2. COMPUTER AIDED PROCESS PLANNING

2.1 Need for Process Planning

This is the planning strategy for manufacturing the part. It is defined as the activity that translates part design specifications from an engineering drawing into the manufacturing operation instructions required to convert a part from a rough to a finished state. It represents the link between engineering design and shop-floor manufacturing. It is a major determinant of manufacturing cost and profitability. The gap between CAD and CAM can be shortened considerably by developing better systems for process planning.

There are two levels of process planning

High-level planning: The planner identifies the machineable features (surfaces) of the part, groups them into set-ups, and orders these set-ups. The features to be cut in each of the set-ups, and the tools for cutting each feature.

Low-level planning: Specifying the details of performing each step that results from the first level such as choosing machines, cutting conditions (speed and feed), type of fixture, cost and time estimates, etc.

2.2 Approaches of Process Planning

There are three approaches of process planning

Manual approach

Computer assisted variant approach

Computer assisted generative approach

The later two are known as Computer Aided Process Planning (CAPP)

The following are some of the drawbacks of manual approach

- The approach becomes rapidly inefficient and unmanageable when the number of process plans and revision to those plans increase. Consequently, inconsistent plans and large time requirements for planning often result.
- The plans by this approach reflect the personal experiences and preferences of the process planner.
- This is considered a poor use of engineering skills because of the high clerical content in most of its functions.

These limitations have logically lead to computerized approach to process planing.

2.2.1 Conventional Process Planning

Traditionally, skilled planners perform process planning. Planning is based on planner's decisions. The quality of the plan highly depends on individual skill, knowledge and experience. Planning is very time consuming, because of voluminous routine work and calculations. Only little time is left for creative work and updating planner's knowledge. The functions of process planning in the conventional manufacturing industry are shown in Fig. 2.1.

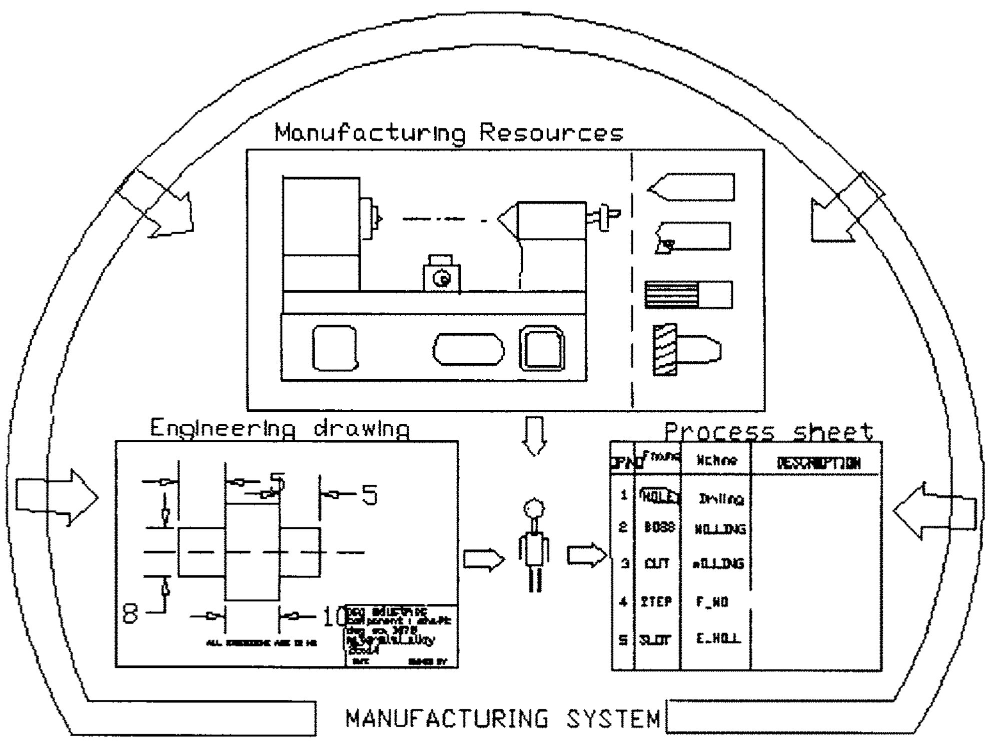

Fig.2.1 Conventional Process Planning

2.3 Importance of Computer Aided Process Planning

The importance of CAPP has already been identified by industries. Many companies in manufacturing sector have started developing CAPP for their internal use. The aim of Computer Aided Process Planning is to eliminate or at least reduce the manual intervention in process planning. The role of Process Planning from design to part is shown in Fig. 2.2.

It is also found that there is generally a lack of consistency among process plans prepared by different individuals with varying manufacturing backgrounds and levels of skill. It is therefore imperative to automate the process planning function and this makes CAPP important even in the absence of CAD and CAM. By using a computer, the tedious and repetitive aspects of process planning can be speeded up and this helps to optimise the total manufacturing function by releasing the experienced planners and enabling them to concentrate on those aspects outside the scope of a computer. At the same time, more consistent process plans can be obtained by applying a standard set of rules, which increases confidence in the system and helps in the rationalisation of production. To automate process planning, the logic, judgement and experience required for process planning must be captured and incorporated into a computer program.

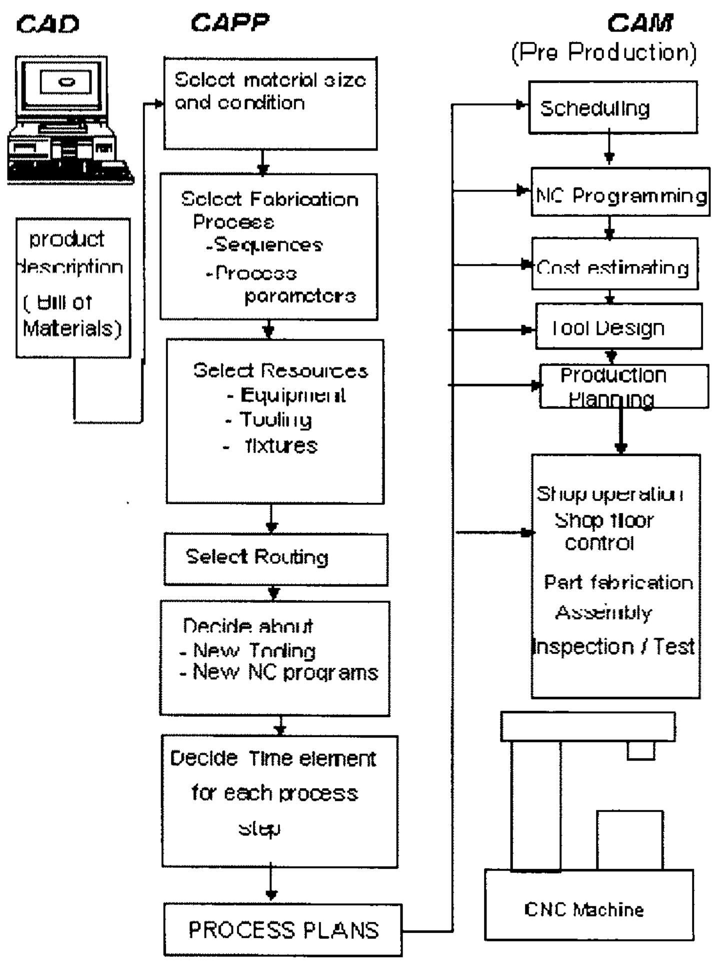

Fig. 2.2 The role of CAPP in Integration of CAD/CAM

2.4 Conventional Process Planning versus CAPP

To manually plan processes for complicated parts, the process planners must be quite experienced persons. A Process planner usually spends considerable time to plan a process and complete the process documents depending the complexity of the part. It is thus evident that the development of a CAPP for the prismatic components is even more meaningful. The aim of Computer Aided Process Planning is to eliminate or at least reduce the manual intervention in process planning.

The advantage of CAPP over conventional process planning is manifold.

- It improves the quality and consistency of process plans.
- Savings in lead time: In today's concepts of TQM and batch manufacturing lead time seriously effects the delivery time of the product which plays a major role in deciding the market share of any company.
- Process rationalisation: CAPP generated process plan is more likely to be consistent (because the use of same software for all plants), logical and optimal (because the company has presumably incorporated the experience and judgement of its best manufacturing people into process planning software and computer can evaluate more number of alternatives in a less time).
- Integration with manufacturing support functions: These functions involve NC part program generation, computerised work standards etc., If done independently these functions involve duplication of clerical work.
- Increases the efficiency of process planning.
- Decreases the variety of tooling.
- Error reduction: Helps in overcoming the casual errors committed by human process planners. If the error goes unnoticed, it penalises heavily from the cost point of view.
- It can reduce the skill required by planners.
- It can increase productivity.
- It can consider all available equipment while process planning.

Nobel (1965) first discussed the use of computers in process planning. Early investigation of automated process planning was done at Purdue University by Scheck (1966) and by Berra and Barash (1969). Many investigations were updated in the late seventies, and research work gained momentum in eighties. CAPP is the application of computers to assist the human process planner in process planning function. In its lowest form it will reduce the time and effort required for preparing process plans and providing more consistent process plan. An advanced CAPP will provide the automated interface between CAD and CAM.

Automated process planning makes use of CAD model as input to the system. The subject of features and their role in product design, process planning and many other activities spanning the product life cycle is playing a vital role in today's technology. Already work has been carried out on Feature Extraction using Attribute Adjacency Graph (AAG) method at PSG College of Technology. This method extracts simple polyhedral features like slot, step, etc. But it fails to extracts V slots, T slots, curved features and complex features.

One of the widely used CAD/CAM packages, CADDS5, has been used in the development of this package. Even if the component is modeled in other modeling packages, we can use this software by adding a simple routine which will convert the part internal representation in that package into linked lists of Faces, Edges and Vertices whose structures are defined in the software.

2.5 Emergence of CAPP

Design, planning, manufacturing, assembly, inspection and testing are major stages of product development. Computer based technologies are available today to carryout most of these activities except process planning. Process planning is a heuristic and knowledge based activity and is one of the missing elements in the integration of CAD and CAM. Though process planning covers a wide spectrum of manufacturing operations like machining of components, sheet metal processing, and other secondary manufacturing operations, machining offers considerable challenge for computerization. Here too, process planning of prismatic component is more involved than rotational component. Processing of prismatic components requires the use of several machines like precision milling, boring, drilling and tapping and these operations can also be performed in a CNC machining center. Proper sequencing of operations, selection of right cutting conditions and tools, proper filtering etc. are necessary for satisfactory realization of the components, meeting the high level of precision, and accuracy required for application in missiles. Many researchers have attempted this problem.

Process Planning establishes the methods and means of converting the raw material into a finished part. The planning function interacts with the manufacturing system through

a. The design specifications. b. Manufacturing resources. c. The process plan.

Its basic task is to determine by what means and how a product is to be manufactured economically and competitively.

Process planning involves, according to the part specification, determination of processes, machine tools, cutting tools, operation sequences, machineability data and calculations of time and costs. The results obtained must be reflected in documentation.

Computer aided process planning should diminish as much as possible deficiencies in traditional process planning.

A set of process plans would include,

Design input

Material selection

Process sequence

Machine and tool selection

Fixture selection

Machining parameter selection

Cost/time estimation

Clear-cut pictures about the necessities have to be formed before starting the development of a project. George P. Sutton [16] had done a survey for CAM-I (Computer Aided Manufacturing - International) on CAPP practices, plans and future needs in 1987. Fifty companies participated in this survey and it was found that there were no fully automated CAPP systems and almost all of them required extensive manual operations. However benefits that accrued to those companies that had a semi-manual CAPP system were substantial. The survey indicated a user desire for standardizing the interfaces of CAD with CAM, as well as with other manufacturing oriented systems (like scheduling, inventory control, cost estimating, etc.). There seems to be agreement that CAPP is an essential element of future CIM systems.

The first CAPP system was developed under the direction and sponsorship of CAM-I (Computer aided manufacturing - International) and was presented at the "1976 NC conference". In the same year MIPLAN was developed by the OIR (Organization of Industrial research) since then CAPP has begin to be widely addressed. Meanwhile, due to the increase in competition, companies started implementing integrated manufacturing. CAPP as a main element in the integration of design and manufacturing has not kept pace with the development of CAD and CAM. This situation made the process planning, a bottleneck in the implementation of integrated manufacturing. Thus more and more effort has been applied in the CAPP area and numerous CAPP systems have been reported.

2.6 CAPP systems

Some prominent computer aided process planning systems are discussed in the following section.

ASCAPP

ASCAPP is a generative CAPP system for process planning of aircraft structural parts. This has been developed at Nanjing University of Aeronautics and Astronautics, Peoples Republic of China. In the developed CAPP system a 6- orientation, multi level feature oriented method is adopted for part description. The technological decision module of the ASCAPP system is an expert system that is composed of a knowledge base, a inference engine and a data base for storing part information and interim decision results.

APSS (Automated Process selection and sequencing)

In APSS, the 'bottom-up' or backward planning approaches have been adopted. APSS has been written in PROLOG and has been implemented in the prototype knowledge based CAPP systems, ACES (a CAPP expert system), which is an automated process planning system for the manufacture of complex prismatic machined parts.

OPPS-ROT:

OPPS-ROT is generative CAPP system for rotational parts. This has been developed at university of Gazintep, Turkey. The sequential operational planning method is used and it is based on the assumption that a single feature on a component usually considered as a single operation. It is implemented with C++ on a personal computer.

APPAS, CADCAM AND TIPPS

APPAS is one of the first generative CAPP systems. Wysk developed it in FORTRAN. Process planning logic has been implemented using the decision tree approach. The input to the system is text input in the form of special codes. CADCAM is an extension of APPAS, developed by Chang and Wysk, which links APPAS with interactive computer graphics terminal. TIPPS is new generation of APPAS and CADCAM, once again developed by Chang and Wysk. It is one of the first systems that integrate CAD and generative process planning into unified system utilizing the AI and decision tree approaches.

AUTAP and AUTAP-NC

AUTAP is one of the complete generative process planning systems developed in the early stages. AUTAP is capable of determination of raw material, operation sequence, selection of machine, calculation of estimated time. AUTAP-NC is similar to AUTAP but aimed for doing real time work. Apart from the above works AUTAP-NC does lathe chuck selection, determination of manufacturing segments and generation of part program

CMPP

CMPP is a generative system developed in FORTRAN 77, aimed at high technology machined cylindrical parts. Parts characterized by expensive material, tight tolerances and complex machining processes are most suitable for this system. CMPP is interfaced to many CAD/CAM systems in American aircraft companies.

EXCAP AND ICAPP

EXCAP is an expert system aimed at machining of rotational parts. Rule based technique with backward planning mechanism is implemented in this system. ICAPP is a variant system developed in FORTRAN for prismatic parts. ICAPP is feature oriented interactive system, capable of eight basic machining processes.

GENPLAN

GENPLAN is generative system developed in 1981. It uses a GT based coding system that covers part geometry and process variables to generate comprehensive operations sequence. GENPLAN can be interfaced with management decision support systems, automatic shop loading and scheduling, tool order processing systems.

GIFTS

GIFTS is a generative interactive feature-based system for process planning of rotational components. This was developed at IIT Delhi. GIFTS selects the operations, machines, tools, cutting parameters for each feature by taking the relevant data from the data base and finally sequences the operation.

Part of the slow progress in this area is due to the complex and dynamic nature of the planning domain which posses a great challenge to the research community. Because our present understanding of process planning activities is limited to local micros, we can attain some success in programming specific kinds of process planning activities (e.g., to machine a cylindrical part), but are unable to automate the whole process which would require a much broader understanding of the necessary tasks. Currently, the variant and semi-generative approaches seem to be the most practical ones, and these systems are readily amenable to certain real-world applications.

2.7 Objectives of Process Planning Systems

Notable requirements for process planning systems are consistency, accuracy, and ease of application and completeness. These are explained below.

2.7.1 Consistency

One of the most common problems of manual process planning is the existence of inconsistent process plans. Consistency is essential not only in the application of data and knowledge to generate process plan, but also in the acquisition and presentation of manufacturing information. Process plans prepared by different process planners will vary depending on the variations in their knowledge, process logic and experience etc., A good process planning system should provide consistently same process plan for same set of input data.

2.7.2 Accuracy

Accuracy is another important objective to maintain in any process planning system. Inaccuracies in process plans and corresponding information in them can greatly undermine the integrity of the system.

2.7.3 Ease of application

This is another important trait, which determines how quickly a response can be made to generate a new process plan or make revision to an existing process plan. This is of particular importance in today's short lead-time environment

2.7.4 Completeness

Information about manufacturing processes, machines, tools, cutting parameters etc., must be completely known while decisions about process planning g are made. If complete data is not provided, then the choice can easily lead to inconsistency in processing methods and corresponding inconsistencies in part quality and costs.

2.8 Challenges in the area of CAPP

The complexity of manufacturing activities makes it impossible to generate an ideal plan in the first time. In practice, it usually takes much iteration based on feedback from the plan execution stage to gradually refine a plan into its optimal form. Most current planning activities are mainly concerned with the plan generation phase; no major effort has been made to link plan generation with its execution and monitoring activities. But since the execution of a manufacturing plan normally spans a period of time with the involvement of multiple departments, this manual monitoring and feedback task is difficult to accomplish effectively in practice. The lack of this self-improving ability due to the open-loop nature is one of the reasons why most CAPP systems are not up to the mark.

Current research efforts tend to focus on a specific kind of planning function for a specific type of part. These micro-view point planning approaches produce computer systems that perform individual tasks in isolation from other planning activities. They result in many small, and still isolated, islands between the islands of design and manufacturing.

Due to this micro-view point of planning activities and the lack of an overall planning structure, most planning systems developed to date focus on a narrow range of activities, which severely limits their applicability in practice. For example, most efforts in current generative CAPP systems are aimed at generating machining sequences of certain limited part shapes. Since they are based on machining handbooks and databases, decisions made at the operation-planning level are treated as a black box, without detailing how each sequence will be carried out in actual operation.

There is no single best approach that can handle all the functions required in an integrated planning system. Hybrid approaches, which logically combine the strength from several different techniques, should be devised and used. For example, various techniques from optimization and operation research should be incorporated into plan sequence generation and mathematical models of processes should be part of the operation planning systems.

Process planning systems, in order to provide integration, automation and flexibility should

- be generative
- be technology based
- use features as a technological and communicational interface between design and process planning
- be able to extract automatically all product data
- use a supervisory control system to ensure user-friendliness and flexibility in use
- integrally support all planning tasks, including capacity planning and scheduling
- take decisions based on optimization techniques
- be fit for close-loop planning

2.9. Approaches to CAPP

Traditionally two approaches are recognized for computer aided process planning, the variant approach and generative approach. In variant approach the GT principles are used. Further making use of the similarity in design or manufacturing of the parts are used in producing the new process plans. In generative CAPP the process plan is generated automatically, the input being the details from CAD drawing. However with the rapid development of new techniques, many CAPP systems do not exactly fit into this classification and combines both approaches.

2.9.1 Variant approach

The variant approach is comparable with the traditional manual approach where a process plan for a new part is created by recalling, identifying, and retrieving an existing process plan for similar part, and making necessary modification making it suitable for the new part. In general this system has two operational stages.

i. Preparatory stage: in this stage the parts are coded and families are formed based on group technology (GT) principles. Standard process plans are prepared for each family and stored in database.

ii. Production stage: Process plan for a new part can be made in this stage. Whenever a new part comes for process planning, it's code and family will be identified and the standard processing plane for that family is retrieved. Necessary modifications are made by the process planner to satisfy the component design.

The CAPP system may be either semiautomatic or automatic. In the semiautomatic there is a need for manual input of the required data. Inputting the feature details, finished material details and raw material details to the computer is time consuming and tedious. This is a form of under utilization of manpower and here are also chances that the user may input the data wrongly. These drawbacks can be avoided by providing a bridge between the generated automatically from CAD model or drawings. This will also help in enhancing the role of computers in industry. This helps to move towards computer integrated manufacturing whose is a paper less industry.

The majority of existing CAPP systems is of variant approach. Some of the process planning systems that follow this approach are CAM-I CAPP, MIPLAN, MITURN, MIAPP, ACUDATA. The disadvantages of this approach are that the quality of process plan still depends on the knowledge of process planner because of editing. Process planning for an entirely new type of component is not possible.

2.9.2 The Generative approach:

Generative process planning synthesizes process information in order to create process plans for a new component automatically. The input of such systems may be either CAD drawing or models or text input. Knowledge of process planning is captured and implemented in software using different techniques. The process logic can be implemented in the system by means of decision tables, decision trees, axiomatic, rule based or constraint based. The decision logic consists of checking for some conditional requirements of the component and selects the processes. Other planning functions like machine selection, tool selection, process parameters selection etc., can also be automated using the generative process planning techniques.

The biggest advantage of this approach is that process plan developed is consistent, and fully automated. This is especially useful for product mix of number of products with small lot sizes. APPAS, TIPPS, AUTAP, GENPLAN, TURBO-CAPP, TOM and ICAPP are some of the generative process planning systems.

2.9.3 Semi-generative approach

This approach is the combination of variant and generative approaches. However, compared with the variant systems, editing work is less. The advantage of using such systems is reduced time for preparation of process plans; modifications of generated process plans are necessary in order to implement in the real work.

2.10 Implementation Techniques

Various techniques can be followed in the implementation of CAPP systems. Notables of them are discussed in the following sections.

2.10.1 Group technology

The typical utilization of GT is in the part family concept where coding and classifying of the part are done. The GT principles are mainly used in the variant process planning systems. CAPP-I, SAPT, TOJICAP, WICAPP are some of the systems which are implemented using the GT principles.

2.10.2 The Bottom-up approach

This approach develops the CAPP systems by filling in materials to convert a finished part back to the initial blank.

This is similar to conventional computer assisted process planning method oriented towards the variant approach.

2.10.3 The Top-Down approach

This approach develops the CAPP system by means of tracing the task of process planning from top to bottom i.e. from raw material to finished part. This is an automated computer aided process planning method oriented towards the generative approach. This requires the general rules of manufacturing strategy to be built into algorithms which can operate on brief input data describing the geometric features and engineering requirements of part.

2.10.4 AI & Expert system techniques

An expert system can be defined as a tool that has the capability to understand the problem specific knowledge and use the domain knowledge intelligently to suggest alternative paths of action. CAPP systems using this technique are called as either expert system (ES) or knowledge based system (KBS). The decision logic is implemented using the IF.... THEN.... rules are frame-based rules. TOM, GARI, EXCAP, KAPPS, XPLAN are some of the CAPP systems in which these techniques are implemented