3. The force act on the job holder is represented by source of flow (SF). The k_{pad} and b_{pad} is adjusted according to the system requirement.

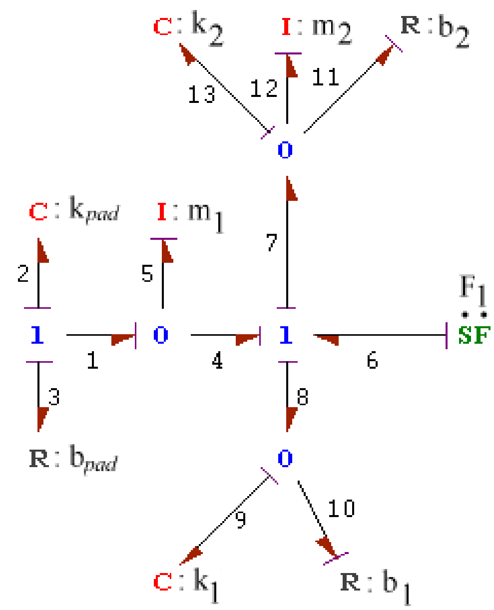

Fig. 3 Bond graph model of the double mass damper spring system

The optimum spring and damping constant of the tuned mass damper system is calculated as follow:

Mass ratio

$$\mu = \frac{m_2}{m_1} \tag{1}$$

Natural frequency of tuned mass damper

$$\omega_2 = \sqrt{\frac{k_2}{m_2}} \tag{2}$$

Natural frequency of main system

$$\omega_1 = \sqrt{\frac{k_1}{m_1}} \tag{3}$$

Ratio of natural frequency

$$\alpha = \frac{\omega_2}{\omega_1} \tag{4}$$

Optimum ratio of natural frequencies

$$\alpha_{opt} = \frac{1}{1+\mu} \tag{5}$$

Hence the optimum spring constant of the tuned mass-spring-damper

$$k_2 = \frac{m_1 k_1 m_2}{(m_1 + m_2)^2} \tag{6}$$

Damping ratio

$$z = \frac{b_2}{2 m_2 \omega_2} \tag{7}$$

Optimum damping ratio

$$z_{opt} = \sqrt{\frac{3\mu}{8(1+\mu)^3}} \tag{8}$$

Hence the optimum damping constant of the tuned mass-spring-damper

$$b_2 = \frac{1}{2}\sqrt{6}\sqrt{\frac{m_2}{m_1\left(1+\frac{m_2}{m_1}\right)^3}}\, m_2 \sqrt{\frac{m_1 k_1}{(m_1+m_2)^2}} \tag{9}$$

By using Eq. (1-9) the value of constant k_2 and b_2 is determined which is further used in equation of motion for system.

Equation of motion for whole system is

$$m_2\left(\frac{d^2}{dt^2}x_2(t)\right) = -k_2\left(x_2(t) - x_1(t)\right) - b_2\left(\frac{d}{dt}x_2(t) - \frac{d}{dt}x_1(t)\right) \tag{10}$$

$$m_1\left(\frac{d^2}{dt^2}x_1(t)\right) = -k_1 x_1(t) - b_1\left(\frac{d}{dt}x_1(t)\right) - k_2\left(x_1(t) - x_2(t)\right) - b_2\left(\frac{d}{dt}x_1(t) - \frac{d}{dt}x_2(t)\right) + F(t) \tag{11}$$

Initial conditions:

$$x_1(0) = (0), D(x_1)(0) = 0, x_2(0) = 0, D(x_2)(0) = 0$$

4. Simulation Results

By using the Eq. (10 and 11) the simulation results are presented in this section. The frequency response of the tuned mass damper and not tuned mass damper is shown in Fig. 4(a) and dynamic response is illustrated in the Fig 4(b).

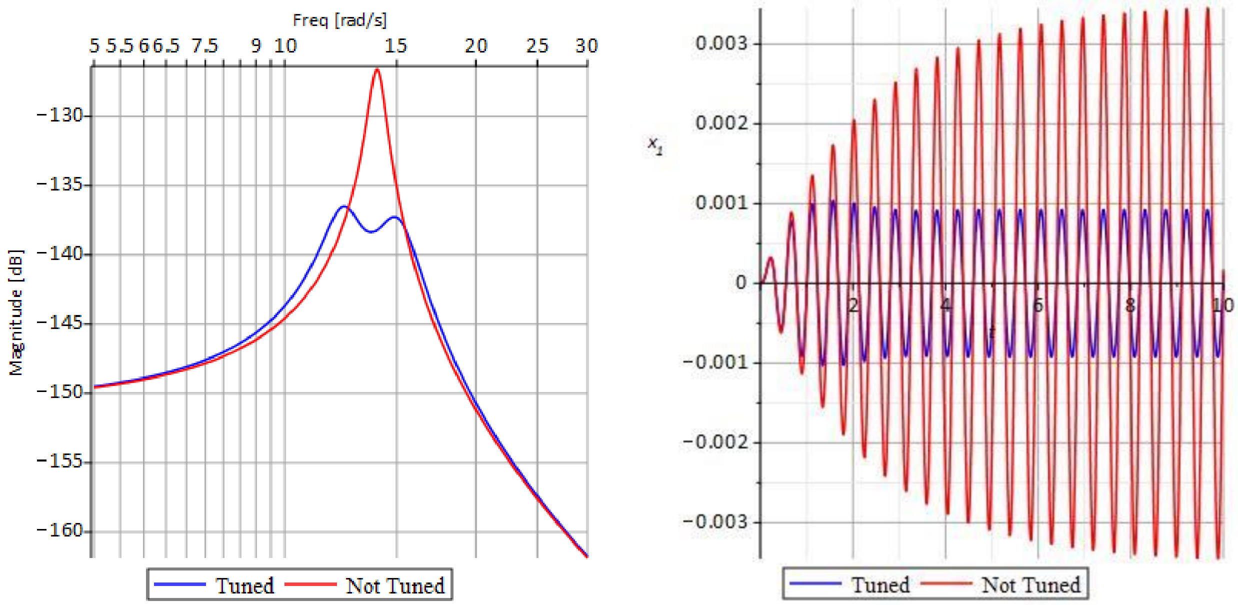

Fig. 4 Simulation results (a) Frequency response and (b) Dynamic response

As depicted from Fig. 4(a) the frequency response of tuned system is quite better than not tuned system. Also dynamic response of the tuned mass damper system is more stable. Figure 5 shows the pattern of the power spectrum of both tuned and not tuned system.

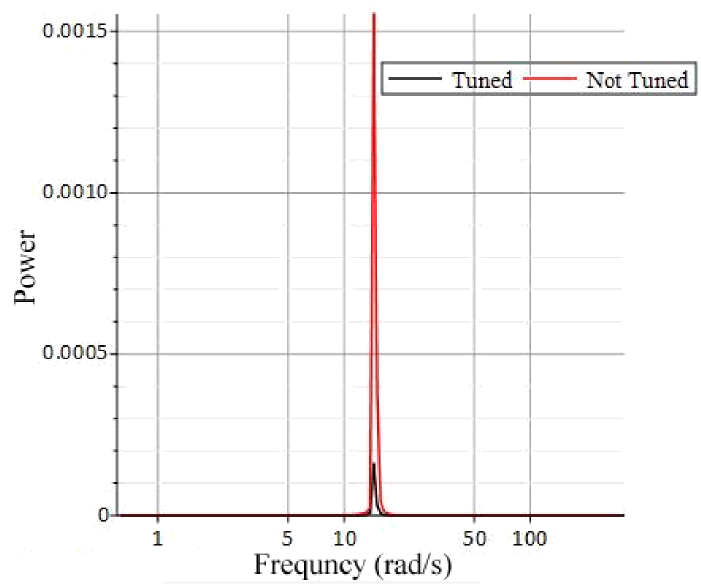

Fig. 5 Power spectrum results

5. Conclusions

The design and modeling of the machine platform based on spring damper system is developed in this paper. The bond graph model of the double mass damper spring system is developed. The expression of optimum value of damping and spring constant is generated for tuned system. Also the equation of the motion of the quarter system is developed. The performance validation of the proposed tuned system is done in terms of frequency response, dynamic response and power spectrum.

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Application of Red Mud in Construction Materials: A Review

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Abstract- Aluminum is the earth's third most abundant element and is one of the most widely used metals with a variety of applications, including transport, construction, packaging and other appliances, due to its diverse properties. Over the years, extensive work has been done by researchers worldwide to develop various economic ways for the utilization of red mud. Since the use of red mud for producing construction and building materials has the potential to consume the waste in large quantities, more and more attention has been paid to the utilization of red mud for cement production. Utilizing red mud in the cement industry has been put into practice gradually all over the world.

The aim of this paper is to summarize the chemical and mineralogical characteristics of red mud and gift a detailed review of this progress on the use of red mud in cement production, and clearly show 3 directions for mistreatment red mud in cement production, specifically the preparation of cement clinkers, production of composite cements still as alkali-activated cements.

Keywords: Red mud; Waste utilization, Material properties; Construction materials

I. Introduction

With shortage of derived materials and the concerned use of top soils has raised the demand of widespread utilization of industrial wastes/by-products and for sustainable development of infrastructure. Large volume of by-products or wastes has been generated with industrialisation, and these wastes cause an environmental pollution problem in the surrounding disposal area. As such, during the alumina production the Red mud is red colour industrial waste slurry insoluble water produced [1]. Out of the total red mud, over the globe, India contributes about 4% of total world's production, and present about 10 million tons of red mud is generated each year [2, 3].

With the process of filtration, treatment and disposal of red mud, it causes the disposal of red mud becomes uneconomical and also requires large area for its disposal/dumping of the waste. In India Closed cycle disposal system,direct disposal system, dry disposal method are the three types of methods adopted for the disposal of red mud [4, 5]. Dumping of red mud into secured large inland artificial ponds is closed cycle disposal type and is most commonly used and economical. Red mud is directly dumped into seawater and seawater dilutes neutralizes the causticity of the red mud and the iron oxide released into sea water helps the marine life algae, corals and other crawling life system grow at a faster rate. Many of the shore based alumina refineries in the world are continuing with this form of red mud disposal system despite occasional agitations by the environmentalists. Dry disposal method in which the wet slurry undergoes several Stages of filtration and water is separated from it. After that, the dry mud is disposed of as pyramids or dumped at the pond side. The dry mud is covered by cotton soil and requires regular water sprinkling to prevent the metallic dust from polluting the air, livestock and crops around.

Reddy and Rao (2016) [1]-Theutilisation of industrial wastes in infrastructure is essential for developing countries like India for sustainable development.

Power et al. (2011) [2]-Each year, about 120 million tons of red mud is discharged all over the world.

Rai et al. 2012 [3]-About 1.2-1.4 tons of red mud is generated per each ton of alumina produced.

Hind et al. (1999) [4] It is the most improved solution for disposal of red mud. Red mud is very toxic in nature Chemical analysis shows that red mud contains silicon, aluminium, iron, calcium, titanium, sodium as well as an array of minor elements.

II. Physical and Geotechnical Characteristics of Red Mud

About 0.8-2.5 tonne of red mud is generated per tonne of alumina production. In India, it is estimated that more than 10 million tonnes of red mud are being generated per annum from several numbers of aluminium plants [3]. Red mud is highly alkaline in nature with pH ranging from 10.5 to 13 because of excessive caustic soda (NaOH) content, which is added during the Bayer's process.

- **Parekh and Goldberger (1976)** [5] Red mud is a residual waste generated during the extraction of alumina from bauxite by Buyer's process.
- **Li (1998) and Rout et al. (2013**) [6, 7] usually, red mud is disposed of into encapsulating facilities in the form of slurry containing about 15 to 40% solids.
- **Gray and Somogyi(1974) and Somogyi and Gray (1977)** [8, 9]
- -Interestingly, in the absence of either quartz or clay minerals, red mud exhibits compression and plastic behaviour similar to that of clay soils and frictional behaviour closer to sandy soils, and many of its geotechnical properties matches with the clayey tailings.
- **Parekh and Goldberger (1976)** [5] Red mud mostly contains fine particles in the range from sand to silt size, but completely free from either quartz or clay mineral constituents. However, geotechnical properties like compaction, consolidation, settlement, shear strength, permeability, etc., are strongly influenced by chemical and mineralogical characteristics of the waste. The properties of red mud are given in Table: 1.

Specific gravity of the red mud will be very high due to the iron materials minerals present in it. Geotechnical properties like compaction, consolidation, shear strength, permeability, etc., are strongly influenced by chemical and mineralogical characteristics of the waste and source of bauxite [5]. The usage of the red mud mainly depends on the physical characteristics like mainly its strength, specific gravity, maximum dry density, optimum moisture content etc., strength can be known by compaction process and unconfined compressive strength tests. Different chemicals with ratios can be added to find out the strength as the material consists of the different type of minerals and their properties differ.

TABLE I. Physical and geotechnical properties of Indian red mud's [1, 7, 10, 11]

Property	Typical	Values
Source of material appearance	HINDALCO, Renukoot Fine material	NALCO, Damanjodi, fine material
Colour	Red	Red
Odour	Slightly pungent, earthy odour	Slightly pungent, earthy odour
pH	10.2-11	10.5-11.5
Liquid limit (%)	40-45	21-45
Plastic Limit (%)	30-35	16-35
OMC (%)	28-34	30-34
MDD (g/cc)	1.45-1.64	1.45-1.60
Grain size distribution (%)sand silt	10-14	2-10
Clay	43-57 32-29	22-35
Free swell index (%)	No swell	No swell
Specific gravity	2.85 - 2.97	2.85-3.05
Co-efficient of Permeability (cm/sec)	$2\text{-}30*10^{-6}$	$-10*10^{-6}$

III. Chemical and Mineralogical Characteristics

Many types of minerals present in the red mud the chemical properties will differ with the amount of chemicals present and their chemical composition. The chemical composition mainly depends on the method of extraction, mineralogical origin their efficiency and method of disposal. The hydroxyl groups on the surface of red mud particles surface generated from bauxites of various mineralogical compositions are the responsible for its zeta potential, flocculation, dispersion.

- The pH in the range of 10.5 to 13, high ionic strength, red mud contains silica, aluminium, iron, calcium, titanium, sodium as well as of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As, and etc [4].

- The zeta potential increases (higher positive) with the decrease of pH. The higher negative potential is due to high value of pH [12, 13].

Table 2 list the chemical compositions of red mud that are produced by the Bayer process.

TABLE II. Typical composition of red mud [3, 13]

Composition	**Percentage**
Fe_2O_3	30-60%
Al_2O_3	10-20%
SiO_2	3-50%
Na_2O	2-10%
CaO	2-8%
TiO_2	Trace-25%
Zeta Potential	+23 to -45 mV
pH	10.2-13
Mineralogical Phases	Hematite, Goethite, Gibbsite, Diaspore, Perovskite, Rutile, Sodalite, Quartz, Cancrinite, Calcilte

IV. Utilization of Red Mud as a Construction Material

A. Utilization of red mud in cement production

During the past decades, many researchers to develop various economic ways for the utilization of red mud have done extensive work. One of the economic ways is using red mud in cement production, which is also an efficient method for large-scale recycling of red mud. Liu and Zhang

[14]used red mud mainly in three ways for the production of cement they are preparation of cement clinkers, production of composite cements as well as alkali-activated cements.Use of red mud cement not only reduces the energy consumption of cement production, but also improves the early strength of cement and resistance to sulfate attack [14].

B. Utilization of red mud in the concrete and brick industry

Red mud was added as a pigment in various proportions (dried, not ground, ground, calcinated) and the idea to use red mud as pigment was based on extremely fine particles of red mud (upon sieving: 0.147 mm up to 4 wt%, 0.058 mm up to 25 wt% and the majority smaller than 10 microns) and a characteristic red colour[15]. Red oxide pigment containing about 70 % iron oxide was prepared from NALCO red mud by after hot water leaching filtration, drying and sieving [15]. Arhin, et al [16] have been investigated bauxite red mud-Tetegbu clay composites for their applicability in the ceramic brick construction industry as a means of recycling the bauxite waste. The initial raw samples were characterized by X-ray diffraction (XRD) and thermo gravimetric (TG) analysis.

C. Utilization of red mud as a road base material

High-grade road base material using red mud from the sintering process is promising, that may lead to large-scale consumption of red mud. Qi [17] suggest using red mud as road material. Based on the work of Qi, a 15 m wide and 4 km long highway using red mud as a base material was constructed in Zibo, Shandong. A relevant department had tested the sub grade stability and the strength of road and concluded that the red mud base road meets the strength requirements of the highway [18].

Rao et al. (2012) [19] Experimental study on the behaviour of red mud with GGBS adding 5% increment from 5 to 30%. UCS, Spilt tensile test, CBR were conducted at 1, 3, 7, and 28 days curing periods, found that 25%GGBS has shown higher values compared to other percentages and at 28 curing periods a CBR value of CBR i.e., 35% was obtained as it satisfy the sub base, base course requirement and also used as sub grade material for high traffic volume roads. Similar studies have been carried out by Satyanarayana et al. (2012) [20], stabilized red mud with lime in the increment of with 2% to 12% and corresponding UCS, Split tensile strength, CBR were conducted at 1, 3, 7, and 28 days curing periods. Observed that 10% lime has shown higher values compared to other percentages. At 28 days it has shown maximum values than other curing periods for all percentages of lime. The CBR value obtained for 10% lime at 28 days is 25% so that it can be used as sub grade and sub base material in road construction.

D. Utilization of red mud as an embankment material

The Highway Engineering Laboratory of the Aristotle University of Thessaloniki studied a pilot project to utilise red mud in the construction of a road embankment and is constructed in three sections. Section I consisting of natural soil and in the red mud with partial in section II, the last section III is constructed with red mud in combination with 4% fly ash. The results of the investigation have demonstrated that the performance of the red mud as embankment material is satisfying the requirements and also observed that no signs of rutting or disintegration appeared on the surface [21]. Ghosh P.K. (2009) [22] carried out a feasibility study of red mud and Pond ash for construction of Embankment. Shows, the 10% of fly ash shows improvement in compaction, direct shear and triaxial tests results, from study concluded that, the mix is having 90%-10% is suitable for embankment.

E. Utilization of red mud as a filling material in mining

Yang et al. (1996) [23], from the Institute of Changsha Mining Research, have studied the properties, preparation and pump pressure transmission process of red mud paste binder backfill material. Based on this study, a new technology named “pumped red mud paste cemented filling mining” has been developed with a mixed ratio of red mud, fly ash, lime and water as 2:1:0.5:2.43, and then pumped the mixture into the mine to prevent ground subsidence during bauxite mining. The tested 28- day strength can reach to 3.24 MPa. Underground exploitation practice on the bauxite has proved that cemented filling technology is reliable and can effectively reduce the filling costs, increase the safety factor of the stop and increase the comprehensive benefits of mining [24].

V. Conclusion

A review on physical, chemical, and geotechnical characteristics of red mud wastes as a construction material in civil engineering has been discussed above. Red mud, could become a potential construction material, based on the critical review the following general conclusions have been drawn:

- Red mud having least plasticity it can be an advantage in practical utilization such as road material and could become alternate as a substitution to natural materials.
- Lime, other waste and/or in combination with cement, can be used to stabilize the red mud. Red mud can be used in subgrade and subbase layers after stabilisation.
- Utilization of red mud in embankment construction has been demonstrated successfully, though needs to be treated for its high pH value.
- By seeing all these properties of the red mud we can utilize the red as geotechnical material like Backfill material, road sub-grade material embankment material. Red mud is further stabilized to enhance the more strength with lime, gypsum, fly ash etc
- Utilization of red mud is established in brick manufacturing, partial cement refilling, in concrete industry and stabilization process.

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Hydraulic Spring Stiffness Testing Machine

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Abstract

In various sophisticated engineering application like machine and mechanism spring is essential component is used for various purpose. The various application of spring in Automobile suspension system, IC engine valve, brakes, clutches, Hydraulic Cylinder spring loaded, pressure relief valve, flow control valve, pressure compensated valve, due to time usage the material get fatigue and then the spring of spring changes. In order to replace the spring in machine or mechanism stiffness of spring need to be checked before it get installed. As per the market survey there will be a manufacturing defect because of it we cannot install the without it being checked. Due to this problem of replacement and installation of spring, we want to establish a Spring Stiffness Testing Machine which is based upon hydraulic principle.

Introduction

An engineer is always focused towards challenges of bringing ideas and concepts to life. Therefore, sophisticated machines and modern techniques have to be constantly developed and implemented for economical manufacturing of products. At the same time, quality and accuracy factor is considered. A spring is defined as an elastic machine element, which deflect under the action off the load and returns to its original shape when the load is removed. Stiffness and spring index are the main parameters of spring design. Spring stiffness is the force per unit deflection (k=f/d). These parameters are considered for defining the spring. In designing and developing the spring testing machine, these parameter is considered. It is very difficult to find the stiffness of such spring without having such machine. In low cost we have hydraulic operated spring stiffness testing machine, this machine contains less part easily understandable. This machine is easily affordable for small garage and industry. Digital machine is costlier than simple hydraulic spring stiffness testing machine.

Definition

- In various hydraulic application like relief valve, variable displacement pump etc. We need to check the stiffness before it gets into installation.
- Low cost machine is required for check in small workshop.
- Another stiffness testing machine are available in market which are much higher cost as compared to this hydraulic based stiffness testing machine.
- By knowing two value (i.e. Pressure in cylinder and Deflection of spring) in this system we can get stiffness.

Objectives

1. Main objectives of this machine are to checking the stiffness of spring with higher accuracy and precision.
2. Designing and constructing a spring stiffness test rig that is capable of testing a various types of springs of different length, diameters and of different materials.
3. To reduce the time required for testing and increase the profit of small scale industries and also to reduce inventory and investment cost.
4. Low initial cost of machine and easily operated.

Principle of Hydraulic Spring Stiffness Testing Machine

It is based on the Principle of Pascal law according to which the intensity of pressure at any point would be same in all direction

Fig1: Spring Under Testing

Selection of Spring and Hydraulic Cylinder

For this system we can check the stiffness with a factor that it sustain certain load which we consider for this system.

Assumption for this system

Load Carrying Capacity = 135kg

Spring design																			
Spring	d	Dm	Do	Di	If	Lo	INSTALLED LENGTH	G (kg/mm2)	ω = Dm/d	R (STIFFNESS)	DEFLECTION	F = DEF X R	τ (shear stress)	κ (wahl's factor)	Tκ = κ X τ (corrected shear stress)	solid length	PERMISSIBLE SHEAR	Lp (OPERATING LENGTH	LENGTH LEFT (SHUD BE >= 0	FOS
Project Spring 1	4	50	54	46	16	304	200	8,150	12.5	0.1	104.0	13.6	27.0	1.1	30.1	72.0	115.0	225.6	121.6	3.8
Project Spring 2	6	63	69	57	14	304	200	8,150	10.5	0.4	104.0	39.2	29.1	1.1	33.2	96.0	115.0	199.6	95.6	3.5
Project Spring 3	8	75	83	67	13	304	131	8,150	9.4	0.8	173.0	131.6	49.1	1.2	56.7	120.0	115.0	173.6	0.6	2.0
Project Spring 4	10	65	75	55	13	304	200	8,150	6.5	2.9	104.0	296.8	49.1	1.2	60.5	150.0	115.0	141.0	37.0	1.9

Spring Design Calculation for the Selection of spring as per IS-7906-1.

HYDRAULIC CYLINDER:

Let max load carrying capacity for system is 135kg then

Pressure rating is 100 bar

$P=\frac{F}{A}$ --» $A=\frac{F}{P}$ --» $A=\frac{135\times9.81}{100\times10^5}$

$\frac{\pi}{4}\times D^2= 1.324^{-4}$

D = 0.01298 m =12.98mm

Thus 12.98 mm bore is required for this system.

As per the standard of hydraulic cylinder we have to buy a cylinder of bore diameter of either 32mm or 40mm diameter.

D =32 mm

Working:-

1. First of all close the bleed off valve of Hydraulic jack so that hydraulic oil can go to larger cylinder that use for the lifting purpose.
2. Place a spring in between the hydraulic cylinder and hydraulic jack.
3. Start actuating the hydraulic jack by using rod.
4. Now spring lead to compress till certain point.
5. Measure the pressure in cylinder by using pressure gauge.
6. Also measure the spring that is deflected through certain distance.
7. Using formula

F= P*A

$$F = P^*\{\ \pi D^2)/4\}$$

F = Force required to deflect the spring

D= Hydraulic cylinder diameter

P= Pressure inside cylinder

8. Stiffness k = $\frac{F}{\delta} = \frac{Force\ required\ to\ deflect\ the\ spring}{Deflection} = \frac{Gd^4}{8D^3N}$

Advantage

1. Spring of wire diameter range from 4mm to 10 mm can be easily checked.
2. Spring can be check without damaging it.
3. The testing is carried out in very less time, so production rate is very high.
4. One man effort is enough to check the spring.
5. The system is self-lubricating.
6. The system is noiseless.

Disadvantage

1. Lower stiffness spring cannot be checked accurately.
2. As system is hydraulic, leakage may occur and hence refilling of coil is necessary.

3 Only ground ended spring can be tested.

Conclusion

As compare to digital stiffness testing machine hydraulic spring stiffness testing machine is cheap. Hence this machine we can use in garages and small industries, also we can use in collages for practical purpose. Hydraulic spring stiffness testing machine is easily manufacture in workshop. For more convenient we can be digitalized this system.

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Development and Testing of Water Serving Robot

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Abstract

This paper introduces a new concept of mechanism in the design of water Serving robot, which navigates from one place to other, decided by path programming and perform specific assigned tasks. These types of robots can be used for serving water, transferring food items and many other goods under defined specifications. In this study, we focused on the conditions for achieving good stability and proper working of the system in different situations, like a sudden obstacle in the path of motion, smooth turning and proper water flow as per one's requirements.

Keywords: Serving robots, Mechatronics, Arduino, Path Programming, Bluetooth Controlled Robot.

Practical Application: Automation in food and water processing industry, Domestic use.

Introduction

I. Robot

A robot is a machine, particularly programmable by a PC, equipped for completing an arrangement of activities automatically. Robots can be guided by an outside control gadget or the control might be implanted inside. Robots might be built to make work easy and to provide comfort in daily lifestyle. The designed robot implements its motions with the help of three moving wheels, in which two wheels are connected with gear motors for smooth and best performance while taking turns.

Types of robots: -

Stationary Robots, Wheeled Robots, Swimming Robots – Robot Fish, Flying Robots, Modular Robots, Micro Robots etc.

In this paper we introduced a self-working water serving robot, this is a very unique concept to serve water and other food items from one place to another. Mostly, we can use this product in hospitals, restaurants, and other desired places according to one's need.

Water serving robot is an approach to make serving an easy and time efficient task also to give comfort to human life by doing the domestic works.

Functions of water serving Robot: -

1. Serving water on the bases of programming.
2. Path estimation to reach that position.

3. The motion of Path is designed on the bases of sensors.
4. Programmed to wait if any obstacle comes in the path of Motion.

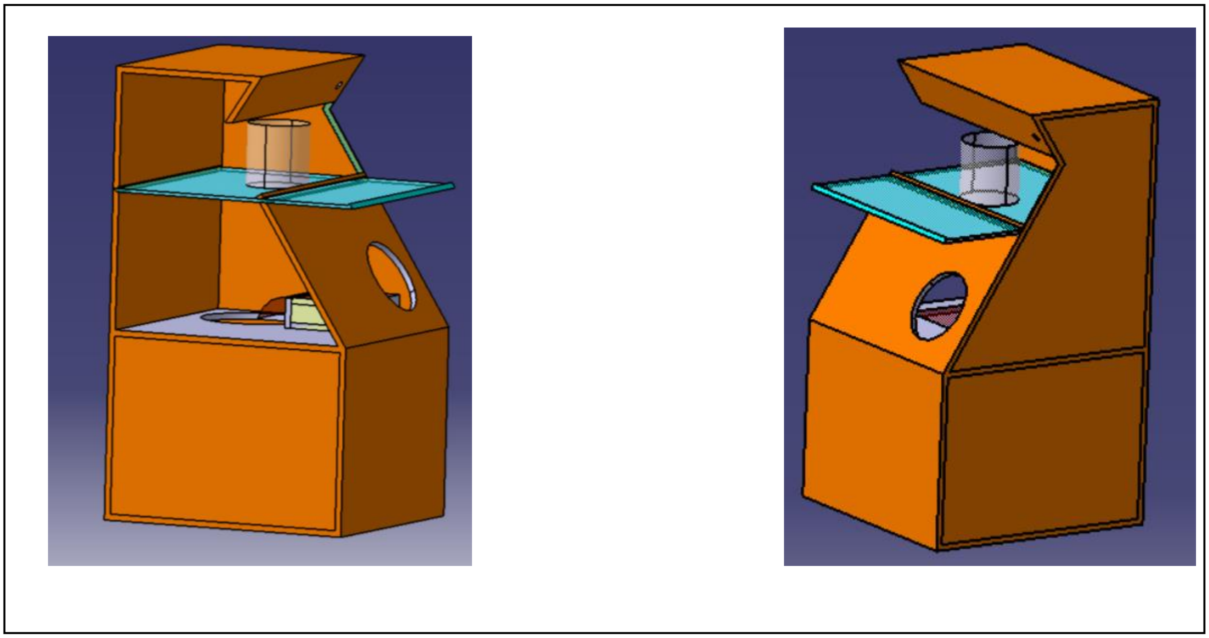

Fig 1.0 CATIA Design

II. Bluetooth

Bluetooth is used as a remote control and sensor application which is suitable for a long-range communication system. These modules are used to control the gadgets which are battery powered. The low-powered consumption is a key requirement and in this, the data is sent in the packet. The range in which we can control this robot is 80m to 90 Meters. This module can be operated in the free band range of 2.400 to 2.485 GHz.

III. Encoder

An encoder is a gadget, circuit, transducer, programming system, calculation or individual that proselytes data starting with one arrangement or code then onto the next, for the reasons for institutionalization, speed or pressure. In this system, we calculated the no. of cycles of the wheel for the exact motion of the robot and to precise the steps of rotation. With the help of encoder we are able to calculate the pulse for the perfect motion of the robot, or in other words, we get the exact fixed distance to travel.

Fig. 1.1 Encoder Design.

IV. Working of water serving Robot

This paper presents the concept of processing in water serving robot as shown in Fig 1.4. All the commands are managed by main controller ATMEGA 328. In this process IR sensors, ultrasonic sensors, and encoders transmit input signals to the main controller and output signals are received by the water pump, led, gear motors to perform different functions.

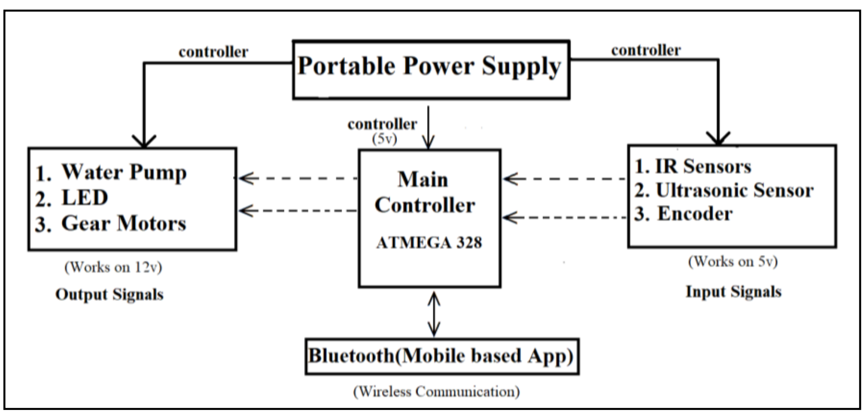

Fig. 1.2 Block Diagram of Control Unit.

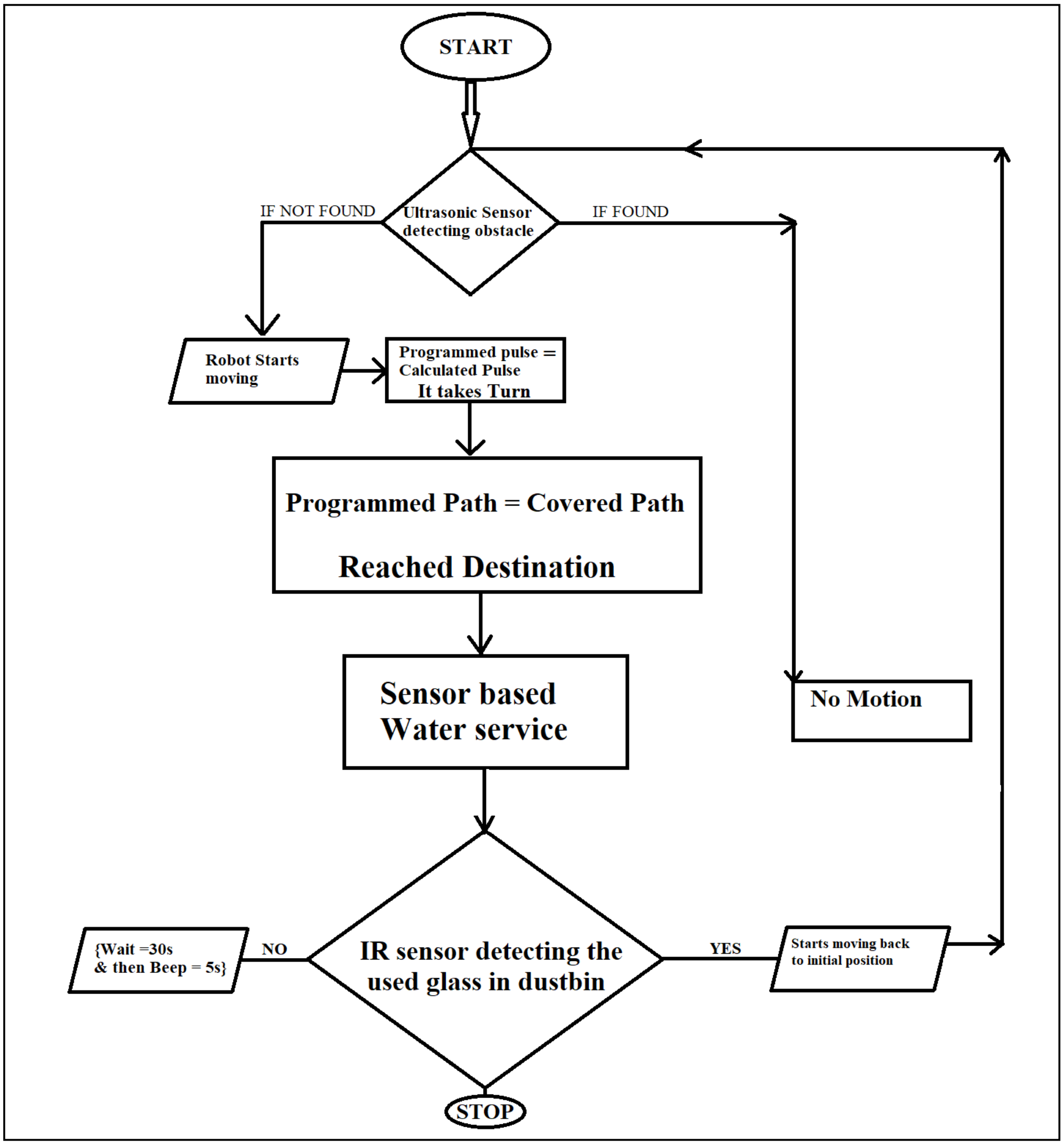

Fig.1.3 Flow Chart of Robotic Programming.

V. Concept

It is an ATMEGA 328 programmed based robot which follows the path as shown in fig. 1.4. Given the flowchart makes our concept easy to understand because of its simply written steps to provide good motion to the robot**.** In the paper, the water serving robot is an automatic working machine, can be controlled by Bluetooth (free band range of 2.400 to 2.485 GHz). Robotic blueprints are designed in Catia software for the best outcomes, Shown in Fig 1.0.

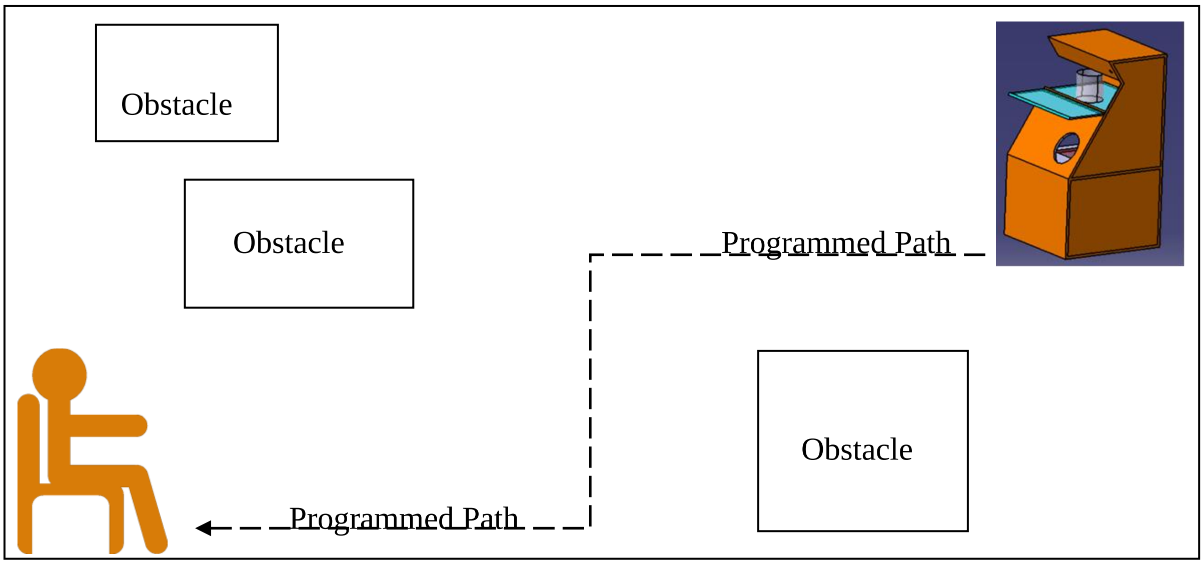

Fig.1.4 Path map of Water Serving Robot.

VI. Conclusion & Future Scope

The working of water serving robot will meet our daily domestic requirements. The functions of water serving robot are fabulous because of its proper working routine as per ones need.
In this study of water serving robot, we conclude the following parameters:-

- Provides better lifestyle.
- The proper working of water serving robot on the basis of different sensors, Gear motors, drivers, relays, transistors, programming, and well maintained mechanical structure.
- All steps of the robot will be displayed on the LED screen which is connected to the perfect position to make serving more effective and attractive.
- It is a self-intelligent robot which purely works on programming to make different decisions (the distance covered by the robot is calculated by the encoder on the behalf of no. of rotations taken by the wheels to reach the programmed destination)
- From starting point to ending point robot works under a given programmed path.

Future Scope

It can work on auto selected paths to touch the needs of upcoming generations, with this it will also operate more rapidly and with durable lifespan after the addition of advanced technologies. It is very useful for handicap patients, restaurants, hotels etc. Increase in population, we require helping hands which will make our living healthy and quick.

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A Brief Review: Vibrational Techniques in Micromachining

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Abstract- Vibration is a mechanical wonder whereby motions happen around a harmony point. The word originates from Latin vibrational ("shaking, displaying"). The motions might be occasional, for example, the movement of a pendulum—or arbitrary, for example, the development of a tire on a rock street. Vibration can be attractive: for instance, the movement of a tuning fork, the reed in a woodwind instrument or harmonica, a cell phone, or the cone of an amplifier. As a rule, be that as it may, vibration is unfortunate, squandering vitality and making undesirable sound. For instance, the vibrational movements of motors, electric engines, or any mechanical gadget in task are regularly undesirable. Such vibrations could be caused by lopsided characteristics in the turning parts, uneven contact, or the cross section of rigging teeth. Watchful plans normally limit undesirable vibrations. We have studied in this work Ultra precision Micromachining of Brittle Materials by Applying Ultrasonic Elliptical Vibration Cutting.

Key Words: - Micromachining, MEMS, Ultrasound, Reliability

INTRODUCTION

Micromachining systems assume a vital job in item scaling down. This part introduces normal micromachining procedures for semiconducting materials (mass and surface micromachining) and for building materials (customary and nontraditional micromachining). The mass micromachining can deliver structures inside a substrate while surface micromachining can manufacture auxiliary thin movies on a conciliatory layer for semiconducting industry. The device based customary procedures (micro milling and micro drilling) and nontraditional procedures (small scale EDM, miniaturized scale ECM, particle/electron/laser shaft), declined from macro scale machining forms, are more mainstream to deliver micro components in aviation, transportation, oil and gas, and medicinal enterprises. The blend of these procedures permits creation of a solitary part, as well as manufacture of micro tools, micro scale shape/bite the dust for mass delivering of different micro components. A significant number of fragile materials, for example, formless materials, single precious stone materials, and sintered amalgams and pottery, are used for an assortment of new items as a result of their one of a kind physical and mechanical properties. Particularly, requests for ultra-precision micromachining of those fragile materials are expanding, which acknowledges advanced optical parts, useful segments and their kicks the bucket for large scale manufacturing. Mechanical micromachining, i.e. cutting, pounding and cleaning, can be utilized for micromachining and also electrical release machining and substance scratching [2]. In any case, it is hard to acquire optical quality mirror surfaces of those fragile materials by the traditional.

Vibration is a mechanical marvel whereby motions happen around a harmony point. The word originates from Latin vibrational ("shaking, wielding"). The motions might be intermittent, for example, the movement of a pendulum—or irregular, for example, the development of a tire on a rock street.

Vibration can be attractive: for instance, the movement of a tuning fork, the reed in a woodwind instrument or harmonica, a cell phone, or the cone of an amplifier. As a rule, in any case, vibration is unfortunate, squandering vitality and making undesirable sound. For instance, the vibrational movements of motors, electric engines, or any mechanical gadget in task are regularly undesirable. Such vibrations could be caused by awkward nature in the pivoting parts, uneven grating, or the cross section of apparatus teeth. Watchful plans ordinarily limit undesirable vibrations.

A. *Surface Micromachining:-*

Surface Micromachining is alleged in light of the fact that rather than gem silicon substrate as a working material this new innovation utilizes thin film layers stored on the substrate surface as working material. This part clarifies the distinctive sorts of surface micromachining forms. It subtle elements the polycrystalline silicon-based micromachining in an exceptionally natty gritty path with the assistance of photos. Combinations ideas are seen in an extremely viable way. Solid reconciliation is a decent decision for assessment of capacitive surface-micro machined sensors, given their low base capacitance esteems and more bolstered by therapist inclinations forcefully focusing on the span of the sensor center. Solid incorporation is a potential choice to be considered not mostly for expense but rather for execution contentions. This exercise clarifies the job of metallic thin movies in MEMS. It clarifies the distinctive properties of metals in MEMS applications in an extremely compelling manner, which incorporates electrical conductivity, low-temperature preparing, and so forth. This part tosses some light on silicononinsulator (SOI)- wafer-based surface micromachining advances, which are accessible as MEMS foundry innovations. The primary preferred standpoint is that the moveable structures are produced using a solitary crystalline gadget layer henceforth have superb, all around characterized mechanical properties and high dependability. The SOI-wafer-based surface micromachining innovation has been created for capacitive inertial sensors. To enhance the electrical conduct of these kinds of gadget, refilled protection trenches are prepared before the manufacture of the mechanical structures.

B. *Bulk micromachining:-*

Bulk micromachining (Kovacs et al., 1998; Chang et al., 2016; Yoon et al., 2016; Zou et al., 2017) includes scratching highlights specifically into silicon wafers or different substrates. Normally, whenever incorporated electrical capacity is required the microelectronic components are made utilizing CMOS forms on the best side of the silicon wafer. At that point mass micromachining starts from the opposite side of the wafer to yield mechanical components, (for example, thin stomachs or bars on the best side of the wafer) or sections for liquid stream. This methodology has been utilized for a long time to make little weight sensors, and all the more as of late to manufacture mm-wave radio wire for remote correspondence applications (Chang et al., 2016). The utilization of the silicon substrate as the reason for mechanical components of gadgets licenses bigger, and especially more profound, highlights to be utilized than in surface micromachining. This is a critical thought in MEMS where higher mechanical power or power levels are wanted, or in applications including liquids, in which vast misfortunes would be related with move through the littler channels that could be acknowledged by surface micromachining. Fig. 2 demonstrates a micrograph of a profound carved, small scale motor rotor, a part of an incorporated miniaturized scale gas turbine motor.

LITERATURE REVIEW

Q.W.Yan et al. [1] suggested that the silicon micro machined gyro without driven structures developed for measuring the rotation frequency of the spinning projectile. The measuring relative error of the rotation frequency is less than 0.2%, and the measuring relative error of the yawing and pitching angular vibration frequency is less than 3.2%.

S. Machida1 et al. [2] recommended that highly reliable CMUTs can be fabricated as a result of (1) adopting the planarization of dielectric material between the upper and lower electrodes by chemical mechanical polishing (CMP) and (2) optimally controlling the driving voltage to avoid direct contact between the membrane and the underlying dielectric. In this driving voltage condition, vibrations over 1011 cycles can be accomplished without dielectric degradation such as a decrease in *breakdown voltage or charging of the dielectric.*

Daisuke Akai et al. [3] recommended that to investigate vibration behaviors of the miniature PMUT in air and underwater environment, the FSI analysis with impact hammer test method was carried out. As the results of the FSI analysis, the vibration modes and resonant frequencies were successfully observed and compared to the scanning LDV measurements. According to these result, some vibration mode and resonant frequencies were appeared in frequency range from 0.1 MHz to 10 MHz which were good agreement between FSI analysis and the LDV measurements. Underwater environment, resonant frequencies were about half of their in air and ultrasonic was effectively radiated by the not only 1st mode vibration, but also high order vibration modes. It was most difference point of their vibration modes compared with in air environment. It is useful for evaluating the characteristics of the PMUT in condition similar to the human body to realize medical endoscopic diagnosis using the PMUT.

Jan Mehner et al. [4] the presented micro machined force coupled oscillator system makes use of a novel approach to detect mechanical vibration signals at low frequencies (<1 kHz) without subsequent Fourier transformation. The principle of operation is based on amplitude modulation and selective filtering at one specific frequency as known from the super heterodyne principle. The sense frequency can be adjusted by a simple frequency tuning mechanism. The new sensor is characterized by a high signal-to-noise ratio and can be manufactured by simple electronic circuitry. Hence, it will be an interesting alternative to wideband accelerometers for industrial automation and wear state monitoring. Together with Siemens A&D, prototypes are currently tested under harsh industrial conditions.

Anupam Viswanath et al. [5] suggested that the depths and surface finish of machined features are evaluated as functions of work piece vibration amplitude. Batch patterns were successfully transferred onto ceramic substrates with average depths ranging from 2–26 μm for work piece vibration amplitudes ranging from 1–5μm. This corresponds to average machining rates ranging from 6–90 nm/sec. The average surface roughness, Sa, was ≈50 nm. The tool wear, i.e., the ratio of the tool height worn to the machined depth, was <4%. In comparison, μUSM performed by vibrating the tool has been reported to result in machining rates of >100 nm/sec and tool wear <6% for similar conditions [2], [3]. Further, simulations indicate that tools with 20-μm feature sizes provide fluid velocities that are similar to the 50-μm tools in each of the five regions (A–E). These results suggest that the dimensional scaling limits for this fabrication approach are <20 μm. The machining results obtained in this μUSM process using work piece vibration are very encouraging for practical use in the future. Specifically, a process can be envisioned for batch mode post fabrication machining of an array of 3-D microstructures, improving the throughput.

WORKING TECHNIQUES

A. *Elliptical vibration cutting Technique:-*

The apparatus is vibrated circularly and bolstered in the ostensible slicing bearing moderately to the work piece in the meantime, with the goal that the chip is shaped discontinuously and hauled out in every vibration cycle. Since the grating between the chip and the instrument rake confront is turned around, the shear edge is expanded and subsequently the cutting power and the cutting vitality are lessened fundamentally. It is elucidated that ultra-precision machining of solidified

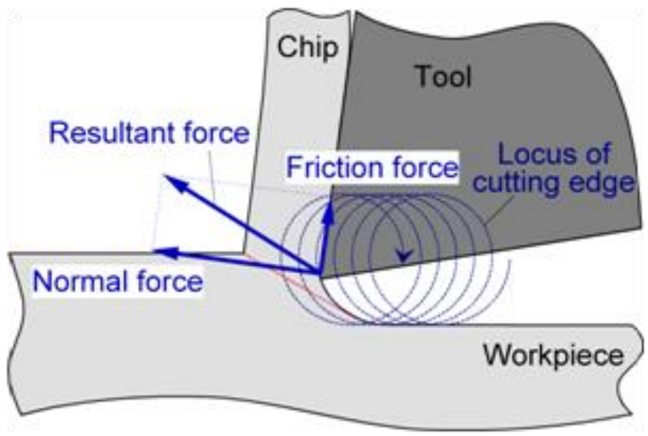

Figure (1): Elliptical vibration cutting process[12]

Steel with single point precious stone device can be acknowledged by applying the curved vibration cutting [10]. Moreover, the basic profundity of slice to understand the pliable cutting of fragile materials is expanded essentially [6]. It ought to be noticed that the cutting procedure relies upon the circular vibration locus and also the cutting conditions in the present technique [13]. It is, along these lines, important to choose an appropriate vibration locus on every work piece material property.

B. *Ultrasonic Elliptical vibration cutting Technique:-*

The vibrator has 4 huge piezoelectric plates as actuators and 2 little plates as sensors. It is vibrated in the cutting course in the third resounding mode by applying sinusoidal voltage to the upper and lower actuators with a stage move of 180 degrees. It is likewise vibrated the typical way to the cutting course and the vibrator hub by energizing the front and back actuators. The precious stone device tip is set toward the finish of the vibrator and vibrated circularly by reverberating the vibrator in the two headings with some stage move. The two directional vibrations are identified by the two sensors separately.

It is essential to control the vibration locus, and hence the vibration control framework is used, which has been produced in the past research. The vibration amplitudes and their stage move are kept to be wanted qualities by the control framework. The full frequencies are marginally extraordinary in the two bearings even after alteration, and they change because of cutting power and temperature change. Therefore, their normal full recurrence is pursued consequently by the control framework. Previously mentioned vibration control framework is mounted as appeared in Figure 3 on a ultra-precision planning machine, NIC-300 made by Nagase Interrex Co., Ltd., which comprises of three feed tables with twofold hydrostatic oil guide ways in XYZ tomahawks, two turning list tables in BC tomahawks and a five hub control framework [13]. Work piece is fixed to the dynamometer on the lower index table of the ultra-precision planning machine. It is known that there is a critical depth of cut, at which the cutting process transits from ductile mode to brittle mode when machining brittle materials. Thus, the cutting feed is given by the X axis table in synchronization with the Z axis table, as shown in Figure 4, so that the depth of cut is gradually increased in cutting and the effect of the depth of cut on the ductile to brittle transition can be investigated.

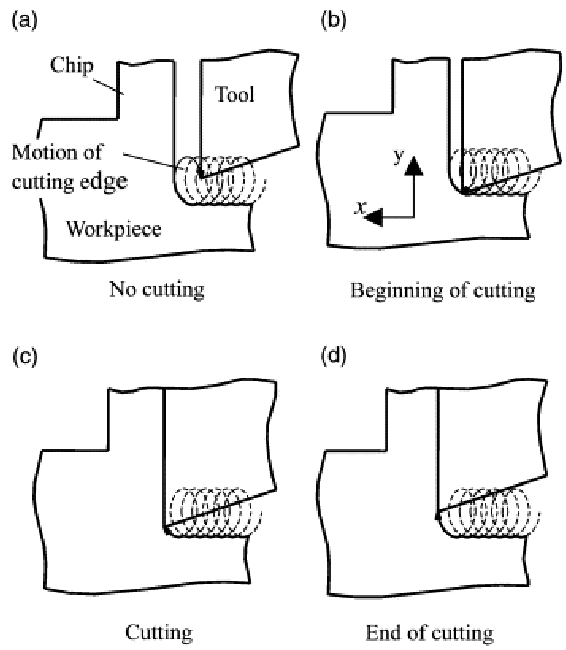

Figure (2): Ultrasonic Elliptical vibration cutting system[12]

***C.** Ultra precision micro grooving experiments:-*

Ultra precision micro grooving experiments with single point diamond tools, whose cutting edges are formed to a circular shape with a radius of 1mm, were carried out to clarify the basic effects of the elliptical vibration on ductile machining of sintered tungsten carbide. Its grain size is 0.5 µm. The cutting speed is set to 150 mm/min, and the amplitude in the cutting/vertical direction is set to 2/1 $\mu m_{p\text{-}p}$ in the elliptical vibration cutting. Microphotographs of the grooves of the sintered tungsten carbide obtained by both cutting methods. Close-ups of the grooves are also shown in the figure, which are taken at a depth of cut of 1.9 µm.

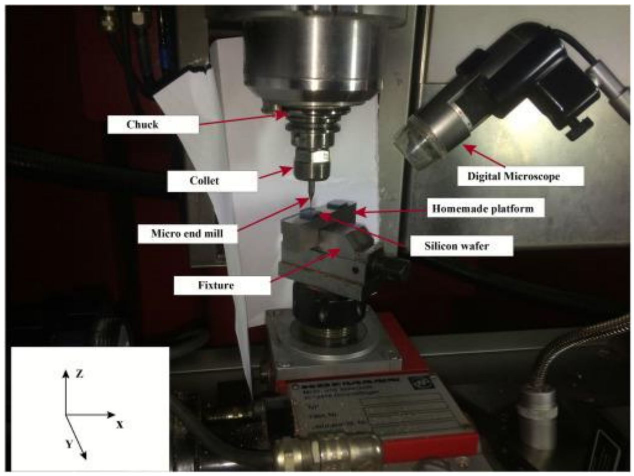

Figure (3): Ultra precision micro grooving experiments [7]

The groove formed by the ordinary cutting is filled with asperities due to micro fractures, while a smooth mirror surface is obtained by the elliptical vibration cutting. Figure 6 shows the groove surfaces taken with a scanning electron microscope. Many fractures appear to occur vertically to the cutting direction on the surface finished by the ordinary cutting, while there are not such fractures on the surface obtained by the elliptical vibration cutting. The ductile to brittle transition is not clearly observed in the both cutting methods for the sintered tungsten carbide. This reduction of specific cutting forces and the improvement of surface quality can be explained as follows. The thickness of work piece material cut in each cycle of the elliptical vibration is significantly small as compared to the nominal depth of cut, especially when the cutting edge passes the bottom point and the finished surface is just generated as shown in Figure 8. Therefore, ductile machining at the large depth of cut, where the ordinary cutting cannot be performed in ductile mode, can be realized by applying the elliptical vibration cutting.

CONCLUSIONS

The aim of this review article is to summarize existing knowledge and highlight current challenges, restrictions and advantages in the field of micro manufacturing. Although natural curiosity and industry demands are responsible for active research in this field for some time, particular issues and challenges still exists. Additional research motivation lies in bridging the knowledge gap between materials at the macro and micro scale. The macro and micro machining processes share the same material removal principle and there are many similar issues between them, such as regenerative chatter, tool wear, monitoring strategies, etc. We have contemplated in this work Ultra precision Micromachining of Brittle Materials by Applying Ultrasonic Elliptical Vibration Cutting and also we will discuss about different techniques used in micromachining.

Future scope

In the future scope we can extend this project by applying different technique on micromachining vibration and also reduction in micromachining vibration by different meth.

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Magnetic Abrasive Flow Machining - A Critical Review

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Abstract- Product quality is main need of the customer in present world of competition. With traditional methods of machining, it is almost impossible to get required degree of accuracy and quality. So it is the need of the time move towards non-traditional methods. A new non-traditional finishing process known as abrasive flow machining (AFM) is used to deburr, radius, polish and remove recast layer of components in a wide range of feasible applications such as aerospace, dies and moulds, automotive parts, medical components, electronics industries etc. Low material removal rate (MRR) happens to be one serious limitation of almost all such processes. Magnetic abrasive flow machining (MAFM) is a new development in AFM which improves surface finish and material removal rate by applying a magnetic field around the workpiece. Material is removed from the workpiece by flowing a semisolid visco-elastic/visco-plastic abrasive-laden medium across the surface to be finished. This paper highlights development of MAFM set up as an improvement over AFM. This review provides an insight into the fundamental and applied research in the area and creates a better understanding of MAFM process, with the objective of helping in the selection of optimum machining parameters for the finishing of varied work pieces in practice. The results shown by different authors indicate significantly improved performance of MAFM over AFM. The surface finish of high quality can be achieved by this process.

Keywords: abrasive flow machining (AFM); magnetic abrasive flow machining (MAFM); EDM; WEDM; material removal rate (MRR); surface finish.

1. INTRODUCTION

AFM process was originally developed by Extrude Hone Corporation, USA in 1966. The low finishing rate, low MRR, bad surface texture etc. leads to the development of new non-conventional machining process namely Magneto Abrasive flow machining (MAFM) which uses a magnetic field around the work piece improves the MRR as well as suface finish. It deflects the path of abrasive flow. This process have excellent capabilities for finish or machining of inaccessible areas of a component and also used to debur, radiusing, and remove recast layers of precision components. Fine surface finish and close tolerances have been attained for a wide range of components. It produces surface finishes ranging from rough to extremely fine. In MAFM, a semi-solid abrasive laden medium consisting of a polymer-based carrier and magnetic abrasives in a definite proportion is extruded under pressure through the surfaces to be finished/machined. This medium acts as a grinding tool. Here 'Microchipping' of the surface is done. Here chips are formed by small cutting edges on magnetic abrasive particles. A typical fixture is required to direct the medium to the desired locations in the component to be machined.

For three-dimensional machining of complex components, an improvement over AFM called the orbital flow machining process has been found recently. These processes can be classified as Hybrid Machining Processes (HMP)—a novel concept in the advancement of non- traditional machining. The reason for developing a hybrid machining process is to make use of combined or mutually enhanced advantages and to avoid or reduce some of the adverse effects the constituent processes produce when they are individually applied. These are non-traditional in the sense that the traditional tools are not employed for material removal and surface finish. The energy in its direct or indirect form is utilized. In almost all non- traditional machining processes such as Electro Chemical Machining, Electro Discharge Machining, Ion Beam Machining, Laser Beam Machining (LBM) etc., low material removal rate (MRR) is considered a general problem and attempts are continuing to develop processes to overcome it. One such process namely MAFM improves the MRR as well as surface finish. It deflects the path of abrasive flow. The process has found applications in a wide range of fields such as aerospace, dies and moulds, automotive parts, medical components, electronics industries, defence, and tool manufacturing industries etc. Extrusion pressure, magnetic abrasive laden media, number of cycles, flow volume and grit size are the main machining parameters that control the surface finish characteristics. Unlike traditional grinding, lapping or honing processes with fixed tools, MAFM applies no such rigid tool with important advantage of subjecting the work piece to substantially lower stresses.

This review provides an insight into the fundamental and applied research in the area and creates a better understanding of this finishing process, with the objective of helping in the selection of optimum machining parameters for the finishing of varied work pieces in practice.

2. EXPERIMENTAL SET-UP

2.1. MAFM set – up

An experimental set-up of MAFM is shown in figure 1 [2]. Singh et al [1] developed a set-up for a magneto abrasive flow machining (MAFM), and studied the effect of key parameters on the performance of the process. Relationships are developed between the material removal rate and the percentage improvement in surface roughness of brass components when finish-machined by this process. Analysis of variance has been applied to identify significant parameters and to test the adequacy of the models. Experimental results indicate significantly improved performance of MAFM over AFM. Jha et al [2] developed a new precision finishing process for complex internal geometries using smart magnetorheological polishing fluid is developed. Magnetorheological abrasive flow finishing (MRAFF) process provides better control over rheological properties of abrasive laden magnetorheological finishing medium. Magnetorheological (MR) polishing fluid comprises of carbonyl iron powder and silicon carbide abrasives dispersed in the viscoplastic base of grease and mineral oil; it exhibits change in rheological behaviour in presence of external magnetic field. This smart behaviour of MR-polishing fluid is utilized to precisely control the finishing forces. Hence final surface finish. A hydraulically powered experimental setup is designed to study the process characteristics and performance. The setup consists of two MR-polishing fluid cylinders, two hydraulic actuators, electromagnet, fixture and supporting frame. Experiments were conducted on stainless steel workpieces at different magnetic field strength to observe its effect on final surface finish. No measurable change in surface roughness is observed after finishing at zero magnetic field. However, for the same number of cycles the roughness

reduces gradually with the increase of magnetic field. This validates the role of rheological behaviour of magnetorheological polishing fluid in performing finishing action.
MAFM set up has two hydraulic cylinders and two medium cylinders. The magnetic abrasive laden medium is extruded, hydraulically or mechanically, from the filled chamber to the empty chamber via the restricted passageway through or past the work piece surface to be abraded. Typically, the medium is extruded back and forth between the chambers for the desired fixed number of cycles. Counter bores, recessed areas and even blind cavities can be finished by using restrictors to direct the medium flow along the surfaces to be finished.

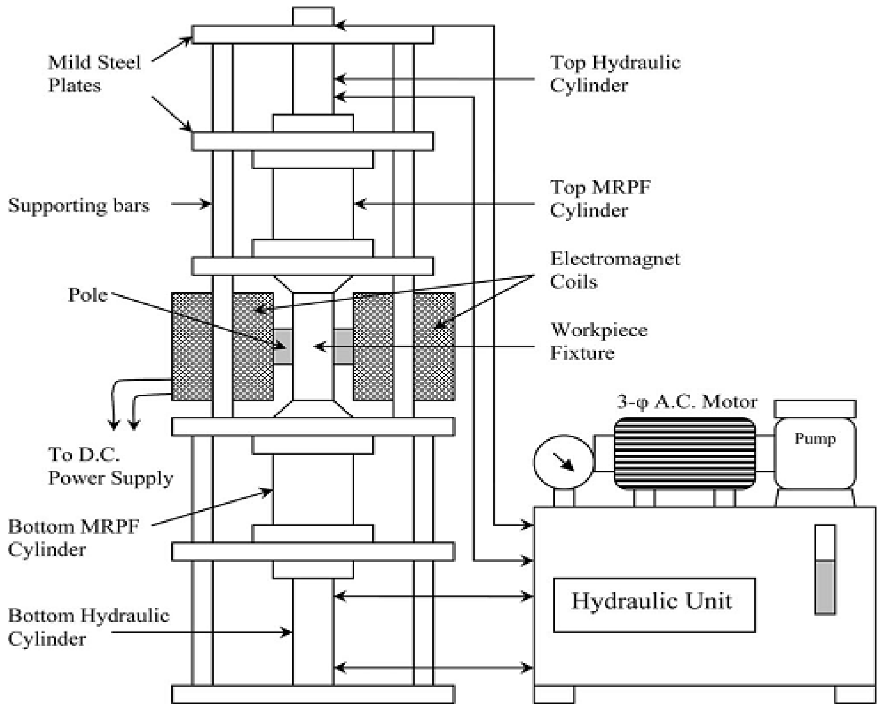

Fig. 1. Schematic of magneto abrasive flow machining set up [2]

The work piece to be finished internally is hydraulically clamped in between the two media cylinders. Further two media cylinders are shown in which the piston reciprocates by the motion of the hydraulic cylinders. The magnetic abrasive media is placed in the lower media cylinder and then it is moved in the upward direction by the reciprocating drive given to the media cylinder piston. After completing the upward stroke the DC valve will operate in the other direction and the pistons will start coming downward, by pushing the media in the downward direction against the restrictions in the geometry of the fixtures to obtain the required pressure for abrasion to get finer finishing in the work piece.

The key components of MAFM are the machine, the tooling, types of abrasives, medium composition. Extrusion pressure, number of cycles, grit composition and type, and fixture design are the process parameters that have the largest impact on AFM results. Abrasive action accelerates by change in the rheological properties of the medium when it enters and passes through the restrictive passages. The viscosity of polymeric medium plays an important role in finishing operation. This allows it to selectively and controllably abrade surfaces that it flows across. The work piece held by fixture is placed between two medium cylinders which are clamped together to seal so that medium does not leak during finishing process.

2.2.The Fixture

A fixture is a tool of the manufacturing industry used in mass production. Fixtures are used to hold objects in place and clamp them to machines or operating surfaces, so that the object can be machined or assembled. The fixture selection and design largely depends upon the workpiece configuration. According to the dimensions of the workpiece the fixture is fabricated. The fixture is used to clamp the work piece and to control the media flow. During the conception of the device, special attention has to be paid to the requirements of abrasive flow machining i.e. the tooling must be a converging one so that the requisite pressure can build which will help in the effective working of the media. **Kamble et al [3]** designed the fixture which was made of nylon, a non-magnetic material. It was specially designed to accommodate electromagnet poles such that the maximum magnetic pull occurs near the inner surface of the work piece.

2.3.The Electromagnet

The electromagnet was designed and fabricated for its location around the cylindrical work piece. It consists of two poles that are surrounded by coils arranged in such a manner as to provide the maximum magnetic field near the entire internal surface of the work piece.

2.4.The Magnetic Abrasive Laden Medium

The medium used for this study consists of a silicon based polymer, hydrocarbon gel and the magnetic abrasive grains. Wang et al. [4] developed lower-cost and effective abrasive media to enhance the finishing of the WEDM surface. Vinyl-silicone polymer (or silicone rubber) has good deformation and low flow effect; it can flow through the complicated holes easily. Moreover, the silicone rubber will not stick on the workpiece surface after machining. Abrasive particles and silicone rubber were mixed uniformly to prepare the flexible media. Then a chain hole, cut by WEDM, is polished by these media in AFM. The surface roughness decreased from 1.8 to 0.28 mRa and the roughness improvement rate (RIR) achieved was 84%. Kar et al [5] developed butyl rubber based media for abrasive flow machining. The developed media is based on viscoelastic carrier and its characterization for fine finishing through AFM process. The developed media was again characterized through rheological properties. It is concluded that temperature, shear rate, creeping time and frequency have impact on rheological properties and the percentage ingredients of media govern trends of their relations.

3. PRINCIPLE OF MATREIAL REMOVAL

Before machining, the abrasive laden media is inserted into the lower cylinder. The work piece is positioned in the specifically designed fixture and clamped between the media cylinders. After clamping, the media is pressed upward into the work piece. The volume of magnetic abrasive particles is carried by the abrasive fluid (media) through the work piece. Abrasives are impinged on the work piece with a specified pressure which is provided by the piston and cylinder arrangement.

The pressure energy of the fluid is converted into kinetic energy of the fluid in order to get high velocity. The abrasive grains strike the various projections of the surface on which surface finish is desired. The surface roughness peaks peal in the form of microchips, improving the surface finish (Figure 2). After that, the process is repeated in the opposite direction. This machining cycle is repeated until the desired work result is obtained. The basic principle of MAFM is that the magnetic abrasive and material removing effect of the abrasive media is in direct proportion to the speed of the abrasive. Following this principle, the conception of the tooling determines the position of the highest speed of the magnetic abrasive medium.

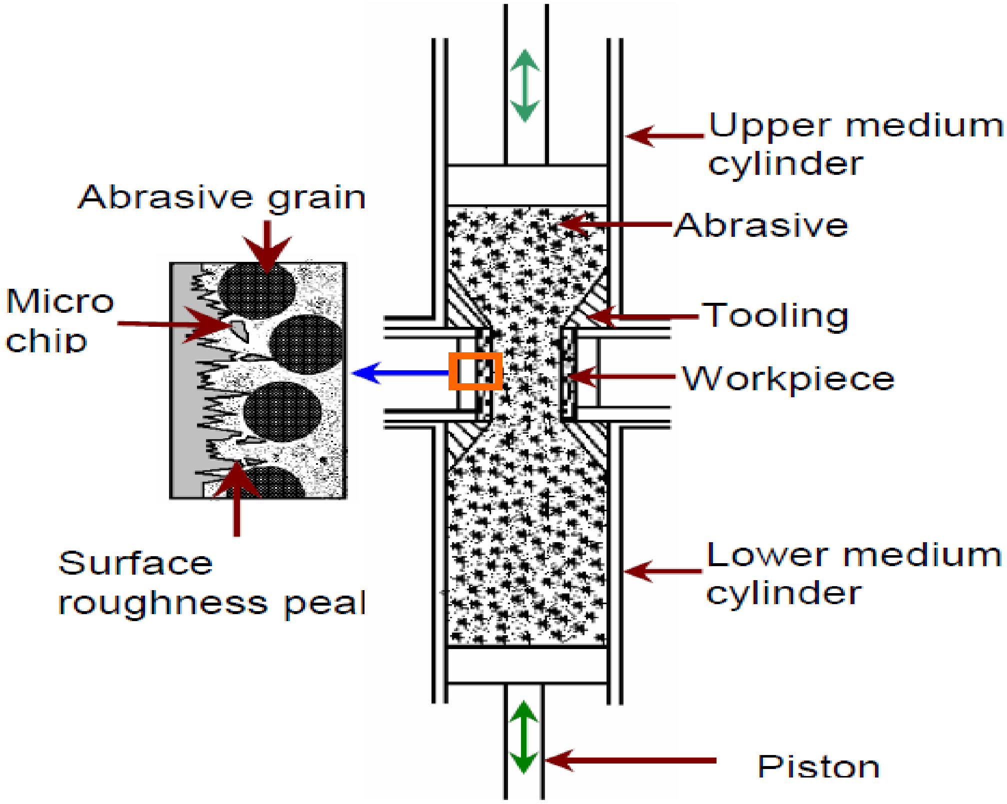

Fig. 2. Principle of Material Removal [3]

4. MAFM MACHINES

MAFM Machines are classified into three types, namely: (1) One-Way Machines (2) Two-Way Machines (3) Orbital Machines.

4.1. One-way machines

The apparatus includes a hydraulic reciprocating piston and an extrusion medium chamber adapted to receive and extrude medium unidirectional across the internal surfaces of a work piece having internal passages formed therein. The flow of medium is directed by the fixture from medium chamber into the internal passages of the work piece, while a medium collector collects the medium as it extrudes out from the internal passages. The schematic diagram of the two way abrasive flow finishing setup is shown in Fig. 3.

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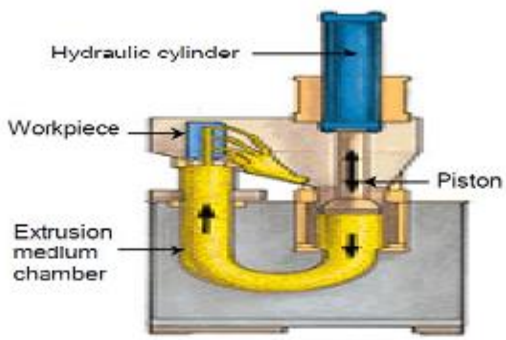

Fig. 3. Unidirectional MAFM Process [3]

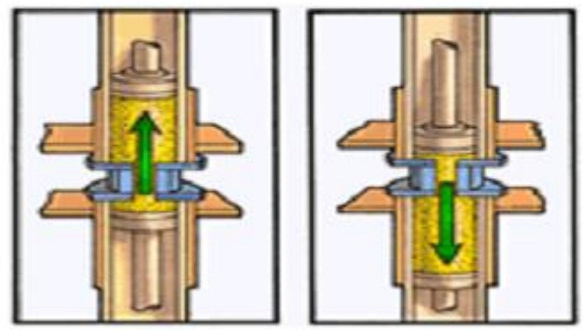

Fig. 4. Two–way MAFM Process [3]

4.2. Two-Way Machines

The two way MAFM machine has two hydraulic cylinders and two medium cylinders. The medium is extruded, hydraulically or mechanically, from the filled chamber to the empty chamber via the restricted passageway through or past the work piece surface to be abraded. Typically, the medium is extruded back and forth between the chambers for the desired fixed number of cycles. Counter bores, recessed areas and even blind cavities can be finished by using restrictors to direct the medium flow along the surfaces to be finished. The schematic diagram of the two way abrasive flow finishing setup is shown in Fig. 4.

4.3. Orbital Machines

In orbital MAFM, the work piece is precisely oscillated in two or three dimensions within a slow flowing ‘pad’ of compliant elastic/plastic MAFM medium. In orbital MAFM, surface and edge finishing are achieved by rapid, low-amplitude, oscillations of the work piece relative to a self-forming elastic plastic abrasive polishing tool. The tool is a pad or layer of abrasive-laden elastic plastic medium, but typically higher in viscosity and more in elastic. Orbital MAFM concept is to provide transitional motion to the work piece. When work piece with complex geometry translates, it compressively displaces and tangentially slides across the compressed elastic plastic self-formed pad which is positioned on the surface of a displacer which is roughly a mirror image of the work piece, plus or minus a gap accommodating the layer of medium and a clearance. A small orbital oscillation (0.5-5 mm) circular eccentric planar oscillation is applied to the work piece so that, at any point in its oscillation, a portion of its surface bumps into the medium pad, elastically compresses (5 to 20%) and slides across the medium as the work piece moves along its orbital oscillation path. As the circular eccentric oscillation continues, different portions of the work piece slide across the medium. Ultimately, the full circular oscillation engages each portion of the surface. To assure uniformity, the highly elastic abrasive medium must be somewhat plastic in order to be self-forming and to be continually presenting fresh medium to the polishing gap.

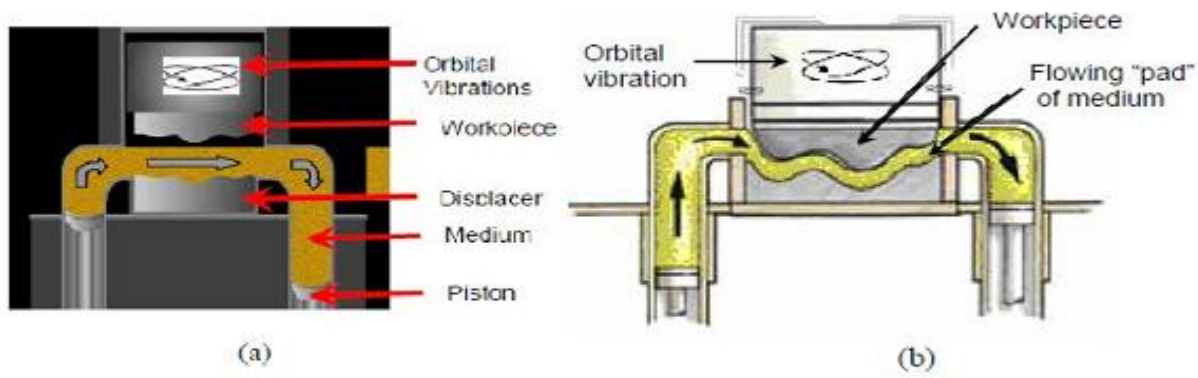

Fig. 5. Orbital MAFM Process (a) Before start of finishing (b) While Finishing [3]

5. PERFORMANCE EVALUATION IN THE FIELD OF AFM AND MAFM

Fang et al [6] examined that the influence of temperature on work efficiency is more as compared to other factors such as, media viscosity, abrasive hardness, particles sharpness and density, workpiece hardness, pressure, piston moving speed, etc. in AFM. AISI1080, 1045 and A36 steels were used as work specimens. AFM experiments shows that media temperature increases with increasing cycles, which means media viscosity decreases with increasing cycles and also results in decreasing materials removal and surface roughness decreasing efficiency as shown in Fig. 6,7.

When media with different viscosity is used media with high viscosity has more effective material removal efficiency as shown in Fig. 8. The high viscosity media to surface roughness improvement is also better than the low viscosity media at the initial several cycle numbers. With further increasing cycles the roughness improvement difference among different media with different viscosity is reduced. It is found from Mooney viscosity–temperature relation of media that temperature rising directly results in the decrease of media viscosity as shown in Fig. 9. When work cycles are increased the media temperature is quickly increased. The media viscosity is also decreased dramatically.

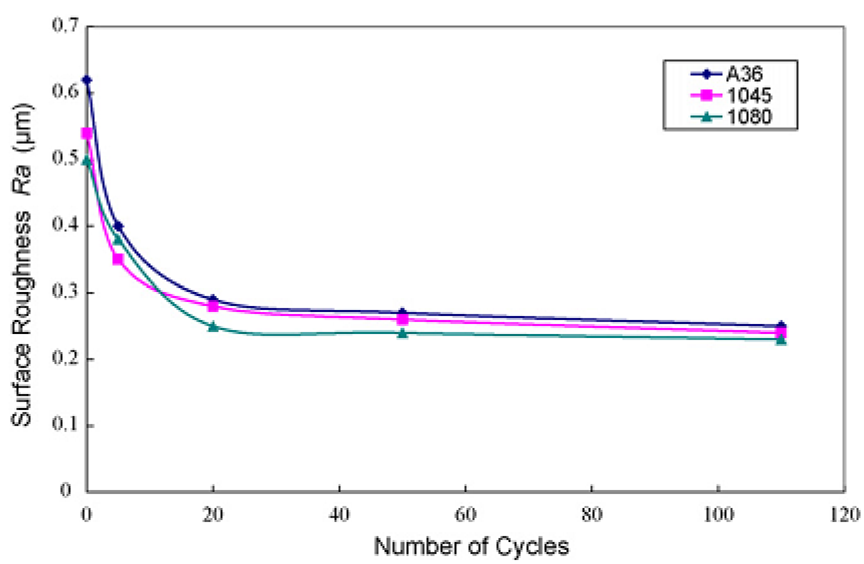

Fig. 6. Relation of the number of cycles to surface roughness Ra for AISI 1045, 1080 and A36 steel [6]

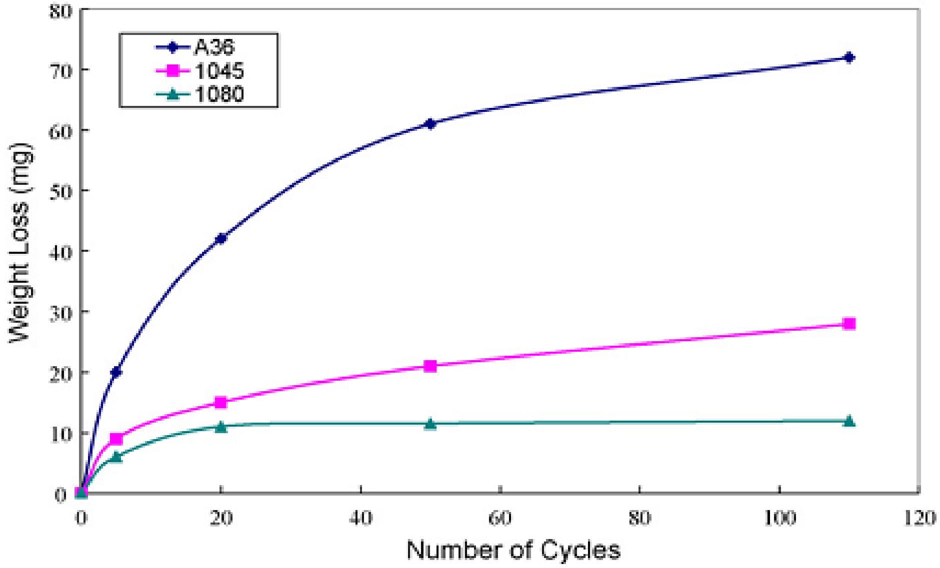

Fig. 7. Relation of the number of cycles to wear weight losses for AISI 1045, 1080 and A36 steel [6]

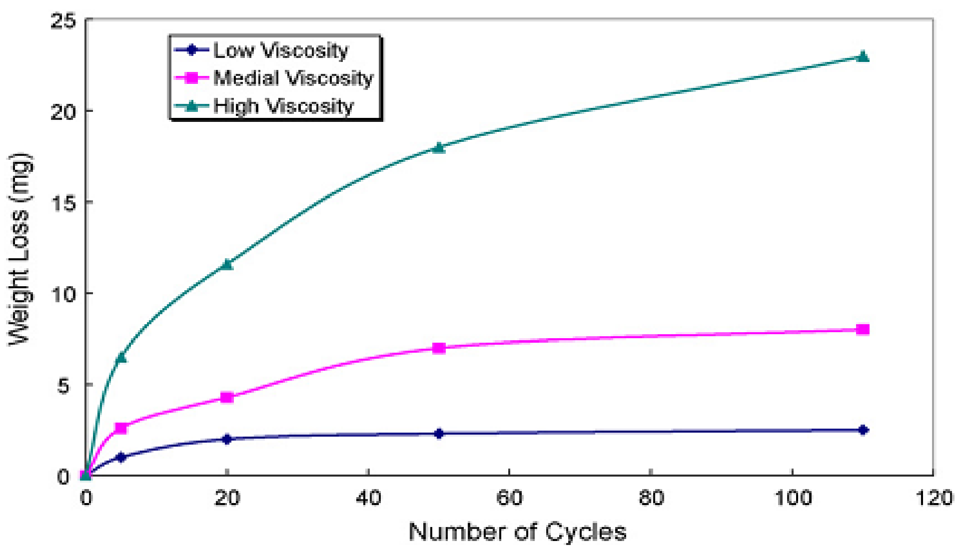

Fig. 8. Relation of the number of cycles to wear weight losses for low, medial and high viscosity suspension [6]

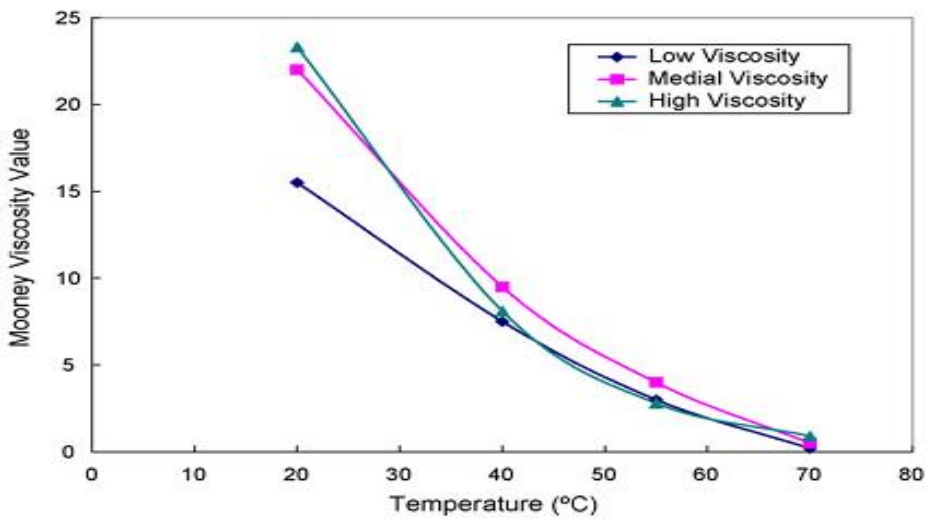

Fig. 9. Variation of Mooney viscosity with temperature for three types of suspensions [6]

Jain et al [7] experimentally investigated the effects of different process parameters, such as number of cycles, concentration of abrasive, abrasive mesh size and media flow speed, on material removal and surface finish for AFM of brass and aluminum as work specimens. The dominant process parameter found was concentration of abrasive, followed by abrasive mesh size, number of cycles, and media flow speed. It was also found that material removal (MR) is governed by initial surface finish and workpiece hardness. Softer material has higher material removal and more improvement in surface finish (ΔRa) as compared to harder material. As the percentage concentration of abrasive in the medium increases, material removal increases while the surface roughness value decreases. With higher abrasive mesh size, both material removal and improvement in the ΔRa value decrease. The experiments were performed according to the plan given in Table 1 [7].

Table 1. Plan of Experiments [7]

Plan of experiments[a,b,c]

Variables	Constant parameters	No. of times media changes
No. of cycles, *N* (00, 20, 40, 60, 80, 100)	Conc=80%; *U*=515 mm/min; Ab. mesh size=100	One time
Concentration (50, 60, 70, 80); *N* (00, 20, 40, 60, 80, 100)	*U*=515 mm/min; Ab. mesh size=100	Four times
Ab. mesh size (100, 150, 180, 240)	Conc=80%; *U*=515 mm/min; *N*=50	Four times
Media flow speed (mm/min) (406, 515, 652, 812)	Conc=80%; Ab. mesh; size=100; *N*=50	One time

[a] All experiments were conducted on both aluminum and brass workpieces.

[b] Material removal and surface roughness values were responses in each case.

[c] Ab. mesh size=Abrasive mesh size; Conc=Concentration of abrasive in the media by weight; MR=material removal (g); Ra=surface roughness value (μm); *U*=media flow speed (mm/min); *N*=no. of cycles.

Singh et al [8] experimentally studied the mechanism of material removal (MR) and the wear behavior of some materials when processed by AFM and magnetically assisted abrasive flow machining (MAAFM). The results suggest that the magnetic field has a strong effect on the MR in AFM. Furthermore, the nature of work material plays an important role in controlling the MR on the surface.

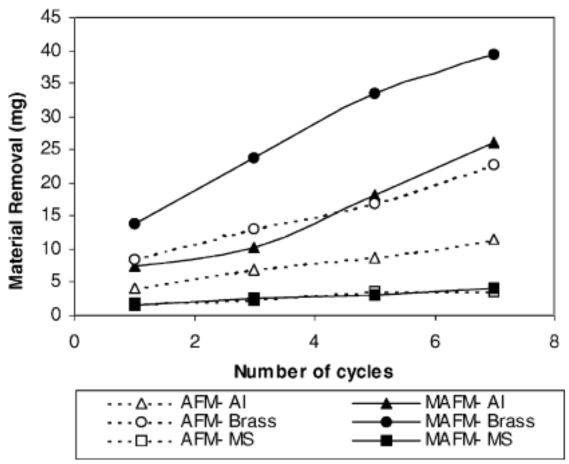

Fig. 10. Effect of magnetic field on MR of various materials

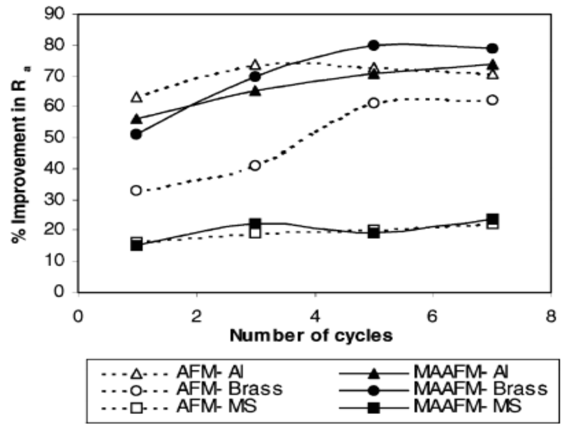

Fig. 11. Effect of magnetic field on percentage improvement in Ra of various materials [8]

From Fig. 10, it can be noticed that in AFM the MR in case of brass workpieces is consistently greater than that of aluminum workpieces. Lower total material removed from MS workpiece as compared to that from brass and aluminum (Fig. 10) may be due to its higher hardness, the Al2O3 abrasive particles could not have caused sufficient abrasion in the few number of process cycles employed in the experiment.

Fig. 11 shows the comparative variation of percentage improvement in Ra (ΔRa) of three different materials when processed by AFM and MAAFM. It can be clearly seen that highest improvement in Ra was for Brass finished by MAAFM.

Kenda et al [9] investigated the influence of the process parameters on surface integrity, i.e. surface roughness and induced residual stresses. The EDM pre-machined hardened tool steel AISI D2 specimens further with AFM. The results showed that AFM is capable to remove EDM damaged surface and significantly improve surface roughness. The process parameters used in this work are presented in Table 2.

Table 2. Used AFM process parameters [9]

	Parameter	Value
Polishing media parameters	viscosity	2650 Pas
	abrasive mesh	Mesh 80
	abrasive concentration	57 %
AFM machine parameters	pressure	3.5 MPa, 6.0 MPa
	volume flow	0.00000109247 m^3/s, 0.00000355053 m^3/s
	machining time	1800 s
Workpiece parameters	Roughness before AFM	R_a=1.67 µm, R_z=10.66 µm

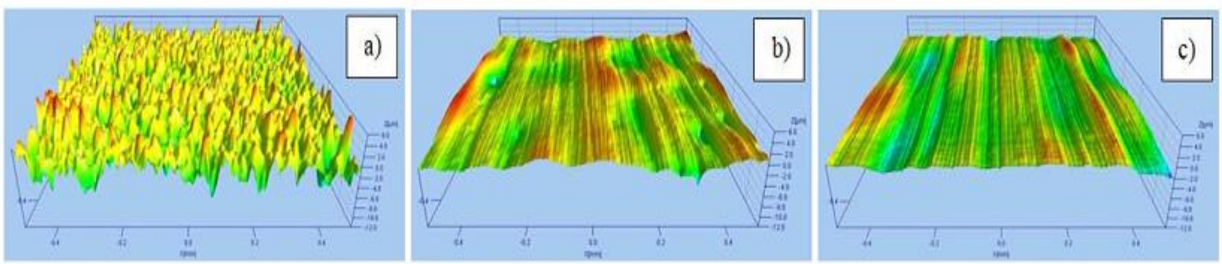

Fig. 12. Surface texture obtained after various manufacturing procedures, a) EDM, b) EDM + AFM with polishing media under pressure of 3.5 MPa and c) EDM + AFM with polishing media pressure 6.0 MPa [9]

The values are the average values of several measures. The corresponding 3D surface textures are shown in Fig. 12. It can be seen that surface obtained by EDM exhibit texture with no significant orientation or trend. In contrast, the AFM modified surfaces contain scratches in direction of finishing, with significant lower amplitudes.

Ravi Sankar et al. [10] experimentally investigated rotating workpiece by AFM. It has been found that rotational speed of workpiece has significant effect on output responses (Ra) and Δ*R*a increases with increase in the number of cycles, extrusion pressure till 6.5 MPa and processing oil content till 10%. Better *R*a was achieved on Al alloy/SiC (10%) MMC among three workpiece materials by AFM.

6. CONCLUSIONS

The following conclusions can be drawn from the present study:

1. The application of magnetic field around the workpiece increases the MR rate for non-ferromagnetic work materials as compared to AFM.

2. The MAFM improves more surface finish of brass workpieces (hard material) than aluminum workpieces (soft material).
3. The rate of MR for brass with MAAFM is higher as compared to that for aluminum workpieces.
4. The temperature of media is as important monitor which can be used to judge the work efficiency in MAFM process. When media with different viscosity is used media with high viscosity has more effective material removal efficiency. The high viscosity media to surface roughness improvement is also better than the low viscosity media at the initial several cycle numbers. With further increasing cycles the roughness improvement difference among different media with different viscosity is reduced.
5. It is found in general that the percentage concentration of abrasive in the medium is the dominant process parameter followed by abrasive mesh size, number of cycles and media flow speed. With the application of MAFM process, the surface integrity induced by EDM can be significantly improved.

Acknowledgments

All the authors whose work is referred here are sincerely acknowledged.

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Sliding Wear Behaviour of Ni_3Al Coated Steel

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Ni_3Al metallic powder was coated on AISI 309 SS steel by shrouded plasma spray process. The wear behaviour of the Ni3Al-coated AISI 309 SS steel and uncoated steel was investigated according to ASTM Standard G99-03 on a Pin-on-Disc Wear Test Rig. The wear tests were carried out at normal loads of 30 N and 50 N with a sliding velocity of 1 m/s. Cumulative wear rate and coefficient of friction (μ) were calculated for all the cases. The worn-out surfaces were then examined by scanning electron microscopy analysis. Both the as-sprayed coatings exhibited typical splat morphology. The XRD analysis indicated the formation of Ni3Al phase for the Ni3Al coating. It has been concluded that the plasma-sprayed Ni3Al coatings can be useful to reduce the wear rate of AISI 309 SS steel. The coatings were found to be adherent to the substrate steel during the wear tests. The plasma-sprayed Ni3Al coating has been recommended as a better choice to reduce the wear of AISI 309 SS steel.

Introduction

Wear is a process of removal of material from one or both of two solid surfaces in solid state contact (Ref 1). These wear related problems can be minimized mostly by using high-cost wear-resistant alloys/metals better than the existing low-cost alloys or by improving the wear and corrosion resistance of the existing metals and alloys by surface modifications. As the wear is a surface phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to use latter method of making surface modification than using the former one.

Among the various commercially viable surface coating techniques, plasma spraying fosters progress in both developments of materials and modern coating technology because of advances in powder and wire productions. The advanced plasma technique has many advantages such as high productivity for thick-coating films of more than 100 μm and good applicability for a wide range of coating materials including ceramic powder, further the process does not cause degradation of the mechanical properties of the alloy substrate (Ref 2). Plasma spraying is a well- established means of forming thick coatings used, for instance, for their resistance to wear, corrosion friction, and ionic conduction properties. They are used in many industrial applications; to improve the abrasive, erosive, and sliding wear of machine components. Developments in plasma spraying techniques as well as advances in powder and wire production have resulted in surface coatings with excellent properties under service conditions, thus enlarging the field of its application (Ref 3). In this presented work on wear, the plasma spraying was implemented to improve the wear properties of AISI 309 SS steel material.

In this study, AISI 309 SS steel has been studied with reference to its wear behaviour. AISI 309 SS steel is extensively used in Thermal Power Plant Components, especially in the boiler parts and the hoppers for handling pulverized coal from the coal crushers. AISI 309 SS steel plates are fixed on the inner sides of the hoppers, where they come in contact with bulk of free flowing pulverized coal mass. Therefore, they suffer heavy erosive-wear and need replacement at regular intervals. This eventually causes economic loss and downtime also. To reduce this wear problem, the plasma spray coatings have been deposited on AISI 309 SS steel and they were investigated with regard to their wear characteristics. Ni3Al coating were selected to be deposited on AISI 309 SS steel substrate after a comprehensive literature survey (Ref 4-14).

Experimental Procedure

The substrate material for this study has been selected after discussion with Guru Gobind Singh Super Thermal Plant, Ropar (Punjab), India. The chosen steel material is designated as AISI 309 SS. Table 1 shows nominal chemical composition of AISI 309 SS, whereas Table 2 reports some important mechanical properties of AISI 309 SS. These data were provided by the supplier of the steel. Small pins having circular cross section of diameter 8 mm and length 50 mm were prepared from AISI 309 SS. These pins were required to perform pin-on-disk experiment at room temperature. The faces of the pins were grinded, followed by polishing with emery papers down to 1000 grit. coating powder: (1) nickel and aluminum (Ni3Al) were deposited by plasma spray process on the substrate specimens. The particle size for powder Ni3Al was prepared by mixing Ni (particle size 74 μm) and Al (fine powder) powder in stoichiometric ratio of 3:1 in a ball mill for 8 h.

The coating work was carried out by a commercial company Anod Plasma Ltd., Kanpur (India). The specimens were grit blasted with Al2O3 powder before being plasma sprayed. The 40 kW Miller Thermal (USA) plasma spray apparatus was used to apply the coatings. Argon was used as powder carrying as well as shielding gas. The process parameters for the shrouded plasma spray process employed for applying the coatings are summarized in Table 3. The thickness of coatings was monitored during the process of plasma spraying with a thickness gauge; Minitest-2000 made in Germany. Efforts were made to obtain coatings of uniform thickness of 100 lm. Scanning electron microscopy (SEM) surface morphology and XRD analysis of the similar type of as-sprayed coatings have been studied earlier by the authors with a Ni-base super alloy Superni 75 as the substrate material (Ref 15-17). Dry sliding wear tests for the uncoated and plasma-sprayed AISI 309 SS were conducted using a pin-on-disc machine (Model: Wear and Friction Monitor Tester TR-20), supplied by M/S DUCOM, Bangalore (India) according to ASTM standard G99-03. A complete description of the wear testing has been reported elsewhere (Ref 18). The wear tests were carried out for a total sliding distance of 2400 m (10 cycles of 4 min duration each), so that only the coated surface was exposed for each plasma-sprayed sample.

Tangential force was monitored continuously during the wear tests. Weight losses for the pins were measured at the end of each cycle to determine the wear loss. The wear rate data for the coated as well as uncoated specimens were plotted with respect to sliding distance to establish the wear kinetics. The specific wear rates for the materials were obtained by

$$W = \Delta w / L\rho F \qquad \text{Equation (1)}$$

where W denotes specific wear rates in mm^3/Nm, Δw is the weight loss measured in grams, L is the sliding distance in meters, ρ the density of the worn material in g/mm^3, and F is the applied load in N. The coefficient of friction (μ) has been plotted against the sliding time to give the friction behavior of the materials, which was calculated as below:

$$\mu = \text{Frictional Force (N)} / \text{Applied Normal Load (N)} \qquad \text{Equation (2)}$$

Some of the worn-out surfaces were analysed by SEM analysis using a JSM scanning electron microscope (Model: JSM 6100).

Wear Behavior

Wear Behavior at a Normal Load of 30 N. The variation of the cumulative wear rate (CWR) with the sliding distance for plasma Ni3Al coated and uncoated AISI 309 SS steel has been plotted in Fig. 1. It is evident from the plots that the uncoated steel shows much higher wear rate as compared to its coated counterparts. Further, the CWR for the former case shows an approximately linearly increasing trend with increase in sliding distance, whereas in the latter cases the same has shown the tendency to become uniform. A uniform wear rate is a favorable trend from the point of view of wear resistance. Therefore, it can be concluded that the coating are useful to enhance the wear resistance of the base steel. Furthermore, the plasma-sprayed Ni3Al coating showed lowest CWR than uncoated. In other words, the plasma-sprayed Ni3Al coating is better than coating under the stated conditions. The coefficient of friction (μ) determined from the frictional force, and the normal load has been plotted against the sliding distance for the uncoated as well as plasma-sprayed Ni3Al-coated AISI 309 SS steel subjected to wear testing at a normal load of 30 N and sliding velocity of 1 m/s in Fig. 1. It can be observed that the μ for the uncoated AISI 309 SS steel, as well as plasma-sprayed

AISI 309 SS steel shows more abrupt changes in their values, whereas Ni3Al-coated AISI 309 SS steel shows minor variations in its μ values. Furthermore, the Ni3Al-coated AISI 309 SS steel has shown (Fig. 1) some- what relatively higher values of coefficient of friction. The mean value of μ are calculated as 0.34 (SD 0.04) for the AISI 309 SS steel, 0.36 (SD 0.05) for the Ni3Al-coated AISI 309 SS steel.

Wear Behavior at a Normal Load of 50 N

The variation of CWR with sliding distance for the plasma- sprayed Ni3Al coated, as well as uncoated AISI 309 SS steel has been shown in Fig. 1. It is evident from the figure that the CWR for the Ni3Al plasma spray-coated samples do not show significant change with wear distance, while that for the uncoated AISI 309 SS steel does, for the latter case, the CWR increases with the sliding distance. This shows that coatings are successful in enhancing the wear resistance of the base steel. It is found that CWR for the plasma-sprayed Ni3Al coating do not differ significantly, however as compared to that for the AISI 309 SS steel case, the values are insignificant for both the coated samples. Moreover, the Ni3Al coating shows better wear resistance in comparison with uncoated.

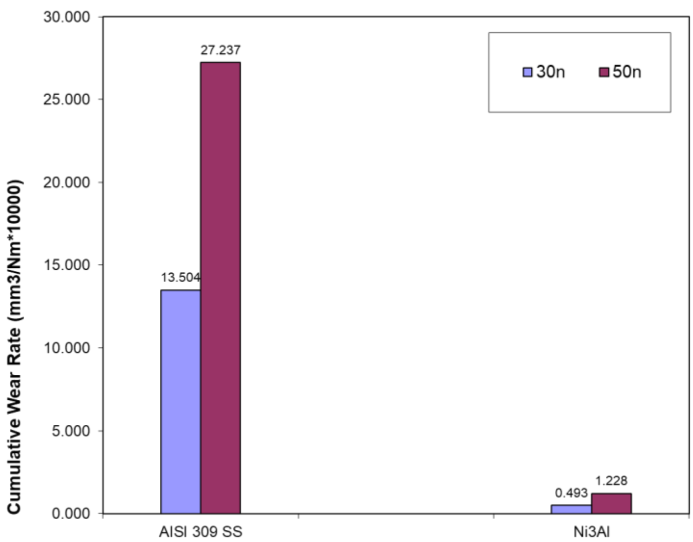

Fig. 1: Observed Cumulative wear rate at different Loads

Discussion

The Ni3Al powder were successfully deposited on AISI 309 SS substrate steel by the plasma spray process. The thickness of the coating was 100 µm in both the cases. A comprehensive discussion on phase formation and microstructure of similar coatings can be found elsewhere (Ref 15-17). The uncoated AISI 309 SS steel showed higher CWR in comparison to the plasma-sprayed Ni3Al-coated AISI 309 SS steel under all the investigated load variants of 30 and 50 N. Moreover, this CWR increased with increase in sliding distance for the uncoated steel, whereas the same become nearly uniform in the plasma-sprayed coated cases. This indicates that the wear resistance of the AISI 309 SS steel.

got increased significantly after the application of the coatings. Although the coefficient of friction has increased for the coated case yet this increase is marginal. It has been observed from the overall results of investigation (Fig 8) that the Ni3Al coating has shown comparatively lower CWR among the investigated case in general, under the normal load testing of magnitudes of 30 N and 50 N. Therefore, it may be concluded that the Ni3Al coating is more wear resistant than the uncoated. The surface of the uncoated steel suffered damage of its contact surface in the form of micro pits, which most likely may have occurred due to micro ploughing effect of the wear debris between the contact surface of steel and rotating disc. Similar observation has also been reported by Singh et al. (Ref 18) and Mishra (Ref 19). Whereas no such damage of the contact surfaces of the coatings has been observed. Moreover, the coatings were found to be successful in keeping their surface contact with the substrate steel when subjected to wear tests.

The coefficient of friction (µ) for the uncoated AISI 309 SS steel is less in general when compared to plasma- sprayed coatings under all normal load conditions. Moreover, the observed variations in µ values are due to several factors, such as intrinsic properties of the material, operating conditions (temperature and humidity), sliding speed, and applied load. Khruschov (Ref 20) has also suggested that it is difficult to get the exact value of l. The l value follows the order as shown below:

AISI 309 SS < Ni3Al

It is interesting to note that the mean values of l for the uncoated, Ni3Al-coated AISI 309 SS steel under 50 N normal load are found to be higher than their respective 30 N normal load values. From the ongoing discussion, it can be concluded that the wear resistance of the AISI 309 SS can significantly be improved with the application of plasma-sprayed Ni3Al coating.

Conclusions

The plasma process provides the possibility of deposition of Ni3Al powders on AISI 309 SS steel. A uniform coating thickness of 100 µm was achieved. The wear resistances, as well as, the coefficient of friction values for AISI 309 SS steel, plasma-sprayed Ni3Al coating followed a general trend irrespective of the value of normal load as given below:

AISI 309 SS < Ni3Al:

From the current investigation, the Ni3Al coating may be recommended as a better choice to reduce the wear of AISI 309 SS steel

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A Paradigm Shift from ICE to EVs: Global versus Indian Perspective

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Abstract: Electric vehicles (EVs) for road transport boost energy efficiency require no direct fuel combustion and rely on electricity – the most diversified energy carrier, thereby contributing to a wide range of transport policy goals. These include enhanced energy security, better air quality, less noise and, in concert with a low-carbon power generation mix, reduced greenhouse gas emissions. Plus, as one of the most innovative clusters in the automotive sector, EVs have substantial potential to enhance economic and industrial competitiveness and to attract investment where major markets can be developed.

Key words: Internal Combustion Engine, Electric Vehicles, Emissions, electromobility

1. Introduction

The automotive industry is gradually shifting from producing traditional cars powered by internal combustion engines (ICE) to less carbon-intensive drive technologies, including fully battery-electric as well as hybrid-electric cars. The latter combine electric engines with smaller combustion engines. This shift implies major changes in the automotive and related industries. New technologies and new capabilities are required, and some old ones will lose their previous importance. Battery-electric vehicles (BEV), for example, need new generations of powerful batteries, electric motors and inverters; and they no longer require some of the core technologies of traditional cars, such as internal combustion engines and gearboxes [2]. New forms of thermo-management need to be developed, as there is no longer a combustion process generating heat which can be used for heating or cooling. Essentially, a major part of the automotive architecture needs to be redesigned.

This paper explores the depth, the direction and the potential implications of the global shift to electromobility. The term ‘electromobility’ comprises several powertrain and car concepts:

(i) **Hybrid electric vehicles (HEV)**, also called parallel hybrids, have a conventional combustion engine supported by an electric motor. The battery capacity is limited and is used as a temporary complementary power source to assist the main engine or replace it at low speed. The batteries are charged by the electricity generated by the engine and brake energy recuperation. Purely electric propulsion is possible, but only for a quite limited range.

(ii) **Plug-in hybrid vehicles (PHEV)** are similar to HEV but in addition offer the possibility of plugging them into the power grids. This increases energy storage and driving range. Some PHEV are designed for electric propulsion mainly and therefore use larger batteries.

(iii) **Range-extended electric vehicles (REEV)** are equipped with a strong electric motor and a grid chargeable battery. Propulsion is purely electric, but a small combustion engine is installed to recharge the battery in order to extend the driving range.

(iv) **Battery-electric vehicles (BEV)** use an electric motor with batteries for electricity storage. The batteries provide energy for all motive and auxiliary power onboard the vehicle. They are recharged from grid electricity and brake energy recuperation, and also potentially from non-grid sources, such as photovoltaic panels at recharging centres.

(v) **Fuel-cell electric vehicles (FCEV)** use an electric motor and a fuel cell for energy supply. The fuel cell converts energy from hydrogen. FCEV also use a battery for brake energy recuperation.

2. Paradigm Shift from ICE to EVs

The shift from the old transport systems based on fuel-driven cars to electromobility is thus potentially a true techno-institutional paradigm change, as Freyssenet [5] claims in his book titled "The second automobile revolution". This paradigm change, however, is just in the making, in all industrialised and emerging economies. Predictions about the speed and the depth of the change vary greatly: How rapidly will the combustion engine technology be phased out? How long will it take to overcome the range problem of battery-electric vehicles? Will the bridging technology of hybrid vehicles be a short episode in the history of cars or a long-lasting alternative? Will we mainly see a replacement of internal combustion engine (ICE) cars by electric cars, or will there be more profound changes towards new forms of mobility? And who will be the drivers of change? Will industry incumbents be seriously challenged by newcomers or will the old players gradually adapt and maintain their leadership? How profoundly will supply chains be affected? These are important questions.

How things evolve will have enormous repercussions on decarbonisation pathways globally as well as on the global distribution of technological capabilities and competitive advantages. Hence the questions asked in the previous paragraph will play out differently in each country, each regional productive cluster, and each automotive value chain.

2.1 Electric Vehicles Initiative

The Electric Vehicles Initiative (EVI) is a multi-governmental policy forum established in 2009 under the Clean Energy Ministerial. It is dedicated to accelerating the deployment of electric vehicles worldwide. The EVI facilitates exchanges between policy makers working in governments that are committed to supporting EV development and a variety of partners, bringing them together twice a year. The EVI serves as a platform for knowledge-sharing on policies and programmes that support EV deployment.

Governments currently active in the EVI include Canada, the People's Republic of China ("China"), Finland, France, Germany, India, Japan, Mexico, Netherlands, Norway, Sweden, United Kingdom and United States. This group includes the largest and most rapidly growing EV markets worldwide and accounted for the vast majority of global EV sales in 2017. Canada and China are the co-leads of the initiative. As shown in figure 2.1 the global stock of electric cars surpassed 3 million vehicles in 2017 after crossing the 1 million threshold in 2015 and the 2 million mark in 2016. It expanded by 56% compared with 2016. In 2017, China had the largest electric car stock: 40% of the global total. The International Energy Agency serves as the EVI co-ordinator. In addition to the 13 EVI countries listed in this paragraph, Chile and New Zealand recently announced their intention to join the EVI as of May 2018.

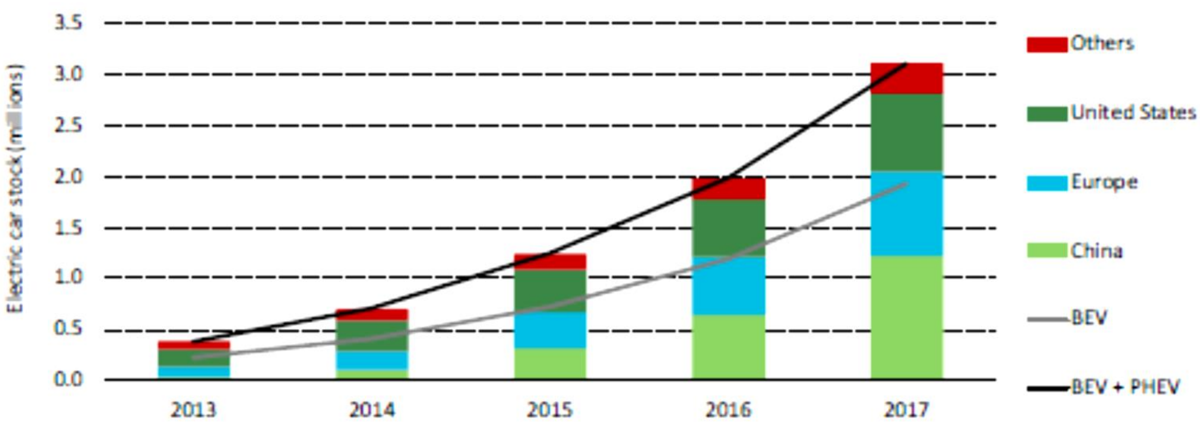

Figure 2.1 Evolution of global EV car stock, 2013-17 Sources: IEA analysis based on country submissions [6, 7]

2.2 The EV30@30 campaign

The EV30@30 campaign, launched at the Eighth Clean Energy Ministerial in 2017, redefined the EVI ambition by setting the collective aspirational goal for all EVI members of a 30% market share for electric vehicles in the total of all vehicles (except two-wheelers) by 2030. The campaign includes several implementing actions to help achieve the goal in accordance with the priorities and programmes of each EVI country. These actions include:

- Supporting the deployment of EV chargers and tracking progress.
- Galvanising public and private sector commitments for EV uptake in company and supplier fleets.
- Scaling up policy research, including policy efficacy analysis, information and experience sharing and capacity building.
- Supporting governments in need of policy and technical assistance through training and capacity building.

- Establishing the Global EV Pilot City Programme, a global co-operative programme that aims to facilitate the exchange of experiences and the replication of best practices for the promotion of EVs in cities.

2.3 The Logical basis of Supporting Electromobility

When justifying policy support for electromobility, governments around the world typically bring up four arguments – but they attach quite different priorities to these arguments, which has considerable implications for the way policies are shaped [2]. The four arguments are substantiated as follows:

2.3.1 Climate change mitigation

To curb greenhouse gas emissions, traffic needs to be decarbonised. Worldwide, the transport sector accounted for approximately 23% of total energy related carbon dioxide emissions. Moreover, no other sector has recently increased its emissions as much as transport. In China alone, car sales skyrocketed from 2.3 million cars in 2001 to 18.5 million cars in 2011. In response to these developments, policymakers in the world's largest economies have recently introduced a series of policies to reduce CO_2 emissions from vehicles. In 2009 the EU and Group of Eight (G8) leaders both accepted that, in order to stay within the target of maximum 2°C global warming, CO_2 emission needed to be reduced by 80%, which would imply reducing CO_2 emissions from road transportation by 95%, given that some other activities cannot be decarbonised as radically.

Electromobility may contribute significantly to the decarburization of road transport. If a national government wants to mitigate carbon emissions, then it needs to set incentives for reducing the emissions of the whole production process ('well-to-wheel') and not just the emissions from different internal engines ('tank-to-wheel' resp. 'battery-to-wheel'). Table 2.1 shows how different these are, depending on the underlying national energy mix. Assuming that cars are charged with 100% electricity from purely renewable sources, emissions would be minimal. Likewise, the French energy mix, with a particularly high share of nuclear energy, produces very low CO2 emissions. It should be noted, however, that this is achieved in exchange for new risks related to radioactive contamination. Finally, the average EU 27 energy mix also reduces well-to-wheel emissions, but not to the extent needed to meet agreed international climate change mitigation targets.

Energy Mix	Well to Tank (Batteries)	Tank (batteries) to Wheel	Total Well to Wheel
Conventional ICE car	25-35	120-180	145-215
EV EU-27 mix 2010: (27% nuclear, 20% renewable, 53% fossil)	85-105	0	85-105
EV French mix (75% nuclear, 20% renewable, 5% fossil)	20-25	0	20-25
EV 100% renewable: (50% photovoltaic, 50% wind)	8	0	8

Table 2.1 ‘Well-to-wheel’ CO_2 emissions (g/km) of ICE and electric vehicles (EV) assuming different energy mixes. Source ERTRAC (2010) [1]

2.3.2 Urban air pollution

Combustion engines are a major source of air pollution and noise. Emissions of toxic gases and particular matters, especially from diesel engines, cause health problems. With the trend to megacity development and an increasing density of cars, these problems are bound to increase greatly unless emissions per car and kilometer travelled are greatly reduced. By 2050, the OECD (2012) [2] predicts that outdoor air pollution will become the main cause of environmentally related deaths worldwide. The enormous increase in road traffic, especially in China, contributes greatly to air pollution. Coming to grips with urban air pollution is the most important political driver of electromobility initiatives in China.

2.3.3 Enhancing competitive advantage

Countries may pursue the aims of building new or enhancing existing competitive advantages. The shift to electric and hybrid drive technologies may on the one hand enhance the competitive edge of established automotive industries if these manage to build upon existing technological capabilities and incorporate new technological demands into their existing innovation systems; but it may also threaten the incumbents if newcomers manage to take advantage of the paradigm change, leapfrog directly into the new generation of technologies without having to care about sunk investments in the old technologies, and thereby take market shares away from the incumbents. The desire to create such advantages and reap the related job and income effects is one of the strongest motives for investing in electromobility.

2.3.4 Fuel saving and energy security

Decarburization would save finite fossil fuels and reduce import dependency for fuel-importing countries. In the European Union, 97% of all transport energy still comes from fossil fuels, thereby pushing the import bill up. The prospect of future fossil fuel shortages provides a strong economic incentive for developing alternative energy sources. For some countries, fuel saving and independence from imported fossil fuels are strong motives for supporting electromobility – but this presupposes the expansion of non-fuel sources of electricity in the country.

2.4 Regional Developments

China and Europe: China and Europe are the global regions with the fastest development of EVs in both scenarios and in virtually all modes (Figure 2.2). In the New Policies Scenario, EVs reach a market share (or sales share) of 26% in China and 23% in Europe by 2030 when accounting for all modes (except two- and three-wheelers).

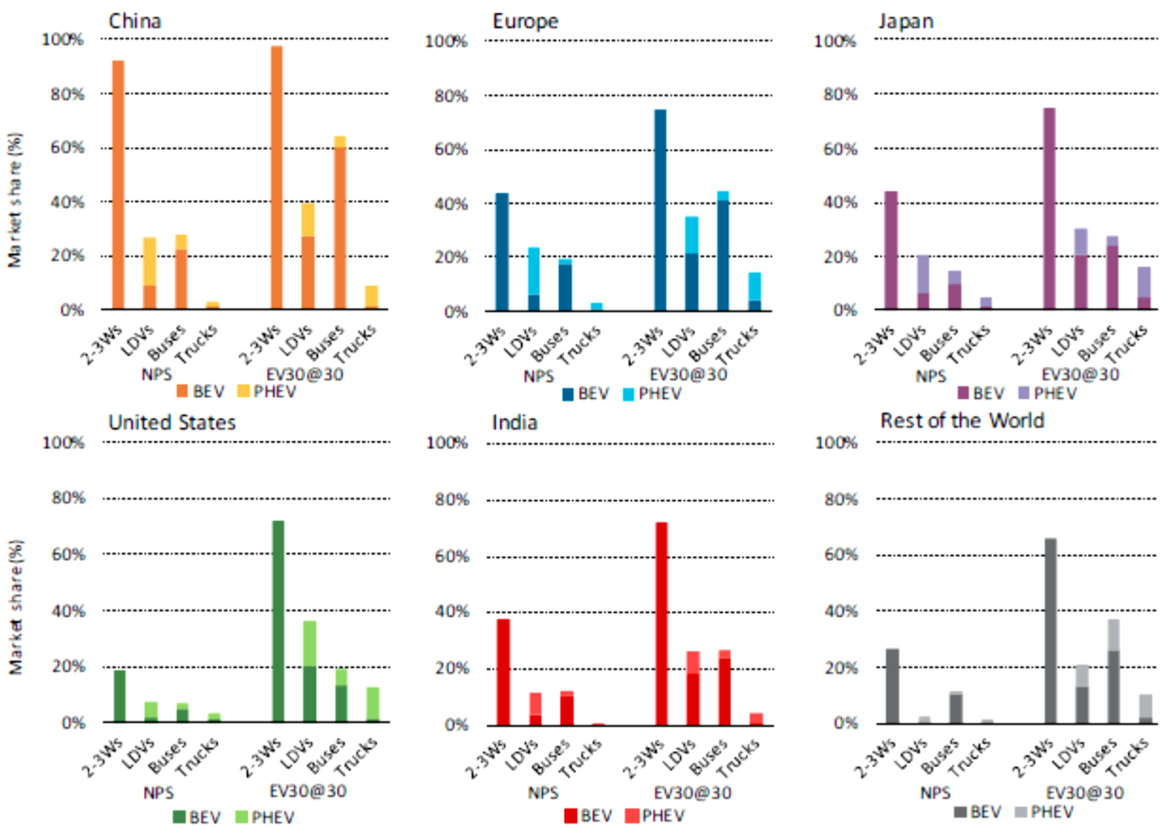

Figure 2.2: EV market share by type and scenario in selected regions, 2030

Note: NPS refers to New Policies Scenario; 2-3Ws refers to two- and three-wheelers. Source: IEA Mobility Model (2018b) [1].

Japan: Japan is the world's fifth-largest EV market and has stated targets for the future. The country has strong design and manufacturing experience in vehicle hybridisation, and is home to a number of OEMs that are embracing the electric mobility transition faster than others (e.g. Nissan, Toyota). A number of Japanese manufacturers are also making major investments for the deployment of automotive batteries (such as Panasonic). Japan's dense urbanisation lends also itself to easier deployment of a comprehensive network of charging infrastructure than in other regions. Japan is also a global leader in the promotion of hydrogen FCEVs as part of a clean transport future. In the EV30@30 Scenario, EV market shares in Japan approach the values of the European and Chinese markets for LDVs in 2030, consolidating the role of Japan as a global leader in the transition to vehicle electrification.

United States: Electric mobility deployment in the United States occurs at two speeds. On one hand, there are market leaders with clearly defined ambitions such as California and the ZEV states, which achieve rapid market penetration. On the other hand, taxes on petroleum fuels are lower than those applied in China, Europe and Japan; vehicle characteristics (power, size, weight and footprint) indicate that cars are much larger than in other areas of the world; and uncertainly about the announced revisions of current CO_2 standards, recently deemed too strict by the federal government (EPA, 2018), lead to lower EV uptake in the United States in the New Policies Scenario than in other countries. In the EV30@30 Scenario, the Unites States is assumed to adopt rapidly a broadly supportive policy framework. In this scenario, the market share of electric LDVs reaches similar levels as in China, Europe and Japan, while the shares of electric buses are lower.

India: India reaches an 11% EV market share by 2030 (for all modes combined, excluding two- and three wheelers) in the New Policies Scenario. This reflects the country's ambitions and actions towards the development of electric mobility, including proactive engagements from the local automotive industry (Mahindra, 2018; The Economic Times, 2018) [1], and actions from the government on the procurement of electric cars (Government of India, 2017b; Government of India, 2018b) [1]. In the EV30@30 Scenario outlook, India boosts momentum for the electric mobility transition, develops a favourable policy environment and achieves a 25% EV market share by 2030 across all modes (except two- and three- wheelers, of which over 70% of sales are electric units by the same year).

Other regions: The largest EV markets included under "rest of the world" in Figure 2.2 include Asia (excluding China and Japan), Africa, Australia, Middle East, Canada, Latin America, the Middle East, New Zealand, Turkey and the Russian Federation. Electric LDV shares in these regions on average are lower compared to China, Europe, Japan, India and United States in the New Policies Scenario by 2030. This reflects the fact that most of the major global economies that are at the leading edge of the policy development supporting EVs are included in the subset of regions discussed in greater detail above. Electric bus shares in other regions (taken together) are higher than in the United States, reflecting a stronger economic case in countries that apply higher fuel taxes, despite bigger challenges for the access to capital for electric bus purchases in some of the regions. Electric LDV shares in the EV30@30 Scenario are similar to India, and therefore reflect a context where swift policy action enables sizeable commitment to the deployment of chargers and a dynamic uptake of EVs. Electric buses are subject to a swift transition too, almost comparable to the case of Europe.

3. ICE to EV shift-Indian preparedness

The world is moving towards electric vehicles and India too needs a clear-cut policy. But for a country that still meets 75% of its electricity needs by burning fossil fuel, many argue that it will only move the pollution off city roads to its hinterlands, where that power is generated. RC Bhargava, chairman, Maruti Suzuki, points out that unlike other automotive technologies, EV technology is still in the evolutionary phase and there are a lot of uncertainties with regards to cost structures and the evolution of the ecosystem. “The industry can’t expect the government to do its planning. The industry should do its homework and suggest to the government what it they would like is,” he says. “Then the government can look into demands of the industry and only after that go for an EV policy. The technology is still evolving, so I don’t think it makes sense to have any targets right now.”

So are hybrids — vehicles that run on both battery and internal combustion (IC)engines — the only plausible interim way out to address the issue of a higher imports bill and reduce emissions? Recently, two leading Japanese automotive delegations met up with the government to convince them of the need to focus more on hybrids — including plug in hybrids (PHEVs).

“The government cannot have a policy for a technology, as technology keeps changing… Technology is always ahead of rules and regulations,” argues Vikram Kirloskar, vice-chairman, Toyota Kirloskar. “So don’t tell us what technology to use. The customer and the manufacturer can decide that.”

However, Pawan Goenka, managing director, Mahindra and Mahindra, feels too much is being read into the statements. He asserts that the government has clearly defined a push for EVs. The state-run Energy Efficiency Services (EESL), a joint venture of PSUs under the power ministry, has already issued letters of authorisation for the first lot of 10,000 vehicles and another tender will be issued soon. Many states are also issuing tenders for electric buses. “I don’t see any mixed signals. The only thing that can be concluded is that it is becoming clear that 100% EV by 2030 is neither feasible nor desirable and, therefore, this is not being mandated. Even 30% penetration for electric vehicles by 2030 will mean a market in excess of 3 million with zero tail pipe emissions and over 7 million vehicles with conventional combustion engines that will be much cleaner with BS VI emission norms. This will ensure that vehicle makers invest in all forms of power train.

So for now, the power ministry will continue to drive adoption of electric vehicles with government buying through EESL and work on building the charging infrastructure. The department of heavy industries will continue to offer subsidy under the scheme for Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles or FAME, incentivising purchase.

The immediate focus now for car companies is upgrading from BS IV straight away to BS VI. To do so within three years and get a reliable and safe product in the market is also an extremely complex engineering task. Europe has taken almost nine years to make a similar transition.

Mercedes, for instance, recently launched BS VI vehicles for the Indian market, a feasible on-ground action to address pollution. The particulate matter limit in the BS VI diesel engine is lower by 82% than that of the BS IV diesel engine. Original equipment manufacturers and suppliers also need to work in tandem to achieve this changeover. Passenger car and heavy truck costs may rise 1-3 lakh per vehicle, so the industry needs to be prepared for a period of increased cost burden, says Jan O Röhrl, chief technology officer and director, Bosch.

4. Conclusion-Driving Forward

The changes unfolding rapidly in the automobile industry will impact virtually every other industry on the planet. Energy production, metals and mining, global trade and transport, technology, environmental policy, tax credits, and incentives will all undergo massive transformation. The challenge for businesses operating in this environment is not so much that the change is happening, but the unpredictable, often uneven pace at which it is happening.

While a great deal of the regulatory activity that's driving such active EV adoption in Europe and Asia can be linked directly to environmental policy and the Paris Agreement goal of achieving carbon neutrality by 2050, the U.S., the second largest automobile market in the world, is notably absent from that group. Additionally, the Trump administration signaled that it will not extend the current minimum fuel economy requirements imposed on the auto industry beyond 2025.

As far as Indian market in concerned, for component makers, building cost effective 'India solutions' that are BS VI-compliant is now a top priority. While most components inside vehicles will remain the same, revamping the supply chain will require a renewed strategic outlook. They will need to overhaul the entire manufacturing ecosystem to generate profitable returns.

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Wireless Pesticide Spraying Machine

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Abstract

In Farming, it is most important to protect the plant from disease, insects, and atmosphere (sometimes). So different pesticides are used for this purpose, most of them are in liquid form and sprayed on the crop. For this spraying of pesticide different type of machines are used but most commonly backpack type sprayer is used because it is cheaper and very easy to use. But the huge disadvantage of this machine is that it requires too much time for spraying, hence high operational cost. The spray of pesticide is not uniform over the crops. It also leads to various health problems like it causes lumbar pain due to the weight of the tank on the back. The person spraying with this machine can also come in direct contact with toxic pesticides and this may lead to death causing diseases. This paper suggests the machine that will save the time and operational cost for spraying so the per capita income can be increased. It can be operated from a distance; hence will not have any adverse effect on the human body of toxic pesticides.

Keywords: Pump, Nozzle, Battery, Remote Control, DC Motor

1. Introduction

Indian farmer is less productive, because to lack of technology involved in agriculture. Framers are not using advance machine or technology to decrease the overall cost and time. In agriculture main loss in crop yield due to attack of pest, diseases and weeds. To avoid this, lose chemical control method is used. In this mixture of chemical is sprayed directly on the crop as this is most efficient method for applying chemical in small volume so that it does not affect crop in other ways and also not harmful for consumption. Spraying is done with different methods like hand sprayer, knapsack sprayer, aerial sprayer, tractor mounted sprayer, bicycle mounted sprayer etc. In last few decades a lot of research is done of in spraying machine but till now no machine is there that can help farmer to increase their productive and profit. So, we have to make machines that can help them to save their time and money and to increase the production rate and their profit. We have to make machineries which are economical to the farmers so that farmers can purchase them easily. The per capita income of our country's farmers is low and also our country's per capita income is low as compared to other countries since our country is developing country. Present scenario in agricultural field in India related to sprayer is that farmers are using hand operated sprayer or motorized sprayer. In the current project we are making a small 4-wheel kart or vehicle which is electronically operated by a wireless remote which runs on power source as a DC battery. Nozzle is fitted on these back so that it can spray pesticides both the sides. As more number of nozzles are there hence spraying is done rapidly and time and money are saved.

2. Literature review

Bharatbhai [1] is his work explained the various factors that decrease **c**rop yield that are mainly due to attack of pests, diseases and weeds. So chemical control is the popular method adopted for controlling most of these problems. In the chemicals are applied either by spraying, sprinkling or on the crop with help of pumpor dusting. Spraying is most efficient most. Spraying pesticide has also many issues because it affects human body and harmful chemical get in contact with the body cause dead full diseases. Hence there is need to develop the machine that can be operated from distance through remote and is economical also. Bhatkar [2] in his review paper give the various type of spraying machine from hand sprayer to tractor operated. Concluded that none this is very advantageous because that economical high is price and not very one can afford he methods like ariella sprayer. In other method still there is need of one person to operate these machine and those also not eco-friendly. So there is need of mechanization we can efficiently reduce the effort of labors and uniformly spray the pesticide all over the farm. So there is need of development of user friendly, efficient and low cost mechanization in agricultural sector especially in pesticide spraying machine. Phanindra [4] is his work gives an idea for developing a wireless car that can be control by an android application through Bluetooth connectivity. He give the brief information about the microcontroller used and other components, how to built circuits and upload the program. The calculations for the range of the Bluetooth are also given in the paper. The advantage of this wireless system is discussed in brief and simple flow chart of signal processing is also there for better understanding. Kumbhare[5] discussed drawback in present spraying system and give suggestion of developing a wireless operated car that can spray the pesticide through nozzle. All the calculation for spraying jet and discharge rate are given in the work. The cost price calculations are also given to make sure it is economical and everyone can buy it. Other advantage of use the wireless operated system were discussed

3. Objectives

The followings are the main objectives of the project work:

- To spray pesticides without direct human contact
- To make low budget automatic pesticide spraying
- To make non- polluting vehicle
- To reduce human labour

4. Design & Experimental Setup

The design of the system is divided into two categories (Hardware & Software)

A. Hardware used in the current work

S.No.	Name	Specification
1	Arduino UNO	ATMEGA328P
2	Bluetooth module	HC-05
3	Motor driver	L298N
4	Chassis	Cast Iron
5	DC Motors	Geared motor
6	Dc Pump	12V
7	Water Tank	2 liters
8	Li ion battery	12V

The basic hardware components of the project have been described below:

Arduino UNO (Microcontroller) acts as the brain of the robot. The robot movement is decided by the microcontroller. In this system, we have used microcontroller named Arduino UNO which contains ATMEGA 328P microcontroller chip (Figure 1). The Microcontroller is programmed with the help of the Embedded C programming. Arduino has its own programming burnt in its Read Only Memory (ROM). C- program has been used for programming the Arduino UNO.

Figure 1. Arduino UNO [6].

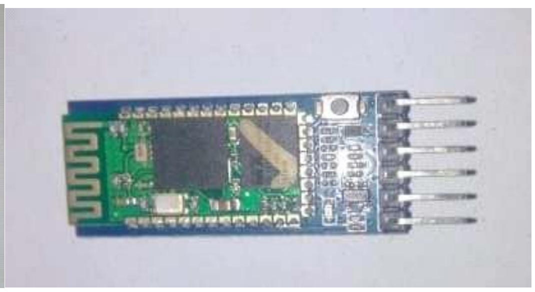

Figure 2. Bluetooth Module[7].

The Bluetooth module (HC-05) acts as an interface between smartphone and microcontroller. Bluetooth module HC-05 has been used for the system, which act as receiver andtransmitter. Smart Phone transmits signal and Bluetooth module (Figure 2) receives that signal and the signal is further transferred with the help of wires to the microcontroller. The Motor driver IC is used to control the DC Motors. It interfaces with the Microcontroller (Figure 3 (a)) and with circuit connections (Figure 3(b)). In Android application when we tap on control icons, a corresponding signal is sent through the Bluetooth to Bluetooth module (HC-05) which is connected with the

Arduino board. The output from Arduino is fed as input to the motor driver section. Motor driver switches accordingly the data bit. If the data bit is low, then the corresponding pin of the motor driver doesn't work else high bit then the corresponding pin of the motor driver is ON.

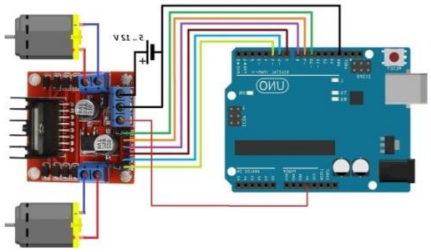

Figure 3(a): Motor Driver connections with Arduino[8].

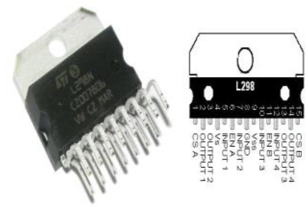

Figure 3(b): Motor Drive IC[10].

Chassis is the frame work of an artificial object which support the object in its construction and use. The chassis of Robotic car is self-made. To reduce the weight and for assembly of nuts and bolts the holes are drilled in it. The chassis consists of various parts such as: Upper plate, Suspension, Tires, Front and Rear axles, Links, Nut and Bolts. Electric Motors produce mechanical movements by using the electrical energy and producing equivalent mechanical energy. Hundreds and thousands of devices are powered by electrical motors- from small pick-and-place robots to big turbines- motors find applications in every industry. DC pump (Fig. 4a) is used to pump fluid. It is 12v, 3.5amp. Tank (Fig. 4b) is the unit where we can store the mixture of water and pesticides. To protect it from corrosion and for life and to reduce weight it is made up of plastic. A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) asit exists (or enters) an enclosed chamber or pipe. The pipes are used to connect nozzles with pump. Fluid from the pump is pumped and through pipes it reaches nozzle.

Figure 4(a) :DC pump

Figure 4(b) : Water Tank

B. Software

3D Modeling**:** The modeling of the robot is done in solidworks software. The different views of the robotic car are shown below:

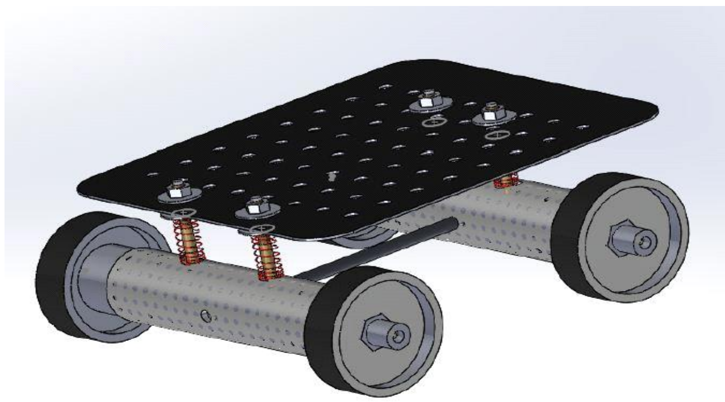

Figure 5: Realistic View of Robotic Car

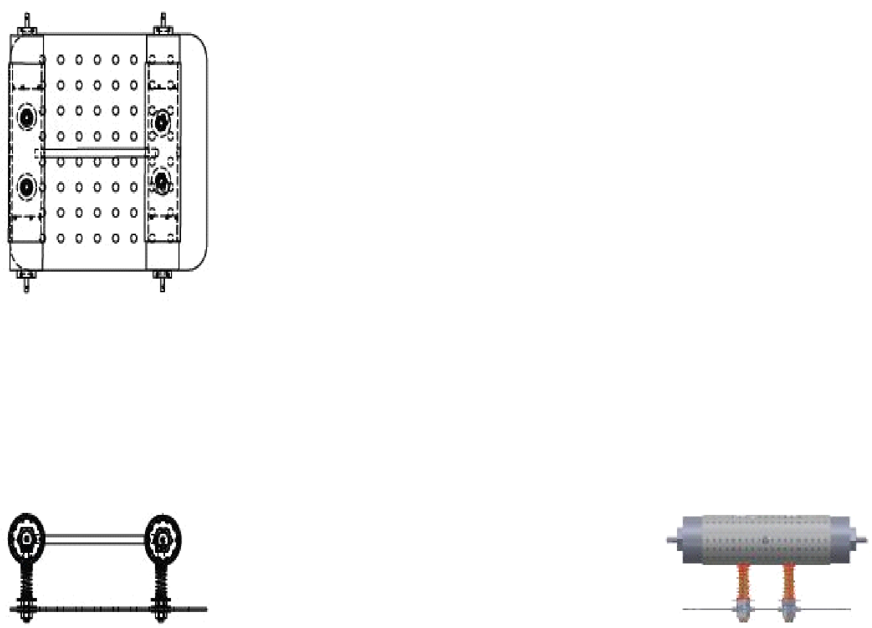

Figure 6: Projected views (Top, Side & Front)

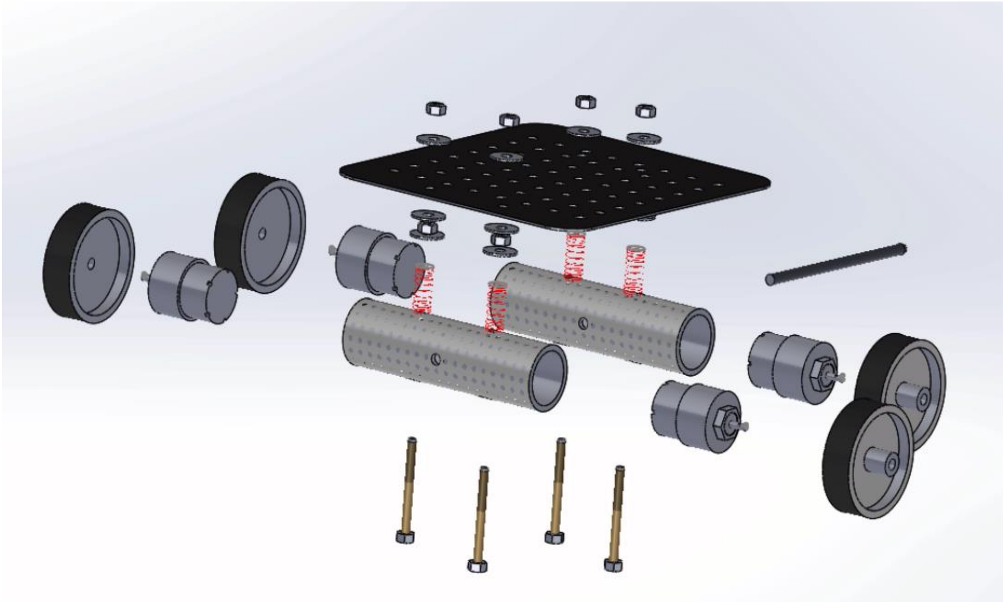

Figure 7: Exploded View

Programming

The Arduino Integrated Development Environment or Arduino Software (IDE) is used to put the instruction of whole functions of this system to the Microcontroller. It contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuine hardware to upload programs and communicate with them. The program for executing this project has been written in C language. The program is uploaded in the Microcontroller. The program is stored in the EEPROM ofthe Arduino. Circuit diagram of Bluetooth controlled car is shown in Fig. 8.

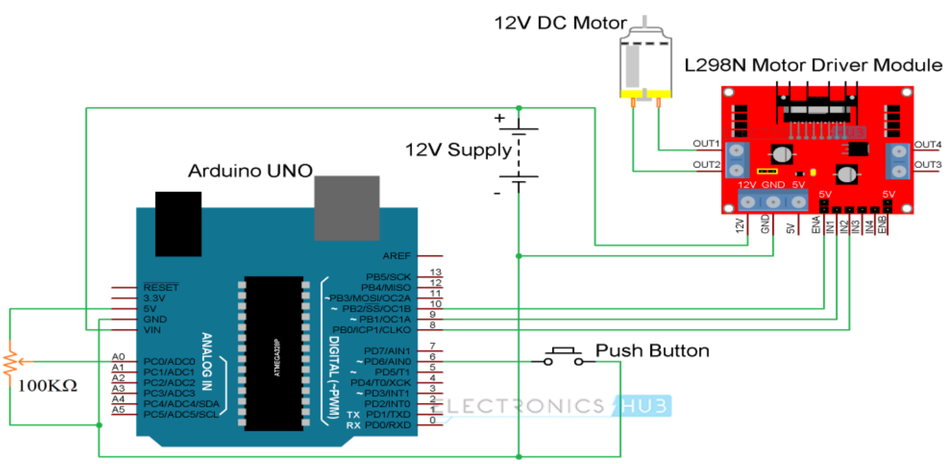

Figure 8: Circuit Diagram for Bluetooth controlled car [8].

Circuit diagram for Bluetooth controlled car is shown in a figure8. A Motor driver is connected to Arduino to run the robot. Motor drive module input pins 2, 7, 10 and 15 are connected to Arduino's digital pin number 12, 11, 10 and 9 respectively. We have used four DC Motors to drive robotic car in which two motors are connected at output pin of motor driver 3 and 6 and another two motors are connected at 11 and 14. A 12volt Battery is also used to power the motor driver for driving motors. Bluetooth module's Rx and Tx pins are directly connected at Tx and Rx of Arduino respectively and Vcc and ground pin of Bluetooth module is connected at +5 volt and gnd of Arduino. And a 12volt battery is used for power the circuit at Arduino's Vin pin.

5. Working Explanation

DC power is supplied to the Microcontroller as well as Motor driver. Microcontroller receives data through Bluetooth module which is connected to Arduino & Bluetooth module receives data from Smartphone. Here Bluetooth module acts as a receiver and Smartphone acts as a transmitter. Basically we can say that the output from the smart phone is the input of the Bluetooth module and output from the Bluetooth module is the input of the Microcontroller. Microcontroller also connected with Motor driver and motor driver further connects with DC Motors. As microcontroller receives commands according to the program embedded in it and by the user action through Bluetooth and it gives the output of the command to motor driver and output of the motor driver going to DC Motors**.**

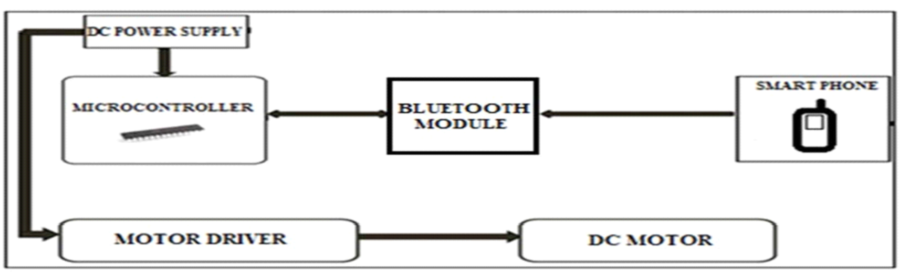

Figure 9: Block Diagram of the project[10].

Bluetooth Control Application

Bluetooth controlled car moves according to icon tapped on the AndroidBluetooth mobile app. To run this project first download Bluetooth app form Google play store but we developed our own Android Bluetooth application. You can use any Bluetooth app which is compatible to send data. Name of some other apps that might work correctly are.

- Bluetooth controller

-Arduino Blue control

Figure 10: Bluetooth Control Application

After installing open the app then search Bluetooth device and select desired Bluetooth device and then configure keys. Here in this project we have used Bluetooth controller app.

1. Download and install Bluetooth Controller.
2. Turned ON mobile Bluetooth.
3. Now open Bluetooth controller app
4. Press scan
5. Select desired Bluetooth device
6. Now set keys by pressing set buttons on screen. To set keys we need to press 'set button' and set key according to picture given below:

Figure 11: Bluetooth Connecting

Functioning

When we touch forward icon in Bluetooth controller app then robot start moving in forward direction and moving continues forward until next command comes.

When we touch backward icon in Bluetooth controller app then car start moving in reverse direction and moving continues reverse until next command comes.

When we touch left icon in Bluetooth controller app then car start moving in left direction and moving continues left until next command comes. In this condition front side motor turns front side wheels in left direction and rear motor runs in forward direction.

When we touch right icon in Bluetooth controller app then car start moving in right direction and moving continues right until next command comes. In this condition front side motor turns front side wheels in right direction and rear motor runs in forward direction.

If we do not touch any icon, then robot will stop

Working Snapshots

Figure 12 Automatic pesticide spraying machine

Calculations

Following are the calculations:

Power = energy per second

Power = V * I (Battery 9 Ah current, 12 V)

= 12 * 9

= 108 WH

Backup Time of Sprayer = (Power stored in battery /Power consumed by motor and pump)

= 108*2 / {(4*2*12) + (2.1*12)}

= 1.78 hrs

Flow rate of Nozzle

Qn = 28.9 * D2 * √P

Where,

Qn = flow rate of water from nozzle (gpm)
D = Nozzle diameter (inch)
P = Pressure at nozzle (Psi)
Qn = 28.9 * (0.039)
2 * √25

Qn = 0.21 gpm
Qn = 0.79 lit/min

6. Advantages of proposed system

- No harmful effect of toxic chemicals on human body
- Spraying pesticides without direct human intervention
- Controlling is very easy
- The robot contains suspension system so it can also work on off roads
- Bluetooth RC controller application is more user friendly
- It is cost effective project
- 24/7 continuous working because it is a programmable machine
- It can move from one location to another location
- Nooperational cost,there is only one-time investment
- Feasible to implement Bluetooth communication between smart phone and Microcontroller.

7. Applications of proposed system

- For spraying pesticides
- For irrigation purpose

8. Future Development

With the help of few sensors and mechanism’s it can be made fully automated and use for plantation and irrigation purposes.

9. Results

Final assembled machine has been successfully tested for agricultural purpose without direct human intervention. Since toxic pesticide chemical is sprayed by this robotic machine, there is no harmful effect of toxic pesticides on human body. Thus it will reduce cancerous diseases. This is indeed a cost-effective and efficient project. The range of the pesticide jet is 2.5m and range of Bluetooth is 10m. The running time of batteries is 5 hours.

10. Conclusion

The machine is designed and assembled in house and tested on ground with the range of the pesticide jet a 2.5m and range of Bluetooth as 10m. The running time of batteries is 5 hours. The overall manufacturing of machine is economical. The user can operate the machine in range of 10 meters. The machine is ecofriendly with no emission.

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