GROUP TECHNOLOGY WITH CODING AND CLASSIFICATION

by

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INTRODUCTION AND OVERVIEW

INTRODUCTION

The conventional manufacturing systems of today are challenged by needs, mainly economic in nature, that are forcing productivity improvements. One aim of optimising in manufacturing is to increase productivity as measured by a reduction in the total production cost. Also there is need for more diversified products which suggests the requirements of producing them in small lots economically.

In the U.S., it has been estimated that, in next decade, about 75% of all industrial parts produced will be on a small lot basis, as against 25% at present. It is also reported that (108) three-fourths of all U.S. metal-working production consists of lots numbering less than 50 items.

A look at the sources and magnitude of costs in manufacturing would show that the actual production cost is often a relatively insignificant fraction of the total cost. The real economic problems lie in areas such as product design, tool design, tooling setups, production scheduling, labor and equipment utilization, and in-process inventories. Because of this, a growing amount of attention has been turned to a manufacturing system which deals with the areas of job-shop manufacturing, in particular to those systems that deal with small lot sizes and a variety of products. This system is called Group Technology (GT).

Definitions:

The manufacturing system we are discussing has many names and definitions. Group Technology is the most popular. Others are, Family Manufacturing, Family Planning, Matrix Method of Production, Cell System of Production, etc.

A few well defined concepts are as follows:

According to Professor Burbridge (18)

"The key features required for a successful GT application are Group Layout, short-cycle flow control, and a planned machine loading sequence.

"The first of the key features of GT, as said above is Group Layout. In most factories it is possible to divide all of the manufactured components into Families and all of the machines into Groups (cells), in such a way that all of the parts in each family can be completely processed on one group of machines only. When the plant is laid out in this manner, the factory is said to have Group Layout.

"The second essential feature is, short cycle flow control. Flow control is essential for efficient GT. With flow control, throughput times are short, and we can use short-cycle production control, thus being able to follow changes in market demand very quickly and to work with minimum stock. So flow control achieves its major savings when it uses very short cycles.

"The third essential key feature is a planned loading sequence for loading work on machines. This brings parts together for loading, which can use the same or similar tooling set-ups. In this way the set-up time per part is reduced and the capacity is increased.

"Used alone, none of these features will give significant savings. Used together however, they provide a powerful new production strategy, of great economic and sociological importance."

The author, however, does point out later in the same text (18) that introduction of any of the three key features individually also makes the operation more profitable, even with other things unchanged.

According to Pamela Weintraub of Metalworking News (164),

"GT, concept is aimed at bringing some of the economics of scale inherent in mass production to the manufacture of parts in small batches.

"GT is a manufacturing concept under which parts are grouped into families of units with common characteristics - shape and size for example - or the machining steps required to produce them.

"On the shop floor, the concept calls for machines to be organized into work cells, each designed to produce a family of similar parts from start to finish."

According to Saloja (142),

"GT is the realization that many problems are similar and that, by grouping similar problems, a single solution can be found to a set of problems, thus saving time and effort."

Historical Overview

The term Group Technology is of relatively recent origin, but the ideas of producing components of similar shape on specially grouped machines, or of using flow line method for batch production are not new. The major difference between contemporary and past practice are: first, one coherent body of knowledge has evolved from what were previously many scattered ideas and techniques, and second, this body of knowledge is now being applied internationally in industry on a scale and breadth which is of quite a different order of magnitude from past practice. A few examples will emphasize the historic development.

In 1925, a paper was presented by R. E. Flanders to the American Society of Mechanical Engineers (169), describing "...difficulties in manufacture and production control were avoided by the Jones and Lamson Machine Company," by using an approach which could be called GT today.

J. C. Kerr (170) in a paper presented to the Institution of Production Engineers in 1938 on planning in a general engineering shop, suggested the "sectionalising of groups of machine tools. The whole idea ... is to give the machines certain standard work to do in sequence with other machines. This should smooth the flow of production, as it does in a one-product shop."

In 1949, Ann Korling (71), of the Swedish lorry and bus firm Scania-Vabis, presented a paper in Paris on "Group Production and Its Influence on Productivity ", describing an extensive reorganization of the firm using group production.

Although drawn from three western countries, these examples are only intended to emphasize how long the basic ideas behind Group Technology have been considered. A detailed examination of the engineering journals of any of the developed countries in the west or in East Europe for the earlier part of this century would probably result in many similar examples.

The following paragraphs comprise, not a formal history, but rather a brief list of some of the important organizations which have contributed to the subject over the last 40 years or so, arranged on a geographic basis.

The consideration of GT started in Soviet Russia, somewhere in early 1950's. The major work was being done by S. P. Mitrofanov. The first formal proposals of Group Technology were presented in 1940 by Mitrofanov (65), and wide interest in the subject was generated by the publication in 1958 of his book, The Scientific Principles of Group Technology.

Although the Germans used this technique informally, in the period of World War II, and the Swedes around 1948, the first well documented GT operation was started at Forges and Ateliers de Construction Electriques de Jeument, France (65) in 1968.

The Germans took renewed interest in early 60's. They extended their original concepts through the manufacturing process to take into account similarities in part designs. The German method goes a bit further than the Russian method. It is based on similarities in machining sequence and operations rather than purely on the geometrical likeness of parts as in the Russian method.

Much of the early work was carried out at the Aachen Technical University, under Professor H. Opitz. German researchers found that the capacity of a shop's machinery is rarely employed effectively. They showed that one way to improve the machine capacity would be to group parts that require similar operations. The investigation of workpiece statistics at this institution later became the basis for the Opitz Classification System for machined components. It is now one of the most popular in European industry.

Professor J. L. Burbridge (15) of the International Center for Advanced Technical and Vocational Training, Turin, Italy, has also done considerable

writing on the subject and is most noted for his concept of "Production Flow Analysis." In fact, the first international seminar on Group Technology was held at the Turin International Center, Italy under his leadership.

In Britain the industrial firms of Serck-Audio, Ferredo and Ferranti each implemented GT. As an industrial consultant, Brisch, a classification and coding specialist, developed an early interest in the technique. Today, Britain seems to be a fairly well organized user of GT. Work was also started by two groups at Manchester University Institute of Science and Technology and at Production Engineering Research Association, a GT section was formed. Also, a government supported GT center was established in 1968.

In Eastern Europe, substantial work has been carried out in Czechoslovakia at the VUOSO and VUSTE industrial research institute. In East Germany at the Karl Marx Technical University, and at the Zeiss factory. In Poland, at the IOPM Industrial Institute, and in Yugoslavia at the IAMA Institute.

In the remaining countries of Western Europe, work has been carried out by the TNO Institute in Holland; the NAAK organization in Norway; the SAT and PTE organizations and COPIC Consultants in France; the PGM Consultants in Sweden, Fiat in Italy, and Sulzer in Switzerland.

In the U.S., the general concept and approach of GT has been practiced for a long time under different names in various forms of industrial engineering functions for more efficient, scientific optimization of manufacturing operations. However, it had not received formal recognition until early in the 70's. Also, it was not rigorously practiced as a systematic scientific technology applied to small lot production which is most common to small and medium industries. Although there have been many application examples of GT in various forms and degrees in the U.S., there were very few published studies, data or case histories available to the public compared to European countries and Japan.

Most of the work in recent past, was carried out at Purdue University, under Professor J. ElGomayal, and at Penn State University, under Professor I. Ham.

The earliest work found was an article by A. O. Putnam, in American Machinist (132) of November 28, 1960, "OR Shows How to Machine Job Lots on Production Lines." According to Putnam in this article, Jones and Lamson estimated that it can save $300,000 a year by doing most of job-shop operations on a production line. Also for the same study Rath and Strong determined how to set up a series of production lines, each producing parts with "family similarities - and then demonstrated that it would work" by playing a game.

In 1974, Bendix Corporation started considering implementation of GT. In 1975, Lock heed Georgia Company, a subsidiary of Lock heed Aircraft Corporation, got into GT. Their first machine shop cell was to go on stream, last January, producing 938 different parts on a total production of 23,000 units per year.

In 1976, SME held the first GT seminar in the U.S.

Another company weighing the pros and cons of GT is Northrop Corporation's Aircraft division at Hawthorne, California. Their views on GT are still very much up in the air, they began experimenting in October 1978.

An even more cautious approach is being taken by United Technological Corporation, at East Hartford, Connecticut. Boeing Company is moving into GT, but without rearranging its machine tools into work cells.

Some of the latest developments

Article - "Microcomputers invade production lines" [160]:

In Norway, the first full scale laboratory production line to use a cellular concept has been set up. Manufacturing operations are broken down

into cells, each at a different plant. Products are complex diesel engine parts.

The output per manhour of labor when using GT is reported to be considerably higher than that of conventional manufacturing methods. Each cell has as its core, one robot. The cell system can be operated day and night, requiring worker participation during day only. All that is needed for unattended night operation is proper planning, so the robot has an ample supply of materials and enough storage areas for completed assemblies.

Some of the latest techniques, integrated quite frequently with GT are, CAD (Computer Assisted Design), CAM (Computer Assisted Manufacturing) and CAPP (Computer Assisted Process Planning). Much of the current work in the U.S. is done in the above mentioned areas, coupled with GT. According to Dr. Ham of Penn State University (162),

"One of the essential steps in the successful implementation of CAD/CAM is GT application in the layout and organization of the factory, in its manpower, and in its equipment on a part-family basis rather than on a functional basis."

COMPONENT FAMILY AND CELL FORMATION

The National Economic Development Office, London has defined the Group Technology as "the organization of production in self-contained and self-regulating groups or cells, each of which undertakes the complete manufacture of a family of parts having similar manufacturing characteristics. There are usually more machines than men in a group so that each man operates more than one machine." This definition highlights the key requirements of family formation.

The successful implementation of G.T. depends upon our ability to identify these part families, which depend upon the complexity of the products, the family formation method adopted, and last but not least, the skill with which it is applied.

The crux of the above discussion is that successful family and cell formation is a milestone in the implementation of G.T., although the forming of families is only part of the solution.

This part of the report deals with the general principles of family formation.

Natural families

If the product is a simple one made of a small number of parts, natural families may exist, e.g. some pumps, valves, electric motors, milling cutters, etc. A butterfly valve, for example, may consist of only four machined parts, a body, a blade, a shaft, and a bearing ring together with some purchased parts. In such a case the company may have organized production along G.T. lines without calling it G.T.

Design and Production families

Manufacturing characteristics are important factors when identifying families. Design characteristics are important only in so far as they imply

manufacturing characteristics. Conventionally, we can distinguish two types of families.

a) Design Family: The parts are of similar design and will usually have all or most operations in common. See Fig. 2.1.

b) Production Family: The parts may be dissimilar in design but nevertheless have one or more operations in common. See Fig. 2.2.

Figure 2.2 shows a production family whose components have a variety of names, functions, and general shapes, yet they all require boring and drilling operations.

Family formation is a compromise between many factors. One of the extremes is that we have a very large family consisting of nearly all the components that we make; or, on the other extreme, we may have very many families with one part in each family. Neither of the above approaches is useful in investigating the prospective use of G.T. Therefore some compromise must be adopted.

Family formation procedure: a) successive subdivision versus b) clustering.

a) Successive subdivision: With this procedure the entire population of parts is considered and then it is divided into a few very large families by a single characteristic, e.g. metal cutting workpieces being classified as either rotational or nonrotational. Each of these large families is subdivided into smaller families by considering a second characteristic, e.g. the family of rotational parts can be further subdivided by considering outside diameter, since the larger the diameter, the larger the machine required. Suppose these parts are divided into small, medium and large diameter parts, now we have three small families. Again these small families can be subdivided into smaller families, until the families are small enough and/or homogeneous enough to fulfill the purpose of G.T.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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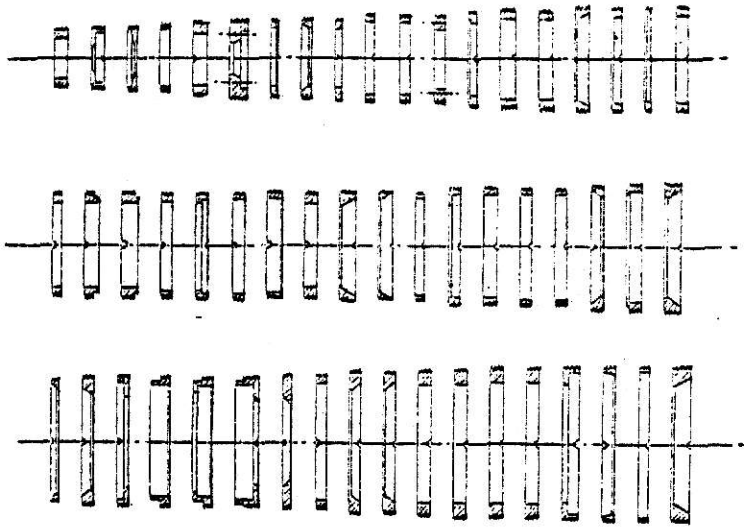


Fig. 2.1. A Design Family

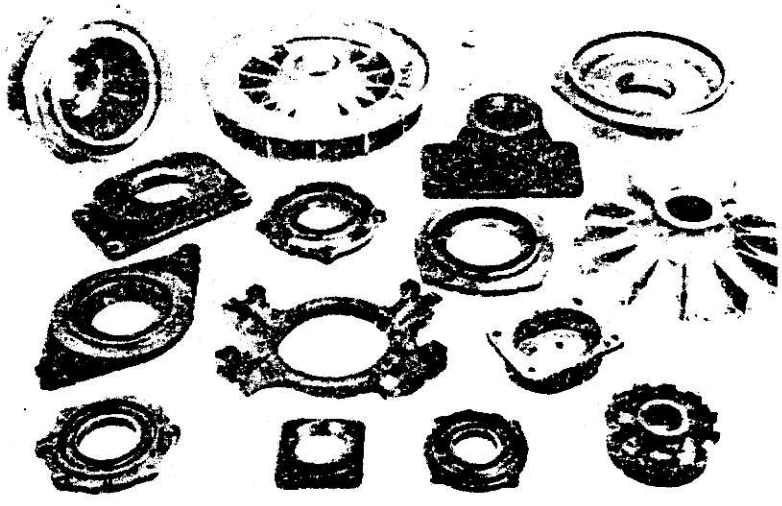


Fig. 2.2. A Production Family

b) Clustering uses the other extreme. It assumes there exists a very large number of single item families, and then merges these items into larger families according to the similarity of characteristics. The first step is to identify the characteristics of each item. Then one can construct an item-characteristic matrix. For the purpose of classification, items have only binary characteristics, i.e. they either possess or do not possess the characteristic under consideration. A measure of the commonality of characteristics between pairs of items can be expressed as a coefficient:

$$S_{ij} = N_{ij}/(N_i + N_j - N_{ij}).$$

N_{ij} is the number of characteristics possessed by both items i and j, N_i is the number of characteristics possessed by item i, and N_j possessed by item j. S_{ij} lies between 0.0 and 1.0. S_{ij} = 0 means that there are no characteristics in common, and 1.0 means all characteristics exist in both parts. Clustering is done by considering the coefficients in descending order.

In the above discussion, all of the characteristics were considered equally important. It is possible to give each characteristic a weighting factor. Clustering generally involves more data processing, since all of the characteristics of all the parts must be considered.

Family Formation: Constraint Factors

a) Groups should be self-contained: It should be possible to completely manufacture the parts of the family within that group. This may be difficult to achieve, where certain processes must be centralized e.g. heat treatment. This may necessitate that parts travel out of their cell for an operation. An alternative is to have one cell processing the parts prior to heat treatment and another cell, after heat treatment.

b) Machine Utilization: This may be one consideration while forming families. But sometimes it may be wise to plan for underutilization to insure ready machine availability to gain the advantages of rapid throughput, low work-in-progress and high manpower utilization.

c) Manpower Utilization: If certain machines are underutilized, we may not keep them fully manned. Operators may be willing to operate more than one machine or move between cells. The flexibility on the part of the operators may have to be negotiated with the operators or may be readily acceptable to them.

d) Load Balance: When similar machines are assigned to different cells, it may be that one machine is idle in one cell while the other machine of the same type in a different cell is working overtime. One solution it to provide scheduling flexibility. Under certain circumstances it may be advantageous to allow a few parts to be worked on in another cell with available time, rather than investing in an extra machine.

e) Flexibility: All companies seek to innovate and to expand their market share. There will be continual change of product mix, with new products being introduced and other products being discontinued or changes in level of production. Family formation must consider this situation. Families should be kept large enough to absorb some of these effects without significant disruption. Families and groups may change with time.

f) Material Handling: One must not only look at the set of machines required to produce each part but also must look at the sequence in which the machines are used.

This may occur when some parts require the same set of machines, but in a different sequence of manufacturing operations. Here

flexibility of material handling equipment is important, which means we should use hand trucks, cranes, etc.

While the parts requiring the same set of machines in the same sequence can probably be supplied by conveyors to provide rapid and efficient movement of material.

Designs families are more likely to be of the latter types, and Production families of the former types.

Family Formation Methods

a) By Eye

Drawings of the parts are collected. The production engineer(s) then examine the drawings and assign the parts to families by visual examination. This method is largely subjective, relying upon the consistency and skill of the engineer. It is quick and inexpensive but less effective than other methods.

b) Using Coding and Classification

The classification system requires a comprehensive examination of all active parts regardless of the origin or use of those parts. There are a number of suitable classification and coding systems, also there are a number of approaches to the formation of part families. The basic approaches taken are as follows:

1) Parts being manufactured within a defined time period are classified and coded, then examined with respect to similarity of their production process, and collected into part families for sequential manufacture in a machine shop with a functional layout. The advantage of this system is that only the parts required to be produced in the short term are considered. The main disadvantage is the expense incurred in continually forming new families as production schedules change.

2) Formation of part families from one of the company's products. Advantages of this process are that of working in a defined area, and the information is readily available. However, part families thus formed may be more complex than necessary. This approach may be used as a short-term measure to create a pilot machine group and then each product can be dealt with in order of priority.

3) Formation of part families based on a total analysis of parts from the company's complete product line. If possible, this method is preferred. The drawings and associated production data of the selected parts are collected and coded according to the classification system and then sorted in code number order.

There are many classification and coding systems in existence and we will discuss the more important ones briefly in the next section.

c) Family Formation by Production Flow Analysis

Production Flow Analysis (devised by Professor J. L. Burbridge) is a technique for finding families of components and associated groups of machines to form a basis for group layout. It is also applicable to those areas outside the engineering industry (primarily metal cutting), where the shape of the components manufactured may bear little relationship to the manufacturing methods used. This occurs in areas such as foundry work, stamping, forming, and assembly work, etc. This results in identifying families of less similar parts but requiring common operations.

By progressive analysis of the information, contained in the route cards for the components and assemblies produced in a factory, production flow analysis uses the natural division into groups and families based upon the existing plant, tooling and processing methods. It does

not attempt to change the routing of the process or achieve technological innovation, and at the same time change to group layout. The idea is to get into G.T. with the existing factory layout and with the least possible investment.

In essence, it is a technique for pre-planning a whole factory into groups. The objective is to achieve a more ordered layout resulting in improved work flow. The savings from this initial reorganization can then finance further tooling and equipment improvements.

Production flow analysis analyzes the manufacturing sequences at three levels: Factory Flow Analysis is used to determine the departmental structure; Group Analysis is used to determine the component families and machine groups in each department; and Line Analysis, to determine the most suitable layout of each machine group in order to simplify the material flow.

Before we proceed to flow analysis, we must be sure that: (i) there is a route card for every component, (ii) all operations on every route are included, (iii) the machine type is shown for each operation, (iv) the routes should be an accurate record and (v) operation times should be given.

The primary aim of Factory Flow Analysis is to achieve a simple inter-departmental material flow system. Some secondary aims are: (i) as far as possible, each component should be fully processed in one department only, (ii) each machine type should exist in one department only, (iii) departments should draw material from a minimum number of sources, and issue them upon completion to the minimum number of destinations, and (iv) incompatible processes should be separated from each other.

These aims are incompatible and it is never possible to achieve them completely, however they provide a useful guide, to simplify the material flow system.

The seven main steps followed in FACTORY FLOW ANALYSIS are:

1) Divide the plant into departments on the basis of major processing differences e.g. machine shop, foundry, etc. The aim is to minimize the duplication of machines between departments. Another objective is to separate component manufacturing processes and assembly processes into separate departments.

2) Allocate machines to departments and find usage frequency. Allocation is made on the basis of processing type. In doing so, most of the components will be made in one department, in few cases two departments and a minority of parts will require intermediate operations in other departments. These minority of parts can be eliminated by providing a few types of machines in more than one department. The need for equipment duplication between departments may be based on machine usage frequency.

3) Determine the Process Route Number (PRN) for each component. PRN is a code number formed by listing in correct sequence all the departments visited by a component.

4) Analyze the route cards by PRN. A list is made of all PRNs in use and the number of parts with each PRN is counted.

5) Draw a Basic Flow chart, that illustrates the material flow system. The number of different parts using each flow path is determined from the PRN frequency chart, and these are also shown on the basic flow chart. See Fig. 2.3.

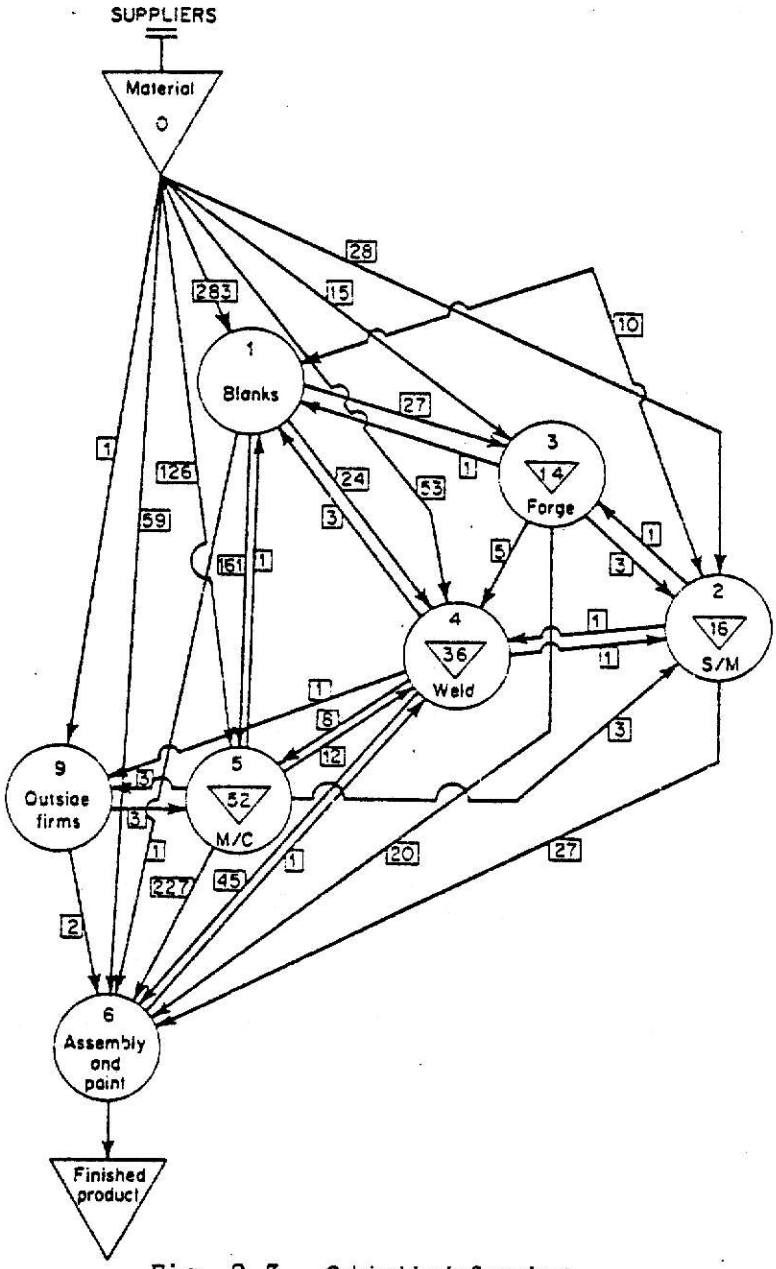


Fig. 2.3. Original basic flow chart

6) Determine those parts to be treated as exceptions, requiring rerouting to fit the majority pattern. These parts are found by direct examination of the basic flow chart.

7) Eliminate exceptions. Exceptions are all of the components with complex PRNs, which do not fit the simplified basic flow chart. Five main ways to simplification are: (i) re-allocate equipment between departments, (ii) re-route operations to other machines already existing in the department, (iii) change the manufacturing method, (iv) change the design, (v) purchase the part instead of manufacturing it. See Fig. 2.4.

GROUP ANALYSIS

The primary aim is to achieve the simplest possible material flow system within each department. Secondary aims are: (i) to have each part processed in one cell only, (ii) to have each machine type exist in one cell only and (iii) incompatible processes should be in different cells. These aims are not always compatible.

The seven main steps in GROUP ANALYSIS are:

1) Renumber the operations on the route cards: Now it is also necessary to know which machines are visited by each component. Operations in each department are numbered consecutively, starting with operation 1, but with the following exceptions. (a) Particular equipment used on a component, more than once, is numbered only once. (b) Manual operations, are numbered only if special equipment is provided.

2) Sort route cards into packs: The route cards for all components that use the same equipment in the same sequence are collected together in packs. Packs are first sorted by the machines used for Op. 1; then into subpacks for Op. 2, and so on, until no further division is possible. See Fig. 2.5.

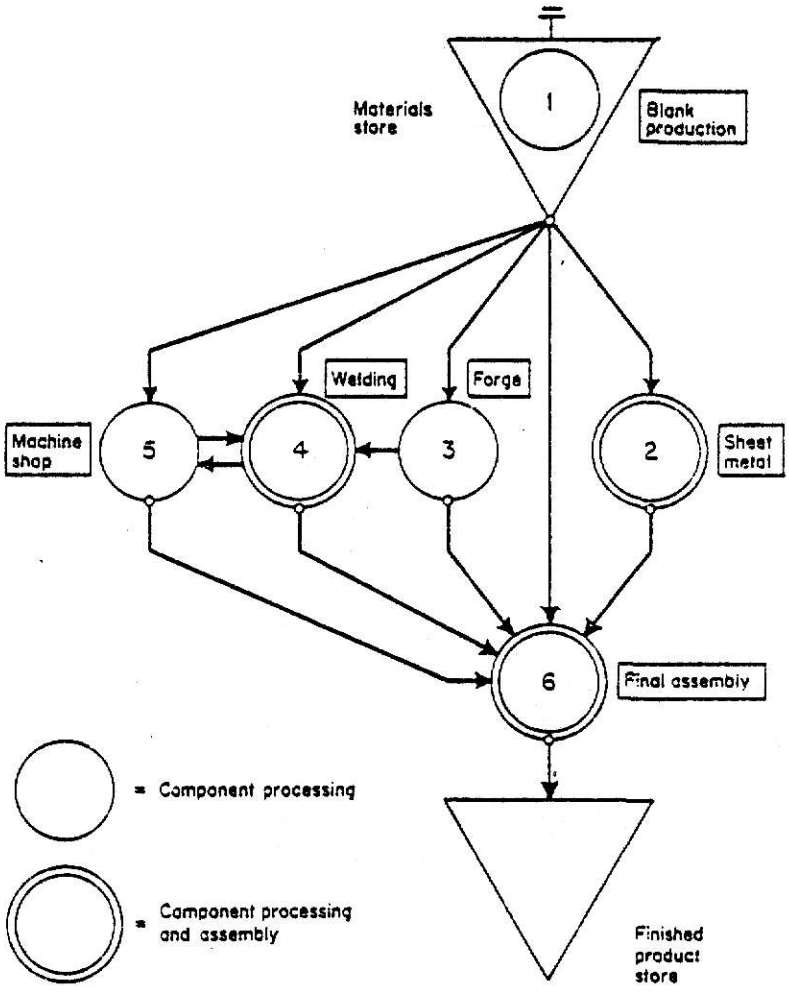


Fig. 2.4. Simplified basic flow chart

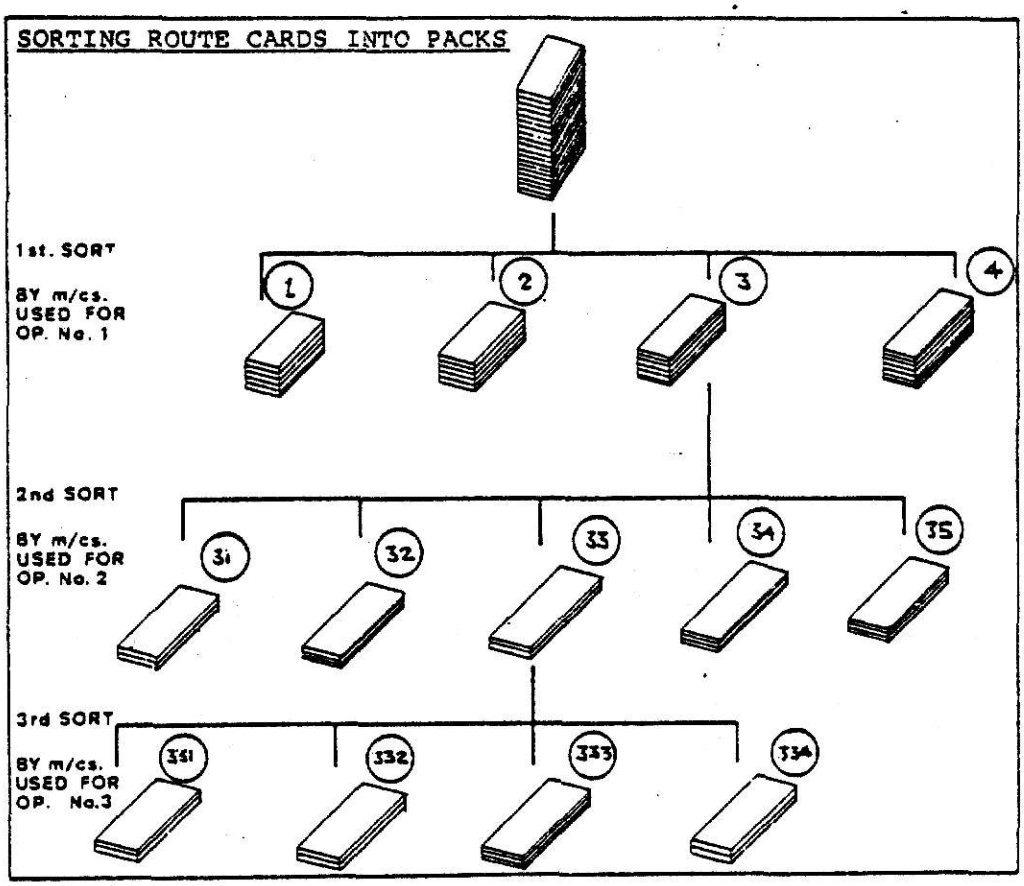


Fig. 2.5. Sorting route cards into packs

3) Draw Pack-Machine chart and find families and groups. Families and groups are found by changing the sequence in which components and machines are listed on the chart. See Fig. 2.6.

4) Check work load and allocate equipment to groups: If there is sufficient capacity with a Functional Layout, there will be more than enough with a Group Layout.

5) Investigate and eliminate exceptions: This is possible by rerouting the parts through the operations, by further division of machines between groups, by a change of method, by a change of component design, or by purchasing the part instead of making it.

6) Specify cells and families: by listing all the machines allocated to each machine cell and the parts allocated to each family.

7) Draw the final flow system network: The complete examination of this may reveal further possibilities of simplification.

LINE ANALYSIS

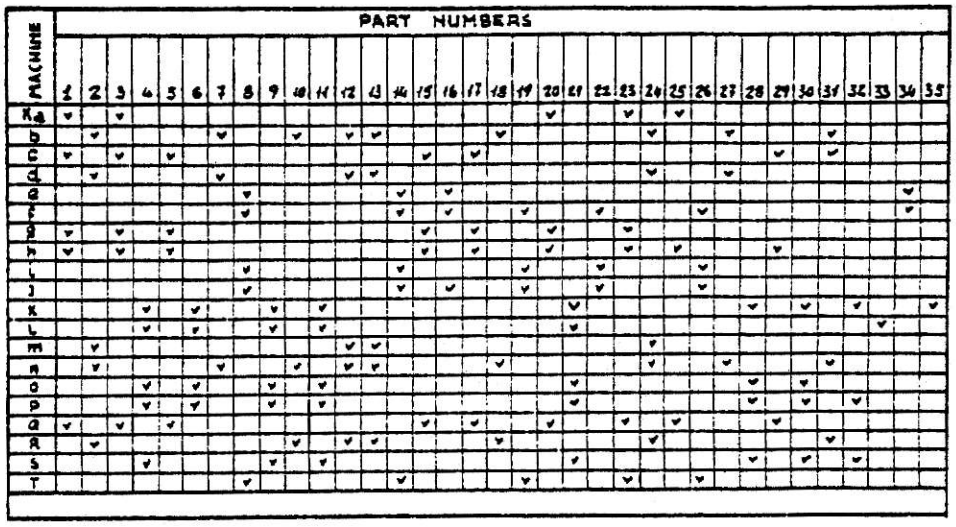
The third and final level of PFA is Line Analysis. If all of the components in a family use all the machines in the group in the same sequence, line layout can be used for batch production also. This can be done even when some components may have slightly different manufacturing sequences.

MACHINE GROUPING (CELL FORMATION)

Of the methods suggested above, only analysis of operation sequences will simultaneously identify machine cells as well as part families.

Generally identifying machine groups does not pose a problem once part families are formed. This permits the computation of the machine load, in hours, for each machine in the machine group. There will be some compensation necessary because the reduced setup and machining times resulting from group production. In practice, an effort should be made for a maximum utilization of

(A) ORIGINAL RECORD



(B) AFTER SORTING INTO FAMILIES AND GROUPS

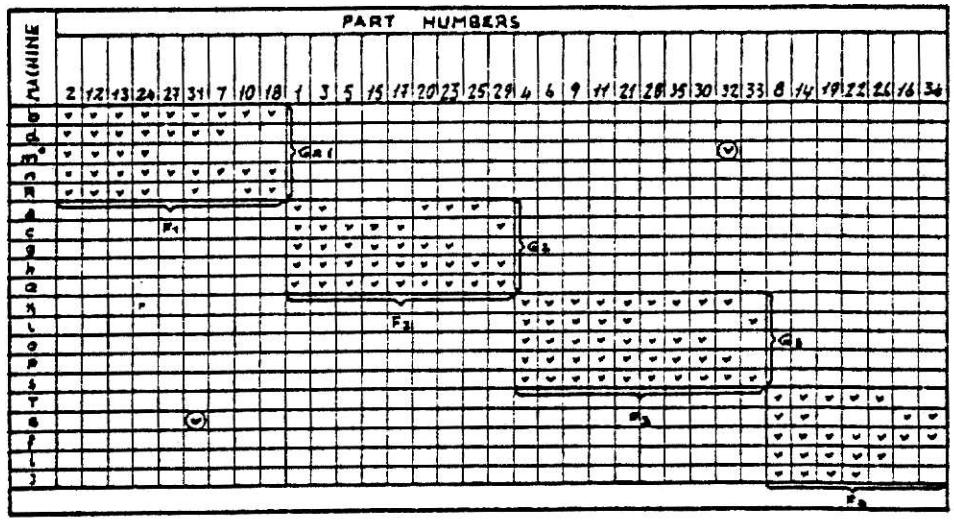


Fig. 2.6 - PRINCIPLES OF PRODUCTION FLOW ANALYSIS
Both charts are identical except for the sequence in which parts and machines are listed.

machines in a group by increasing the machine loads. Machine loads can be increased by either (a) extending basic part family by adding parts of a similar type or merging two or more subfamilies; or (b) by machining two or more families on the same machine group.

The choice of the method of Classification and Coding depends upon:

1) Complexity of products
2) Number of parts to be analyzed
3) Particular circumstances motivating the project
4) Data available
5) Existence of computer data files, and
6) Time limits

COMPUTER AIDS FOR FAMILY FORMATION

The use of computers is a more sophisticated method but it is still rarely used. Some papers have been published dealing with the use of computers through the application of cluster analysis for production flow analysis (15, 165) and two software packages have been described.

The Dutch organization, TNO, has developed a software package (166). This package includes a conversational code-building program, which should eliminate the errors inherent in manual coding and should speed up the process of building the file of part code numbers. The package also includes facilities for clustering, process planning and machine selection.

Carrie (167, 168) has developed a package, PLANTAPT, which utilizes a data base containing information similar to a production control data base, and includes facilities for code number analysis, for operation sequence analysis (both sorting and clustering), for work load evaluation, and for analysis of material handling flow paths for layout planning.

CODING & CLASSIFICATION SYSTEMS FOR INDUSTRY

The pioneers of Group Technology were classification enthusiasts, and nearly all the early applications of G.T. were based on component classification and coding. Component classification and coding (C & C) - although highly desirable for its own merits, - is no longer essential in the initial stages of the introduction of G.T.

Until recently, component C & C was the only method used for forming part families. With the introduction of Production Flow Analysis it is no longer a pre-requisite for family formation.

C & C for G.T. applications is a very complex operation. Although many systems have been developed throughout the world and countless efforts have been made to improve them, there is as yet no system that can be universally acclaimed.

Each company has its own specific needs and conditions therefore, it is necessary to search for a suitable system to meet their objectives.

We will now look at the definitions of classification and coding.

CLASSIFICATION:

According to Professor Burbridge [18], "classification can be defined as either the division of a list of items into classes according to their differences, or as the combining of individual items into classes according to their similarities. The first definition takes an analytical view of the problem and the second a synthetic view."

CODING:

"Coding can be defined as the assigning of symbols to classes, in such a way that the symbols convey information about the nature of classes." [18]

According to Roger Eckert [29] of General Motors, definitions given at the CAM-I's C & C workshop (June 1975), at Arlington, Texas:

"To classify is to group or arrange into classes according to some system or principle, while a code can be a body of rules or a system of symbols used in information processing. More specifically, parts classification groups parts together because of their component similarities and differentiates them according to their differences. A coding system then is simply a consistent set of rules governing the assignment of identifiers to these classified groups so that we can talk about them or manipulate them as families of parts."

Although there are many systems, the fundamental concepts underlying these systems leads to a recognition of the following basic models:

1. Product - Oriented - Components are grouped by products.
2. Function - Oriented - Components are grouped by names, indicative of their function, e.g. impellers, spur gears.
3. Design - Oriented (D.O.) - Components are grouped into families by the similarity of design.
4. Production - Oriented - Components are grouped into families requiring closely similar or identical technological processes.
5. Design & Production Oriented - Aims at satisfying the requirements of designers and production engineers by a single system.

System (1) is obsolete and of little value for G.T.

In most cases each system employs combinations of the above features in one way or the other. Thus it is difficult to compare systems strictly on the basis of the concepts mentioned above.

To select a suitable system, it is necessary to make a comparative evaluation of the currently available systems. The selection process must consider the needs for specific applications in a company, especially from the standpoint of G.T.

The two major uses of coding and classification systems are namely (a) for design retrieval, (b) for the grouping of part families for group production. For a successful G.T. implementation both are important. However, one use may be emphasized more than the other depending upon the company's prime needs and/or policies.

We will now look at some of the recent C & C systems, their advantages and disadvantages.

The following is the list of some of the representative systems available:

Czechoslovakia	VUOSO, VUSTE
Germany (West)	OPITZ, ZATO, PITTLER, GILDEMEISTER
Germany (East)	DDR standard
Holland	TNO-MICLASS
Japan	KC and KK
Sweden	PGM
U.K.	BRISCH, PERA, etc.
U.S.A.	ALLIS-CHALMERS (Code MSDI), BRISCH (U.S.A.), TNO-MICLASS (U.S.A.), PART-ANALOG, CODE
U.S.S.R.	MITROFANOV, NIITIMASH, VPTI, LIMO
Yugoslavia	IAMA

FORMS OF COMPONENT CLASSIFICATION

There are basically two types of coding; hierarchical codes and fixed digit significance codes. In the latter, a certain digit value always indicates that the same feature is present and, therefore, the codes are easy to read. In hierarchical code, information carried under each subsequent digit depends

on the preceeding digit, and the classification number is obtained after a step-by-step procedure using a series of coding charts. Thus the hierarchical code is shorter than the fixed digit significance code. However, considerable work is involved in generating hierarchical code. From the sorting point of view, i.e. the extraction of particular feature, say all parts with keyways; it is difficult since the whole code number must be considered and quite elaborate search procedures are required.

In general there are three basic parameters for classifying engineering components: the shape, function and the manufacturing operations and tooling. Table 3.1 shows a number of C & C systems grouped according to the number of coding digits used in them. The first column lists two systems which do not specify any coding, and the last column lists the more complex systems, based on punched card or paper tape. The number of coding digits in some of these systems is extended considerably by the addition of supplementary codes and/or secondary codes to the basic code system.

For more objective considerations and detailed study, we can group the various systems in following manner:

1) Machined component classification systems
2) Metal forming classification systems
3) Sheet metal classification systems
4) Casting classification systems

Machined Component Classification Systems

1) The VUOSO basic system (Czechoslovakia)

   This system uses four digits, three of which are arranged hierarchically to give the component shape, including the size and proportions, while the fourth digit has fixed significance and defines the component material. The system was originally developed for the study of

Table 3.1. Some Available Classification Systems

CZ.	Czechoslovakia	R.	Russia
EG.	East Germany	U.K.	United Kingdom
J.	Japan	WG.	West Germany
JUG.	Jugoslavia	SW.	Sweden

Zero Classification (no coding)	1-6 digits	7-10 digits	11-19 digits	20+ digits	Variable (Open ended codes)	Tape and punched card systems
Mitrofanov (R)	VUOSO (CZ) 4	Iama (JUG) 8	NIITMASH (R) 15	Zafo (WG) 21+	VPTI (R)	VUOSO (CZ)
Ivanov (R)	VUSTE (CZ) 4	Pittler (WG) 9			Brisch (UK)*	DDR Std. (EG)
	Brisch (UK) 4-6	Opitz 9†			Opitz (WG)*	PERA (UK)
	KC-1 (J) 5	PGM 10†				
	Opitz (WG) 5	Gildemeister (WG) 10				
	PGM (SW) 6					

* With secondary codes to basic system.

† With supplementary code.

workpiece statistics, but was also used for the selection of families for G.T. See Fig. 3.1 for details.

Rotational parts are coded in more detail than nonrotational parts. This system is not as easy to employ since some combinations of the component features e.g. tapered parts with some other features, or combinations of internal and external gears are difficult to define. We need to establish certain rules, as to which feature should be regarded as dominant.

Some of the families formed by this code may be quite large, owing to the limited details of the code or the fact that it is intended for use by all branches of industry.

2) The OPITZ system (West Germany)

This system was developed around 1964 at the Technical University of Aachen, West Germany, by Professor Opitz and his collaborators. A brief explanation of the system is as follows. Fig. 3.2 shows the layout of classification system. This system is in two parts. The form or the basic code and the additional code.

This system achieves a high degree of fixed digit significance after the first digit for rotational components and the second digit for nonrotational components. The structure of the primary 5 digit code is based on the definition of the main envelope shape and proportions, and indications of the presence of various other shape elements follow in the subsequent digits. This classification system proceeds by following the general sequence of operations required; for instance, in the case of rotational components the elements produced by turning are coded with the first three digits, followed by the elements produced by surface machining with the fourth digit and elements

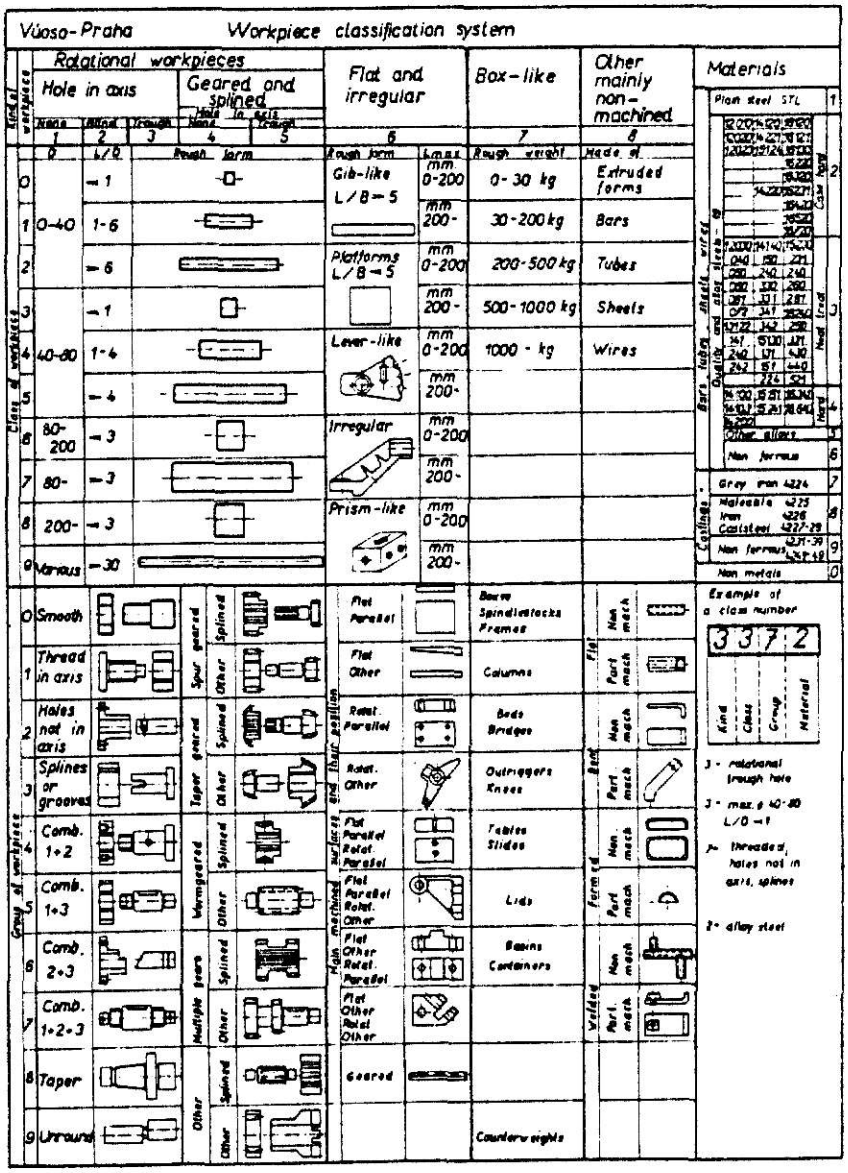


Fig. 3.1. Layout of VUOSO system

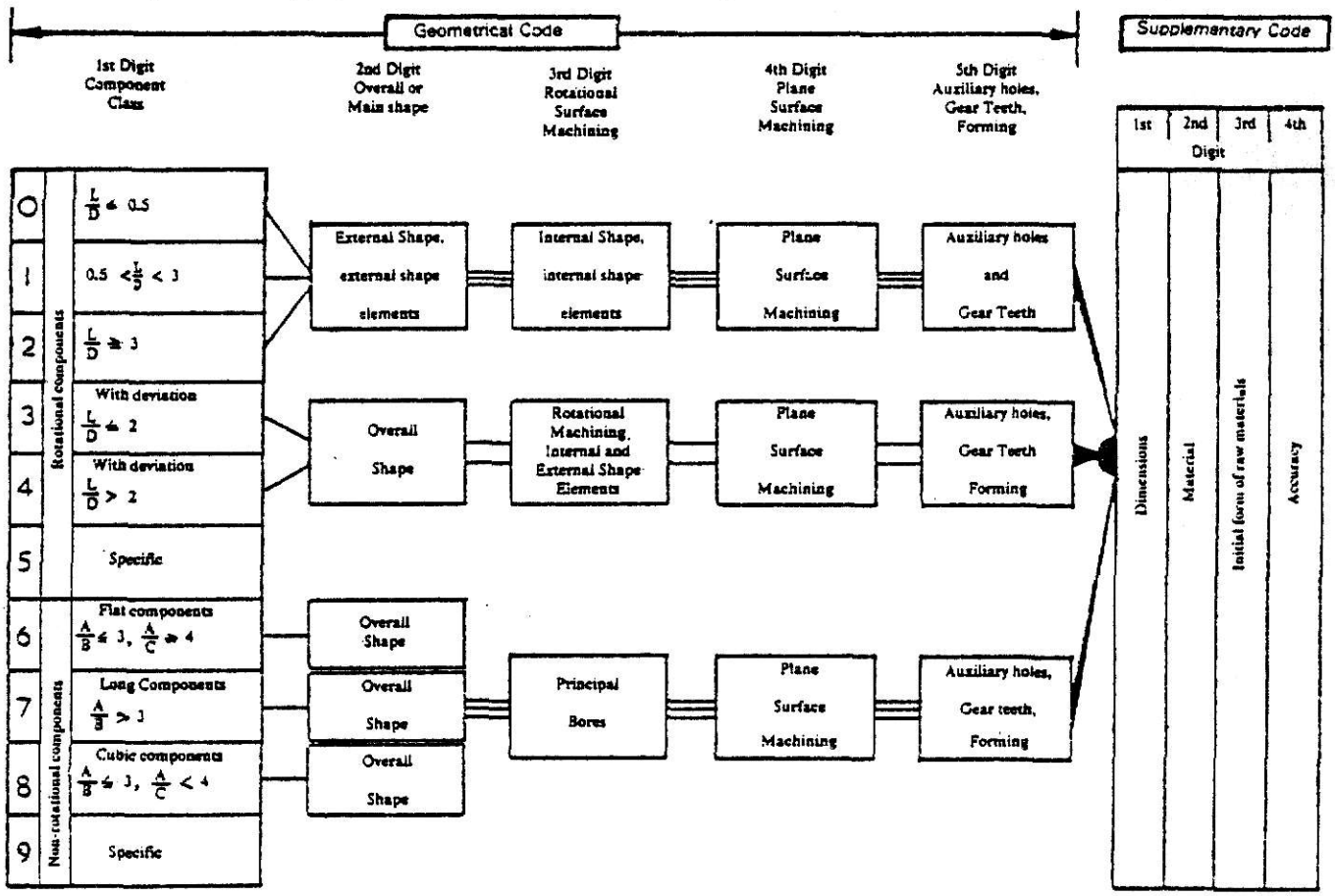


Fig. 3.2. Layout of OPITZ system

involving drilling and gear cutting with the fifth digit. As each digit value increases, a more complex component is indicated. See Fig. 3.3.

Rotational parts are subdivided according to the length-to-diameter ratio, and can be recognized as either disc-type, medium or shaft-like parts. Similarly, nonrotational parts are divided into flat, long and cubic parts, according to the ratio of their length and width. The four digits in the supplementary code are used to classify size, material in the original form and accuracy. See Fig. 3.2.

The addition of a serial number to this code would make the system highly suitable for the identification of parts for design-retrieval purposes. Fig. 3.4 shows an example of the coding of a workpiece. It is a rotational part, progressively stepped, with a slot and axially indexed drill holes. The use of fixed digit significance to classify the individual shape features is a considerable aid in the standardization of component features.

3) The MICLASS system (Holland, U.S.A.)

This system classifies workpieces by their characteristics, such as shape, tolerance and machinability, and not by their functions. The system is an outcome of the critical evaluations of the previously known classification systems, so it combines their best features.

Although this system can be used manually, MICLASS is one of those few classification and coding systems that is computerized. The system includes a conversational code building program, and the facilities for clustering, process planning and machine selection. It is a product independent system, so a change in products does not require the system to be revised. It is universal, i.e. almost every part can be classified. The system also takes into account the shape

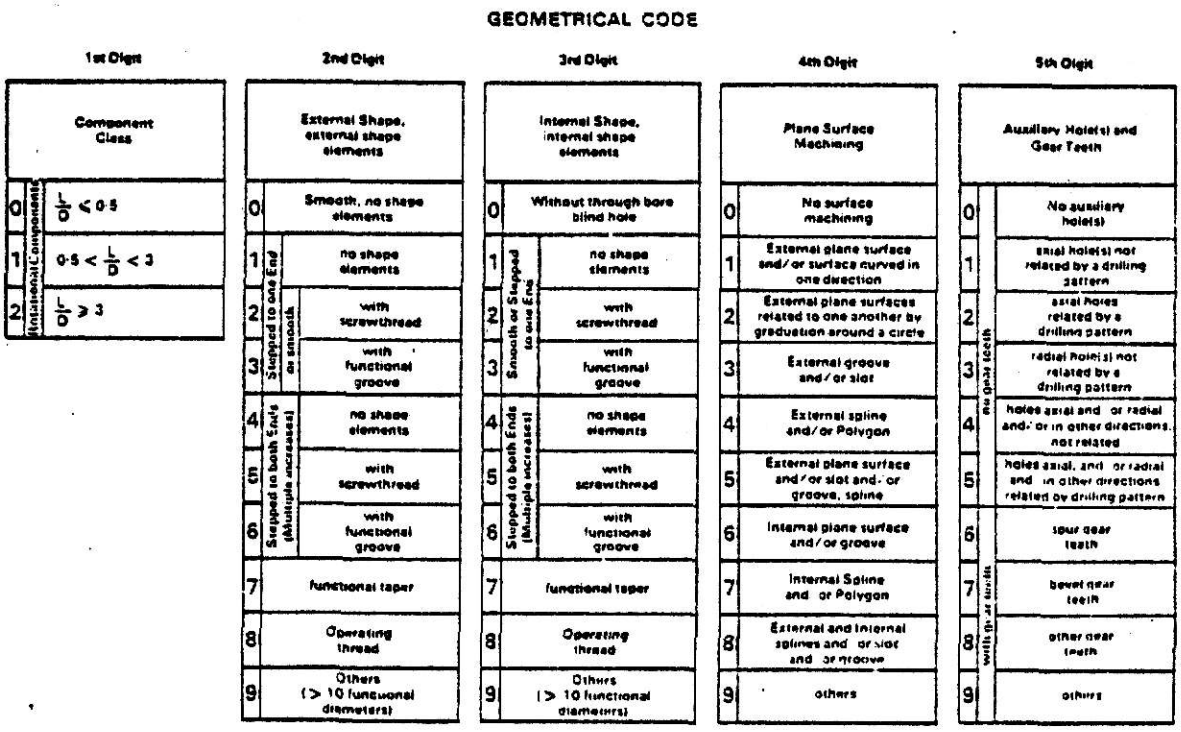
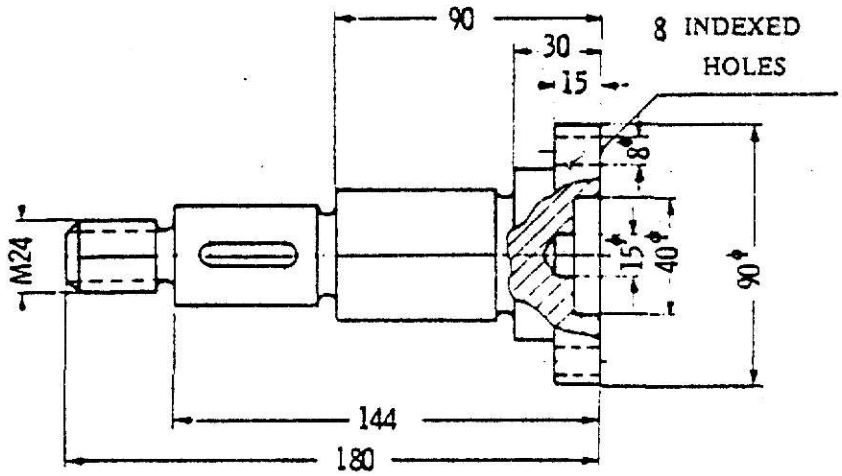


Fig. 3.3. Geometrical code for round parts, OPITZ system



1	ROTATIONAL PART 0.5 < L/DIA. < 3	SEQUENCE OF OPERATIONS TURNING, GROOVING
12	CONTOUR PROGRESSIVELY STEPPED THREAD	CHAMFERING, THREAD CUTTING
121	INTERNAL SHAPE	TURNING, BORING
1213	SURFACE: SLOT	SLOT MILLING
12132	DRILL-HOLES, GEAR CHIPLESS FORMING	DRILLING

AXIAL INDEXED DRILLING-HOLES, NO GEAR GENERATION

Fig. 3.4. Coding a rotational component, OPITZ system

of a workpiece, the various operations required to produce it and provides accurate and usable information for production planning and other management activities. It can also be used to generate the tapes required to manufacture a workpiece on an NC machine.

Shop drawings may be identified by any number or letter convenient to the company, the MICLASS codes are simply added to them.

MICLASS uses 12 digits to describe and classify the nine "Universal" characteristics of each workpiece.

* Main shape
* Shape elements
* Position of shape elements
* Main dimension
* Ratio of dimensions
* Auxilary dimensions
* Tolerance and surface finish
* Form tolerance
* Material

Additional digits may be used for company based information, which may include:

* Drawing number
* Company nomenclature
* Lot size
* Setup time
* Machining time
* Machine type
* Routing

MICLASS works conversationally [See Fig. 3.5 and 3.6] so that the user can classify a workpiece by answering a series of logical questions posed

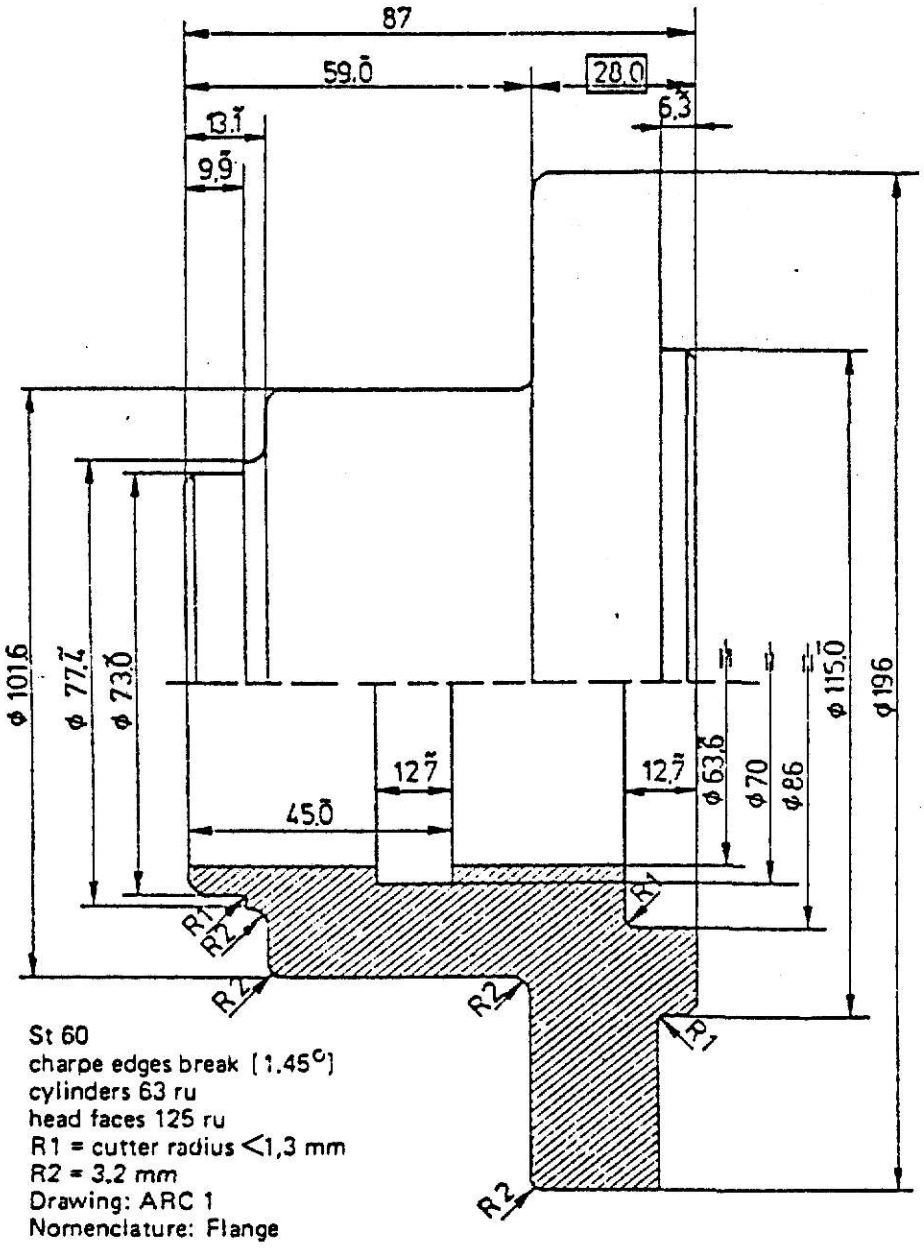


Fig. 3.5. HYPOTHETICAL WORKPIECE DRAWING

```
LANGUAGE:  ENGLISH, FRENCH, GERMAN OR DUTCH? english
DIMENSION STANDARD IN MILLIMETERS OF INCHES? mm
DRAWING NUMBER? arc 1
ANSWER THE FOLLOWING QUESTIONS WHEN POSSIBLE WITH YES OR NO
     IS IT A ROTARY COMPONENT? yes
     LARGEST DIAMETER AND LENGTH? 196,87
     DOES THE ROTARY FORM DEVIATE? no
     IS THE AXIS OF TOTATION THREADED? no
     MUST ANY ECCENTRIC HOLING, PLANING OR SLOTTING OPERATIONS
          BE DONE? no
     MUST THE TOP SIDES OR OUTER FORM BE TURNED? yes
     HAS THE OUTER FORM A SPECIAL GROOVE (S) OR CONE? no
     ARE THE OUTSIDE DIAMETERS INCREASING FROM BOTH ENDS? yes
     MUST THE INNER FORM BE TURNED? yes
     HAS THE INNER FORM A SPECIAL GROOVE OR CONE? no
     ARE THE INSIDE DIAMETERS DECREASING FROM BOTH ENDS? no
     LENGTH AND LARGEST LENGTH COAXIAL HOLE IN MM? 174
     IS DIAMETER TOLERANCE 6 OR BETTER?  OR ROUGHNESS LESS THAN
          33 RU? no
     IS THE LENGTH TOLERANCE LESS THAN 0.3 MM? yes
     ANY FORM TOLERANCE? no
     MATERIAL TYPE? st60
[Once these questions have been answered, the computer will assign a classifi-
cation number to the part.  The print out is as follows:]
     DRAWING NUMBER = arc 1
     CLASSIFICATION NUMBER = 1330 4021 2104
Retrieving Related Drawings
     GIVE CLASSIFICATION NUMBER?  1330 4021 2104
     DRAWING NUMBERS ARE:  p2ur 10
                           stx ≠
                           mvc 12
```

Fig. 3.6. Conversational coding program, MICLASS system example.

by the computer. The user can choose to converse in English, German, Dutch or French and the system can operate in inches or in metric or both.

Uses of the MICLASS system

* Drawing Retrieval
* Retrieval of Manufacturing Information
* Standardization
* Investment Analyses
* Implementation of Group Layout

4) The KCI system (Japan)

This five digit code is very similar to the VUOSO system but it differs by having a further digit added to classify the highest accuracy required, and the corresponding surface finish. The layout is similar to the VUOSO system, except that six main rotational classes are defined instead of five. Threads are considered as primary feature and two main classes for threaded parts are included. When compared to the VUOSO system, the coding of nonrotational parts is in more detail and is extended to the machining required on the part to a limited extent.

5) The PGM system (Sweden)

This system is quite similar to the OPITZ system, with a primary code of six digits, and a supplementary code of four digits. The difference is in the addition of a further coding digit. This digit provides information on the origin of the mainshape, i.e. by casting, forging or flame cutting, etc. This system is slightly biased towards production because it not only defines the component shape elements but also gives some indication of the production technology.

6) The BRISCH system (U.K., U.S.A.)

The basic part of this system, which uses a primary code of four to six digits, is hierarchical in form. A series of secondary codes have recently been added to satisfy the classification requirements of production characteristics.

Generally, the system is designed to meet the needs of a particular client. The complete coding system may not be installed, but one or two classes as required may be used. A code number is obtained by a step-by-step procedure using a series of coding charts. A three digit serial number is added for the purpose of identification.

Since the code is hierarchical, the selection of specific features from the various groups may be difficult. It is well suited to the purpose of design retrieval and variety reduction. The basic features of size, proportions, and material are not generally incorporated in the primary classification. See Fig. 3.7.

This basic code is not ideally suited to G.T. implementation. This need has been recognized by the code designers and recently a secondary series of codes has been added. These polycodes are stored behind the primary code and can be changed or added to without altering the identification of the component. Figure 3.8 shows a comprehensive system of Brisch polycodes covering details of shape, production methods and size. A polycode number gives access to the chart that provides the digit values allocated to the specific features.

7) The CODE system (U.S.A.)

This system was developed by Manufacturing Data Systems, Inc. It was specifically designed for the G.T. users. CODE is a highly effective component classification system for Computer Aided Design and Computer Aided Manufacturing. This system provides a simple approach to defining

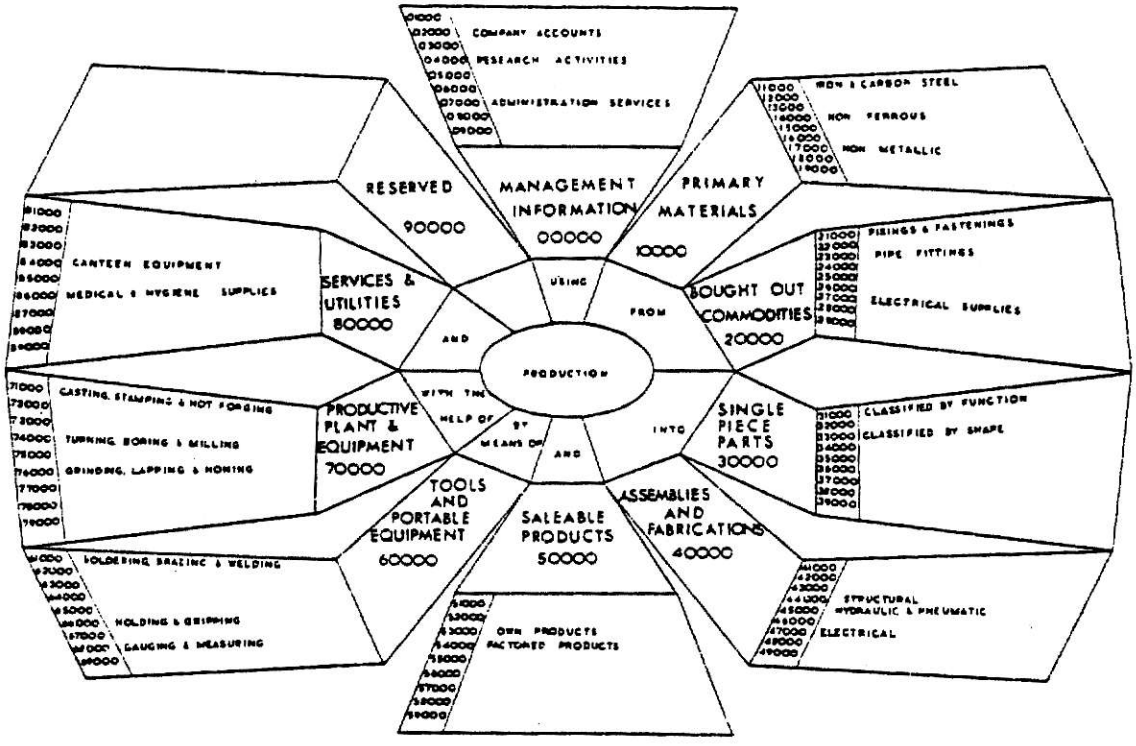


Fig. 3.7. *Basic structure of the complete Brisch coding system*

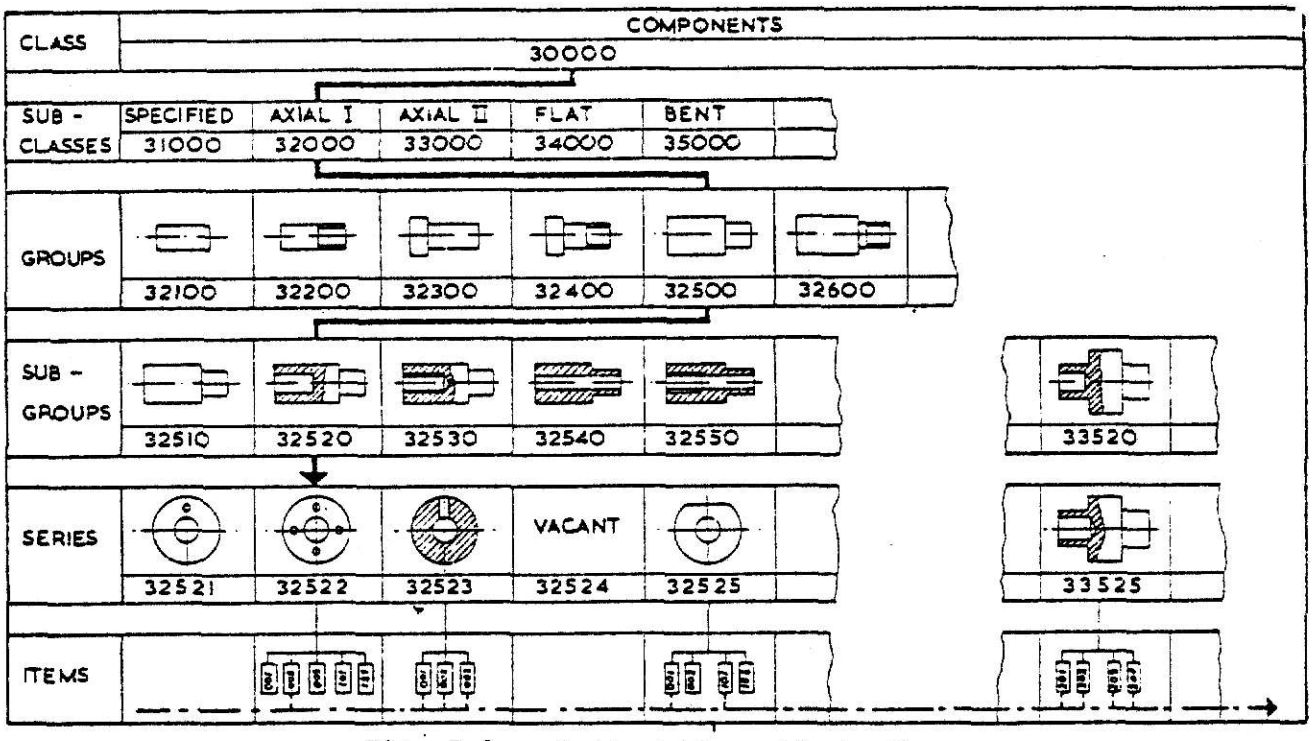


Fig. 3.8. *Development of class 3 code (components)*

piece parts, assemblies or documents by physical characteristics and/or function. The code is divided into 5 major divisions represented by the first character. The second character amplified the information on the part's shape. One can complete the coding by looking at only one chart. Primary and secondary manufacturing processes are established and included in the system.

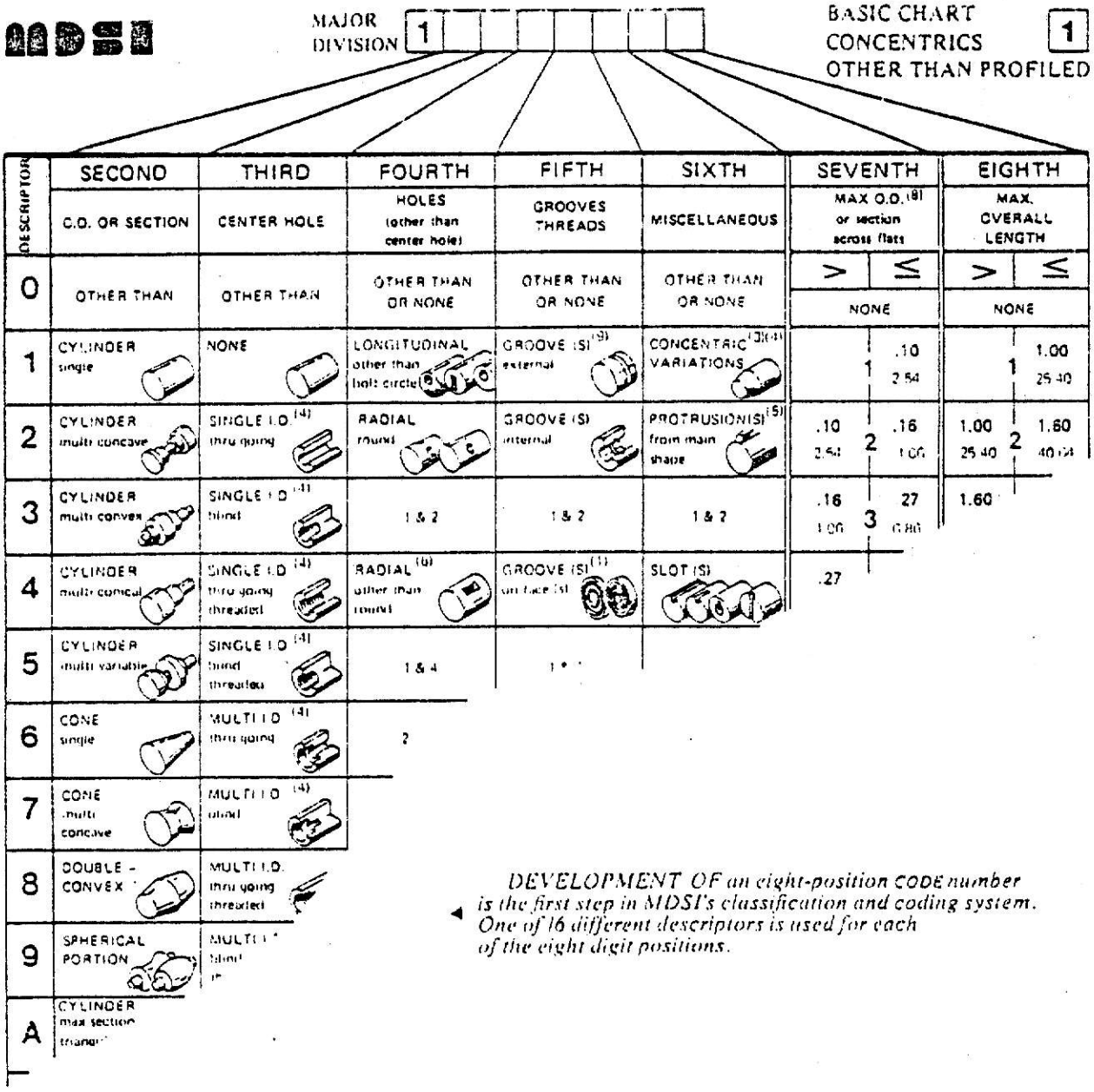
CODE is based on a polycode principle which assists in easy computer implementation and simple data base organization. It is an eight digit code, selected step-by-step according to the descriptions established in the code book charts. See Fig. 3.9.

8) The NIITMASH system (Russia)

The NIITMASH system is a hierarchical code of 10 to 15 digits plus a serial number. The basic form is indicated in Fig. 3.10, some of these categories are optional. The components are allocated to classes by either name or function. Classification is largely by name and is therefore open to some misinterpretation, although this can be reduced to a low level by a comprehensive classification.

For each of these classes, there is a code chart for further classification of the parts into subclasses. Material is coded under sixth digit, and the number allocated at this stage is recorded on the drawing, together with the serial number.

Digits 7, 8 and 9 define weight and secondary design features. Their use is optional. Digits 10 and 11 are allocated to the size range, and digits 12 and 13 to initial material form, followed by the greatest accuracy and finish of the principal surfaces. The code is rather long and further information may be required for the rationalization of production methods.



DEVELOPMENT OF an eight-position CODE number is the first step in MDSI's classification and coding system. One of 16 different descriptors is used for each of the eight digit positions.

Fig. 3.9. Development of CODE system

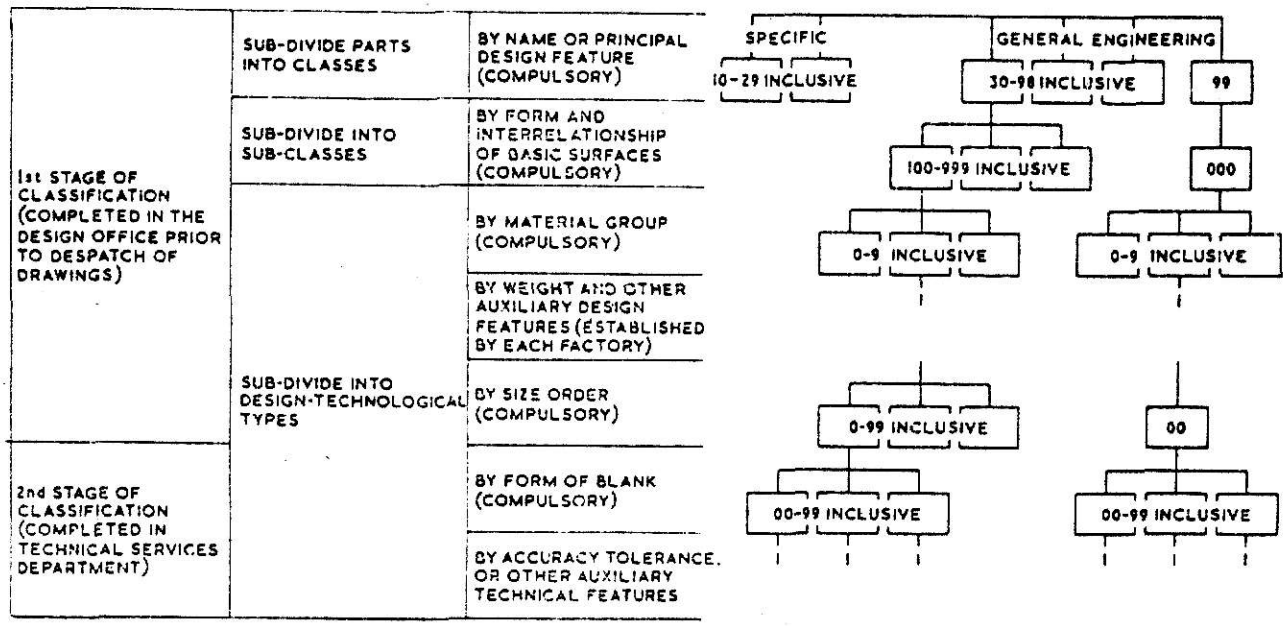


Fig. 3.10. Layout of MIITMASH system

9) The SPIES system for closed die hot forgings (W. Germany)

This system uses three digits to define the shape of a component plus a fourth digit for size classification. Three main shape classes are: square parts, flat parts and long parts. A fourth digit indicates the length to breadth ratio. This system is intended to bring together those parts requiring similar design procedures and production methods.

10) The GUREVICH system for closed die forgings (Russia)

This system uses nine digits, the first of which defines the material of the forging. The next three digits classify the design and technological features. The fifth digit in the code defines the method of forging. The next two digits give the type and capacity of the forging equipment. Final two digits (8 and 9) are allocated to the forging weight.

This system covers the main features which influence the design of forgings, allowing design procedures to be established systematically. These same features also influence die design and production methods, and thus form a basis for grouping parts for forging operations.

11) The OPITZ system for sheet metal (W. Germany)

This system employs a nine digit code, similar to the one employed for machined components. The code is divided into two parts: a main code of five digits and a supplementary code of four digits. In the main code, the first digit divides parts into sheet and profiled components. Further classification is as shown in the Fig. 3.11. A high degree of fixed digit significance is achieved after the first digit.

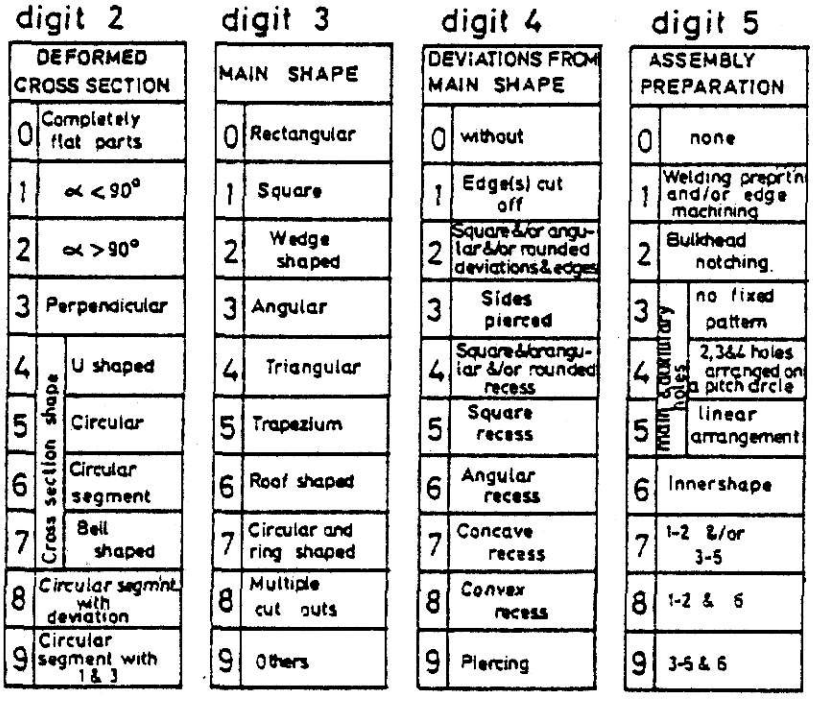


Fig. 3.11. Structure of main OPITZ system for sheet metal parts classification

The supplementary code is common for all parts and covers the main dimensions, and the thickness of the material in the first three digits. The final digit is used to classify the material.

This code is mainly intended for design rationalization. It will facilitate the formation of groups of parts for production, if further information on operations to be performed is made available.

12) The SALFORD system (U.K.)

This six digit code is aimed at the rationalization of press tool design and attempts to classify components by means of those features which influence die design and production technology.

This code is similar to the Opitz system, but it classifies parts more by technological features than by shape. However, details of the work material and size of the components are not given and these do influence the die design to some extent. See Fig. 3.12.

13) The MALEK system for castings (Czechoslovakia)

This classification system is widely used in the application of G.T. in the foundry. The code consists of 12 digits, and covers the following items: Material, digits 1-4 and 10; Casting shape, digits 6-8; size digits, 5, 11 and 12; and the accuracy of castings by digit 9. With this code it is possible to cover most of the castings produced in the foundry industry. It represents a sound basis for the rationalization of design, planning and production systems within an organization.

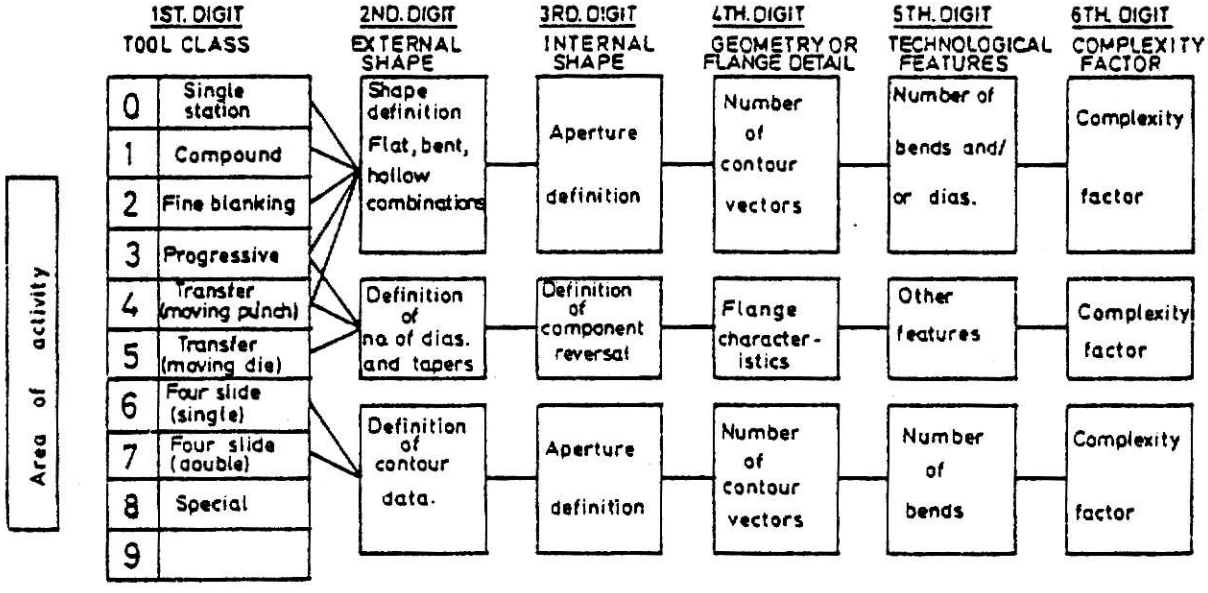


Fig. 3.12. *Structure of the Salford sheet metal parts classification*

GROUP TECHNOLOGY AND DESIGN RATIONALIZATION

(1) Automated Process Planning

For the successful implementation of CAD/CAM systems, one of the essential requirements is computerized automatic process planning (65). CAPP techniques provide a basis for a rational and logical approach to component design and for economical manufacturing planning. CAPP is a key step in achieving the optimum manufacturing productivity in CAD/CAM operations.

Process planning, the subsystem responsible for the conversion of design data to work instructions in the manufacturing system, is one of the key requirements for the optimum production plans. It has been recognized that (172) coding and classification systems, part family formation, etc., the essential parts of G.T., play an important role in the process planning system. In other words the logical approach to a successful automated process planning system is based on the part family concept of G.T.

The manufacturing process plan normally includes the routing, machine by machine, and descriptions of the specific adjustments required to load the part on each machine. Automated Process Planning involves the automatic generation of a manufacturing process plan by computer, once the essential characteristics of the part to be manufactured have been recognized and related to the manufacturing process. It has two distinct advantages: reduction in the engineering time needed to create the process plan, and the consistent application of optimum manufacturing technology for more efficient production.

(2) NC Machine Tools and Machining Centers

G.T. makes it economically feasible to use sophisticated automatic equipment or special tooling, which would be otherwise too costly for the normal job shop. Generally, the advantages of automatic equipment are outweighed by problems and costs of production planning, tooling, and long setup times. With the use of

G.T., these problems can be reduced to such an extent that it becomes economically advantageous to use automatic equipment.

One of the important applications of G.T. is software development for NC machining, called the part-family programming. Part-family programming is an NC program system that groups common or similar program elements into a single, master computer program.

A master computer program, or preprocessor, is a permanent base from which an NC tape can be prepared for any part in the family. So part-family programming increases the productivity of costly NC operations by saving programming time, tape prove-out time, etc.

Machining centers, by virtue of their characteristics and capabilities, consolidate a number of setups into one. The concept of a machine group or cell has a similar effect. A machining center can be considered as a submachine group or cell. Such machining centers are very expensive, requiring high capital investments. Their use must be optimized in G.T. environments where continuous feeding of properly grouped parts gives maximum loading efficiency.

(3) Group Benefits

The benefits of more efficient operations go to the group of components rather than to just one or a few components. As an example, an engineer performs a value analysis on a given component, similar savings will acrue on other parts in the same family. This will rarely be possible where part families do not exist.

(4) Variety Reduction

The prevention of an unnecessary variety of parts is important when considering the total cost of putting a new component through all the stages of design, planning, estimating, costing and then into production. This is

particularly true when all of the associated costs of tool design and manufacture are considered.

Even if we just consider preproduction cost, which are high, there can be a considerable savings. Also when a new component is avoided, it not only avoids the preproduction costs, but an additional return is realized on part investments, each time the existing component is incorporated into a new product.

(5) Design Retrieval

The solution to the problem of retrieving similar designs is to allocate to each component a code number which covers the important design features of that part. Part drawings with similar code numbers are filed together. Design personnel can then, after deciding on the approximate shape and other features of the component required, locate all those parts, which are similar. Wherever feasible we can make use of an existing component. Minor design alterations, if required, can always be incorporated with little or no difficulty.

(6) The Reduction of Component Feature Variety

Considerable savings, particularly in tooling costs, can be achieved by reducing the variety of product features such as a radii, chamfers and undercuts. The idea is to standardize the overall design features. One can formulate the preferred ranges of specified design features for use within an organization.

COMMENTS FROM AUTHORITIES

(1) An analytical approach to measure the effects of G.T.

By Dan Shunk and Ruddel Reed, Jr.

Purdue University, West Lafayette, Indiana [173]

As noticed in the earlier part of this research report, applications of G.T. in the U.S. are very limited in number.

Those authors believe that very little work has been done on the analytical aspects necessary to convince american industry that G.T. does have some merits. Several experiments are necessary. A few of these would be:

a) To test algorithms of part grouping procedures.

b) To test algorithms for machine assignments to groups.

c) To test material handling systems to serve machine groups.

d) To test part processing, planning and control for machining center shops.

Two parameters they studied were: (1) what coefficient (S_{ij}) for part grouping works best? and (2) what fraction of utilization of a machine is necessary to assign a machine to a G.T. center versus assignment to the centralized job shop center?

Questions they attacked were the:

1) Effect on lot processing time when the above parameters were varied.

2) Effect on lot processing time variability.

3) Effect on work-in-progress (W.I.P.).

4) Effect on need for material handling.

The authors felt that G.T. groupings, if they do not exist realistically, should not be forced upon the shop. The following is the summary of the results of their findings:

1) It was impossible to measure by simulation the improved control and improved material flow effects on through-put time. However, when the machine utilization fraction required to assign a machine to machine center was reduced to 0.5, a significant saving in leadtime was noticed. [Looks obvious, isn't it?] One must look into the economic analysis of the benefits gained versus added capital cost of the addition of a new key machine.
2) With a G.T. shop, a definite, but not highly significant, decrease in through-put time variability was noticed.
3) The material handling move-distance statistics did show the significant savings of 15-20%.
4) Although total through-put time remained about the same in both types of layout, i.e. job-shop as well as group layout, the amount of time the job was in the shop was reduced up to 10%. The authors considered this savings an almost unexpected result by use of G.T.
5) Other attributes such as queues, W.I.P. values and wait times all showed at least some improvement with G.T. The values can be obtained from authors upon request.

(2) Numerical taxonomy applied to G.T. and Plant Layout

A. S. Carrie, Dept. of Production Engineering, University of Strathclyde, Glasgow, Scotland [165]

It is an accepted principle that the design of a production system should take into account the work flow structure of the parts to be made. Most published computer programs, analyze work flow with the objective of designing a specific type of production system. What is generally lacking in a simple and efficient technique which is capable of showing which type of layout is most suited to a particular case.

The author's interest in numerical taxonomy arose because the technique appeared to have the necessary flexibility to fulfill these requirements and could be readily implemented on a computer.

Taxonomy is a science of biological classification of objects based upon their possession or lack of relevant characteristics. When the extent to which they possess each of these characteristics can be expressed numerically, the objects can be classified by Numerical Taxonomy. This technique studies the similarities between objects in a quantative manner, in contrast with the classification techniques of G.T. which tend to be descriptive.

The author summarizes relevance of a numerical taxonomy to G.T. and Plant Layout as follows:

a) It provides a means of assessing whether group production methods will be effective, or if the functional type of layout should be adopted?

b) It provides a means of forming component families for group production, based on the principles of production flow analysis.

c) It provides a means of analyzing work flow for the development of a functional type layout.

d) It does not complicate the task of reconciling analytical procedures with subjective judgment, but can present its results in various forms so that the Industrial Engineer may select the one which is most useful.

(3) The fundamental limitations of cellular manufacture when contrasted with efficient functional layout.

By K. Rathmill and R. Leonard, Dept. of Mechanical Engineering, University of Manchester, Institute of Science and Technology, Manchester, England [174]

This work describes the results of a series of investigations which have been conducted by the authors into the many claims advanced by advocates

of G.T. The study comprised of a number of distinct, yet related areas including: analytic investigations incorporating queueing theory and batch size selection; the use of 'company profiles' to establish the general suitability of individual engineering forms for operation of G.T. on F.L. principles; and finally a series of case studies to evaluate, realistically and practically the results of established G.T. systems.

The authors indicate that the Americans and Germans use F.L. extensively and their output per man is double that achieved in the U.K. Thus the question the author posed is: "Is G.T. superior to efficient F.L.?"

The authors are convinced that the single machine, specifically tooled to manufacture a restricted design and G.T. flowline, skillfully designed to produce a family of similar components, are highly viable. It is erroneous to extrapolate the results obtained for G.T. flowlines and to assume that some degree of net advantage will always exist in G.T. cells.

The authors believe that G.T. should be restricted to situations where parts have a high similarity of design and a low level of manufacturing complexity. Also, components should exhibit a stable mix and stable demand characteristics.

Before deciding on a change to G.T., a company must investigate the differences between themselves as well as publicized case studies. The company must evaluate comprehensively, the numerous likely implications of G.T., and also the potential results of a well designed G.T. system with those of well designed F.L. system.

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GROUP TECHNOLOGY WITH CODING AND CLASSIFICATION

by

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ABSTRACT

Group Technology is a manufacturing concept under which parts are grouped into families with common characteristics. On the shop floor, the concept calls for machines to be organized into cells. Each cell is arranged to produce a family of similar parts.

The concept is aimed at bringing some of the economics of scale inherent in mass production to the manufacture of parts in small batches. Nearly all the early applications of group technology were based on component classification and coding which is one of the more common ways of generating part families. Production Flow analysis is another way of generating families although not used as extensively, it is claimed to be better by some authorities.

Classification and coding not only helps in the implementation of group layout but also provides a rapid and efficient method of information retrieval for decision making. The technique also has value in reduction of variety of parts and in computer assisted process planning. Since there is virtually no limit to the amount of information that can be stored it is necessary that we be selective and only store that information which is necessary for our purposes.

In recent years a large number of classification codes have been developed. The objective of this report is to present those various methods of coding and classification presently being used in industry.