DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR COMPUTER AIDED PROCESS PLANNING SYSTEM

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Abstract: A decision support system for Computer Aided Process Planning (CAPP) system has been designed, developed and implemented. The need to introduce decision support system for CAPP system arises specifically to solve the poorly structured stages in process planning such as determination of blank size, setup planning, operations planning in each setup, selection of machine tools, calculation of machining time etc. Decision Support System (DSS) is capable to support operations like turning, facing, tapering, arcing, grooving, filleting, chamfering, knurling, threading etc. The proposed system is capable to generating process plans for different types of rotational parts.

1 INTRODUCTION

In a manufacturing system manufacturing data are to be transformed into work instructions by means of process plans. Process planning is a function in a manufacturing organization that establishes the manufacturing processes and process parameters to be used in order to convert a piece part from its initial design to the final form which is predetermined on a detailed engineering drawing (Chang, 1990; Chang and Wysk, 1985). It has been defined as: “The subsystem responsible for the conversion of design data to work instructions” (Link, 1976).

Process planning is a bridge between product design and manufacturing. Since a large number of factors and data need to be considered, process planning may be a very complex and time-consuming job. In general, several people need to participate in developing a process plan since one may not have the broad expertise required. On the other hand, additional complication is introduced by the fact that a process plan is a critical element in making a part correctly and economically. The activities of process planning include understanding of the part specifications or product design data, selection of raw material, selection of operations, selection of machine tools, sequencing the operations, sequencing the setups, determination of process parameters, and generation of process sheets.

The process of transforming component data, process capabilities and decision rules into computer readable format is still a major obstacle to overcome. In the present paper, a decision support system has been introduced in generation of process planning to liquidate this obstacle.

2 THE PROPOSED CAPP SYSTEM

The proposed CAPP system is designed to generate process plans for axisymmetric components using a decision support system. A DSS can be defined as "an interactive system that provides the users with easy access to decision models in order to support semi-structured or unstructured decision making tasks". In the present study, it performs functions such as data interpretation, stock determination, setup selection, sequencing of operations, selection of process parameters etc.

Figure 1 shows a pictorial framework for considering issues relevant to the design and evaluation of DSS (Chitta et al., 1990). The three types of interfaces (DSS and user, user and decision making organization, and organization and environment) are by no means independent.

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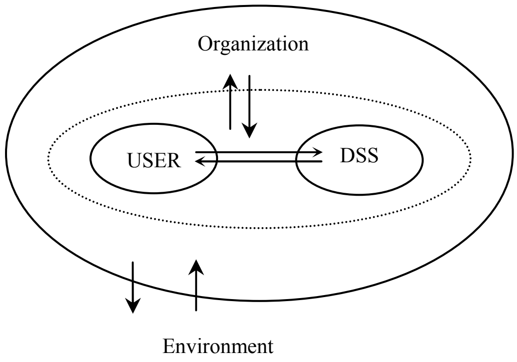


Figure 1: Nesting of Issues Relevant to Design and Evaluation of DSS.

The DSS consists of rules, which are framed on the logic based on technological considerations and operations feasibility. The rules when fired succeed in inferring some goals, which determine the sequence of operations. The proposed DSS is applicable for axisymmetric components and operations like facing, turning, boring, taper turning, threading etc. It performs the following tasks (Grabowik and Knosals, 2003 and Younis and Wahab, 1997):

1. Determination of blank size.
2. Setup planning.
3. Sequencing of operations in each setup.
4. Selection of nominal machining parameters and calculation of power requirement.
5. Calculation of part processing time.

The architecture of the proposed CAPP system is depicted in Figure 2.

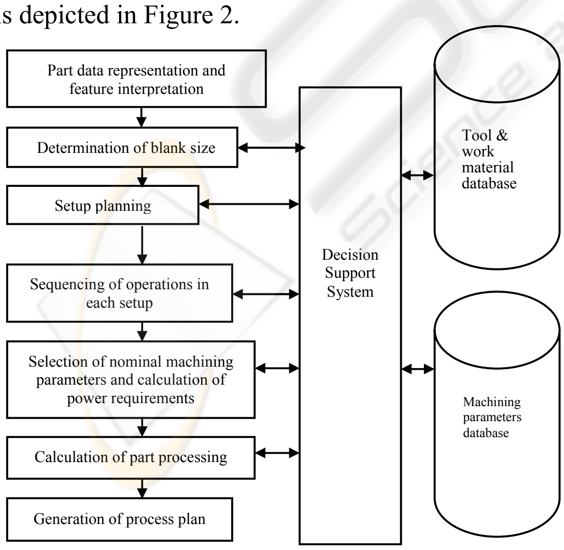


Figure 2: The Proposed CAPP System Architecture.

Each step is controlled and executed in liaison with DSS, which interacts with various knowledge and databases. The DSS contains the knowledge of process planning and technical know-how for manufacturing axisymmetric components using typical rule-based approach for knowledge representation in the form of IF <antecedent> THEN <consequence> decision tables.

For part data representation and feature interpretation a feature-based modeling system (FBMS) has been developed using interactive representation of feature data in customized format and syntax including geometric as well as technical details of the part.

3 MODULES OF DECISION SUPPORT SYSTEM

3.1 Determination of Blank Size

Ferrous material rods are available in the following standard diameters (Mahadevan and Reddy, 1983).

Stock dia. (in mm) = {6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 71, 80, 90, 100, 110, 125, 140, 160, 180, 200, 220, 240, 260, 280, 300, 320, 340, 360, 380, 400, 420, 440, 450, 480, 500, 530, 560, 600}.

A stock bar diameter equal to or just greater than the maximum coordinate of the part is selected as the raw stock for the part. Length of the required stock is taken as 10 mm more than the maximum X coordinate of the part in order to consider facing operation on both ends of the part and for clamping purpose. It is assumed that the part is to be machined from a cylindrical stock bar. A semi-finished component is not considered as the starting stock for the generation of CAPP.

3.2 Setup Planning

Once the part description and feature representation is complete, the next step is to determine a method of holding the part. Various methods of holding axisymmetric components include: chuck only, between centers and using face plate and dog as driver, chuck and center and using chuck as driver, and special fixtures and collets (Jasthi et al., 1995). The decision about holding method is based on a set of rules using length-to-diameter ratio. Parts are classified as either short or shaft on the basis of these rules. Only short parts that can be held using chuck only holding method have been considered in the present work.

In this module a demarcation line concept has been used which helps primarily to identify the clamping span of the part. Its secondary purpose is to help grouping features under different setups such that all features belonging to one setup can be machined in one clamping of the part. A setup is defined as a group of features that can be machined during a single clamping of the part being processed (Kovan, 1959). Reversing the part on the same machine or shifting the part from one machine to another can be treated as different setups. A setup is planned such that maximum number of features can be synchronously machined with minimum number of setups (Huang et al., 1997). Majority of axisymmetric components can be machined in two setups. At this stage, a setup is considered as a basic element of a process plan.

Tool approach direction is an important factor in planning setups. The tool approach direction of a feature is an unobstructed path that a tool can take to access the feature (Chang, 1990). Features with the same tool approach direction can be grouped into one setup. In case of a single setup condition, all features can be machined from a blank to finished part stage in a single setting. However, if a part needs to be machined in two setups, it is necessary to establish the accessibility limits of various features in each setup. To locate clamping span and to associate various features to different setups, a DL is to be identified which divides the length of the part into clamping span and machining span as shown in Figure 3. It is assumed that a plain cylindrical surface is present in the clamping span. The DL is determined for parts with external and internal features based on the rules provided by Hinduja and Huang, 1989.

The next task is to associate various features of the part to different setups, so that all features belonging to a setup can be machined in a single clamping of the part.

3.2.1 Setup Planning for External Features

The DL can be used to group all the external features of a part in two setups as per the following rule (Figure 3):

- For i^{th} external feature {
    If (X_s & X_e <= DL)
  Then associate the feature with setup 1
  Else associate the feature with setup 2
  }

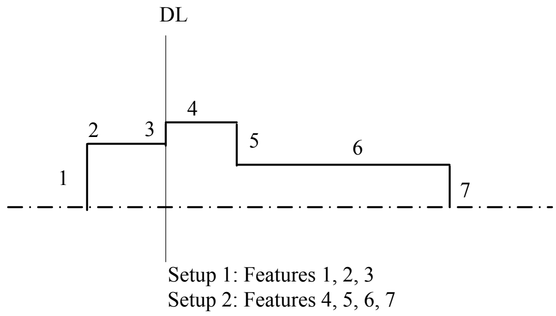


Figure 3: Setups for Part with external features.

3.2.2 Setup Planning for Internal Features

The DL is located on the basis of external features only, and as such cannot be used for grouping internal features in different setups. A separate demarcation line, called Segregating Line (SL), is thus required. The procedure to locate SL and use it to group internal features in different setups depends on the part type.

For parts with through internal features, a SL can be located as follows:

- Find Y_{min} coordinate among all internal features
- For i^{th} internal feature {
    If (Y_s or Y_e = Y_{min})
      Then SL = X_e
  }

Once the SL is located for such parts, the internal features can be grouped according to the following rule (Figure 4):

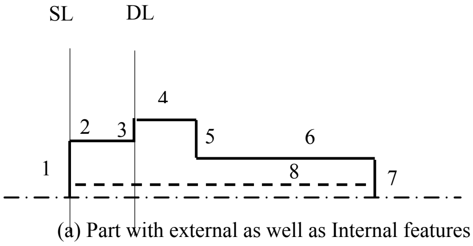
- For i^{th} internal feature {
  If (X_s & X_e <= SL)

  Then associate the feature with setup 1

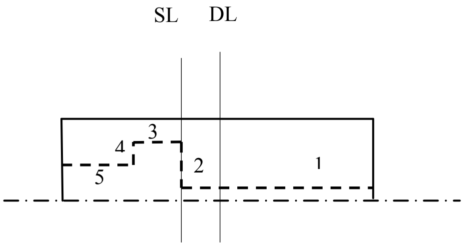
  Else associate the feature with setup 2

  }

It is assumed that a hole of diameter less than Y_{min} is drilled throughout the length of the part in the first setup itself.



(a) Part with external as well as Internal features
Setup 1: Features 1, 2, 3
Setup 2: Features 4, 5, 6, 7, 8



(b) Part with only internal features
Setup 1: Features 2, 3, 4, 5
Setup 2: Feature 1

Figure 4: Parts with Internal Features.

3.3 Sequence of Operations in Each Setup

Sequence of operations to be followed to generate all features associated with one setup is based on the general practice followed in the industry. A sequential order of operations within one setup is recommended as shown in Table 1

Table 1: Recommended Sequential Order of Operations.

S.No.	Operations	Associated feature
1	External facing	EFAC
2	External turning	ETRN
3	External tapering	ETPR
4	External arcing	EARC
5	External grooving	EGRV
6	External filleting	EFIL
7	External chamfering	ECHF
8	External knurling	EKNR
9	External threading	ETHD
10	Boring	IBOR
11	Internal tapering	ITPR
12	Internal arcing	IARC
13	Internal grooving	IGRV
14	Internal filleting	IFIL
15	Internal chamfering	ICHF
16	Internal threading	ITHD

If more than one similar type of features are to be processed in a single setup, then machining is done in decreasing order of Y_s Coordinate for external features and increasing order of Y_s coordinate for internal features.

3.4 Selection of Nominal Machining Parameters

Various job materials considered in this study include: carbon steels (wrought with low or medium carbon), alloy steels (wrought with low or medium carbon), high strength steels (wrought), stainless steels (wrought), and gray cast irons. Different compositions and hardness grades of each of these materials are possible. High-speed steel tools and carbide tipped tools have been considered for machining these job materials.

Recommended values of nominal machining parameters (speed, feed) for various combinations of job material and tool material, type of machining (turning, forming, drilling etc.), and type of cut (rough or finish) and depth of cut are extracted from available standard data handbooks (ASM Metals Handbook, 1997, and Metcut Machining data handbook, 1980).

3.5 Calculation of Part Processing Time

Machining time for each pass of an operation is calculated on the basis of the selected machining parameters. These times are cumulated for various passes to obtain machining time for each feature, and subsequently for each setup. Processing time of each setup includes its machining time, as well as allowances to be provided for tool changes and job setup time. These allowances are assumed to be 50% of the machining time. Thus, the processing time of a job can be determined.

The material removal rate for each pass of an operation is calculated as a product of the machining parameters. Power required at the spindle is calculated by multiplying this material removal rate with unit power extracted from database. Assuming 80% efficiency of the mechanical power transmission system, the power required at the motor can be calculated for each pass of an operation. The maximum power required at the motor can thus be calculated for the whole setup of the job. This helps in identifying the machine tool on which the job can be processed.

In this manner, the final process plan of the part is generated that outlines the operations, their sequential machining order, process parameters, processing time and maximum power requirements on the machine tool.

4 CONCLUSION

This paper discusses development of a Decision Support system required for a generative computer aided process planning system for axisymmetric components. A decision support system performs tasks of input data interpretation, stock determination, setup planning, sequencing of operations in each setup, selection of process parameters, determination of part processing time and power requirements. Some of the tasks, such as setup planning and establishing operations sequence, are semi-structured in nature and can be performed using rule-based approach of the decision support system. The proposed system generates and reports decision support system required for process plan outlining machining sequence, machining parameters, machining time, and power required.

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