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FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
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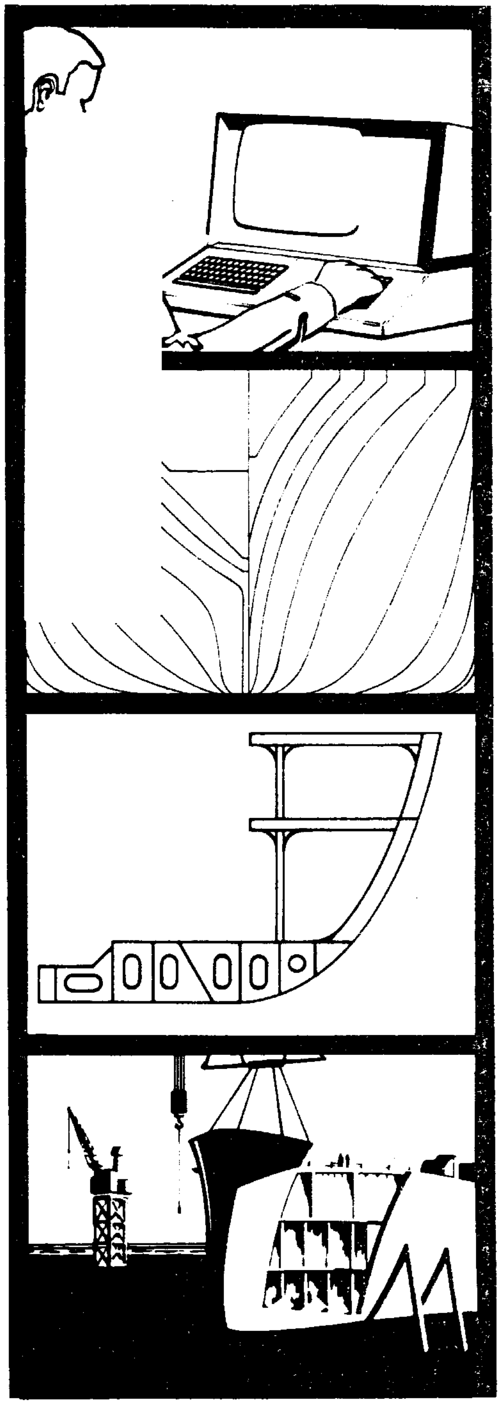

R ESEARCH
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GROUP TECHNOLOGY AS RELATED TO THE SHIPBUILDING INDUSTRY

Inyong Ham
Department of Industrial and Management Systems Engineering
The Pennsylvania State University
University Park, Pennsylvania

Dr. Ham is Professor of Industrial Engineering and member of the graduate faculty. He teaches and conducts research in the areas of manufacturing processes, optimization and group technology. His past experience includes engineering, research and consulting positions for many companies involved in manufacturing.

Dr. Ham has B.S., M.S. and Ph.D. degrees in Mechanical Engineering.

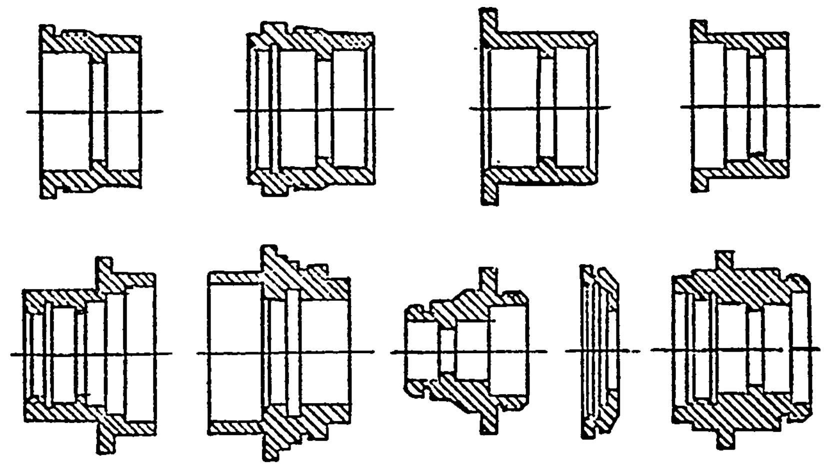
INTRODUCTION

A growing amount of attention has been turned to Group Technology which deals with the area of batch-type manufacturing for those who are engaged with small lot sizes and a variety of products. Development and implementation of integrated computer aided manufacturing (ICAM) will lead to rapid changes in U.S. manufacturing industry. It has been recognized that Group Technology is an essential element of the foundation for the successful development and implementation of ICAM through the application of the part-family concept.

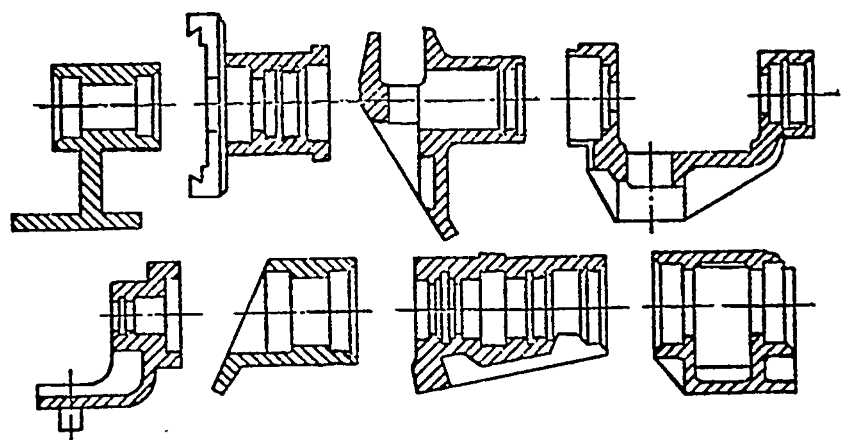
Group Technology is a manufacturing philosophy which identifies and exploits "the underlying sameness" of parts and the manufacturing processes. In batch type manufacturing, conventionally each part is treated as being unique from design to manufacture. However, by grouping similar parts into part families (Fig. 1) based on either their geometries or processes, it is possible to reduce costs through more effective design rationalization and design data retrieval, fewer stocks and purchases, simplified and improved production planning and control, reduction of tooling, and set-up times, flow line production by machine groups/cells, less in-process inventory, reduction of total through-put time, reduction of NC programming, a more efficient NC machine utilization. See Fig. 2.

The basic concept of Group Technology has been practiced in the U.S. for many years as part of "Good Engineering Practice" and "Scientific Management". For example, a coding system developed by F. W. Taylor (1) was used in the manufacturing industry as early as the beginning of this century. Many companies devised their own coding systems and have been using them for many years in various areas such as design, materials, tools, etc. There are numerous examples of machine groups or cells, group tooling devices, part family groupings and programming, etc. which have been in practice for many, many years in various sectors of U.S. industry. These practices and applications of Group Technology Concept's were identified under different names and in various forms of engineering and manufacturing functions.

In Europe, Group Technology also has been practiced in various forms and degrees for many years. Many countries took a new interest in Group Technology in the 1950's and 1960's. At that time coding systems were developed, machine cell concepts were practiced, and many excellent group tooling practices have been reported (2,3). Japan has been promoting Group Technology in order to improve its productivity since the 1960's (4). However, in the U.S., Group Technology has not received formal recognition and has not been rigorously



(a) **Part family with similarity in shapes**



(b) Part family with similarity in production operations

Figure 1, Examples of part family

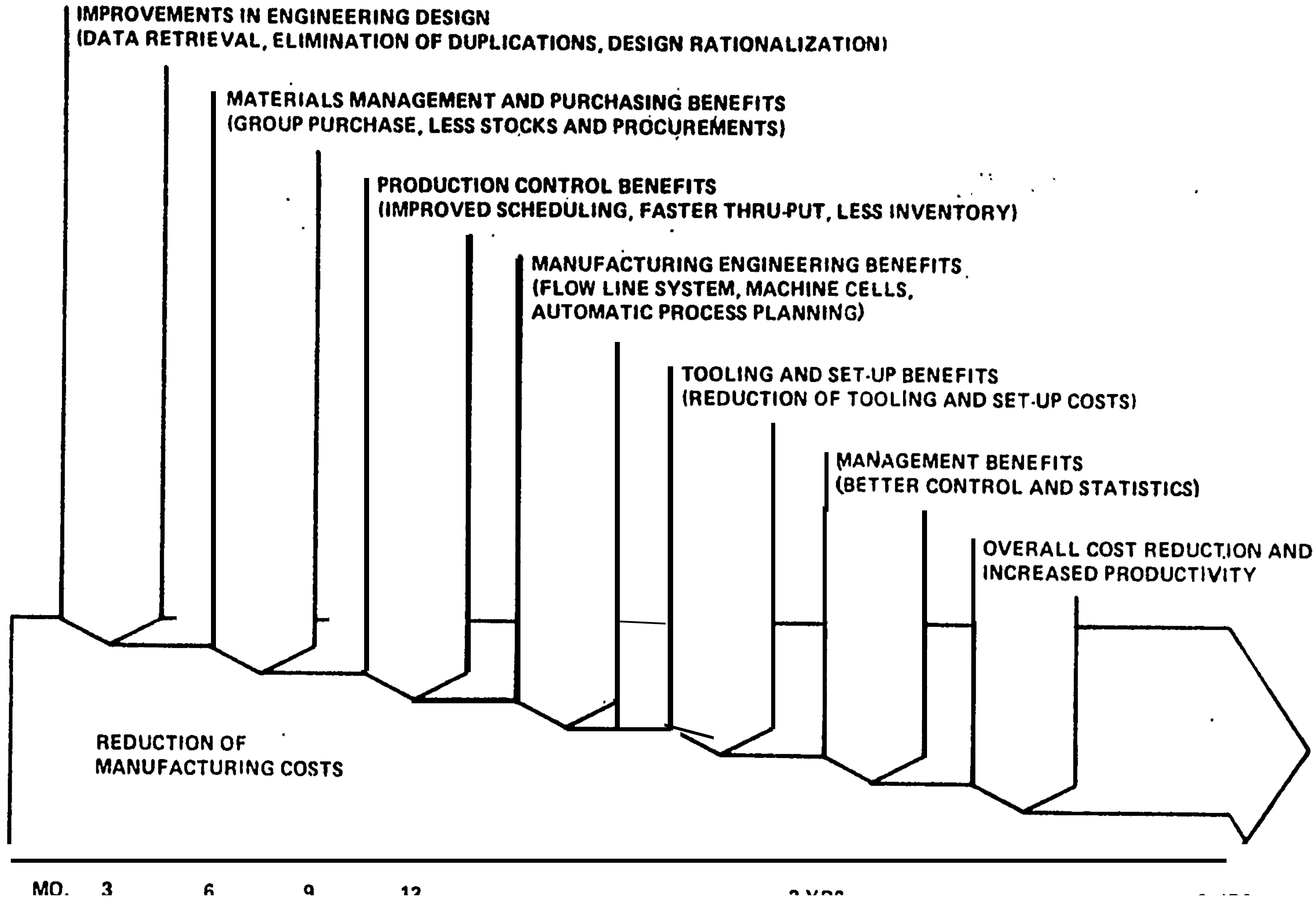


Figure 2, Reduction of manufacturing costs through Group Technology applications and approximate time required for implementation.

practiced as a systematic scientific technology. The most evident aspect of the U.S. manufacturing scene in the last few years is that it is undergoing a revolution through a critical self-evaluation for improvement of manufacturing productivity. This has led to an intensified effort in integrated computer aided manufacturing. This trend has stimulated a strong interest in Group Technology today since it provides the essential means for higher manufacturing productivity and for computer aided manufacturing, e.g. computer aided process planning, etc. (5, 6, 7, 8, 9).

One of the most important techniques in increasing manufacturing productivity is the economic incentive. Manufacturing normally contributes approximately 30% of the gross national product of modern industrialized countries. Yet in spite of that, manufacturing, although normally thought of as a highly productive and efficient activity, is not generally so. For example, this is clearly true of batch-type metalworking manufacturing environment. In the U.S. manufacturing industry, one of the significant facts to be carefully examined is the change in production trends. It has been estimated that in the next decade, about 75% of all industrial parts produced in the U.S. will be on a small-lot basis, as compared to about 25% at present (10). A recent survey on Group Technology applications in metal working in the U.S. (11) indicates that the average lot size is less than 50 pieces. The metalworking industry employs almost 40% of the total employment in manufacturing in the U.S. Thus, the potential for economic improvement of manufacturing by Group Technology is indeed not only tremendous now, but will grow with time.

It has also been reported that in batch-type metalworking shops, only about 5% of the total production time is actually spent on machine tools while the other 95% of the time is spent in moving and waiting for parts in the shop. Of that 5%, only about 30% is spent as productive time in cutting materials as shown in Fig. 3 (12). Therefore, major efforts should be made to improve this situation for higher manufacturing productivity. Improvements can certainly be achieved by proper implementation of Group Technology and by computer automated manufacturing.

Another area for improvement is more efficient utilization of expensive machine tools and work centers. To achieve the goal for implementation of computer automated manufacturing, this task is an essential requirement. Again Group Technology provides a key element toward this effort.

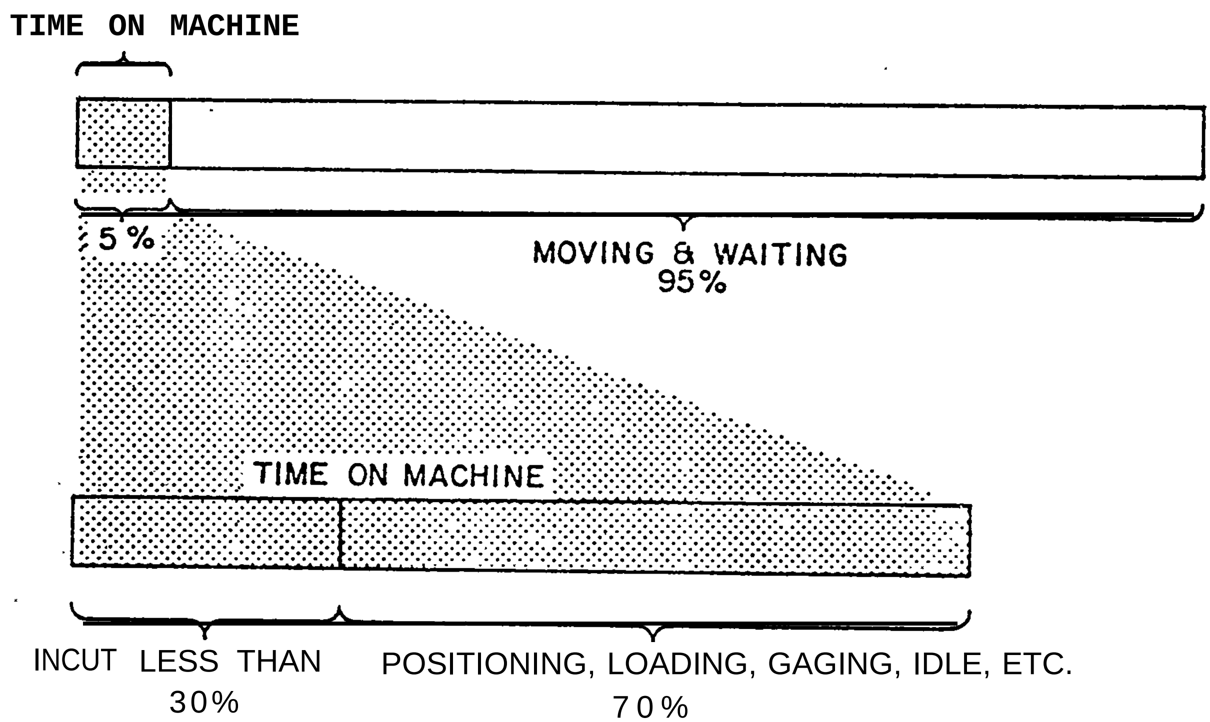


Figure 3, Percentages of the life of the average workpiece in batch-type metal-working production shops

A recent survey conducted by CAM-I (Computer Aided Manufacturing International Inc.) in April 1975 provides strong evidence of the importance of Group Technology applications for batch-type manufacturing industries, (figure 4 (13)) It can be concluded that Group Technology is one of our most important methods of solving present problems and improving manufacturing.

For these reasons, many companies in the U.S. who are related to batch-type component industries (e.g., aerospace industry) have become increasingly interested in Group Technology. The activities related to integrated computer aided manufacturing (ICAM), such as CAD/CAM and computer aided process planning (CAPP) provide more incentive four immediate interest in many sectors of U.S. industries. It is also interesting to note that many U.S. companies are also interested in Group Technology applications to justify their ever-increasing capital investments for expensive NC machines by more efficient machine loading through part family grouping.

PART FAMILIES

A part family or group is defined as a collection of related parts which are nearly identical or similar. They are related by geometric shape and size and by similar processing requirements. Alternatively, they may be dissimilar in shape, but related by having all or some common production operations.

The grouping of related parts into families is the key to the Group Technology concept. These families may be constructed in one of two ways as follows:

a) The first type of part family consists of parts which are similar in shape within a certain dimensional range and have most or perhaps all production operations in common.
b) The second type of part family consists of parts of dissimilar geometry but have a similarity in production operations.

The problem which immediately presents itself is how are the parts to be efficiently grouped into these families? There are three basic methods used to form part families, namely:

a) Manual visual search
b) Production flow analysis (Fig. 5)
c) Classification and coding systems (Fig. 6)

CAM-I INDUSTRY SURVEY

(SUMMARY)

Japan	Europe	United States	Combined		Automotive	Electrical	Aerospace	Machine Tool	Research
PRIORITIES					PRIORITIES				
4	_	_	_	Mfg. Data Base Design	4	1	1	1	
6	11	9	10	computerized Mtrl. Handling	9	11			1;
9	11	14	13	Comp. Controlled Transfer Ln.	1	12	1	1	12
3	9	13	12	Comp. Controlled Assy. Line Operations	8	9	11	10	1 0
10	7	8	5	In-Process Inspection	10	2		11	4
2	a	12	11	Die Sinking	3	8	10	13	9
7	6	2	4	schedulinq	11	3	5	3	7
4	3	10	5	n/C Verification System	11	7	4	7	1
1	7	11	7	Automated Drawing Generation	2	8 9	●	12	5
3	4	5	3	Interactive Graphics	6	1	3	8	2
5	1	4	2	Group Technology	5	6	1	5	3
11	12	6	9	Adaptive Control (A/C)	7	10	3	9	7
8	5	7	8	Direct Numerical Control(DNC)	13	4	2	4	3
12	10	3	6	Computerized Numerical Contxol	12	5	6	2	0

Figure 4, Summary results of CAM-I industrial survey (1975) on current manufacturing interests

(a) Original record from operation rout sheets

Machine No. \ Part No	A2	A3	A10	A11	A12	A16	A17	A18	A19	A20	A21	B1	B3	B5	B6	B8	B9	B11	C1	C2	C4	C6	C7	C9
042																								
404			✓													✓								
406															✓									
411	✓												✓								✓			
412					✓	✓	✓			✓	✓	✓							✓					
413				✓										✓										
416	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓			✓	✓
417									✓								✓							
420	✓		✓										✓			✓								
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423		✓	✓										✓			✓								
424						✓	✓		✓								✓							
329																								
306								✓										✓						
304								✓										✓						
312								✓										✓						
445	✓				✓	✓	✓	✓			✓	✓					✓	✓						✓
446					✓	✓	✓					✓					✓							✓
447				✓						✓			✓	✓	✓					✓		✓	✓	

(b) After sorting families and groups

Machine No. \ Part No.	A10	B8	A2	B3	C4	C7	A3	A11	B5	B9	A19	A16	A17	A20	A21	B1	C1	C2	C9	A18	B11	C6	B6
423	✓	✓		✓		✓	✓																
416	✓	✓	✓	✓		✓																	
420	✓	✓	✓	✓																			
404	✓	✓																					
411			✓	✓	✓																		
413	Group 1							✓	✓														
417										✓	✓												
416										✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
412												✓	✓	✓	✓	✓	✓						
424										✓	✓	✓	✓				✓						
306																	✓						
421																			✓	✓	✓	✓	
306												Group 2								✓	✓		
304																				✓	✓	?	
312																				✓	✓		
406																			Group 3				✓

Figure 5, Example of Production flow analysis

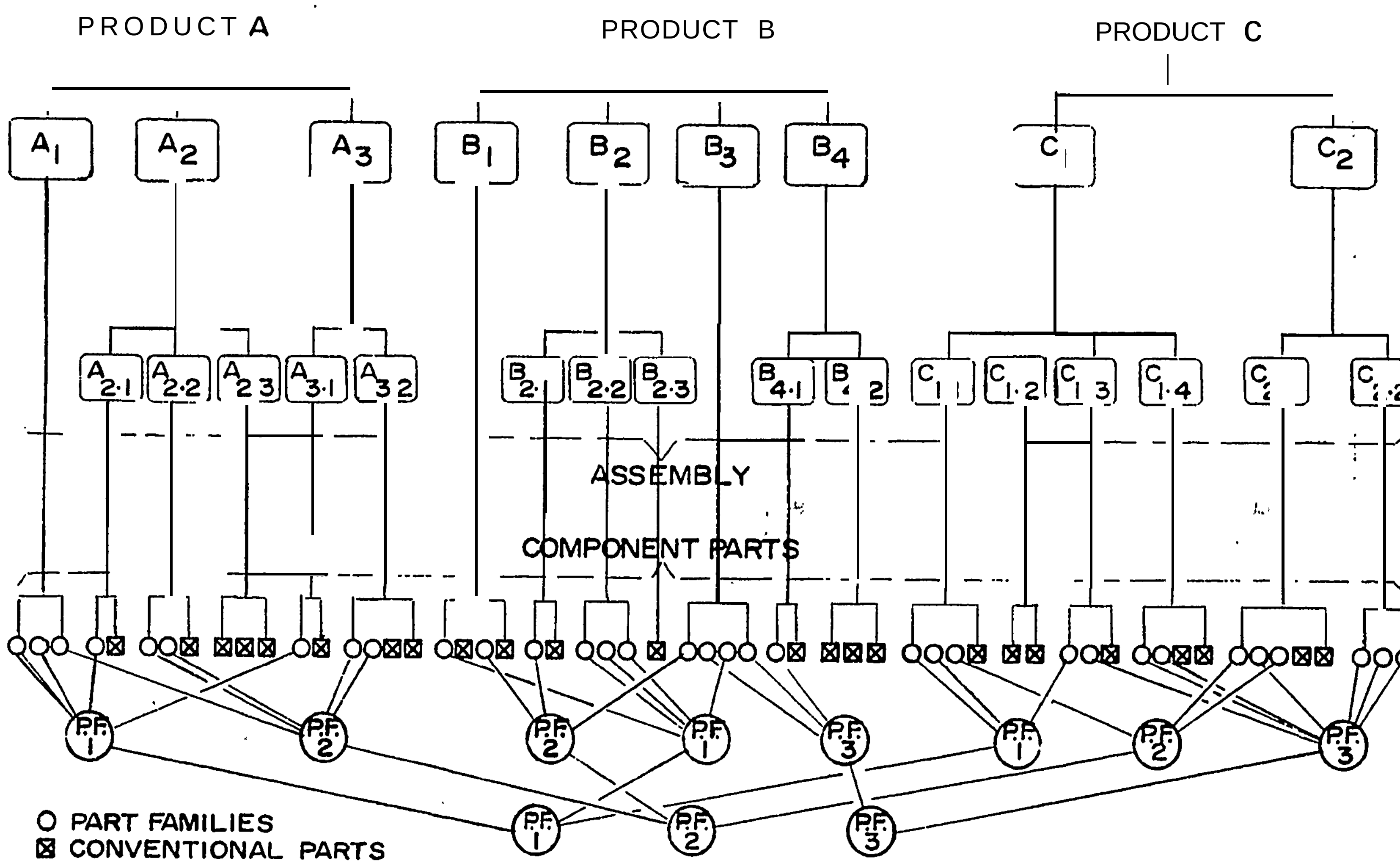


Figure 6, Schematic diagram for formation of part families

CLASSIFICATION AND CODING

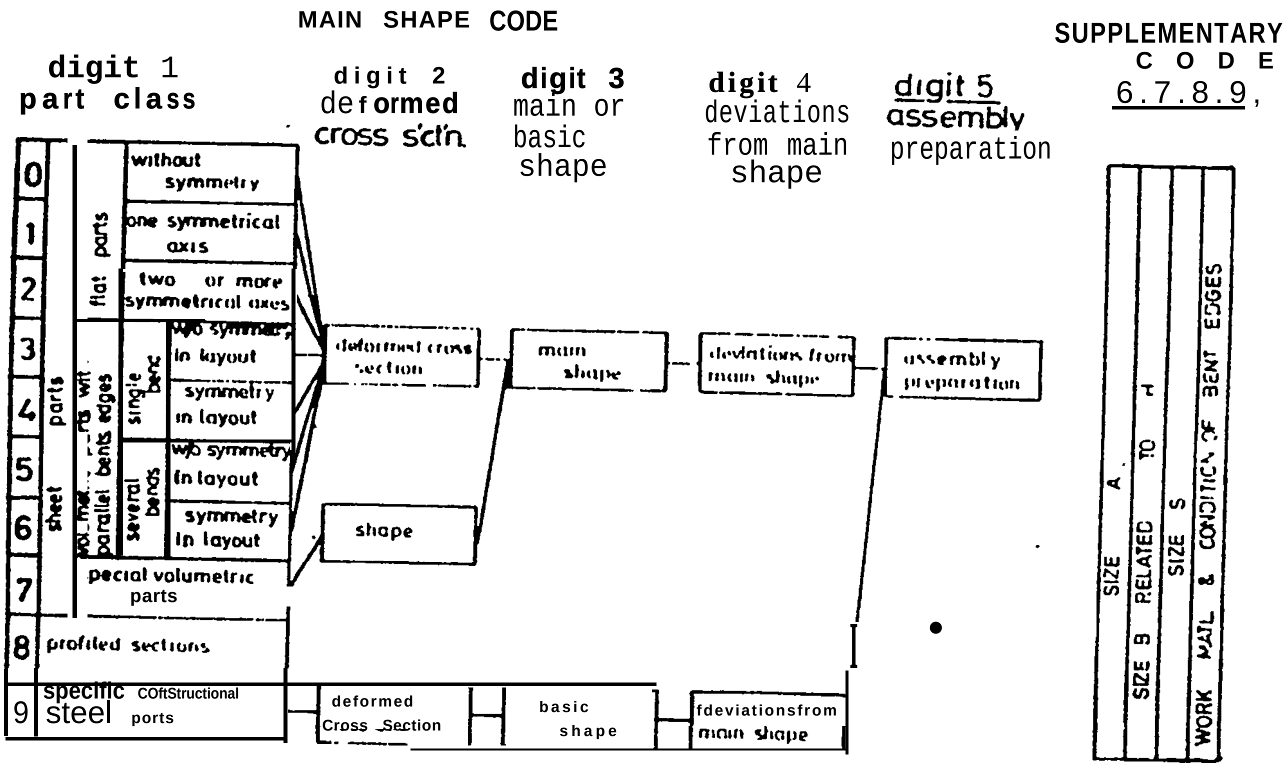
Classification is arranging items into groups according to some principle or system whereby like things are brought together by virtue of their similarities, and then separated by a specific difference. A code can be a. system of symbols used in information processing in which numbers or letters or a combination of numbers and letters are given a certain meaning.

There are many varieties of classification and coding systems being used around the world. The best coding system is one which is properly adapted to meet the specific needs of the company where it is being used. A company can devise its own unique system based upon publicly available systems or adapt a commercially available system to meet its needs. It is essential that an adapted system be applicable to and usable by all concerned departments in the company, including design, engineering, planning, control, manufacturing, tooling, management.

A well-designed classification and coding system for Group Technology implementation should meet several basic requirements. (Fig. 7)

DESIGN DATA RETRIEVAL

An important application of a good classification and coding system is in connection with design data retrieval and rationalization. Not only design information, but material specification, production planning and other production information can be readily available. All relevant production information can be retrieved for scheduling, group machining, group tooling and set-up. A classification and coding system also facilitates a part reduction and standardization program which can be valuable to the company as well as to customers of the company. It has been reported (11) that an average cost of introducing a new part into engineering and manufacturing systems is around $1,300 to $2,500 (average $1,900) per part. One company reported that about 2,500 new parts were released annually (thus an average of ten new parts every day), while about 30,000 active parts were in their design files. It can be estimated that the annual cost of new part introductions in this company approximates $4,750,000 per year (=2,500 parts x $1,900 per part). It is clear much can be saved by eliminating the duplication of parts thus reducing the number of new parts. It has also been reported that about 5 to 10% of new parts can be avoided by the proper use of classification and coding systems. Thus, the company re-



Developed in West Germany at Aachen Technical University around 1970. The coding system consists of five numeric primary digits and four numeric secondary digits. The code describes parts as sheet or profiled components and further defines them according to shape, cross-section and necessary preparation. The supplementary code covers main dimensions, thickness and material.

Figure 7, Example of sheet metal classification and coding system (23).

ferred to can save about $237,500 to $475,000 per year in the reduction of duplicated designs.

MACHINE GROUP

There are three types of plant layout, namely: a) line layout, b) functional layout, and c) group layout. In the practice of Group Technology, a group of machines for a part family or more may be formed such that it can perform all the operations required by the family or families of parts. The machines themselves are arranged in a flow line to minimize transportation and waiting problems. The result is very similar to a modern machining center. If conditions warrant, a machining center may be used instead of a group of single purpose machines. An example of a group layout of machine tools based upon the G.T. concept as compared with a conventional functional layout is shown in Fig. 8. This illustrates the advantages of a group layout.

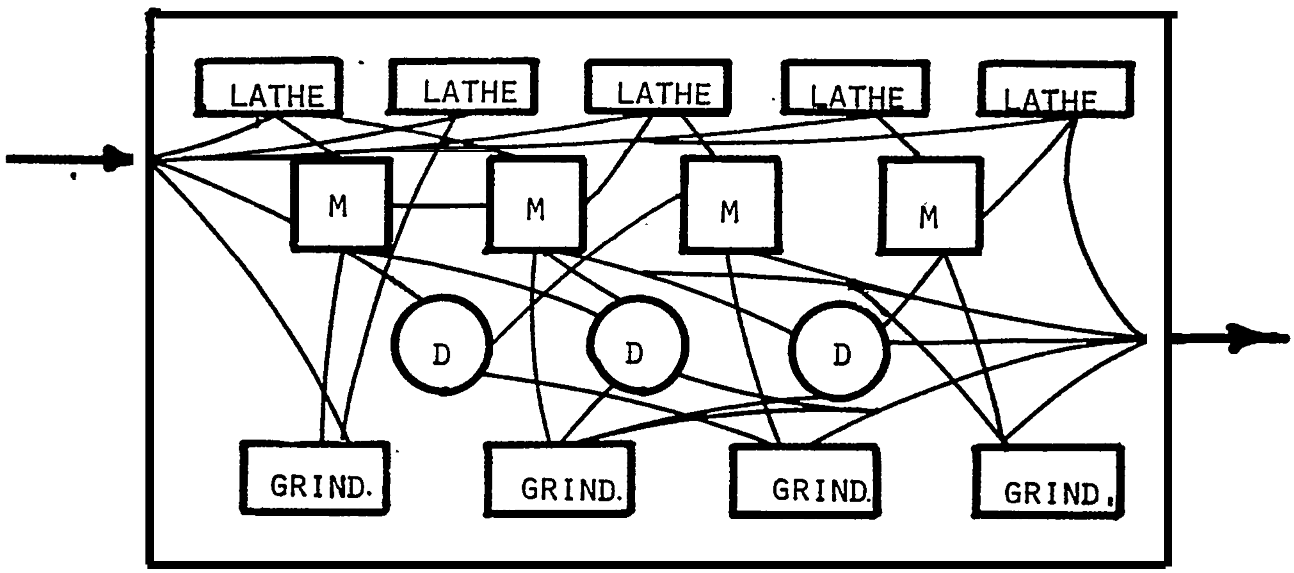
COMPOSITE PARTS

The composite component provides production aid for the application of G.T. in the standardization of parts, machine grouping, designing of group jigs and fixtures, the planning of group tooling set-ups, and standardization of process routings. Fig. 9 illustrates a group of parts represented by a composite component which possesses all the shape characteristics and processing features of a part family. If tooling is developed for the composite component, then any part in the family can be processed with the same tooling.

GROUP JIGS, FIXTURES AND TOOLING SET-UPS

To get the maximum utilization from tooling set-ups, tooling for the operations within a part family should be arranged so that all the parts, or as many as possible, in a family can be processed with one group type fixture and/or one set-up. Group jigs and fixtures are designed to accept every member of the family. An example of such a group jig for drilling a part family is shown in Fig. 10. To drill the holes of eight (8) different parts in this part family, it requires only one group jig and eight (8) different auxiliary adapters to accommodate some differences in sizes, numbers, and locations of the holes. Therefore, instead of designing, fabricating, and using eight indivi-

(a) Complicated work-flow system with functional layout



(b) Simple work-flow system with group layout

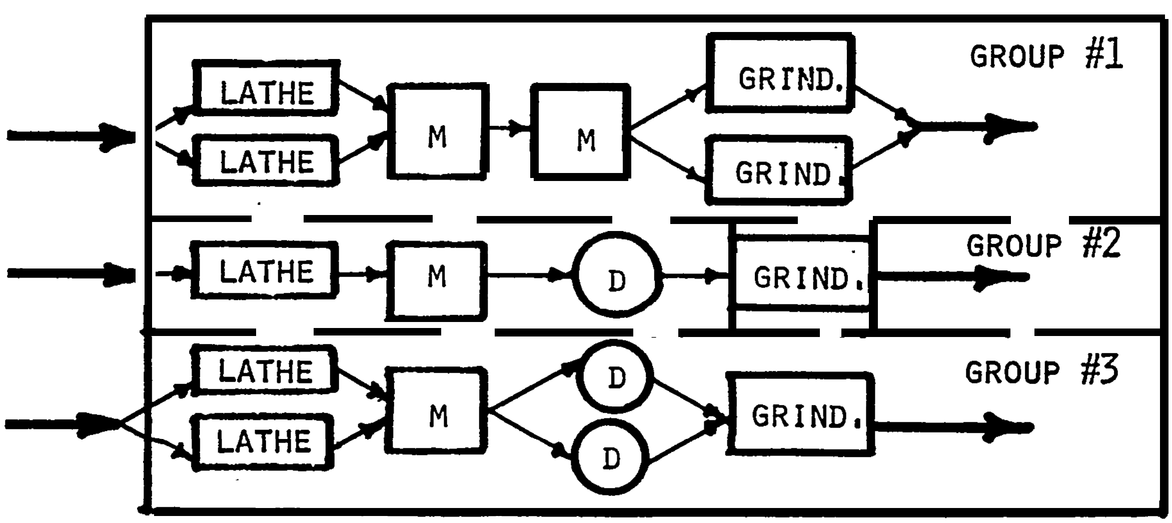


Figure 8, Comparison of functional and qroup layouts of machines: D = drill press, M = milling **Machine**

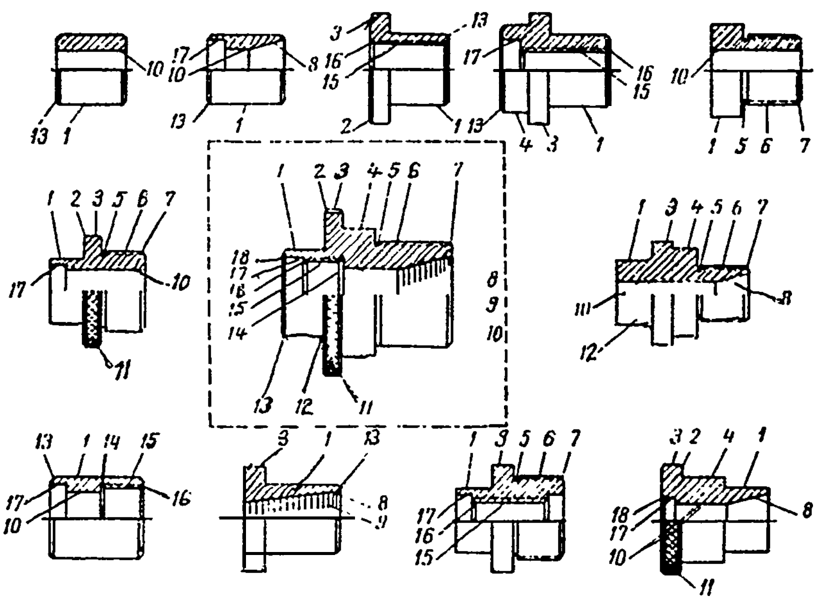


Figure 9, Example of typical composite part

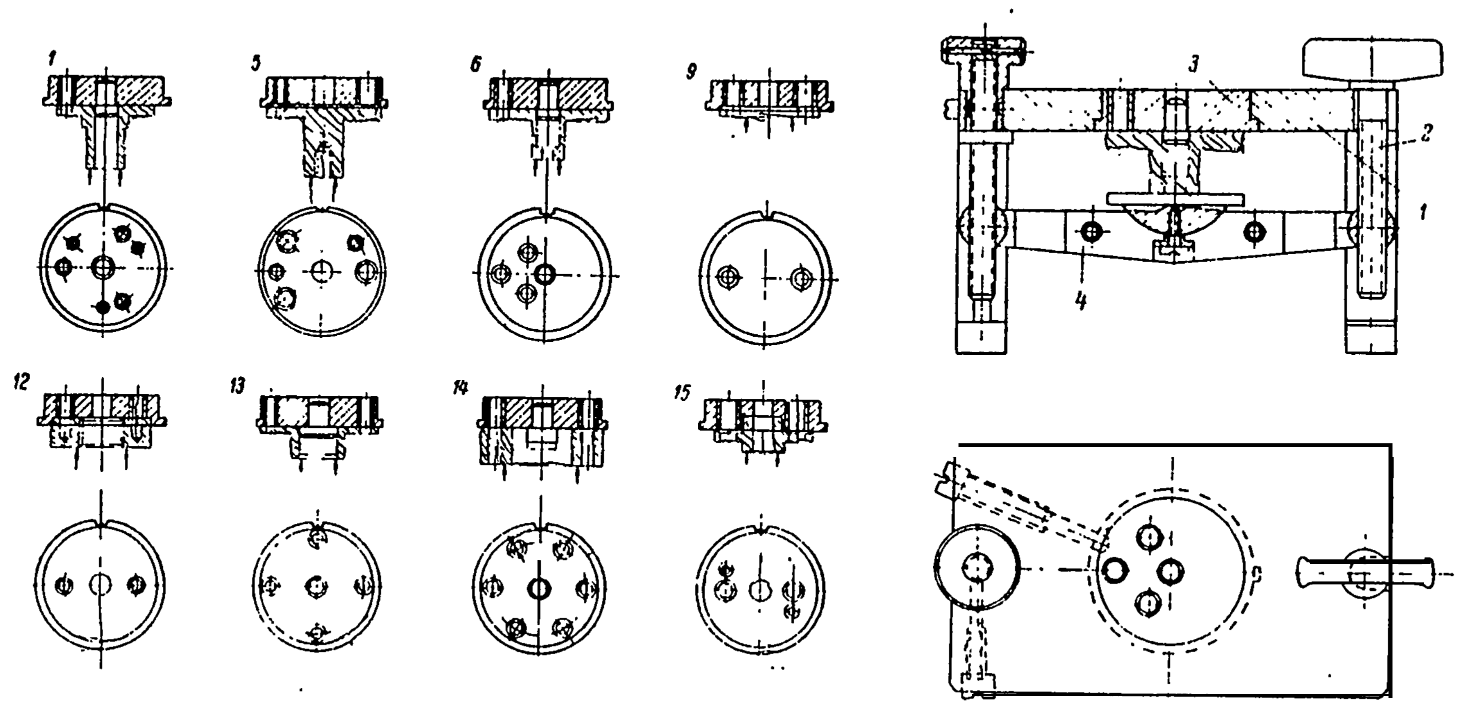


Figure 10, Example of a group drill jig and adapters used for drilling 8 different parts in a part family dual drill jigs as is done in a conventional production method, only one group jig and eight (8) adapters are required for the same jobs. It becomes clearly evident how much tooling costs can be reduced using Group Technology.

NC PART FAMILY PROGRAMMING

One of the important applications of Group Technology is software development for NC machining. This is referred to as "Part-family Programming" (15). Part-family programming is an NC program system that groups common or similar program elements into a single, master computer program. The master computer program, or pre-processor, is a permanent base from which an NC tape can be prepared for any part in the part-family. Therefore, part-family programming increases the productivity of costly NC operations by saving programming time, manpower, and tape prove-out time. It also reduces lead time, tool inventory, and simplifies maintenance and requires fewer computer reruns.

COMPUTER AIDED PROCESS PLANNING

One of the essential requirements for the implementation of CAD/CAM is computer aided process planning. The use of an automated process planning technique is a basis for a rational and logical approach to improve manufacturing productivity in a CAD/CAM system.

It has been recognized that Group Technology is an essential element for the successful execution of computer automated process planning. As indicated in the flow diagram proposed by CAM-I (Fig. 11), the logical approach to successful automated process planning is a system based on the part family concept of Group Technology. The development of part families, using suitable classification and coding systems, will make it possible to systematically form part families and thus rationalize and develop standards of shape and process within the part families, making it possible for the automatic generation of process plans.

FLOW DIAGRAM

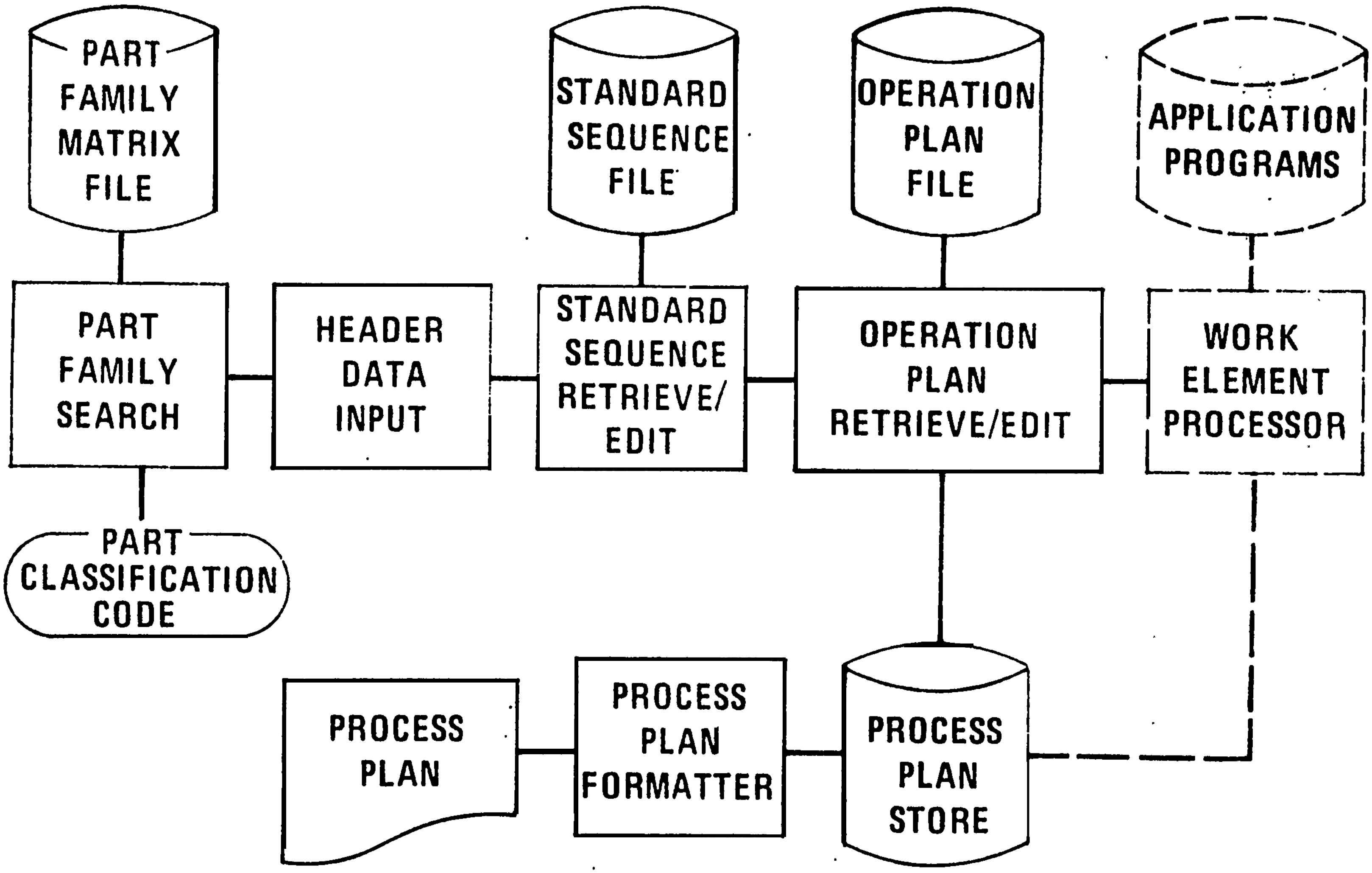


Figure 11, Flow diagram for computer aided process planning by CAM- I (8)

PRODUCTION CONTROL AND SCHEDULING

Production scheduling is greatly simplified by Group Technology. The scope of the problem is reduced from that of a large portion of the shop to a small group of machines. If the families of parts and groups of machines have been formed correctly, each job will indicate by its code number which group of machines will process it. Within the group of machines the scheduling problem is again reduced to simply scheduling the given jobs through the machines in a cell. A computer program can be set up to schedule jobs of a part family to a corresponding machine group/cells. The jobs can be properly sequenced in the family and the families properly sequenced through the machine groups/cells.

Proper scheduling is an integral part of Group Technology. When combined with reduced set-up time and reduced transportation, two significant cost reduction benefits can be effected. The most obvious benefit is reduction of total production time. With reduction of production time, inventories can be reduced substantially and production work can proceed on schedule. At the same time, scheduling becomes reliable to guarantee the delivery date with greater assurance. Let us call production scheduling associated with G.T. applications "Group Scheduling" (16). Proper application of Group Technology will result in:

a) Reduction of set-up times and costs.
b) Optimal decision of group and job sequences.
c) Possibility of flow-line production.
d) Optimum group layout.
e) Over-all economic advantages.

As uses of computers have become more popular in various manufacturing activities, one of the most successful innovations in the area of manufacturing inventory management is embodied in what has become known as Material Requirements planning (MRP) Systems (17). Since Group Technology applications directly relate to and influence various planning and inventory activities, it is important to consider the interrelationships between group scheduling and MRP. There are already several companies who have successfully implemented both G.T. and MRP in production applications.

ADMINISTRATIVE PROBLEMS

a) PERSONNEL PROBLEMS

In group production methods when a job is assigned to a machine group/cell, it is processed under-given production operations by that one group. The flow of production information into or out of the shop becomes both easier and more accurate with the group production method. Since all the jobs in a group are confined to a relatively small area of the shop and a small group of men, the group supervisor can have immediate knowledge of the state of completion of all the jobs in the group.

b) SOCIAL PROBLEMS

As Group Technology has become more accepted, it has also become apparent that efficiencies obtained through Group Technology applications are not determined entirely by its technical characteristics. Additional factors of a social nature are making an important contribution, and these are among the major appeals which Group Technology is making to behavioral scientists (18). It offers some solutions to job satisfaction such as worker involvement in decision-making, personalized work relationships, variety in tasks, freedom to determine methods, group production methods, etc.

MANAGEMENT PROBLEMS FOR G.T. IMPLEMENTATION

Installation of the system calls for a high degree of cooperation between a number of groups or departments in the firm. Personnel in design engineering, planning controls, tooling, and the production shop itself must realize how dependent each group is on the others. This level of communication and cooperation is often lacking. It is absolutely essential if Group Technology is to be implemented successfully.

It is a common phenomenon that a great deal of suspicion follows any form of change to an existing pattern of life, whether this change is within an industrial environment or entirely outside of it. Group Technology will not only change the pattern of work environment for many of the employees in a company, but it will also demand a new form of thinking. For successful implementation of Group Technology, the cooperation of everyone concerned is essential. It is recommended that an ad-hoc committee be formed to plan the company-wide G.T. implementation. This committee should be headed by a senior executive who can get close coordination between the involved departments.

FUTURE TRENDS OF GROUP TECHNOLOGY

A forecast of the future of production technology advancement, carried out by both the University of Michigan (19) and the International Institute for Production Engineering Research (CIRP) (20), strongly indicated that the computer automated factory would be a full-blown reality well before the end of this century. It is especially interesting to note that the survey by the University of Michigan researchers predicts that by 1988 more than 50% of industry will use Group Technology in manufacture, while the survey by CIRP indicates that by 1990 70% of industry will use Group Technology in manufacture. It is evident that new technological innovations, such as DNC, CNC, machining centers, industrial robots, micro-processors, etc., will be continuously introduced toward more automated computer integrated manufacturing systems involving CAD/CAM, and thus lead to more integrated applications of Group Technology for optimum manufacturing and higher productivity. The recent effort by a USAF I-CAM project is a positive approach to achieve those objectives (21).

A part classification system, which is an integral part of and has been used as an essential tool of Group Technology applications, can also be evolved as a means of describing parts in a form that can be integrated readily into a computer data base structure which will link design and production. Such a part descriptive classification system identifies and codes basic shape elements such as cylinders, rings, cones, cubes, etc. These basic shape elements are further expanded to include chambers, keyways, threads, and so forth. These shape elements should be selected so that they correspond to groupings of tooling set-ups, machines or machine stations using Group Technology concepts, and also to provide bases for computer automated process planning. Also as evolution of CAD\CAM leads to generative design and to generative process planning, certain part classification and coding systems will become an integral part of the total generative system evolving with CAD\CAM.

Group Technology is a dynamic and revolutionary development which continues to expand its influence on manufacturing systems. It is evident that the role of Group Technology will certainly be broadened with more innovative advancements in theory and application, not only for improving productivity in conventional batch-type manufacturing systems, but also for proper adaptation of CAD/CAM systems.

APPLICATIONS "OF GROUP' TECHNOLOGY

IN SHIPBUILDING INDUSTRY

Two major areas of shipbuilding in which Group Technology application might be considered relevant are:

(1) Component production by group/cell method.
(2) Assembly unit construction.

There are several classification and coding systems designed for sheet metal works (22, 23, 24, 25, 26) and some of them were applied to a ship hull component classification system as an effort for Group Technology implementation in the shipbuilding industry (27).

Some potential benefits of Group Technology applications for the shipbuilding industry are as follows:

(1) Improved production through group/cell production method for cutting, preparation and assembly of steel work.

(2) Design rationalization and improved production planning through effective data retrieval for component size, shapes, variety and production methods.

(3) Rationalization of raw material supply and preparation through standardization and improved inventory control.

(4) Adaptation to computerized automatic process planning and other management information systems.

(5) Variety reduction and standardization of proprietary purchased items.

(6) Rationalization for pipework and pipe fitting and assembly for ship fitting-out process.

(7) Improvement of shipyard organization and layout through group production method.

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