Module IV

GROUP TECHNOLOGY

INTRODUCTION

Group technology (abbreviated GT) is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged into part families. For example, a plant producing 10,000 different part numbers may be able to group the vast majority of these parts into 50 or 60 distinct families. Each family would possess similar design and manufacturing characteristics. Hence, the processing of each member of a given family would be similar, and this results in manufacturing efficiencies. These efficiencies are achieved in the form of reduced setup times, lower in-process inventories, better scheduling, improved tool control, and the use of standardized process plans. In some plants where GT has been implemented, the production equipment is arranged into machine groups, or cells, in order to facilitate work flow and parts handling.

In product design, there are also advantages obtained by grouping parts into families. For example, a design engineer faced with the task of developing a new part design must either start from scratch or pull an existing drawing from the files and make the necessary changes to conform to the requirements of the new part.

The problem is that finding a similar design may be quite difficult and time consuming. For a large engineering department, there may be thousands of drawings in the files, with no systematic way to locate the desired drawing. As a consequence, the designer may decide that it is easier to start from scratch in developing the new part. This decision is replicated many times over in the company, thus consuming valuable time creating duplicate or near-duplicate part designs. If an effective design-retrieval system were available, this waste could be avoided by permitting the engineer to determine quickly if a similar part already exists. A simple change in an existing design would be much less time consuming than starting from scratch. This design-retrieval system is a manifestation of the group technology principle applied

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to the design function. To implement such a system, some form of parts classification and coding is required.

Parts classification and coding is concerned with identifying the similarities among parts and relating these similarities to a coding system. Part similarities are of two types: design attributes (such as geometric shape and size), and manufacturing attributes (the sequence of processing steps required to make the part). While the processing steps required to manufacture a part are usually correlated with the part's design attributes, this is not always the case. Accordingly, classification and coding systems are often devised to allow for differences between a part's design and its manufacture.

Whereas a parts classification and coding system is required in a design-retrieval system, it can also be used in computer-aided process planning (CAPP). Computer-aided process planning involves the automatic generation of a process plan (or route sheet) to manufacture the part. 1be process routing is developed by recognizing the specific attributes of the part in question and relating these attributes to the corresponding manufacturing operations.

In the present chapter we develop the topics of group technology and p classification and coding. In the following chapter we present a discussion of computer-aided process planning and several related issues. Group technology and parts classification and coding are based on the concept of a part family.

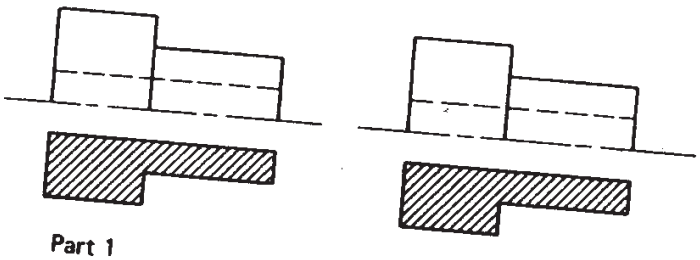
PART FAMILIES

A part family is a collection of parts which are similar either because of geometric shape and size or because similar processing steps are required in their manufacture. The parts within a family are different, but their similarities are close enough to merit their identification as members of the part family. Figures show two part families. The two parts shown in Figure are similar from design viewpoint but quite different in terms of manufacturing. The parts shown in Figure might constitute a part family in manufacturing, but their geometry characteristics do Dot permit them to be grouped as a design part family.

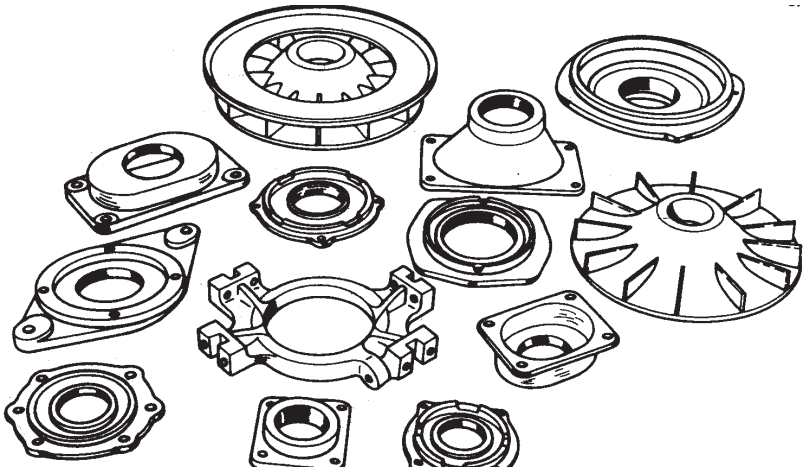
The part family concept is central to design-retrieval systems and mo

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current computer-aided process planning schemes. Another important manufacturing



Two parts of identical shape and size but different manufacturing requirements.

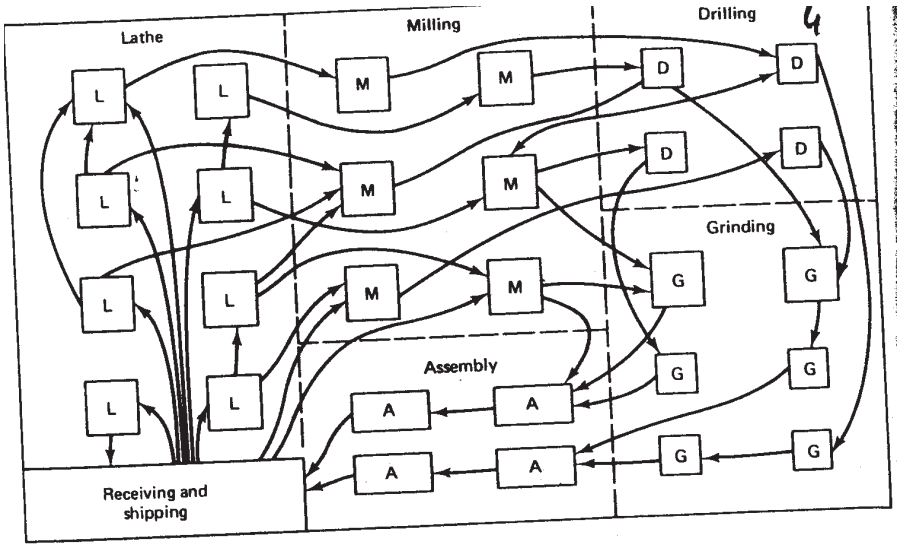


Thirteen parts with similar manufacturing process requirements but different design attributes.

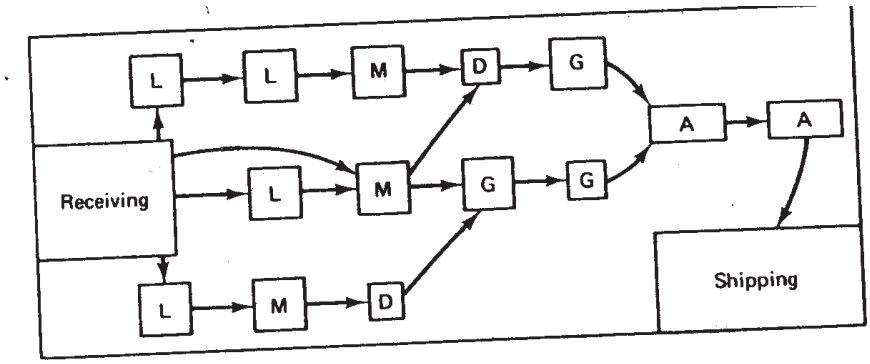
advantage derived from grouping workparts into families can be explained with reference to Figures. Figure shows a process-type layout for batch production in a machine shop. The various machine tools are arranged by function. There is a lathe section, milling machine section, drill press section, and so on. During the machining of a given part, the workpiece must be moved between sections, with perhaps the same section being visited several times. This results in a significant

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amount of material handling, a large in-process inventory, usually more setups than necessary, long manufacturing lead times, and high cost. Figure shows a production shop of supposedly equivalent capacity, but with the machines arranged into cells. Each cell is organized to specialize in the manufacture of a particular part family. Advantages are gained in the form of



Process-type layout.



Group technology layout.

reduced workpiece handling, lower setup times, less in-process inventory, less floor space, and shorter lead times. Some of the manufacturing cells can be designed to form production flow lines, with conveyors used to transport workparts between machines in the cell.

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The biggest single obstacle in changing over to group technology from a traditional production shop is the problem of grouping parts into families. There are three general methods for solving this problem. All three methods are time consuming and involve the analysis of much data by properly trained personnel. The three methods are:

2. Production flow analysis (PFA)

3. Parts classification and coding system

The visual inspection method is the least sophisticated and least expensive method. It involves the classification of parts into families by looking at either the physical parts or photographs and arranging them into similar groupings. This method is generally considered to be the least accurate of the three.

The second method, production flow analysis, was developed by J. L. Burbidge. PFA is a method of identifying part families and associated machine tool groupings by analyzing the route sheets for parts produced in a given shop. It groups together the parts that have similar operation sequences and machine routings. The disadvantage of PF A is that it accepts the validity of existing route sheets, with no consideration given to whether these process plans are logical or consistent. The production flow analysis approach does not seem to be used much at all in the United States.

The third method, parts classification and coding, is the most time consuming and complicated of the three methods. However, it is the most frequently applied method and is generally recognized to be the most powerful of the three.

PARTS CLASSIFICATION AND CODING

This method of grouping parts into families involves an examination of the individual design and/or manufacturing attributes of each part. The attributes of the part are uniquely identified by means of a code number. This classification and coding may be carried out on the entire list of active parts of the firm, or a sampling process may be used to establish the part families. For example, parts produced in the shop during a certain given time period could be examined to identify part family categories. The trouble with any sampling procedure is the risk that the sample may

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be unrepresentative of the entire population. However, this risk may be worth taking, when compared to the relatively enormous task of coding all the company's parts.

Many parts classification and coding systems have been developed throughout the world, and there are several commercially available packages being sold to industrial concerns. It should be noted that none of them has been universally adopted. One of the reasons for this is that a classification and coding system should be custom-engineered for a given company or industry. One system may be best for one company while a different system is more suited to another company.

TABLE Design and Manufacturing Part Attributes Typically Included in a Group Technology Classification System

Part design attributes	
Basic external shape	Major dimensions
Basic internal shape	Minor dimensions
Length/diameter ratio	Tolerances
Material type	Surface finish
Part function	
Part manufacturing attributes	
Major process	Operation sequence
Minor operations	Production time
Major dimensions	Batch size
Length/diameter ratio	Annual production
Surface finish	Fixtures needed
Machine tool	Cutting tools

Design systems versus manufacturing systems

Parts classification and coding systems divide themselves into one of three

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general categories:

1. Systems based on part design attributes
2. Systems based on part manufacturing attributes
3. Systems based on both design and manufacturing attributes

Systems in the first category are useful for design retrieval and to promote design standardization. Systems in the second category are used for computer-aided process planning, tool design, and other production-related functions. The third category represents an attempt to combine the functions and advantages of the other two systems into a single classification scheme. The types of design and manufacturing parts attributes typically included in classification schemes are listed in Table. It is clear that there is a certain amount of overlap between the design and manufacturing attributes of a part.

Coding system structure

A parts coding scheme consists of a sequence of symbols that identify the part' design and/or manufacturing attributes. The symbols in the code can be al numeric, all alphabetic, or a combination of both types. However, most of the common classification and coding systems use number digits only. There are basic code structures used in group technology applications:

1. Hierarchical structure
2. Chain-type structure
3. Hybrid structure, a combination of hierarchical and chain-type structures

With the hierarchical structure, the interpretation of each succeeding symbol depends on the value of the preceding symbols. Other names commonly used for this structure are monocode and tree structure. The hierarchical code provides a relatively compact structure which conveys much information about the part in a limited number of digits.

In the chain-type structure, the interpretation of each symbol in the sequence is fixed and does not depend on the value of preceding digits. Another name commonly given to this structure is polycode. The problem associated with

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polycodes is that they tend to be relatively long . On the other hand, the use of a polycode allows for convenient identification of specific part attributes. This can be helpful in recognizing parts with similar processing requirements.

To illustrate the difference between the hierarchical structure and the chain type structure, consider a two-digit code, such as 15 or 25. Suppose that the first digit stands for the general part shape. The symbol 1 means round workpart and 2 means flat rectangular geometry. In a hierarchical code structure, the interpretation of the second digit would depend on the value of the first digit. If preceded by 1, the 5 might indicate some length/diameter ratio, and if preceded by 2, the 5 might be interpreted to specify some overall length. In the chain-type code structure, the symbol 5 would be interpreted the same way regardless of the value of the first digit. For example, it might indicate overall part length, or whether the part is rotational or rectangular.

Most of the commercial parts coding systems used in industry are a combination of the two pure structures. The hybrid structure is an attempt to achieve the best features of monocodes and polycodes. Hybrid codes are typically constructed as a series of short polycodes. Within each of these shorter chains, the digits are independent, but one or more symbols in the complete code number are used to classify the part population into groups, as in the hierarchical structure. This hybrid coding seems to best serve the needs of both design and production.

THREE PARTS CLASSIFICATION AND CODING SYSTEMS

When implementing a parts classification and coding system, most companies elect to purchase a commercially available package rather than develop their own. Inyong Ham recommends that the following factors be considered in selecting a parts coding and classification system:

Objective. The prospective user should first define the objective for the system. Will it be used for design retrieval or part-family manufacturing or both?

Scope and application. What departments in the company will use the system? What specific requirements do these departments have? What kinds of information must be coded? How wide a range of products must be coded? How

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complex are the parts, shapes, processes, tooling, and so forth?

Costs and time. The company must consider the costs of installation, training, and maintenance for their parts classification and coding system. Will there be consulting fees, and how much? How much time will be required to install the system and train the staff to operate and maintain it? How long will it be before the benefits of the system are realized?

Adapability to other systems. Can the classification and coding system be readily adapted to the existing company computer systems and data bases? Can it be readily integrated with other existing company procedures, such as process planning, NC programming, and production scheduling?

Management problems. It is important that all involved management personnel be informed and supportive of the system. Also, will there be any problems with the union? Will cooperation and support for the system be obtained from the various departments involved?

In the sections below, we review three parts classification and coding systems which are widely recognized among people familiar with GT:

i . Opitz system

2. MICLASS system

3. CODE system

The Opitz classification system

This parts classification and coding system was developed by H. Opitz of the University of Aachen in West Germany. It represents one of the pioneering efforts in the group technology area and is perhaps the best known of the classification and coding schemes.

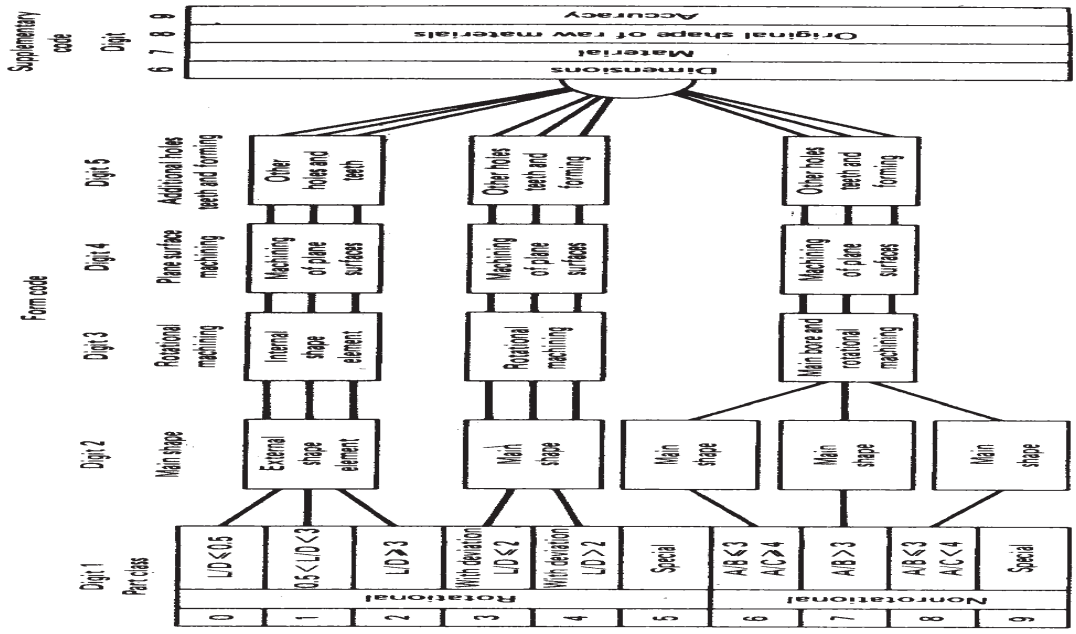
The Opitz coding system uses the following digit sequence:

12345 6789 ABCD

The basic code consists of nine digits, which can be extended by adding four more digits. The first nine digits are intended to convey both design and manufacturing data. The general interpretation of the nine digits is indicated in Figure. The first five

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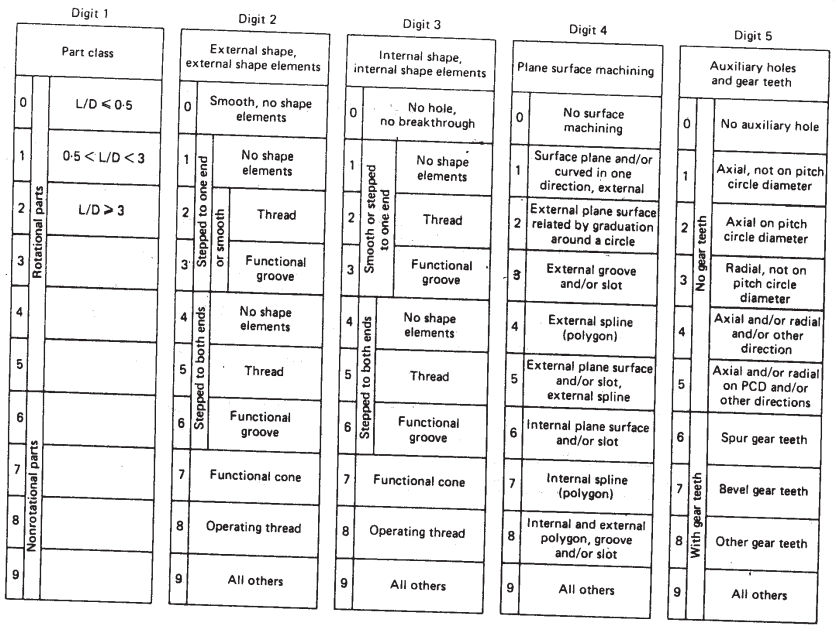
digits, 12345, are called the "form code" and describe the primary design attributes of the part. The next four digits, 6789, constitute the “supplementary code.”



It indicates some of the attributes that would be of use to manufacturing (dimensions, work material, starting raw workpiece shape and accuracy). The extra four digits, ABCD, are referred to as the "secondary code" and are intended to identify the production operation type and sequence. The secondary code can be designed by the firm to serve its own particular needs.

The complete coding system is too complex to provide a comprehensive description here. Opitz wrote an entire book on his system [12]. However, to obtain a general idea of how the Opitz system works, let us examine the first five digits of the code, the form code. The first digit identifies whether the part is a rotational or a non rotational part. It also describes the general shape and proportions of the part. We will limit our survey to rotational parts possessing no unusual features, those with code values 0, 1, or 2. See Figure for definitions. For this general class of workparts, the coding of the first five digits is given in Figure. An example will demonstrate the coding of a given part.

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The MICLASS System

MICLASS stands for Metal Institute Classification System and was developed by TNO, the Netherlands Organization for Applied Scientific Research. It was started in Europe about five years before being introduced in the United States in 1974. Today, it is marketed in the United States by the Organization for Industrial Research in Waltham, Massachussets. The MICLASS system was developed to help automate and standardize a number of design, production, and management functions. These include:

Standardization of engineering drawings

Retrieval of drawings according to classification number

Standardization of process routing

Automated process planning

Selection of parts for processing on particular groups of machine tools

Machine tool investment analysis

The MICLASS classification number can range from 12 to 30 digits. The first 12 digits are a universal code that can be applied to any part. Up to 18 additional

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digits can be used to code data that are specific to the particular company or industry. For example, lot size, piece time, cost data, and operation sequence might be included in the 18 supplementary digits.

The workpart attributes coded in the first 12 digits of the MICLASS number are as follows:

1st digit	Main shape
2nd and 3rd digits	Shape elements
4th digit	Position of shape elements
5th and 6th digits	Main dimensions
7th digit	Dimension ratio
8th digit	Auxiliary dimension
9th and 10th digits	Tolerance codes
11th and 12th digits	Material codes

The CODE system

The CODE system is a parts classification and coding system developed and marketed by Manufacturing Data Systems, Inc. (MDSI), of Aim Arbor, Michigan. Its most universal application is in design engineering for retrieval of part design data, but it also has applications in manufacturing process planning, purchasing, tool design, and inventory control.

The CODE number has eight digits. For each digit there are 16 possible values (zero through 9 and A through F) which are used to describe the part's design and manufacturing characteristics. The initial digit position indicates the basic geometry of the part and is called the Major Division of the CODE system. This digit would be used to specify whether the shape was a cylinder, flat piece, block, or other. The interpretation of the remaining seven digits depends on the value of the first digit, but these remaining digits form a chain-type structure. Hence the CODE system possesses a hybrid structure.

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BENEFITS OF GROUP TECHNOLOGY

Although group technology is expected to be an important principle in future production plants, it has not yet achieved the widespread application which might be expected. There are several reasons for this. First, as we have already indicated, there is the problem of rearranging the machines in the plant into GT cells. Many companies have been inhibited from adopting group technology because of the expense and disruption associated with this transition to GT machine cells. Second, there is the problem of identifying part families among the many components produced in the plant. Usually associated with this problem is the expense of parts classification and coding. Not only is this procedure expensive, but it also requires a considerable investment in time and personnel resources. Managers often feel that these limited resources can better be allocated to other projects than group technology with its uncertain future benefits. Finally, it is common for companies to encounter a general resistance among its operating personnel when changeover to a new system is contemplated.

When these problems are solved and group technology is applied, the company will typically realize benefits in the following areas:

Product design

Tooling and setups

Materials handling

Production and inventory control

Employee satisfaction

Process planning procedures

COMPUTER-AIDED PROCESS PLANNING

THE PLANNING FUNCTION

This chapter examines several process planning functions which can be implemented by computer systems. Process planning is conerned with determining

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the sequence of individual manufacturing operations needed to produce a given part or product. The resulting operation sequence is documented on a form typically referred to as a route sheet. The route sheet is a listing of the production operations and associated machine tools for a workpart or assembly.

Closely related to process planning are the functions of determining appropriate cutting conditions for the machining operations and setting the time standards for the operations. All three functions-planning the process, determining the cutting conditions, and setting the time standards-have traditionally been carried out as tasks with a very high manual and clerical content. They are also typically routine tasks in which similar or even identical decisions are repeated over and over. Today, these kinds of decisions are being made with the aid of computers. In the first four sections of this chapter we consider the process planning function and how computers can be used to perform this function.

Traditional process planning

There are variations in the level of detail found in route sheets among different companies and industries. In the one extreme, process planning is accomplished by releasing the part print to the production shop with the instructions “make to drawing.” Most firms provide a more detailed list of steps describing each operation and identifying each work center. In any case, it is traditionally the task of the manufacturing engineers or industrial engineers in an organization to write these process plans for new part designs to be produced by the shop. The process planning procedure is very much dependent on the experience and judgment of the planner. It is the manufacturing engineer's responsibility to determine an optimal routing for each new part design. However, individual engineers each have their own opinions about what constitutes the best routing. Accordingly, there are differences among the operation sequences developed by various planners. We can illustrate rather dramatically these differences by means of an example.

In one case cited, a total of 42 different routings were developed for various sizes of a relatively simple part called an "expander sleeve." There were a total of 64 different sizes and styles, each with its own part number. The 42 routings included 20 different machine tools in the shop. The reason for this absence of process

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standardization was that many different individuals had worked on the parts: 8 or 9 manufacturing engineers, 2 planners, and 25 NC part programmers. Upon analysis, it was determined that only two different routings through four machines were needed to process the 64 part numbers. It is clear that there are potentially great differences in the perceptions among process planners as to what constitutes the "optimal" method of production.

In addition to this problem of variability among planners, there are often difficulties in the conventional process planning procedure. New machine tools in the factory render old routings less than optimal. Machine breakdowns force shop personnel to use temporary routings, and these become the documented routings even after the machine is repaired. For these reasons and others, a significant proportion of the total number of process plans used in manufacturing are not optimal.

Automated process planning

Because of the problems encountered with manual process planning, attempts have been made in recent years to capture the logic, judgment, and experience required for this important function and incorporate them into computer programs. Based on the characteristics of a given part, the program automatically generates the manufacturing operation sequence. A computer-aided process planning (CAPP) system offers the potential for reducing the routine clerical work of manufacturing engineers. At the same time, it provides the opportunity to generate production routings which are rational, consistent, and perhaps even optimal. Two alternative approaches to computer-aided process planning have been developed. These are:

1. Retrieval-type CAPP systems (also called variant systems)
2. Generative CAPP systems

The two types are described in the following two sections.

RETRIEVAL - TYPE PROCESS PLANNING SYSTEMS

Retrieval-type CAPP systems use parts classification and coding and group technology as a foundation. In this approach, the parts produced in the plant are

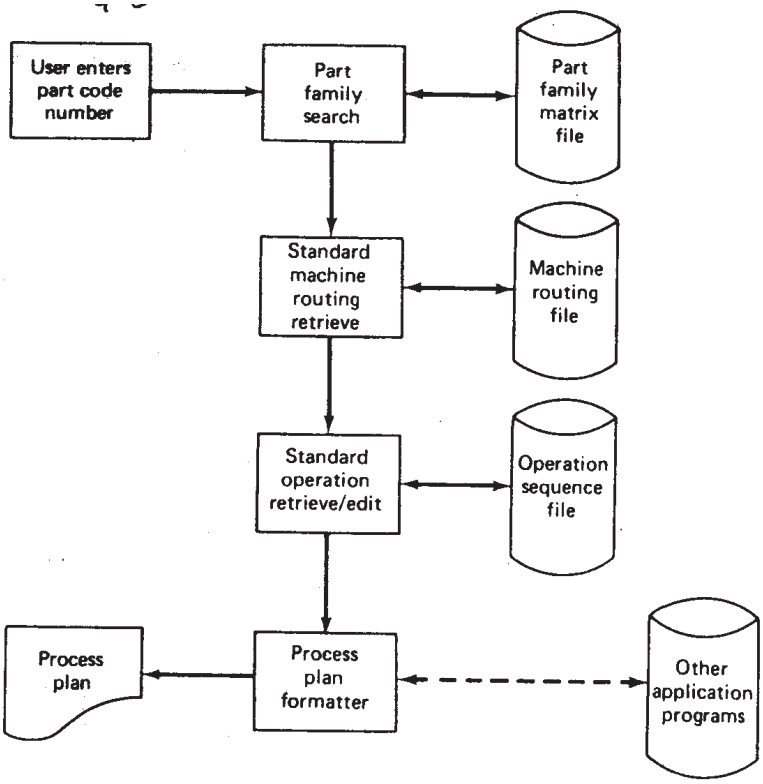
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grouped into part families, distinguished according to their manufacturing characteristics. For each part family, a standard process plan is established. The standard process plan is stored in computer files and then retrieved for new workparts which belong to that family. Some form of parts classification and coding system is required to organize the computer files and to permit efficient retrieval of the appropriate process plan for a new workpart. For some new parts, editing of the existing process plan may be required. This is done when the manufacturing requirements of the new part are slightly different from the standard. The machine routing may be the same for the new part, but the specific operations required at each machine may be different. The complete process plan must document the operations as well as the sequence of machines through which the part must be routed. Because of the alterations that are made in the retrieved process plan, these CAPP systems are sometimes also called by the name' 'variant system."

Figure will help to explain the procedure used in a retrieval process planning system. The user would initiate the procedure by entering the part code number at a computer terminal. The CAPP program then searches the part family matrix file to determine if a match exists. If the file contains an identical code number, the standard machine routing and operation sequence are retrieved from the respective computer files for display to the user. The standard process plan is examined by the user to permit any necessary editing of the plan to make it compatible with the new part design. After editing, the process plan formatter prepares the paper document in the proper form.

If an exact match cannot be found between the code numbers in the computer file and the code number for the new part, the user may search the machine routing file and the operation sequence file for similar parts that could be used to develop the plan for the new part. Once the process plan for a new part code number has been entered, it becomes the standard process for future parts of the same classification.

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Information flow in a retrieval-type computer-aided process planning system.

In Figure the machine routing file is distinguished from the operation sequence file to emphasize that the machine routing may apply to a range of different part families and code numbers. It would be easier to find a match in the machine routing file than in the operation sequence file. Some CAPP retrieval sys• terns would use only one such file which would be a combination of operation sequence file and machine routing file.

The process plan formatter may use other application programs. These could include programs to compute machining conditions, work standards, and standard costs. Standard cost programs can be used to determine total product costs for pricing purposes.

A number of retrieval-type computer-aided process planning systems have been developed. These include MIPLAN, one of the MICLASS modules [6,20] the

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CAPP system developed by Computer-Aided Manufacturing-International [1], COMCAPP V by MDSI, and systems by individual companies [10]. We will use MIPLAN as an example to illustrate these industrial systems.

GENERATIVE PROCESS PLANNING SYSTEMS

Generative process planning involves the use of the computer to create an individual process plan from scratch, automatically and without human assistance. The computer would employ a set of algorithms to progress through the various technical and logical decisions toward a final plan for manufacturing. Inputs to the ~ tern would include a comprehensive description of the workpart. This may involve the use of some form of part code number to summarize the workpart data, but does not involve the retrieval of existing standard plans. Instead, the general CAPP system synthesizes the design of the optimum process sequence, based an analysis of part geometry, material, and other factors which would influence manufacturing decisions.

In the ideal generative process planning package, any part design could presented to the system for creation of the optimal plan. In practice, cu generative-type systems are far from universal in their applicability. They ter fall short of a truly generative capability, and they are developed for a some limited range of manufacturing processes.

We will illustrate the generative process planning approach by means system called GENPLAN developed at Lockheed-Georgia Company

BENEFITS OF CAPP

Whether it is a retrieval system or a generative system, computer-aided process planning offers a number of potential advantages over manually oriented process planning.

1. *Process rationalization*. Computer-automated preparation of operation routings is more likely to be consistent, logical, and optimal than its manual counterpart. The process plans will be consistent because the same computer software is being used by all planners. We avoid the tendency for drastically different process plans from different planners, as described in Section 13.1. The

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process plans tend to be more logical and optimal because the company has presumably incorporated the experience and judgment of its best manufacturing people into the process planning computer software.

2. *Increased productivity of process planners*. With computer-aided process planning, there is reduced clerical effort, fewer errors are made, and the planners have immediate access to the process planning data base. These benefits translate into higher productivity of the process planners. One system was reported to increase productivity by 600% in the process planning function [10].

3. *Reduced turnaround time*. Working with the CAPP system, the process planner is able to prepare a route sheet for a new part in less time compared to manual preparation. "Ibis leads to an overall reduction in manufacturing lead time.

4. *Improved legibility*. The computer-prepared document is neater and easier to read than manually written route sheets. CAPP systems employ standard text, which facilitates interpretation of the process plan in the factory.

5. *Incorporation of other application programs*. The process planning system can be designed to operate in conjunction with other software packages to automate many of the time-consuming manufacturing support functions.

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