UNIT 12 OVERVIEW OF CAPP SYSTEM

Structure

12.1 INTRODUCTION

Process planning consists of preparing a set of instructions that describe how to fabricate a part or build an assembly which will satisfy engineering design specifications. The resulting set of instructions may include any or all of the following : operations sequence, machines tools, materials, tolerances, cutting or operating parameters, processes (such as how to heat treat), jigs, fixtures, methods, time standards, setup details, inspection criterion, gauges, and graphical representations of the part in various stages of completion. It is obvious that process planning can be very complex and time consuming job requiring a large amount of data. In addition, several people may participate in developing a process plan, because no one person may have the complete expertise required. This is further complicated by the fact that the process planning is a critical element in making the part correctly and economically.

Process planning received little attention until the late 1970s. Informally process planning has been performed for hundreds of years – eversince some one first developed instructions to make something. However, industrial revolution fostered a need to formalise process planning in the manufacturing environment. Initially, manufactured parts had few components and were made by few workers. In this type of setup, formal process plans were not required. As the number of parts and complexities increased, a need for formal process plans was recognised. Nevertheless, until the 1970s the importance of process planning was understood primarily by those closely involved in making the individual parts. Consequently, little was done to automate this process. Today's manufacturing environment has become very competitive and complex. This complexity is a function of more intricate parts, and factors, such as manufacturing technologies that permit making several parts in different ways, small lot sizes that do not permit long setup times, increased government regulations that require documentation of process plans, many types of materials that may require special tools and/or processes, and less skilled workers. These factors combined with increased emphasis on reducing the manufacturing costs have affirmed the significance of process planning and corroborated that substantial savings can be achieved by automating the preparation of process plans. Consequently this function has been receiving widespread attention.

The benefits that have been reported from successful application of automating some of the process planning functions are impressive and have one of the shortest pay-back period of all CAD/CAM technologies. Some typical benefits include [1].

(a) 50% increase into process planner's productivity.

(b) 40% increase in capacity of existing equipment.

(c) 25% reduction in setup costs.

(d) 10% reduction in scrap and rework.

(e) 10% reduction in shop labour.

(f) 6% reduction in work-in-process inventory.

(g) 4% reduction in work material.

Some of the benefits may not appear to be related to the automation of process planning. However, this permits the process planners to :

(a) Spend more time on methods improvement and cost reduction activities.

(b) Routing can be consistently optimised.

(c) Manufacturing instructions can be prepared in more detail.

(d) Pre-production lead times can be reduced.

(e) Responsiveness to engineering changes can be improved.

Objectives

After studying this unit, you will be able to understand

- the role of process planning in CAD/CAM integration,
- different approaches to process planning for machining operations, and
- the criteria for selecting the CAPP system for a particular application.

12.2 COMPUTER AIDED PROCESS PLANNING (CAPP)

Early attempts to automate process planning consisted primarily of building computer assisted system for report generation, storage and retrieval of plans. A database system with a standard form editor is what many early systems encompassed. Formatting of the plans was performed automatically by the system. Process planners simply filled in the details. The storage and retrieval of plans are based on part numbers, part name or project ID. When used effectively these systems can save upto 40% of process planner's time. A typical example can be found in Lockheed's CAPP system. Such a system can by no means perform the process planning tasks, it helps in reducing the clerical work to be done by the process planner. Perhaps the one of the earliest, best known automated process planning system is CAM-I (Computer Aided Manufacturing-International). In this system previously prepared process plans are stored in a database. When a new component is planned, a process plan for a similar component is retrieved and subsequently modified by the process planner to satisfy the special requirements. This technique is known as group technology (GT) based retrieval or variant planning. The typical organisation of process planning system of variant type is shown in Figure 12.1.

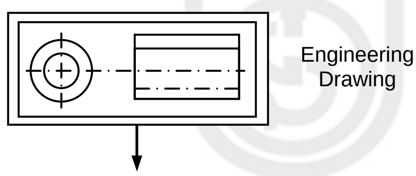


Figure 12.1 : Typical Process Planning System [2]

12.3 THE ROLE OF PROCESS PLANNING IN CAD/CAM INTEGRATION

With the emergence of CAD/CAM integration, the communication between design engineering and manufacturing engineering has become a very important consideration. Most of the firms are using CAD techniques extensively to design their products; similarly, they are using some of the CAM techniques, such as Computerised Numerical Control (CNC) machines, to manufacture products.

Process planning is a key factor in CAD/CAM integration because, it is the link between CAD and CAM. After engineering designs are communicated to manufacturing, either on paper or electronic media, the process planning function converts the designs into instructions to be used to make the specified part. Computer Integrated Manufacturing (CIM) cannot be achieved until this process is automated. Thus, automated process planning is the link between CAD and CAM.

It is also well known and discussed elsewhere that Group Technology (GT) is also an important element in CAD/CAM integration. It provides a basis and a methodology for engineering design and manufacturing communications. Automated process planning provides a means to facilitate this communication and remove the “wall” between engineering design and manufacturing.

12.4 APPROACHES TO PROCESS PLANNING FOR MACHINING OPERATIONS

Process planning involves determining the necessary manufacturing processes and their sequence in order to produce a given part economically and competitively. In terms of machining processes, the major process planning activities are the interpretation of product design data. Selection of machining processes, determination of production tolerances, determination of datum surfaces and fixtures, sequencing of operations, selection of inspection devices, determination of proper cutting conditions, calculation of overall production times and generation of process sheets and NC data as shown in Figure 12.2.

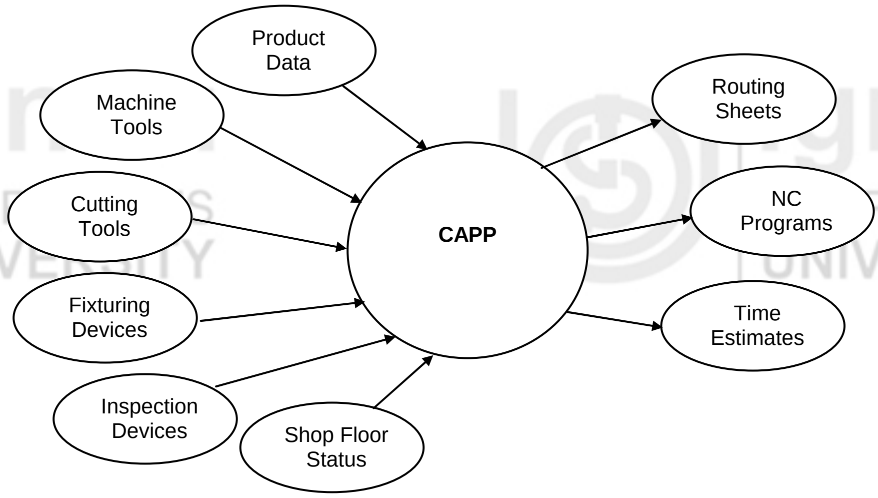


Figure 12.2 : Inputs and Outputs of a CAPP System for Machined Parts [9]

Figure 12.3 shows the process planning information flow.

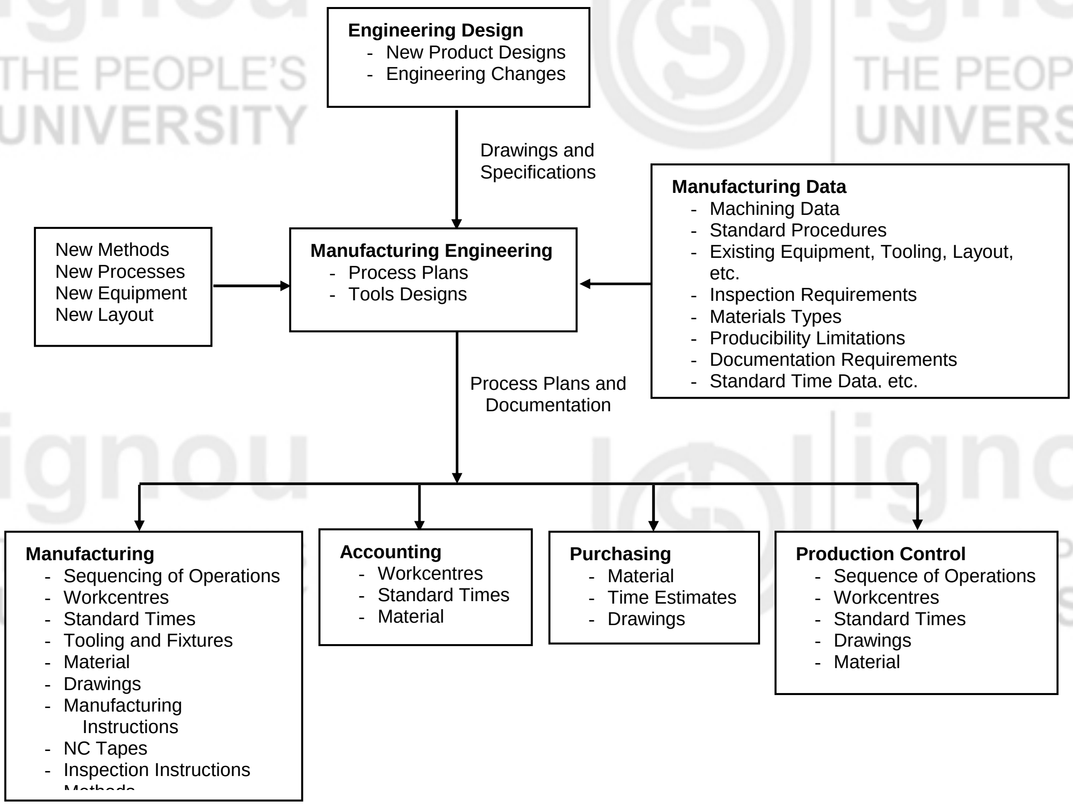


Figure 12.3 : Process Plan Information Flow [1]

It has been more than 20 years since first noticeable efforts to automate process planning using computers began. In this period mainly two approaches have emerged. The first one, which is called variant approach relies on standard plans developed from previously manufactured parts. The second approach which is called generative involves the generation to process plans automatically without referring to existing plans of previously manufactured components.

At the same time, some CAPP system developers have attempted to combine some features of both approaches forming another category what is called semi-generative CAPP.

As a bridge between CAD and CAM, CAPP relies on good interfaces between these systems (or integration of such systems) in order to function effectively. Currently, almost all CAPP systems employ manufacturing features for part description. Several approaches have been developed to extract the manufacturing features of a part from CAD data. The major methods to interface CAD and CAM are described in Section 12.4.2.

12.4.1 Variant Approach

A variant system is much simpler than a generative approach, but it can require more human interaction. It should be realised that all CAPP systems require some one to input the part specifications (shape, features, dimensions, tolerances, instructions, etc.).

Variant CAPP systems are designed to utilise the fast storage and retrieval capabilities of a computer and to provide an interactive environment between the planner and the computer. This type of system is developed so that a planner with limited computer knowledge can effectively prepare a process plan. Thus, the planner is prompted for the necessary data, and the inputs are edited. If errors are detected, the user is prompted to correct the erroneous entry.

A variant system requires a database containing standard plans. Standard process plan for a family of parts consists of all instructions (e.g. operations, tools, etc.) that would be included in a process plan for any part in that family. Group technology concepts are used to form part families and therefrom a standard process plan is created for each of these families and stored in the computer.

The process planning task for a new part starts with coding and classification of the parts in a part family using GT. The standard process plan for this family can then be retrieved from the computer. Since this plan contains instructions for all parts in this family, some editing may be required for a specific part. Therefore, variant systems provide editing programs to facilitate this procedure. Often, very little editing is required, because the new plan is a variant of the standard process plan; and significantly greater consistency in plans is obtained. After editing, the plan can be stored and/or printed out.

If the part being planned cannot be classified into an existing family of parts, the planner can develop a new standard process plan using interactive computer programs.

One of the first variant systems developed was called CAM-I. Initial developments was completed in 1976 under the sponsorship of Computer Aided Manufacturing-International to demonstrate the feasibility of CAPP systems. It was so successful that several companies modified this system to meet their specific needs. Table 12.1 provides a summary of some of the retrieval type CAPP systems that are available commercially.

Table 12.1 : Some Commercial Variant Process Planning Systems

System Name	Company	Part Data Input Form	Decision Logic	Planning Functions
CUTPLAN	Metcut	Code	Standard plans and decision tree[a]	Process sequence, Materials, Machines, Tools, Fixtures, Feeds and speeds
CAPP	CAM-I	Code	Standard plans	Process sequence
COMCAPP V	MDSI	Code	Standard plans	Process sequence
DCLASS	CAM Lab. BYU	Interactive part description	Decision tree[a]	Process sequence, Materials, Machines, Tools
INTELLICAPP	CimTelligence	Interactive part description	Decision tree[a]	Process sequence, Materials, Machines, Tools
MAYCAPP	Maynard	Interactive part description	Decision tree[a]	Process sequence, Materials, Machines, Tools, Standard times, Speeds and feeds

[a] : Some limited generative capabilities.

12.4.2 Generative Type CAPP

In generative process planning, a new process plan is created every time, using a set of algorithms based on general rules about manufacturing routes. The input to the system is in the form of a detailed description of the part, including a geometric description of the part to be manufactured and material specifications.

In a generative process planning database system, process plans are created from the information available in a manufacturing database without human intervention. Technological and logistical decisions are made by the computer using a set of algorithms to achieve a viable manufacturing plan. However, knowledge of manufacturing must be captured and encoded into efficient software. Other planning functions such as, machine selection, tool selection and process optimisation can also be incorporated in the program. Thus, the system can synthesise the design of a manufacturing process. However, current generative CAPP systems fall short of the ideal and are limited to small manufacturing processes. Human intervention is often used during decision making. Implementation of generative CAPP systems require the following :

(a) Logic of process planning has to be identified and captured.

(b) The part to be produced must be defined in 3D model or GT code.

(c) The logic of process planning and part description must be incorporated into a uniform manufacturing database.

Some of the advantages of generative process planning are the ability to generate consistent process plans rapidly, the possibility of planning for new components with relative ease, and potential of interfacing with an automated manufacturing facility to provide detailed control information. Table 12.2 provides a list of some of the existing generative CAPP systems.

Table 12.2 : Some Generative Process Planning Systems[a]

Author	Name of System	Part Data Input	Decision Logic	Planning Functions	Part Shape	Commercial or Experimental
Wysk	APPAS	G	Decision tree	1, 4	H	E
Evershiem, Fuchs, and Zons	AUTAP	D	Decision table	1, 4	R	C
BYU	BYUPLAN	G	Decision tree	1, 4	B	E
Chang	CADAM	D	Decision table	1, 4	H	E
Sack	CMPP	D	Decision model	1, 2, 3, 4	R	C
Kung	GAPPS	D	Decision model	1, 4	R	E
Kung	FREXPP	D	AI	1, 4	N	E
Descotte and Latombe	GARI	D	AI	1, 4	N	E
Tulkoff	GENPLAN	G	Decision model	1, 2, 3, 4	B	C
Darbyshire and Davies	EXCAP	D	AI	1, 4	R	E
Logan	LOCAM	D	Decision model	1, 2, 3, 4	B	C
MGS	OPTA-PLAN	D	Decision model	1, 2, 3, 4	R	C
Phillips	PROPLAN	D	AI	1, 4	R	E
Choi	STOPP	D	Decision model	1, 4	H	E
Chang	TIPPS	D	AI	1, 4	N	E
Sack	XPS-1	D	Decision model	1, 4	R	E

[a] Key :

G = group technology B = rotational/non-rotational

1 = sequence of operations D = part description approach

2 = tolerance control operations 3 = reference surface selection

H = hole 4 = process plan output

N = non-rotational C = commercial

R = rotational E = commercial

Source : From Reference [9].

SAQ 1

(a) Discuss the advantages of automating the process planning functions.

(b) Explain, what factors have been responsible for automating the process planning function?

(c) Discuss the role of process planning in CAD/CAM integration.

(d) Briefly give an outline of the variant process planning approach.

CAD and CAPP Interface Models

The process planning development requires product design data which includes geometric and technological information as input. The methods described herein concentrate mainly on the interpretation of the part geometry for process planning purposes.

Feature Recognition

Most of the generative type process planning systems have been designed on the premise that each part can be described using a set of predefined features. Part features can be of several types :

(a) Design features

(b) Manufacturing features

(c) Dimensions and tolerances

(d) Geometric features

Geometric feature is a collection of geometric entities such as surfaces, curves and points having significance in process planning.

There is a loose correspondence between geometric features and manufacturing features. Some sample geometric features used in development of expert process planning of prismatic parts is illustrated in Table 12.3. Computers very often employ expert system for recognition of geometric features. A production rules for the recognition of geometric features (step) in Figure 12.4(a) is :

Rule 1 : (Step Recognition)

IF face f_1 is adjacent of face f_2.

AND the angle between faces f_1 and f_2 is 90^o.

THEN the faces f_1 and f_2 form a step.

The search process for determining all part features using production rules is computationally complex. To overcome this complexity it is suggested that we should employ attributed adjacency graph (AAG) for feature recognition.

Attributed Adjacency Graph (AAG)

In AAG each mode represents a face of the part and each arc represents the edge. In addition, an arc is assigned an attribute value 0 (1) if the angle formed at the edge of the two faces is concave (convex).

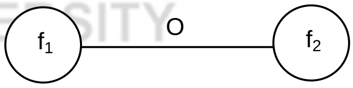
The adjacency graph for the part shown in Figure 12.4(b) is presented in Figure 12.5, whereas Figure 12.6(b) shows the adjacency graph for a step in Figure 12.6(a).

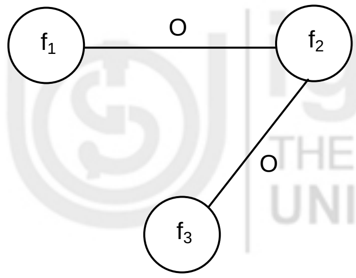
Other developments in the fields of automatic feature recognition modules are :

- Automatic feature recognition using B-rep.
- Syntactic pattern recognition.
- Graph theoretic approach.
- Automatic feature recognition using CSG.
- Logical inference (expert system approach).

(a) Step **(b) Slot**

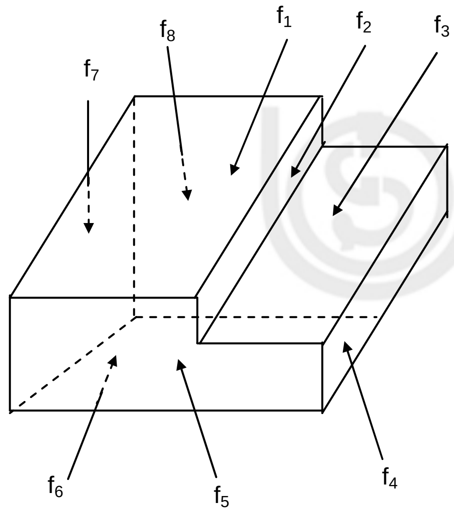
Figure 12.4 : Two Sample Geometric Features



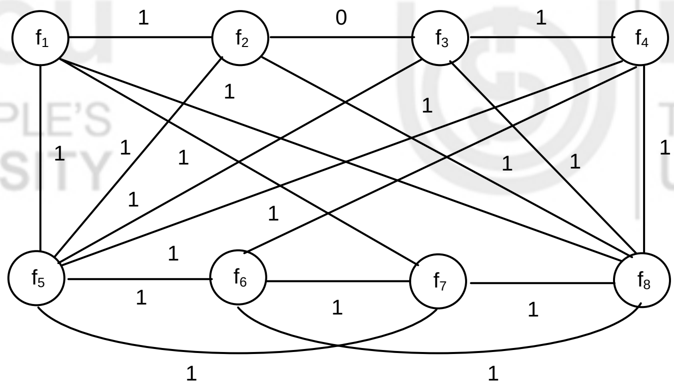


(a) Step **(b) Slot**

Figure 12.5 : AAG Representation of the Step and Slot in Figure 12.4 [4]



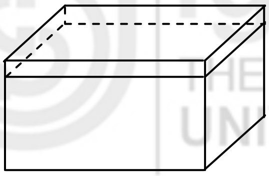
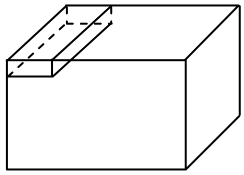
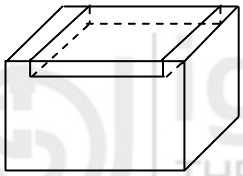
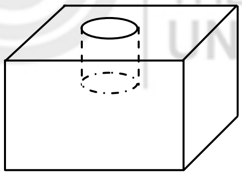
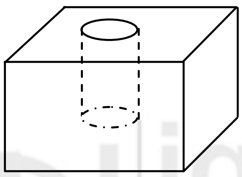
(a)



(b)

Figure 12.6 : A Part and the Corresponding AAG [4]

Table 12.3 : Sample Geometric Features of Parts and Machinable Volumes [4]

Geometry	Geometric Feature of Part	Machinable Volume
	Plane	Plane_volume
	Step	Step_volume
	Slot	Slot_volume
	Blind_hole	Blind_hole_volume
	Through_hole	Through_hole_volum e

Phases of Process Planning [4]

The sequence in which the knowledge based (expert system) process planning may be implemented involve some or all of the phases listed below :

Sl. No.	Phase Name	Solution Approach
1.	Volume decomposition	KB
2.	Selection of alternative machines, tools and fixtures	KB
3.	Machining optimisation	OPT/KB
4.	Decomposition of machinable volume	KB
5.	Selection of machinable volume	OPT/KB
6.	Generation of precedence constraints	KB
7.	Sequencing of machinable volume	OPT/KB

KB : Knowledge based approach.

OPT : Optimisation approach.

12.4.3 Criteria for Selecting a CAPP System

Selecting a CAPP system, like most software selection decisions, is not an elementary process. The initial step in the selection process should be to establish the objectives that are to be achieved by implementing a CAPP system. This will vary from one company to another. The following are representative of the objectives that may be established :

(a) Capture the manufacturing engineering expertise and make it available to all process planners.

(b) Reduce the amount of manual effort and time required to prepare a process plan.

(c) Make it easier to introduce new manufacturing technologies.

(d) Provide the capability to make mass changes to existing process plans.

(e) Develop optimum and consistent process plan for part families.

(f) Provide a database for manufacturing knowledge that can be readily accessed.

(g) Facilitate the integration of CAD and CAM.

(h) Reduce the skill required to develop a process plan.

(i) Reduce the number of errors made in preparing a process plan.

(j) To achieve cost reduction from implementing a process planning system.

(k) Provide the ability to retrieve and store standard text and graphics.

Once the objectives have been established, criteria should be developed for selecting the process planning system. The following criteria provide a basis for structuring a selection procedure :

(a) Classification and coding capabilities.

(b) Graphics capability

- (i) CAD
- (ii) CAD database management

(c) Work instruction creation and maintenance

- (i) Word processing
- (ii) Text and graphics storage and editing
- (iii) Global update
- (iv) Forms generation
- (v) Automatic revision history

(d) Process planning capabilities

- (i) Variant, hybrid or generative
- (ii) Part family identification
- (iii) Capture knowledge of process planners
- (iv) Selection of tools, machines and operations sequence
- (v) Calculation of standards
- (vi) Access to other vendor’s standard time modules

(e) Machining parameters

- (i) Selection of speeds depth of cut feeds
- (ii) Determination of stock removal
- (iii) Tolerance charting

(f) Total system consideration

- (i) Hardware required
- (ii) Database management capabilities
- (iii) Interface to other software system
- (iv) System cost
- (v) Ease of use
- (vi) Future upgrades

(g) Vendor qualification

(i) Years in bussiness

(ii) Numbers of employees to support software

(iii) Experience of employees

12.5 NON-MACHINING CAPP APPLICATIONS

Manufacturing is not limited to only machining. It includes other processes like, casting, forming, shearing, heat treatment, joining, assembly, sheet metal working, inspection, etc. Some researches have made effort to build CAPP system for such non-machining applications.

Akira (5) focused on computer aided assembly planning. Firstly a sequence of assembly operations is determined according to a configuration of parts for assembly and assemblability. Then some successive operations are grouped together. Considering resources like robots, machines or human operators, a planner assigns assembling machines or operators to each group. On the basis of production volume and cost, assembly process in which operation time for each group of operations is less than the cycle time is prepared and resources are selected for maximum economy by effective utilisation of the plant's existing resources. A relational model is used to describe the process. In resource assignment, the order of precedence, correspondence between operations and resources, and the number of resources are considered. Resources are allocated to operations by using an assumption based truth maintenance system with generated logic expressions (ATMS). The process plans generated by ATMS are evaluated by a production line simulator and a good plan is selected on the basis of simulation results.

De vin et. al (6) reported a system (PART-S) for sheet metal components, with considerations on bending sequence. The generation of bending sequences involves the selection of positioning features (or sequence of setups). It is necessary for accuracy aspects and handling rules while generating a collision free bending sequence. The reverse bending sequence approach (from part to initial flat stock) is used. The search space is reduced by eliminating non-feasible solutions. The dimensions and tolerance scheme are also reduced to avoid redundant work. All those dimensions that are not affected by bending operation are eliminated and the rest are grouped in such a way that each group contains relationships between two faces or features belonging to those faces. At each state of the product alternative preceding states are considered by unfolding one bend and searching for candidate positioning feature (CPF). If no CPFs are found, then the state of the product is not feasible. Whenever several CPFs exist, their number is reduced by rational elimination and combination. The alternative solutions are evaluated considering accuracy, handling and tooling, and the most promising solution is selected. Finally an interference check is made if tool data is available. The main operations considered are punching, nibbling, laser welding, laser cutting, and air bending.

Lauwers and Kruth (7) concentrated on EDM operations. Their feature based CAPP system generates process plans using an optimisation algorithm to determine the plan with minimum variable cost. The system first reads the feature based workpiece description from a file, and for each instanced feature, the generic plan is evaluated. During this evaluation machining and electrode costs are evaluated. The system checks the feasibility of combining operations and a global process plan for the whole workpiece is generated based on the evaluated generic plan of all manufacturing features. A branch and bound method is used to define the optimal path. The process planning system is written in LISP and is provided with object oriented programming facilities.

Madden el al (8) developed a prototype system for welding operations called WELDEXCELL. The system consists of two subsystems namely, the Welding Job Planner (WJP) and the Welding Job Controller (WJC). WJP helps the welding engineer to design and setup a weld path along with a weld schedule. WJC performs the actual execution of the weld. The system WJP uses a blackboard architecture which provides the interaction between several expert systems, databases and users. Problem solving is accomplished by dividing the problem into loosely coupled subtasks which are then operated on by specialised knowledge sources. The main problem that the controller must solve relates to selecting the joint design, determining the weld process, selecting the filler metal, writing a procedure using the welding symbol, and other joint details in CAD and downloading the control information to the robot. The WJP is designed to be driven by the user instead of solely by the software. The WELDEXCELL also induces a CAD system which is completely welding specific to facilitate the interaction between the user and the blackboard. It also includes a robot simulator system and a path planner. The robot simulator system allows the user to simulate robot movements relative to the workcell and the parts to be welded. The path planner automatically plans the robot movements, and includes a full kinematic model of the robot system as well as the interpreter. The robot path plan and welding procedure are combined into a full weld schedule by the EXPERT SYSTEM WELD-SCHED. WELDEXCELL includes an Artificial Neural System (ANS) based weld modeling package that allows the welding engineer to explore various combinations of welding parameter values before generating a welding schedule.

SAQ 2

(a) Discuss the basic requirements of implementing the generative CAPP.

(b) Give a list of CAD/CAPP interface model. Give an outline of each.

(c) Describe the various criteria for selecting a CAPP system.

(d) Describe in brief the scope of automating the process planning function in assembly and welding process.

12.6 SUMMARY

This unit discusses the scope of process planning in machining and other manufacturing processes. It provides instructions for fabricating a part or building an assembly that will satisfy the engineering design specifications. The set of instruction may include operation sequence, machines, tools, materials, tolerances, operating parameters, jigs, fixtures, methods, time standards, etc.

Prior to 1970s the process planning, in majority of the cases, was performed manually, however, with the developments in computers and computing facilities, considerable amount of effort has been made towards automating the process planning function. The advantages of automating the process planning function in manufacturing has been listed. It has been shown that the major advantage of automation includes increase in process planner's productivity, considerable increase in the capacity of existing equipment, etc.

Section 12.3 of this unit discusses the role of process planning in CAD/CAM integration and provides a basis for automating the manufacturing system leading to CIM.

Section 12.4 describes two different approaches to CAPP namely, variant and generative. The variant approach is simple and easily implementable and is useful for situations where the part variety is low and of repetitive in nature. It is based on group technology and relies to a certain extent on the skill of process planner. The generative CAPP produces a new process plan every time, using a set of algorithms based on general rules about manufacturing routes. Implementations of generative CAPP requires :

(a) Logic of process planning has to be identified and captured.

(b) Part to be produced must be defined in 3D model or GT code.

(c) The part description and the logic of process planning must be incorporated into an unified manufacturing database.

Generative CAPP makes use of CAD and CAPP interface models which are based on one of the following :

(a) Feature recognition.

(b) Attributed adjacency graph and a number of other models.

Section 12.4 presents a set of criteria for the selection of a CAPP system for application to a particular situation. For the selection of a particular system, firstly the objective of the system to be developed must be clearly specified and once the objective has been stated a set of criteria could be employed for structuring a selection procedure.

Section 12.5 presents a brief description of the non-machining CAPP applications and gives an outline of the CAPP applications to :

(a) Assembly operations,

(b) Sheet metal operations,

(c) EDM, and

(d) Welding process.

12.7 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.

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