An Automatic CAPP System for Rotational Parts

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Abstract – **This paper describes a turning process planning of rotational parts. It also reports general aspects to develop an automatic planning system, from the part geometrical identification to the NC program generation. The minimum number of grippings (based on the part shape), the blank type, the boring operations and the geometrical tolerance presence are established in order to determine the machining operations. The proposed method used to recognize the part geometry is based on a combination between an automatic identification of 2D profiles and a feature-based method. By this way, the developed CAPP system could use geometrical information given by any CAD system.**

I. INTRODUCTION

In the Manufacturing Engineering field, the process planning can be seen as a bridge between the design phase and the manufacturing phase (Fig. 1). It can be said that the input to a Computer Aided Process Planning System (CAPP) is the description of the product and the outputs are manufacturing instructions. An automatic process planning has to take into account:

- Interpretation of the part geometry
- Decomposition of the process in basic machining operations
- Selection of tools and grips
- Calculation of the working conditions
- Generation of NC programs
- Generation of technical documents (worksheets)

The traditional forms used to make this planning are based on variant or generative approaches. On the variant planning systems, parts are codified and classified in families according to design and manufacturing similarities [3][7]. The planning process to each family of parts are loaded in the systems in order to be easily recovered and edited during the application phase of the program. Generative approach systems include logical decisions and algorithms to obtain the process planning automatically from the CAD model of the part [11].

Nevertheless to all efforts made in order to develop a planning system based on computer, only a few systems are now using in industry. The main reasons for the slowness of this process of assimilation are the complexity of planning tasks and the difficulty in adapting a general system to the particular requirements of each factory and sector.

II. TURNING PROCESS PLANNING

The present work tries to make a previous study of all the activities related to process planning of turning operations,

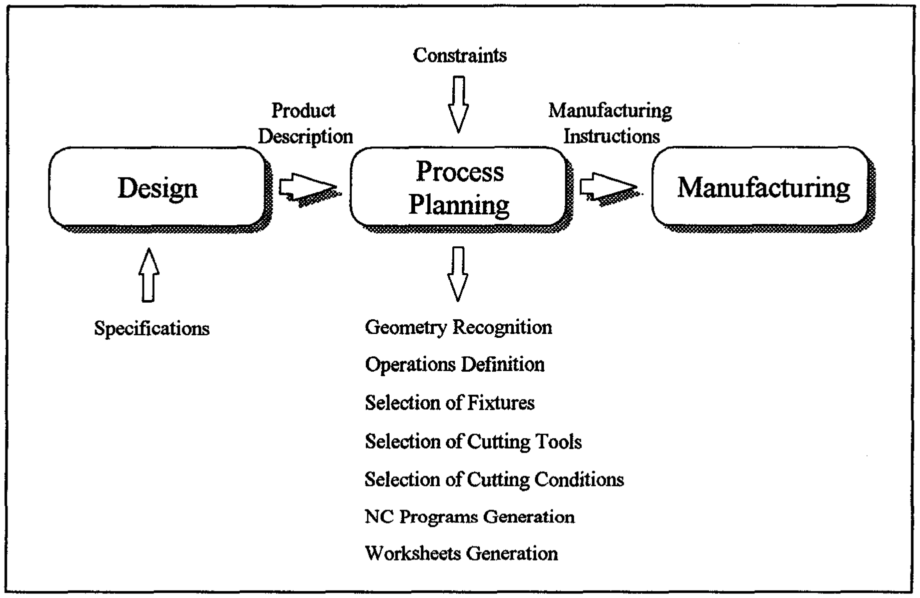

Fig. 1 The Process Planning links design and manufacturing

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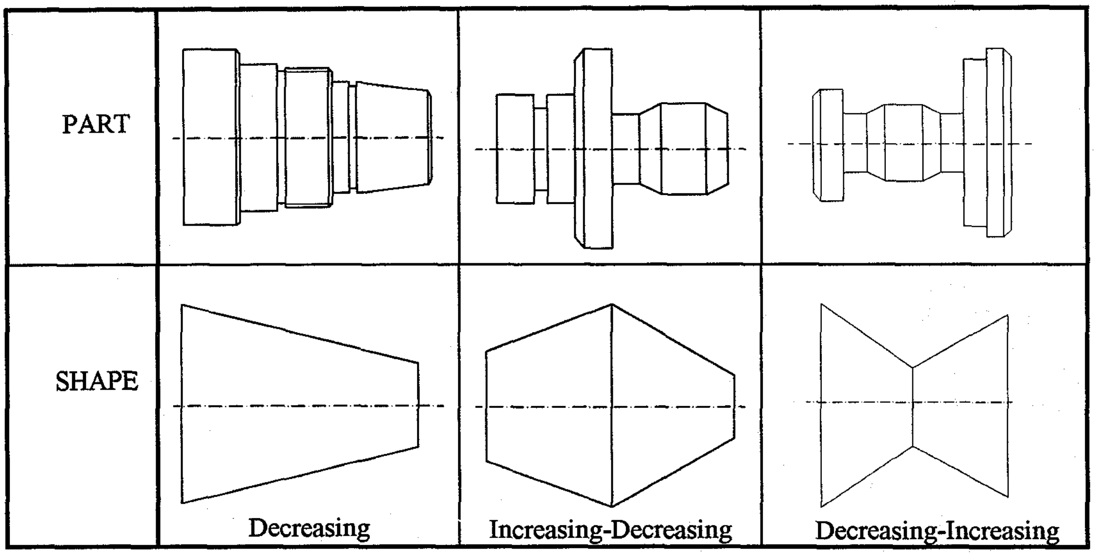

Fig. 2 Basic classification of rotational parts

that allows the development of an automatic planning system using a computer [2] [3]. The system will be able to assist the engineer to take any decision (from the part identification to its final manufacturing) which are aimed to the elaboration of the process planning. This involves the knowledge of all the variants and parameters associated to the turning process and the relations between them and also the elaboration of algorithms and strategies in order to take decisions automatically [10].

The attainment of this general objective implies the solution of several particular problems, which will be explained next.

A.- Recognition of the part geometry

Nowadays it is accepted that the geometrical models need high level of information associated to them in order to adjust to the requirements of an integration between the design and manufacturing systems.

At present, this integration is one of the most important activities in the research field. The main problem is the determination of a schema of product representation. This schema can operate as carrier of information. The aim is to obtain a unique representation for both CAD systems and CAM systems, improving the integration between them.

In order to solve this problem, feature-based model systems arise yet. These features have geometrical information associated to a particular part and also attributes about some (or almost all) activities for its manufacturing.

When working with features, feature recognition systems [1] and feature-based systems can be found [6] [7]. In the present work a combined system has been chosen, This system can make an automatic recognition of the part from the 2D profile, and can also adds modifications using feature patterns such as chamfer, fillet, grooves, etc. A 2D representation has been chosen because it is the most usual for rotational parts.

Most of the rotational parts manufactured on a lathe contain geometrical entities given by only *lines* an *arcs* entities. For this reason the recognition process has to take into account the identification of these two entity types.

The usual method to draw a 2D profile of a rotational part consists of drawing a basic profile and then adding modifications such as chamfer, fillet, thread, etc. These types of modifications have been included as features to accelerate the part design. By adding these features the system can also recognize special manufacturing areas such as threads and knurlings. However the user can also introduce directly these modifications (chamfers, grooves, etc.) during the profile drawing.

B. Elaboration of machining plans

The generation of machining plans requires the previous recognition of the part, from both a geometrical and technological point of view. This information constitutes the base for the selection of elementary machining operations and all possible machining plans [8].

In the case of turning rotational parts, the gripping system and its location in relation with the part surfaces must be taken into account. In this sense, the number of possible solutions can be large. This implies to make an ordering to choose the best plan. This selection can be based on maximum production rate criterion or on the minimum cost per component criterion. For this reason the previous knowledge of the cutting conditions are needed. So, the best machining plan has to be done at the end of the process.

INITIAL SHAPE: BLANK, FINAL SHAPE: DECREASE TYPE								
BORING Operations	TOLERANCES OF FORM AND LOCATION							Special surface
	NO	Left, ext. Right, ext.	Left, ext. Left, int.	Left, ext. Right, int.	Right, ext. Left, int.	Right, ext. Right, int.	Left, int. Left, int.	
LEFT AND RIGHT	2 grips	from Bar 2 grips	2 grips	from Bar 2 grips	from Bar 2 grips	2 grips	2 grips	NO
	2 grips	from Bar 2 grips	2 grips	from Bar 2 grips	from Bar 2 grips	2 grips	2 grips	Left
	2 grips	from Bar 2 grips	2 grips	from Bar 2 grips	from Bar 2 grips	2 grips	2 grips	Right
	from Bar 1 ext. chucking 1 int. chucking	from Bar 1 ext chucking 1 int. chucking	from Bar 1 ext chucking 1 int. chucking	from Bar 1 ext.chucking 1 int. chucking	from Bar 1 ext. chucking 1 int. chucking	from Bar 1 ext chucking 1 int. chucking	from Bar 1 ext chucking 1 int. chucking	All

Fig. 3 Classification matrix for decreasing shape rotational parts with boring operations on their left and right faces

INITIAL SHAPE: BLANK. FINAL SHAPE: INCREASE-DECREASE								
BORING Operations	TOLERANCES OF FORM AND LOCATION							Special surface
	NO	Left, ext. Right, ext.	Left, ext. Right, int.	Left, ext. Right, int.	Left, ext. Right, int.	Left, ext. Right, int.	Left, int. Right, int.	
LEFT	2 grips	from Bar	2 grips		from Bar			NO
	2grips	from Bar	2 grips		from Bar			Left
	2grips	from Bar	2 grips		from Bar			Right
		from Bar	from Bar		from Bar			All

Fig. 4 Classification matrix for increasing-decreasing shape rotational parts with boring operations on their left or right face

With the purpose of establishing the minimum number of grips for a given part automatically, a classification of the part based on its general shape is proposed. This previous classification is very important when clamping lathe phases are considered. In this sense, three basic shapes had been considered (Fig. 2). Besides, they had been subdivided depending on the blank type, whether there are boring operations or not (in one or two faces) and whether there are form and positions tolerances or not (Fig. 3.and 4).

On the identified profile entities, the geometrical information (extreme point coordinates, orientation, length, radius, etc.) can define the different material areas for each grip. These areas have to be removed taking into account the initial and final profile of the part (Fig. 5). The strategy applied here is based on the reconstruction of the initial shape from the final shape.

The material areas defined by this method allow to determine the main roughing areas. Only the concaves areas need to be analized in order to check whether they can be removed in one operation or not. The identification of threaded and knurled areas is immediate because they had been designed using features. Depending on the generation method applied, grooves, chamfers and fillets can be identified through their dimensions (lengths, radius) or by features.

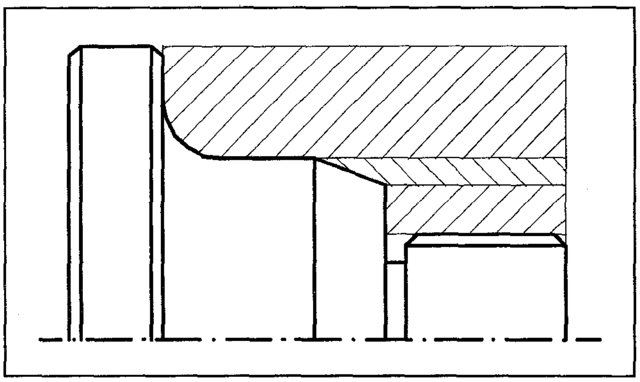

Fig. 5 Roughing machining areas for a decreasing shape rotational parts

C. Selection of tools and cutting conditions

Besides the workpiece (profile, material, machining directions, finishing conditions, etc.) and the machine tool (gripping system, workholding size) the selection of the tools is linked to the cutting conditions due to the great relation between them [4][9][12]. So, in a turning process, the geometry of the cutting inserts will be determined by the tool application area. This application area will be determined by the range of cutting depths and the feedrate of each operation [5]. It also have to be taken into account the possibility of machining several surfaces of the part with the same tool in order to minimize the amount of tools on the lathe turret. Besides, priority criteria must be established to choose among several possible tools.

This phase of the planning process needs a data base related to materials, tools and machines.

D. Toolpaths generation

In order to obtain an integrated planning system in operations with numerical control machine tools, the process have to finish with the generation of toolpaths and the corresponding NC programs. The possibility of automatic identification of the geometry and technological data of the workpiece provides the generation of different NC programs and also reduces the user intervention. With the generated information till now, machining times and costs can be obtained.

E. Generation of worksheets

As a summary, the CAPP system will make worksheets of the different planning tasks. Worksheets include the characteristics of machine tool, the different machining operations, the sequential among them, the tools, the cutting conditions, the NC program and the approximately time and cost of each operation.

III. CONCLUDING REMARKS

Before the establishment of the machining operations, the development of an automatic system for turning process planning obliges to take into account special functions aimed to the identification of the part geometry. The recognition of the part profile must allow not only the machining operation establishment but also the gripping number. To define the order of different machining operations, the part clamping system has to be taken into account. In the present work, a initial classification of rotational parts has been proposed. This classification is based on the final and initial shape part, whether it has boring operations or not and whether it has tolerances or not. Following this method the minimal gripping number can be known. To determine the machining operations, the selected method is based on the reconstruction of the initial shape from the final shape.

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