Dual Input Capp System for Rotational Components

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Abstract: *In compuer integrated manufacturing system (CIMS) the ultimate aim is to be able to manufacture the component on CNC facility by directly using the CAD model without any human interference through seamless integration of CAD and CAM. Computer aided process planning (CAPP) integrates CAD/CAM by developing a relationship between the design features and manufacturing features from a computer compatible geometric model of the component. Methodology used for development of CAPP system depends on the approach used to generate the geometric model of the component. Feature recognition and extraction system (FRES) and feature based modeling system (FBMS) have extensively used for component modeling for CAPP. In FRES a commercially available CAD package is used to develop the geometric model of the component in terms of low level design entities like point, line, arc, etc. and a dedicated software then translates the CAD model into manufacturing featurees. In FBMS the geometric model of the component is generated using high-level product features obviating the need for feature recognition for down stream manufacturing applications. A dual input CAPP system has been designed and developed which works on both FRES as well as FBMS approaches. Methodology used to develop the system is discussed in this paper.*

1. Introduction

In computer integrated manufacturing system (CIMS), CAD/CAM integration is one of the major tasks to use the CAD database for CAM functions without any human intervention for improved quality and productivity. Computer aided process planning (CAPP) forms an important link in the integration of CAD/CAM by developing a relationship between the design features and manufacturing features A computer compatible geometric model of the component forms the input to the CAPP system and the methodology used for development of CAPP system depends on the approach used to generate the geometric model of the component. Two approaches have been used to generate the geometric model of the component i.e. Feature recognition and extraction system (FRES) and feature based modeling system (FBMS). In FRES, computer based drafting package is used to develop the geometric model of the component in terms of low level design entities like point, line, arc, etc. The component database is generated and an automatic feature recognition system then translates design features into manufacturing features. FBMS, on the other hand, is a post design modeling approach where geometric model of the component is first converted into a feature based model in terms of manufacturing features and this feature-based model is then used for component representation. Since the part model is generated using high-level product definition i.e. manufacturing features, database in this case contains only manufacturing information. This obviates the need for feature recognition for down stream manufacturing applications.

In the present work an automated process planning system for rotational components has been designed and developed which can take AutoCAD model as input to the system as well as it has its own feature based modeling module which can be used to generate the geometric model of the component with out using any standard drafting software. The system has been developed using modular approach and consists modules for:

- Feature based modeling
- Feature recognition and extraction
- Operation selection and operation scheduling
- Set up planning
- Machine tool selection
- Cutting tool selection
- Cutting parameter selection and optimization
- Report generation
- NC part program generation

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Figure 1 shows the information flow for the system.

Feature Based Modeling

Feature based modeling is used if the user does not have the component data from AutoCAD and wants to generate the component model in terms of manufacturing entities. Various requirements to be kept in mind while designing a procedual feature based modeling system are given in [1]. A feature based product modeling system, for rotationally symmetric components, based on procedual feature based product modeling, has been developed, in which pre-defined manufacturing features are stored in feature library in parametric form. This system can be used for creating and manipulating all types of turned components by instancing pre-defined features stored in the feature library. Flow diagram of the feature based modeling is given in Figure 2. Various sub modules in feature based modeling system are:

Feature Library: The feature library is used to set up the context for the model in the feature based modeling system, In feature library, pre-defined manufacturing features, internal and external, related with turned components are stored in parametric form. During part modeling user can select the required features to develop the part model.

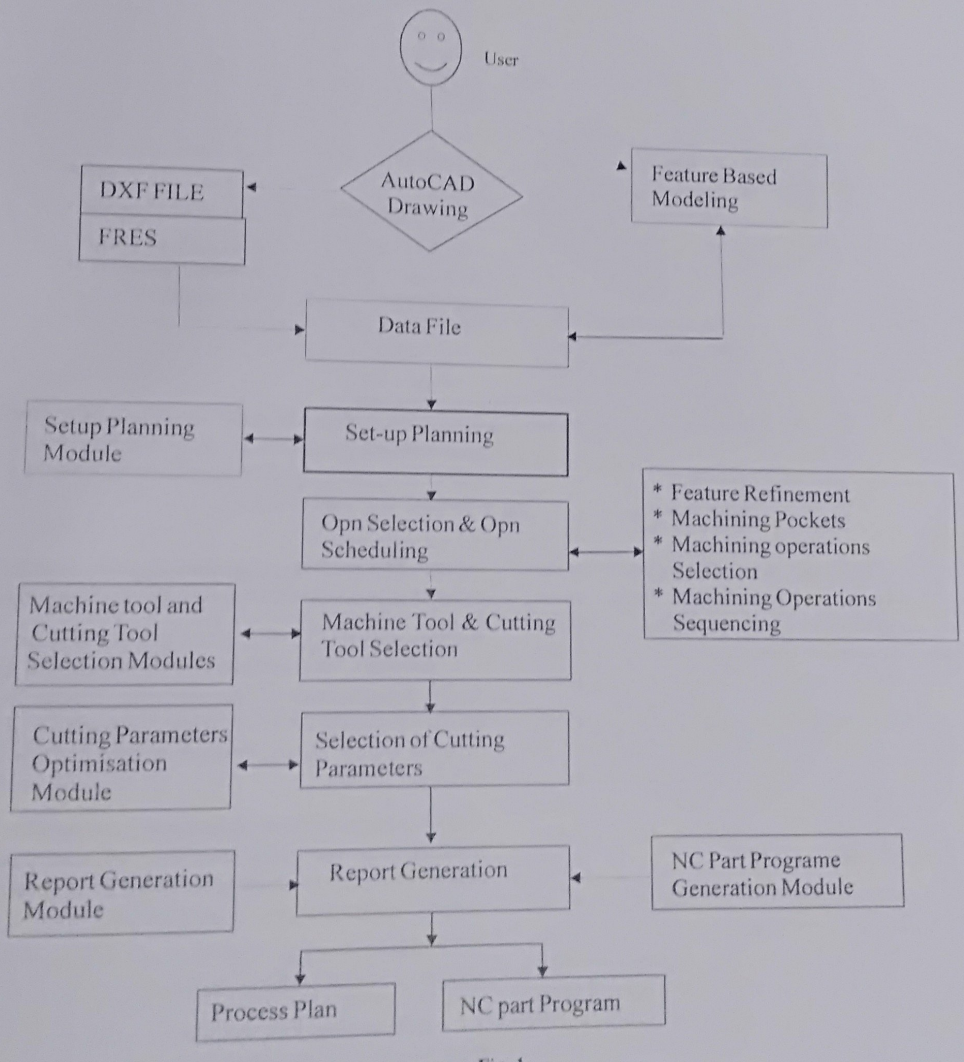

Fig. 1

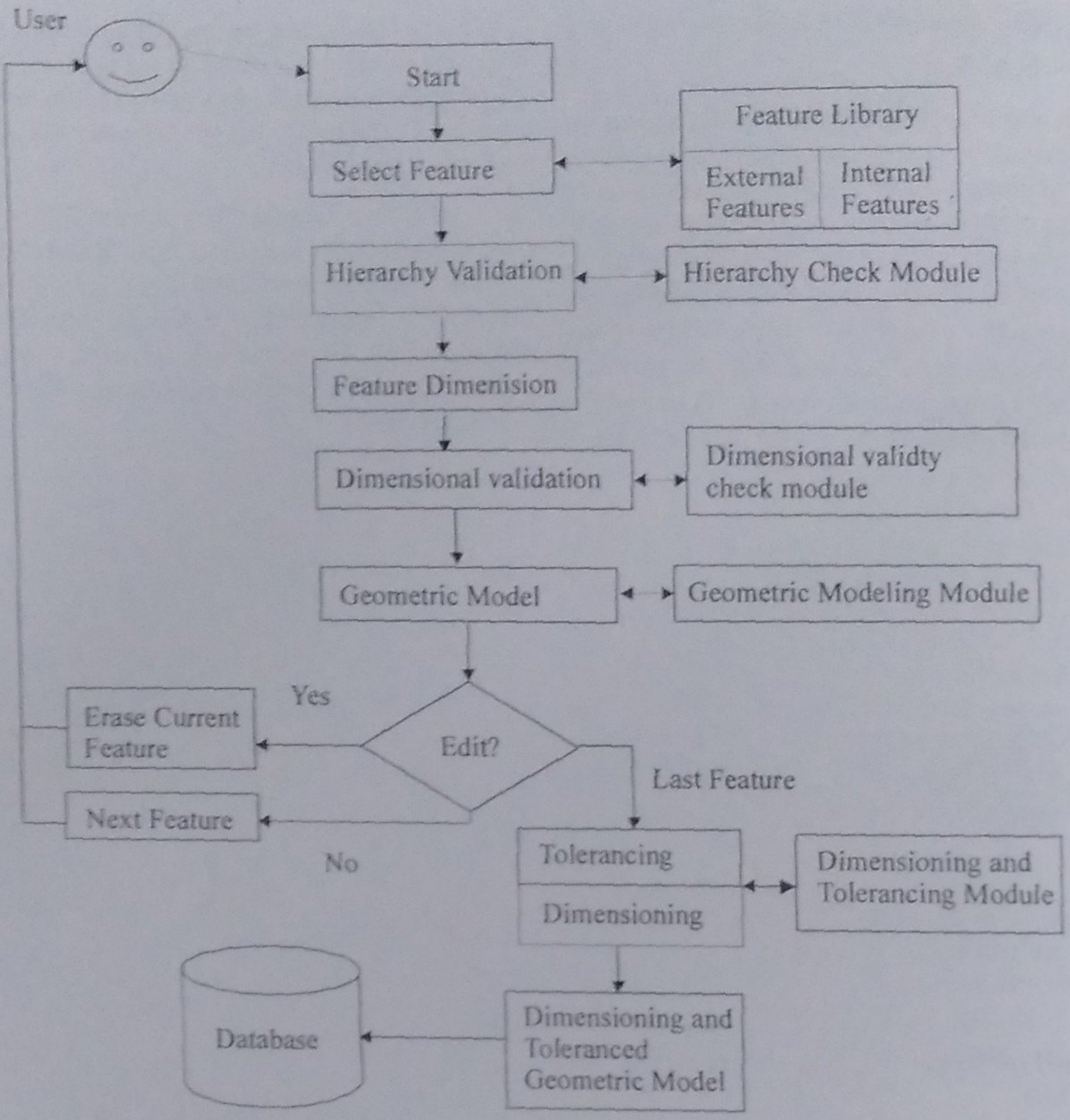

Fig. 2

Hierarchy Checking: This module facilitates the user to select feasible features from feature library during geometrical modeling to avoid modeling of illogical components. The module allows the user to select only hierarchically feasible and correct sequence of features.

Dimensional Validity Checking: This module checks whether dimension(s) entered by the users for each of the features is valid or not. For example feature dimension cannot exceed the bar dimensions or groove depth cannot be equal to or more than the component radius, so as to produce meaningful objects only.

Geometric Modeling: This module develops the graphical image of the dimensionally feasible features in graphics area on the CRT screen. The sub program written for each manufacturing feature generates graphical image of the part. Depending on the user choice, the corresponding sub program is called to draw the respective feature. The system uses color graphics capability for generating part model to improve the legibility of the part model.

Editing: This module allows the user to erase or modify the just selected manufacturing feature to enable the user to correct the errors related to selection of feature from the feature library, or errors related to input data for particular feature.

Updating: This module acts as a translation vector which updates the coordinate of the part model during part modeling process to provide the facility to position a feature at right location during modeling phase.

Dimensioning: This module dimensions of the geometric model without intervention of the user.

Tolerancing: This module stores the component level, inter-feature level and intra-feature level tolerance data by taking tolerance data from user interactively. Concept of tolerance frame has been used to accept the data from the user. The entered tolerances are then attached to the part dimensions and displayed on the part model.

Database: This modeling system creates a database in the form of high-level product definition. The database generated by the geometric modeling module is used in the subsequent modules for process planning and NC program generation.

Feature Recognition and Extraction

If the user wants to create component drawing in AuotoCAD, dimensional as well as technological data are input by the user in the CAD model. To distinguish between the different features on the CAD model and also to differentiate between the internal and external features of the component, various line types available in the drafting software are used. Component data in DXF format forms the input to the feature recognition and extraction module. Feature recognition and extraction consists of following two sub modules:

Data Filtering and Restructuring: DXF file is first filtered to remove the unwanted information. Only the information to be used in further processing is stored for the basic entities line and arc. The data is then restructured and arranged in the descending order of X-coordinate. The coordinates of all the points are recalculated by making the right-center point as (0,0).

Feature Recognition: The entities are separated into internal and external entities. These entities are then converted into manufacturing features, using IF... THEN rules. The external features are recognised first followed by the internal features.

The basic entities are the recognised using IF... THEN rules as under:

IF (x[i][0]= x[i][1] s y[i][0]!= y[i][1]) then entity is a vertical line. (Facing Operation) and

IF (x[i][0]! = x[i][1] s y[i][0] = y[i][1]) then entity is a horizontal line. (Plain Turning).

Setup Planning

Cylindrical components can be machined in either one setup or two set ups depending on the part geometry and the work holding method. In the present work the number of set ups required is decided based on the component geometry. If required the manufacturing features are split into two setups based on the concept of demarcation line (DL). In case there are more than one demaraction lines, the extreme left DL is considered for splitting the activities into different setups. The advantage of using the extreme left DL being that most of the manufacturing features will be machined in the first setting ensuring better inter feature relationships. For external features, maximum diameter is used to fix the DL and minimum diameter is used to fix the DL for internal features. However internal features are split into two setups only if there is a through hole in the component.

Operation Selection and Operation Sequencing

The process of selection and sequencing the operations for the manufacture of a component consists of the following sub functions:

- Feature refinement
- Determination of maching pockets
- Selection of machining operations
- Sequencing of machining operations

Feature refinement: The manufacturing features from FBMS or FRES stage are further refined to link these features with the manufacturing operations. The manufacturing features are refined to get the machining pockets i.e. the material pockets, which need to be removed to get the manufacturing features. The feature refinement is in fact the filling process where the material to be removed to generate the manufacturing features is added to the finished product to get the 'less machined' component. Thread, groove and undercut are first stored separately and the part geometry is refined using the refinement rules. Flow chart for feature refinement, for external features, is shown in Figure 3.

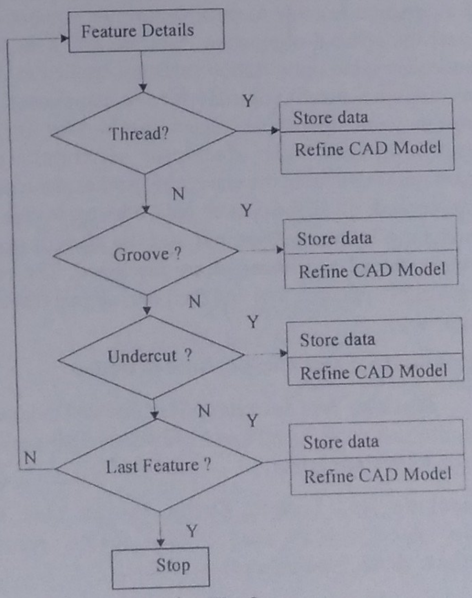

Fig. 3

Determination of machining pockets: Two approaches are generally used in determination of machining pockets i.e. forward and backward planning approach. The first approach, called the backward approach, starts from the finished component drawing and the pockets of material required to be added are identified to reach the raw stock. The second approach, called forward approach, starts from the raw stock and the final shape of the component is reached by deleting the material pockets at the subsequent stages. In the present work second approach has been used to generate the sequence of operations. The features from FBMS or recognised in FRES module are arranged in the form of machining pockets. Except thread, groove and under cut, where the maching pockets are defined by the geometry of the manufacturing features, other machining pockets are defined by entities defining the pocket. Depending upon the type of entities defining the machining pocket, the pockets are defined as plane_turn_cum_face, plane_cum *taper*turn or plane_cum_circular_turn profile. This information is useful in developing automated NC part program for the component.

Slection of machining operations: Depending on the type of manufacturing features and machining pockets, maching operations are identified for rough cut and finish cut maching.

Sequencing of maching operations: Operation sequencing is the act of arranging the machining operations to generate the finished component in the feasible and optimal sequence. Theoretically there can be a large number of operation sequences for the manufacture of a component, but the practical constraints limit the number of alternative feasible to manufacture the component. To select the optimal alternative from the available feasible sequences some optimisation rules are applied to achieve the minimum machining time for the component. In the present work operation sequencing is done for rough machining and finish machining separately. Rough machining starts from the machining pocket at the top level and proceeds till all the pockets have been machined. Finish machining is then carried out and the specific features, groove, thread and undercut are machined. The external features are planned first and then the internal features are sequenced.

Machine Tool and Cutting Tool Selection

Machine Tool Selection: Machine tool database has the information about all the machines, available in a shop, in the following format:

[Machine_No., Length, Swing, Power, Max_speed, Min_speed, Max_feed, Min_feed, Accuracy, Surface_finish, Available/not_available]

The machine tool required to perform the operation is selected by matching the component requirements with the machine capabilities. The machine tool selected should be capable to meet both the geometrical and technological requirements of the component. However conflicts may arise in machine selection as more than one machines may qualify to machine a particular component. In such cases some optimization criteria i.e. minimum production time or minimum production cost, may be used to decide the optimal alternative. In present system machine tool selection is made by matching the component requirements with the capabilities of the machine tools in the machine tool database. Only the machine tools which are available for production are considered. If more than one machines meet the requirements for a particular component, machine tool with maximum spindle power is selected.

Cutting Tool Selection: The cutting tool selection module takes input from the operation selection module. Tool type is determined by the type of machining operation i.e. a grooving tool for a groove and a threading tool for thread cutting operation. Rest of the decisions are made based on work piece material and work piece geometry. Cutting tools are selected from the cutting tool data base by matching the requirements of each maching pocket/machining operation. Cutting tool database contains data about each cutting tool data stored for a turning tool is:

[Tool_Number, Tool_code, Tool_nose_radius, Included_angle, Rake_angle]

Selection of Cutting Parameters

Selection of cutting parameters is one of the important tasks of process planning function as they directly affect the quality, cost and production rate. The selected parameters should yield the desired surface qualities on the surface being machined while utilising the maching resources such as machine tool and cutting tool to the fullest extent possible consistent with the constraints of these resources. Mathematical modeling technique has been used in the present system for optimisation of cutting parameters for facing, plain turning and taper turning operations. Cutting parameters for other operations are retrieved from the database developed on the basis of recommendations made in Sandvick Cutting Tool Catalogue. Optimisation of cutting parameters, for rough and finish machining, is achieved in two steps:

a) **Rough Maching:** For rough maching of each pocket maximum and minimum number of passes are calculated based the minimum and maximum permissible depth of cut based on the work material, tool material and machine tool combination. The starting feasible values of cutting speed and feed rate are calculated for all feasible values of depth of cut

These values are used in the second step to calculate optimum values of cutting speed and feed rate. For all feasible values of depth of cut for a pocket, cutting speed and feed rate are optimised using the interior penalty method coupled with Davidon-Fletcher-Powell method of unconstrained minimisation. The starting values of cutting speed and feed rate calculated in the first step are used as initial feasible values. The set of cutting speed, feed rate and depth of cut which gives the minimum value of objective funct. The ion is chosen as optimal parameters for the machining of the pocket under consideration. Flowchart for calculating the initial feasible values for rough machining are given in Figure 4.

b) **Finish Machining:** Finish machining is a single pass operation and depth of cut is also pre determined. The starting values of cutting speed and feed rate are calculated for finish machining in the first step as in case of rough machining. The cutting parameters for each operation in finish machining are then optimised using the interior penalty method.

Process Plan Generation

The process plan generation module generates the process plan for machining the component on CNC lathe machine. Required information to generate the process plan is taken from the previous modules.

NC Part Program Generation

Last step in the development of integrated CAPP system is the development of a mechanism for generation of NC part program for machining the component. The NC program generation module generates the instructions for component machining in the form of G, M, S, F, and T codes. NC code generation module gets the input from the feature recognition module, operation selection & sequencing module, cutting tool selection module, and cutting parameter selection module. For each machining

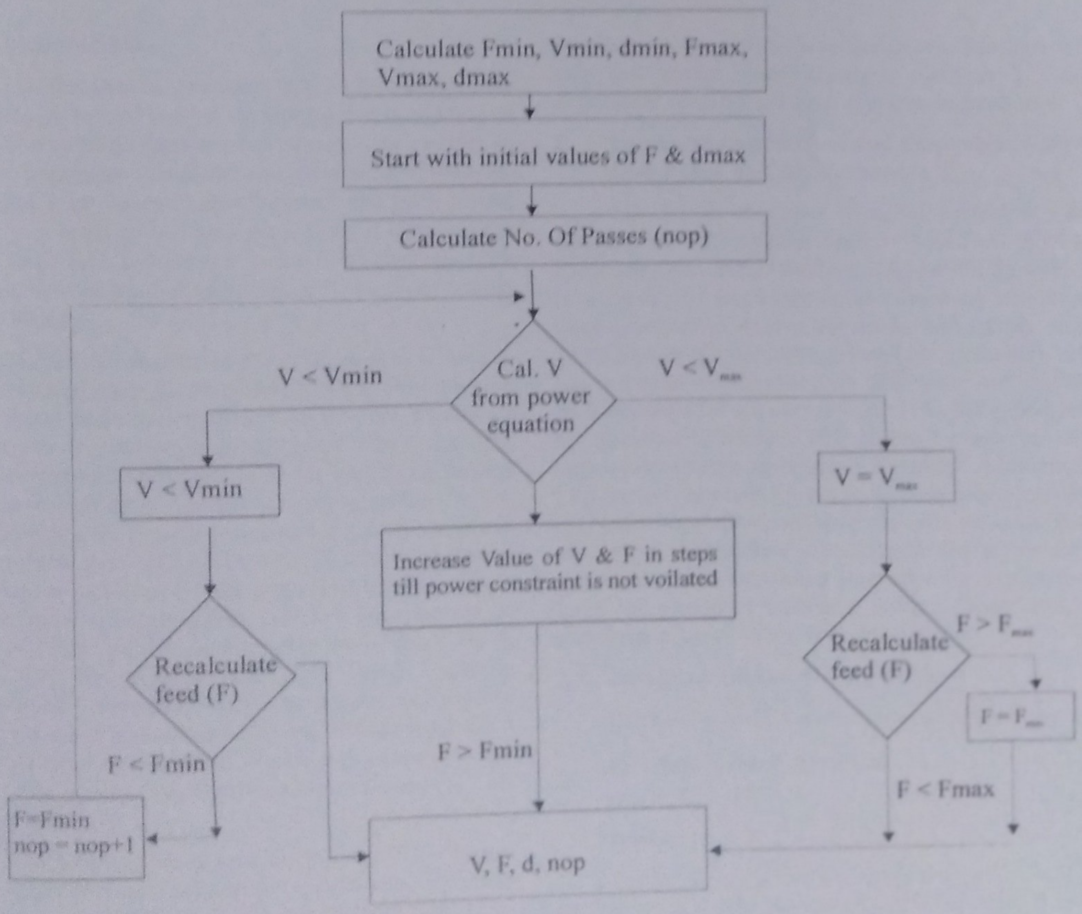

Fig. 4

pocket, the required detailed information is retrived from the different modules and the corresponding sub program is executed to give the NC part program for the pocket. Since the pockets are taken up in a set sequence, the part program for the complete component is the compilation of the output of the individual subprograms developed for the various maching pockets, which define the component. The part program is written to a file, which can be edited by the user, if required.

Validation

The present system has been tested on a large number of industrial components. The results have been very encouraging. The system gives the flexibility to use either AutoCAD or in-built feature based modeling system to generate the component model.

Rerferences

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