A DYNAMIC COMPUTER AIDED PROCESS PLANNING (DCAPP) SYSTEM

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Abstract This paper presents an integrated approach to the Computer Aided Process Planning (CAPP) and shop floor control. The proposed system has been divided into two major modules. The first module deals with design and development of a generative computer aided process planning system. The second module deals with design and development of a real-time data acquisition system to collect shop floor data in on-line basis and the same has been used for generating dynamic process plans. The developed real time data acquisition system has been integrated with the generative CAPP system. The proposed approach provides a better real time process planning environment and generates more realistic process plans that can be operated on the shop floor with minimal deviations against the planned activities. The developed system has inbuilt capability to generate alternative routings in the case of non-availability of a particular resource e.g. machines etc.

Keywords: CAPP, DCAPP, MMS, and TMS

INTRODUCTION

Computer aided process planning has been seen as a critical link between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). In conventional practice, process planning and shop floor control activities are seen as two separate activities. But in actual industrial environment, these two activities are to be seen as single integrated activity in order to preserve maximum flexibility and to minimize the deviation from the actual planned process plans. Process planning can be stated in simple terms that converting the given engineering drawing/3D model into manufacturing instructions which gives information about operations, machines to be used, tools, machining parameters and inspection details. Basically there are two approaches for computer aided process planning. The first one is variant approach, in which a new process plan for the given component is generated using the existing process plans stored in the database. The second one is generative approach, in which a new process plan is generated from scratch i.e. it will not use any existing process plans. The basic requirement for a generative process planning system is that the given component 3Dmodel/drawing is to be interpreted in terms of manufacturable features. The technology used for interpretation of the component 3Dmodel/drawing is called feature recognition technology. As feature recognition technology is not yet fully developed, there is a third category of process planning approach called semi-generative approach. In this approach, researchers have made an attempt to integrate features of the above two approaches and relieving certain requirements of a truly generative process planning system. In fact most of the developed CAPP systems comes under this category. Further, semi-generative approach is considered as a good option for the present industrial application till the development of generative CAPP system. Also, there is a common opinion among the research community that CAPP is an important link missing between CAD/CAM. Further, the overall integration of CAPP with shop floor control activity is yet to be achieved in order to realise Computer Integrated Manufacturing (CIM).

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AN OVERVIEW OF CAPP LITERATURE

Even though sufficiently good amount of search has been put in for the development of CAPP systems for the last three decades, still the benefits of CAPP systems are yet to be realized in industrial applications. In the past [Alting and Zhang, 1989], [Eversheim and Schneewind, 1993], [El Maraghy, et al., 1993], and Faruk Cay, 1997] have made extensive surveys regarding CAPP literature and given future directions for CAPP. A survey, reported by [El Maraghy et al., 1993], has revealed that the industries want to have commercial CAPP systems that have all of the following important features.

1. The CAPP system should act like a decision supporting system rather than an automatic system.
2. The system must have less response time in order to use it for decision support.
3. The user should get support in generating a process plan for the complete range of components of the company.
4. The CAPP system should be integrated with other information systems of the industry e.g. CAD, PPC, shop floor control systems, Tool Management System etc.

Here, it is worthy to note that in the proposed integrated system, most of the above requirements have been incorporated by integration of Tool Management System (TMS), and Machine Monitoring System (MMS). Further, the highlight of the proposed system is that the data required for different modules are taken directly from the shop floor in on-line basis. This feature of the system facilitated in improving the system response time.

The literature shows that there were some efforts towards integration of CAPP and scheduling. The research work reported by [Kempenaers, et al., 1996] deals with integration of automatic process planning and scheduling system based non-linear process plans. In their approach, they used production constraints as a means to realize feedback from scheduling to process planning. Also some work was reported regarding integration of CAPP and scheduling by [Detand, et al., 1991], [Kruth and Detand, 1992], [Cho, et al., 1994], [Chryssolouris and Chan, 1990]. The research work reported by [Dimitris and Parchet, 1996] describes about a system, which uses petri net model for dynamic process planning and sequencing optimisation. In their approach, a reachability tree is created automatically and upon doing reachability analysis using depth-first search algorithms, different process plans were generated. Even though sufficiently good amount of research efforts have been placed in this direction, the development is far from the actual industrial requirement.

The literature shows that the efforts made towards integration of process plan activity and shop floor control activity are inadequate. Further, there is no such integrated system available for collecting shop floor data in on-line basis and which is essential for any real time shop floor control. With this background, in the present work, an attempt is made to design and develop a shop floor data acquisition system to collect data in on-line basis and integration of this module with the CAPP system. This helps in generating dynamic process plans and effective shop floor control. The proposed system has been implemented using Visual Basic 6.0 as front end and Oracle 7.3 as back end. The modelling software is Solidworks98Plus. The following sections will give a brief description of the different modules of the proposed system.

MACHINE MONITORING SYSTEM (MMS)

The scheme for obtaining status information about CNC machines is relatively simple in view of available machine-inbuilt controllers. The data collection for the purpose of obtaining machine status of the conventional machines has been carried out in two phases (i) manual mode and (ii) auto mode. Four signals like power ON etc., are taken automatically and the remaining signals are obtained manually. The complete information obtained both from manual and automatic mode is processed in Programmable Logic Controllers (PLC) to categorize the machine availability information. The combination of status signals have been analysed using truth tables and appropriate logical inferences regarding machine status viz. machine in operation, machine idle, machine breakdown, are made. The processing of data is carried out using software written in Visual Basic 6.0 and database in Oracle 7.3. The software resides in a host-computer, which facilitates in process planning and dynamic scheduling etc. The software helps users to analyse machine utilization and machine down time etc. The above information enables the company to get a real-time feedback about the machine, job details for an appropriate corrective action. Any time an event occurs, a message is sent to the host computer. The software is designed to be responsive to manufacturing events and the same can be configured to suit individual industries. It has the capability to generate utilization reports of the machines via a real time display. These reports helps to have an integrated approach for computer aided process planning and dynamic scheduling for effective shop floor control. The system generates standard reports that graphically show the information such as machine utilization, and display them, on a shift/day/weekly/monthly/yearly basis. In addition, custom reports can be generated using reporting tools.

Status of Machines

The status menu of the system gives a detailed status of a particular machine like machine breakdown, type of breakdown, machine waiting type and operator availability etc. in “on-line” basis. The on-line information enables the shop floor manager to take necessary corrective action viz. rescheduling, alternative operation sequencing, planning for extra working hours in the weekends etc. The status of the different machines available in a particular bay in the shop can be displayed i.e. machine working/machine not working. Whenever, a machine is not working, a red signal appears at the bottom of the machine. As against this, a green signal indicates that the machine is in operating condition. Whenever the machine is not in operating condition the shop floor supervisor can take alternative decisions for the component routing, rescheduling of jobs, planning for temporary capacity expansion by loading selected machines during week-end, or availing

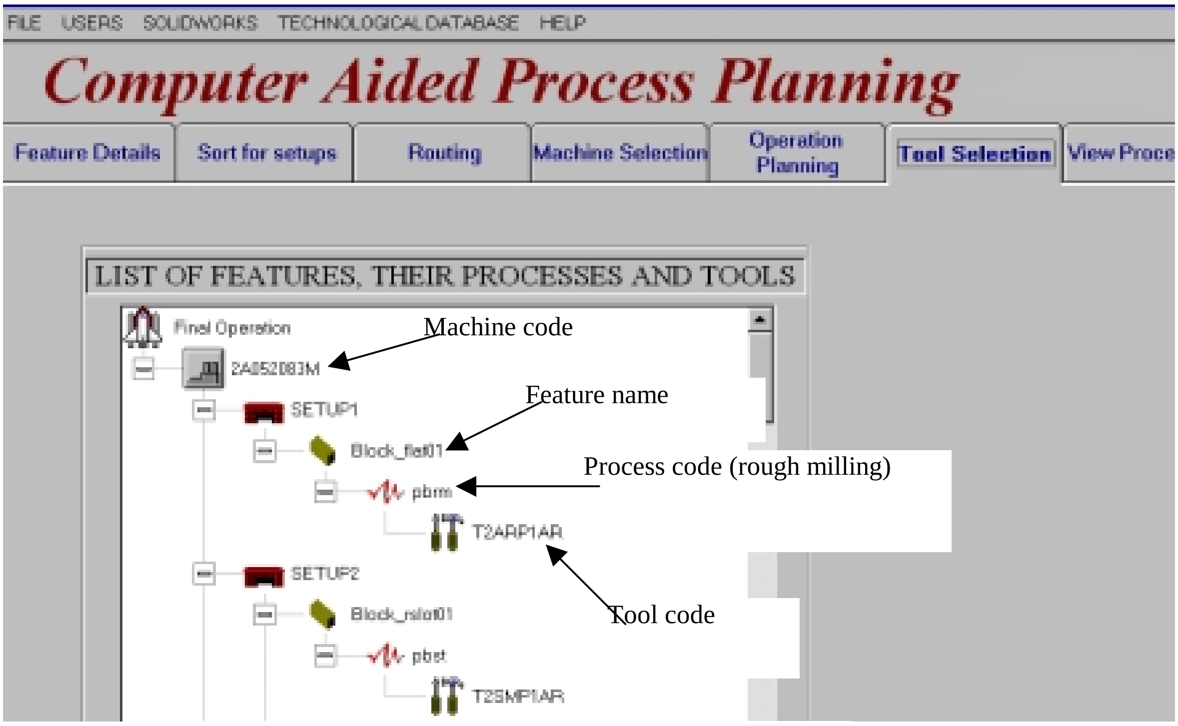

Fig. 1 Tool selection menu of the DCAPP system

subcontract facility etc. Prior to planning an alternative machine for the machine, which is under breakdown, the complete specifications of the machine can be obtained by double clicking the machine icon itself. Further, the MMS module has been integrated with CAPP module in order to facilitate in knowing machine availability.

TOOL MANAGEMENT SYSTEEM (TMS)

The need to develop the tool management module is to ensure the right deployment of right tool at right place at right time and to reduce the down time of machines due to non-availability of appropriate tools. Tooling requirements from the shop for routine production, new tools required for new type of components, tools utilization data, tool pre-setter information, tool issue information, calibration details and availability status are the data fed to the TMS module. The various outputs from the TMS module are tool availability data to process planner and scheduler, tool procurement list, tool utilization report, tool availability and location details in the shop floor, tool reconditioning and calibration details and reports consisting of tools issue, return and damaged details.

Cutting Tool Selection

After selection of machining operations, fixtures and clamping surfaces, process planning moves on to the selection of cutting tools. The main concern in tool selection includes tool type, material, geometry, and tool dimensions. Selection of tool type is based mainly on operations to be carried out and the machine tools involved. A criterion for selecting tools for rough machining, for example, is to minimise the tool changes and to maximise the number of features machined. Several other factors also influence productivity such as tool material, size etc. The process plan generation module of the CAPP system decides the process to be carried out to finish a particular part by means of feature-process correlation available in the knowledgebase. Based on the tool-process correlation the cutting tool class is decided. The tool process correlation holds all the information regarding tools and their operations (Fig. 1). If the feature is a hole, then a drilling tool is to be used. But based on the feature dimensions, the best matching tool is to be selected from the corresponding database, which provides data like tool code, tool length, diameter, insert material etc. Separate databases are developed and maintained for drill tools, milling cutters, grinding wheels etc. The tool selection is facilitated with dual methods, namely automatic selection and manually. Feature extraction module supplies details of feature geometry, blank selection module gives work material size and process planning module gives the type of process with all these data proper cutting tool selection will be done. The whole database for tools and machines has been implemented using Oracle 7.3. The tool selection module of the DCAPP system has been integrated with TMS module, which provides an on-line status of tool availability.

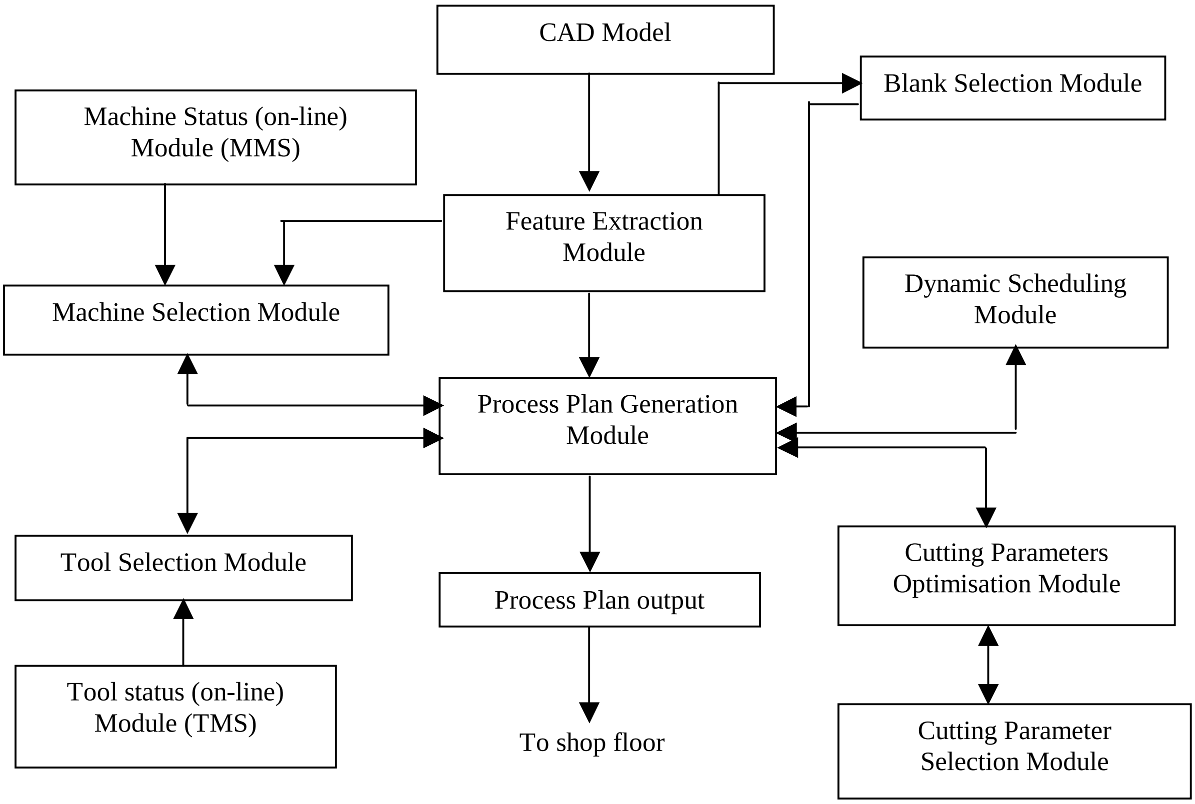

Fig. 2 The different modules of the DCAPP system

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The block diagram of the proposed DCAPP system is shown in Fig.2. It can be seen from the Fig.2 that the information required for machine status and tool status (availability) is being taken prior to preparing a process plan sheet. Here, the data related to machine breakdown and the reasons for the breakdown could be obtained using the machine monitoring system, whereas tool availability can be obtained using tool management system. Using the above information, the proposed DCAPP system can generate dynamic process plans. Since, it is taking on-line data from the shop floor, the process plans generated by the system are more realistic and prone to little changes. Further, in order to realize dynamic scheduling system, a DCAPP system must be capable of generating process plans with alternative routes and sequences to suit the variable status of the shop floor. It is proposed to display the process plans in on-line basis in order to facilitate the system to change process plans dynamically. To realize on-line display of process plans on the shop floor, either the machine monitors or separate monitors may be required to use. Most preferable is to use the existing monitors of the machines (e.g. CNC machines). The information flow between the different modules of the proposed DCAPP system is also shown in Fig. 2.

Process Plan Generation Module of the DCAPP System

Process plan is formulated combining the inputs from the various modules and putting all them together. The speciality of the proposed system is that it considers the shop floor status prior to generating process plan sheet. It also suggests an alternative process plan/route in the case of non-availability of a particular resource i.e. machine or tool etc. The following are the various modules from which the process plan is build up.

1. Feature Extraction module 2. Blank selection module
3. Machine selection module
4. Routing module (for process selection and intermediate dimensions calculation)
5. Machining parameters selection module
6. Tool selection module
7. Set-up planning module
8. Shop floor data collection modules (MMS, TMS)

Using the above modules in addition to the process plan generation, a note mentioning the set-up change after the completion of a set-up, a message indicating the inspection to be carried out are also given at each and every stage. In addition to this, in certain specific cases, heat treatment information will also be given. As the basic aim of the paper is to present the concept of integration of CAPP with shop floor control activity, the

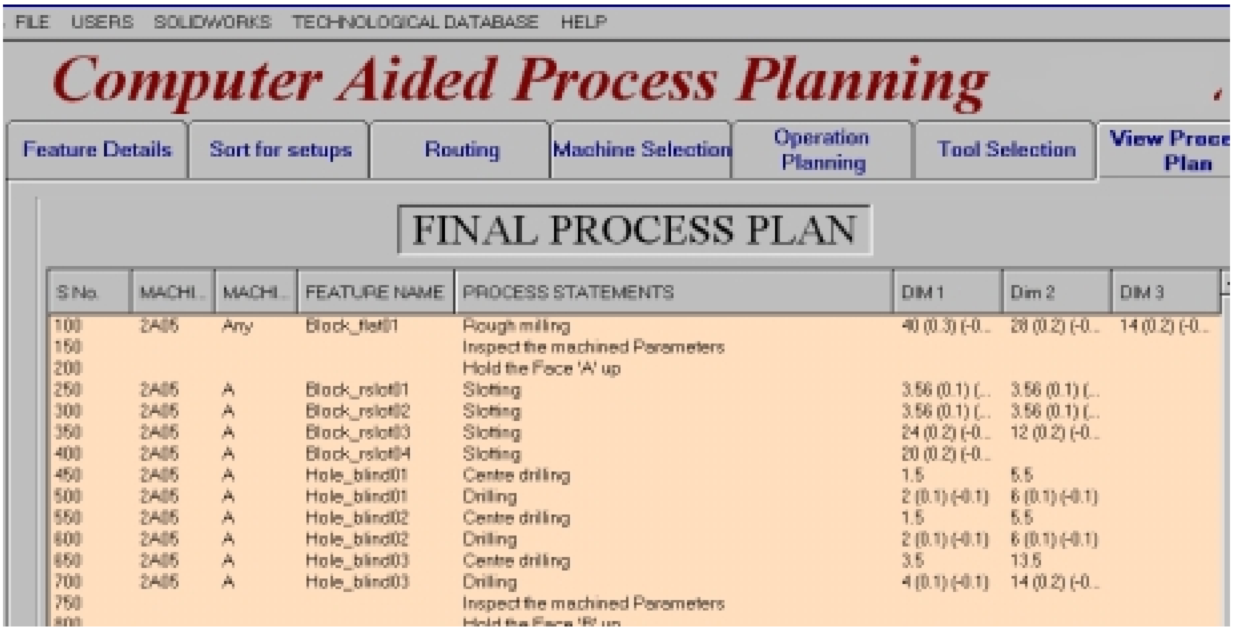

Fig. 3 Specimen process plan generated by DCAPP system

details regarding the different modules of the DCAPP system are explained briefly.

Selection of Appropriate Machines From a List of Alternative Machines

Here, the machines that are selected in the machine selection module, are taken into consideration for further processing. There can be many machines, which can perform the given process to get the required feature. From the list of available machines, which can hold the maximum number of set-ups and perform the maximum number of processes is identified. This module has been integrated with MMS module to get on-line status of the machines available in the shop floor. Prior to selecting a machine, the DCAPP system will check for the availability of the machine. This feature of the system helps in selection of the machines, which are available for assigning jobs. If the process planner is not satisfied with the automatic selection, the system has got the facility to select the required machine manually.

Process Plan Generation

Process plan formulation is the outmost important work and it is carried out collecting information from the various modules described in the preceding sections. The Fig. 3 shows the final process plan format, which is generated by the DCAPP system. It gives the information about, machine, cutting tools, set-up details, the type of process to be used, cutting parameters along with auxiliary data like inspection details and heat treatment details. This can be directly stored in the prescribed format and can be made use of at a later stage. If the shop floor has the facility to display, then it can be displayed directly on the shop floor monitors. This feature helps in changing over to an alternative routing/machine. Further, the software is capable enough to generate inspection chart for a given component.

Features of the Proposed DCAPP system

1. Exhaustive set of feature process-correlation is available
2. Process selection is done automatically and user has enough freedom to change the process selected.
3. Intermediate dimensions can be calculated and it can be used for generating inspection chart.
4. Process plan is formulated automatically and there is a provision to edit the process plan.
5. The speciality of the developed CAPP system is that it is linked with the CAD module and it extracts majority of features automatically prior to process planning.
6. On-line shop floor data acquisition system has been integrated with DCAPP system.
7. The system can suggest an alternative process plan in the case of non-availability of a particular resource e.g. machine or tool etc.

CONCLUSIONS

In this paper, an attempt is made to integrate generative computer aided process planning system with shop floor control activities in order to realize DCAPP system. Here, MMS has been used to get on-line status of machines and TMS has been used for getting on-line availability of tools. Whenever a particular machine is not available, then the shop floor supervisor has to take an alternative decision for the component routing, rescheduling of jobs, planning for temporary capacity expansion by loading selected machines during weekend or availing subcontract facility. As against this, in the proposed DCAPP system, instead of shop floor supervisor, the DCAPP system itself gives an optimum solution. This helps to have an integrated and realistic approach for computer aided process planning and dynamic scheduling for effective shop floor control. In the present system only machine status and tool availability have been considered for generating dynamic process plans. In a fully dynamic CAPP system, there is a need to consider other information like job priority, cost implications etc. To realize the above said DCAPP system, the authors are working to address some of the issues stated above.

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