9.1 Introduction

It is well-known that the process planning is an important activity in converting design ideas into final products using the most economical manufacturing methods. Also, automation with the help of computers is becoming part of manufacturing activity. Under these circumstances CAD, CAM and CAPP are getting a lot of attention from industry as well as academicians. Even though CAD and CAM are established upto the industry usable level, CAPP is still lagging behind due to its dependence on various issues concerning component/drawing interpretation techniques in terms of manufacturing features. Hence, further research in this direction is needed. The present work is an attempt to address some of the key aspects of the CAPP system with regard to its optimisation.

The present work attempts to develop an optimised computer aided process planning system from CAD model. This is achieved by developing three major modules:

- Feature extraction module to CAPP system
- Development of cutting/process parameters
- Development of optimisation module to CAPP system
9.2 Feature Extraction of Prismatic Components

Prismatic components consist of different features like hole, slot, pocket, profile etc. In the process planning point of view these features play a key role in selecting processes, machines, tools etc. Normally, a process planner identifies these features and decides the suitable machines, tools, processes etc. As the complexity of the prismatic components increases in terms of the number of manufacturing features, process planning will become difficult. With a view to reducing the process planner’s effort in identification of features and subsequently helping in process planning, an automatic methodology can be employed for inputting the features data to a process planning system.

In this context, a Graph based Feature Recognition (GFR) module is developed from a STEP input of CAD package. It is seen that the developed feature extraction module could recognise from 75 to 100 percent of the features present in the selected seven components used for the evaluation of the module. However, it can be improved further strengthening the feature extraction module to recognise intersecting features. The feature extraction module has been tested with more than 50 prismatic components. It was observed that the feature extraction module could handle a variety of prismatic components satisfactorily. Further, there is also description of the algorithm used for feature coding. The various features identified by the proposed approach are also reported. The facility to input manually an unidentified feature is also provided in the feature extraction module. It helps in processing totally all the features of the components of a given industry.
9.3 Tool, Machine, Feature, Process Coding and Cutting Parameters

Database Creation

The generative CAPP system requires databases of different technologies and coding methodologies. The codification methodology is primarily aimed at providing the necessary information to the CAPP system. A unique coding system for machines, tools, features and processes suitable for a generative CAPP system has been developed. The methodology for feature-process-machine-tool correlation and the logic involved in selecting them is also developed. Further, an automatic tool and machine coding methodology has been developed for generating codes for a given new machine or tool. An exhaustive machining cutting data base for different work materials, cutting tools and various machining operation has been also developed. In order to facilitate an efficient information flow among different modules of the CAPP system, normalisation of the database has been carried out.

9.4 Development of Process Parameters of Manufacturing Processes

Developing the process parameters of the advanced manufacturing processes is one of the major concerns of the aerospace manufacturing industry. A model of the process is required to understand the technology. Development of a proper model is very difficult due to the non-linear behaviour of the manufacturing processes and large number of interrelated parameters. An attempt has been made to study the process parameters of Wire cut EDM, High Speed Machining and Electron Beam Welding processes which get prominent applications in aerospace industries.
Neural network approach has been used for Wire cut EDM process. The experiments have been planned using Taguchi’s L\textsubscript{18} Orthogonal array and as many as 120 experiments were conducted. The additional experiments were also conducted to test the model developed. It is observed that the effect of combination of parameters is more pronounced in comparison to that of individual parameters. For cutting speed, the average error of neural network model is 0.09 mm/min and for the surface finish it is 0.035μm. The results show that the neural network model can be successfully used to select the required process parameters of the WEDM.

Process parameters of high-speed milling have been studied using multiple regression and fuzzy logic approaches. These approaches are used in an attempt to determine the optimal combinations of control parameters of high-speed milling. Numbers of experiments were conducted, as the required expertise was not available. Additional experiments were conducted to test the validity of the developed model. With statistical analysis, it is concluded that fuzzy logic systems are considered as valid models, which can be used for obtaining the output values within reasonable limits. The cutting parameters have been optimised using ANOVA. To achieve a better surface finish, high cutting speeds with moderate feed rates and low depth of cuts are suggested.

Process parameters of electron beam welding process for Ti alloy (Ti6Al4V) of 5.50 mm. thick plate has been established using multiple regression approach. These approaches are used in an attempt to determine the optimal combinations of control parameters like accelerating voltage, beam current,
weld speed and distance between gun to work of electron beam welding. It is observed with statistical analysis that generated regression model is a valid model, which can be used for obtaining the output values within reasonable limits. The accuracy of predicted results of regression models for weld penetration levels and weld strength is 97% and 99% respectively. The control parameters have been optimised using ANOVA. To achieve a better quality weld, moderate accelerating voltage and low weld speed and distance between gun to work is suggested.

9.5 Process Rules

Comprehensive process rules relating to processing of prismatic components have been identified from engineering practices and consolidated. These process rules are compiled after discussions with shop floor personnel/process planners. Also some critical prismatic components were studied to derive process rules. These process rules were further supplemented from the literature available in the CAPP area. The process rules based on features, machines, setups, operation, datum etc. have been generated. These rules were used for process sequence generation of prismatic components.

9.6 Set-up Planning and Process Plan Optimisation

The input for an automatic set-up planning system comprises of machine resources, raw stock, features to be machined, dimensional specifications and tolerance requirement. The output is high level machining instruction, which will be further detailed by machinist in shop floor production. Various steps involved in set-up planning have been described. Manufacturing
constraints considered during set-up planning are also explained. An optimisation criterion to generate the optimised process plan is described. Automatic set-up planning and operation sequencing for industry standard ANC-101 prismatic component, employing the above criterion has been demonstrated. The component is successfully machined using the generated optimised process plan.

9.7 Evaluation of CAPP System

Developed CAPP system has been evaluated with using an industrial prismatic component. Process plan generated by the system is used to machine the evaluation component. The component is successfully machined using process plan generated by the system. The system was tested on industry standard component ANC-101 with process plan generation and machining as per the generated process plan. The system was tested using over 50 prismatic components and compared with those of process plans prepared by an experienced process planner and found to be satisfactory. It was found that the CAPP system could generate process plans for a variety of prismatic components. Finally, it was observed that by implementing the above approach, an optimised CAPP system could be achieved.

9.8 Process Plan Generation

Process plan formulation is the utmost important work and it is carried out with the information collected from the various modules. The various steps followed in generating process plans are as follows:

- Feature extraction
- Unidentified features input
Tolerance selection

• Blank selection

• Sorting/ precedence constraints of features

• Selection of machines

• Selection of tools and cutting parameters

• Operation sequence/set-up planning

• Optimisation of set-up plan

• Generation of process plan sheet

The generated process plan output of the system gives the information like set-planning, process to be used, machine selection, tool selection, cutting parameters selection etc. In the present work, operations like gear cutting, forming etc are not considered. Extending the present system covering the above operations could be one of the future directions.

9.9 Features of the Optimised CAPP System

The features of the optimised CAPP system for prismatic components are as follows;

• Process plan is formulated automatically and there is a provision to edit the process plan.

• The specialty of the developed CAPP system is that it is linked with the neutral data format (AP-203) of CAD Modeling system. It extracts majority of features automatically prior to process planning. It has provision to input feature details using user interface, in the case of failure of the feature extraction module.
• It has capability to handle variety of prismatic components.
• The system has an inbuilt logic for optimised operation sequencing, machine selection and tool selection.
• The CAPP system has user-friendly interface that helps in easy usage of the software.
• The proposed Optimised Computer Aided Process Planning system can be easily configured for any batch size production industry.

9.10 Future Scope of Work

Strengthening of the Feature Recognition (FR) module for features like intersecting features and other complex profiles can be undertaken as an extension of the present work. Storage of positional and geometrical tolerances of the features can be automated. Application of Artificial Intelligence (AI) techniques like Neuro-Fuzzy techniques and Genetic Algorithms (GA), and integration of CAPP and manufacturability analysis including fixurability analysis could be undertaken. Further experiments can be conducted to find out the effect of focusing current on weld strength and depth of penetration of the welds. Other optimisation criteria for process plan like faster production and optimal tool life of cutters can be also considered. The present approach could be extended to other manufacturing processes like forming, gear cutting etc.