MANUFACTURING SYSTEM

Planning Manufacturing Systems: When planning manufacturing systems, the degree of automation that can economically be justified must be considered. Experience has shown that the most successful ones are those which are not fully automated.

I. Group Technology
II. Process Planning
III. Production Scheduling

Group Technology (GT) in Manufacturing

- Parts in the medium production quantity range are usually made in batches
- Disadvantages of batch production:
    - Downtime for changeovers
    - High inventory carrying costs
- <u>GT minimizes these disadvantages</u> by recognizing that although the parts are different, there are groups of parts that possess similarities

Overview of Group Technology in Manufacturing

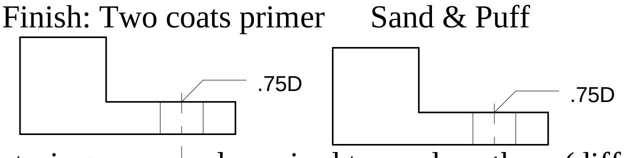
- An approach to manufacturing in which similar parts are identified and grouped together in order to take advantage of their similarities in design and production
- The improvement is typically achieved by organizing the production facilities into manufacturing cells that specialize in production of certain part families
- GT can be implemented by manual or automated techniques
- When automated, the term *flexible manufacturing system* is often applied

I. Group Technology

Definition: GT is a manufacturing concept in which similar parts are grouped together in parts groups families.

i). In their Design characteristics (differ in the production processes)

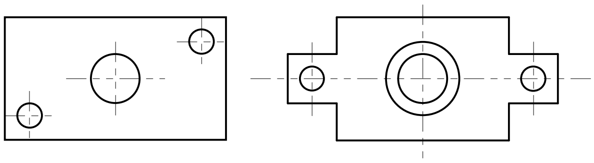
#1	#2
Cold rolled steel	Aluminum
tolerance: ±0.0125“	±0.003"
Finish: Two coats primer	Sand & Puff



ii). In the manufacturing processed required to produce them (differ design)

GT exploits the part similarities by utilizing similar processes and tooling to produce them

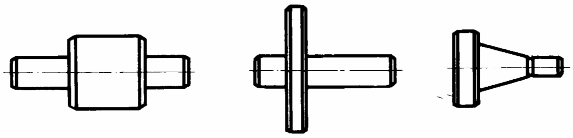
#1	#2
Material: SS	SS
Tolerance: ±0.002"	±0.002"



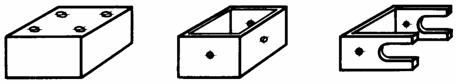
Part family concept

- A part that has been designed for manufacturing usually has to be produced by several succeeding manufacturing operations. If there is a large spectrum of parts to be produced, it will be necessary for workpieces to share common processing equipment.
- It is advantage to group parts together to families either according to their geometric similarities or to similar fabrication methods.

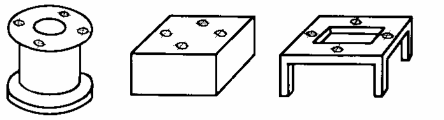
- A change of parts would only require a new part program to generate a new contour. The parts form a design family, they are similar in design, and in this case can also be produced by a similar manufacturing process.



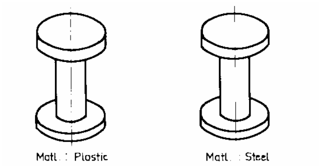
- The cubical parts which are not very similar any more; however, they also form a production family and can be made on the same multi-axis machining center.



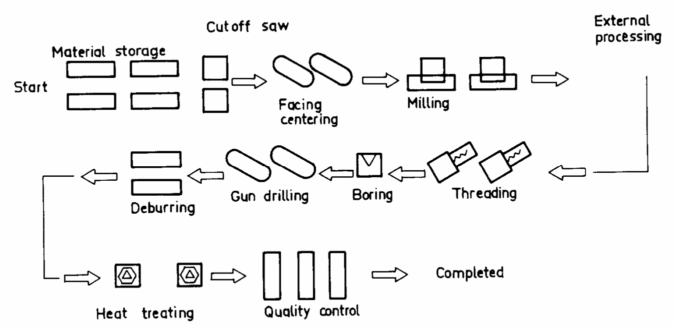
- The dissimilar parts requiring at least one common process, which is to drill four holes. In this case, the other processes needed to shape the part would have to be done with different machine tools. These parts are typical for companies producing a wide spectrum of products.



- Two completely identical designed parts, one made from plastic and the other from steel. The manufacturing processes would be injection molding for the plastic reel and turning for the metal reel. In this case we have a common design family; however, the production processes are unrelated.



- If the parts were to be manufacturing according to group technology considerations, the plant would have to be realigned.



- The production process assumes a flow line operation with machine tools located in the flow line where they are needed. It can readily be seen that intra-plant transportation is minimized. Setup operations and tool changes are also reduced.

Ways to Identify Part Families

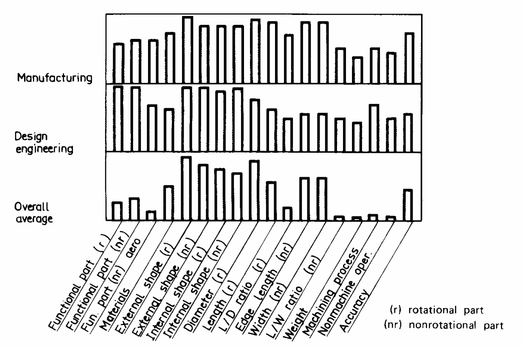
1. *Visual inspection* - using best judgment to group parts into appropriate families, based on the parts or photos of the parts
2. *Production flow analysis* - using information contained on route sheets to classify parts
3. *Parts classification and coding* - identifying similarities and differences among parts and relating them by means of a coding scheme

Classification Procedures

- With group technology the workpieces and machining operations have to be classified. This implies that a suitable method of coding must be found which can easily be used for manual method or computer-aided classification procedures.
- With **the manual method** the description of parts and processed are cataloged. When a

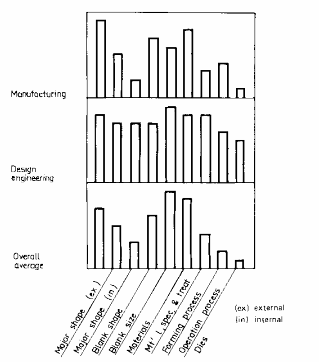
workpiece is scheduled for production, a catalog search is made to find a suitable manufacturing process and sequence.

- When **the computer** is used, the information about the part and the fabrication process is stored in a memory peripheral and the manufacturing data are retrieved automatically.
- One of the main difficulties for coding is to decide which parameters are important for classification. No rigid rule can be given since the parameters may vary, depending on the part spectrum. A common practice is to separate **rotational** from **non-rotational** parts.
- Classification by shape usually determines the manufacturing process, whereas the function is of interest to the designer. If a part that has similar functions is already in existence, the designer does not have to duplicate it.
- The result of an industry survey where different parameters for typical workpieces were ranked in order of importance. The most important ones are candidates to be included in a classification system



Comparative rankings for major parameters

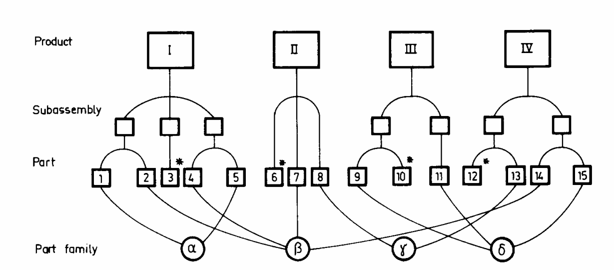
- Example: A similar study with sheet metal parts. The major shape, the material, and the material specification had the highest ranking.



Comparative rankings for major parameters

Other Classification Consideration:

- For classification there are also many processing parameters that must be taken into consideration. This means that the types of processes within the plant and their limitations must be known.
- Tool changes and setup times usually add considerably to processing cost. Similarly, the number of machining sequences should be kept to a minimum. The entire machining operation should be controllable by one operator; otherwise, difficulties may be encountered during rescheduling of production runs.
- One of the most difficult tasks is to balance the load of available machine tools. In adverse conditions it may even happen that most operations are done on only a small number of machine tools and that the rest of the machines are underutilized. This may require an unduly large effort to balance machine tools.
- There are many parts that cannot be handled by any known classification method. It is important to perform economic studies when group technology is introduced and to limit its application to parts that can be grouped together in a family reasonably well.



A structured bill of materials and common part families *, no part family found.

- In this example group technology can be applied to only about two-thirds of the parts at the lowest level. This figure shows the importance of investigating the entire product spectrum.

Classification and Coding:

1. Design Attribute Group
   - Dimensions
   - Tolerances
   - Shape
   - Finnish
   - Material
2. Manufacturing Attribute Group
   - Production process
   - Operational time
   - Tools required
   - Fixtures required
   - Batch size
3. Combined

Benefits of Classification:

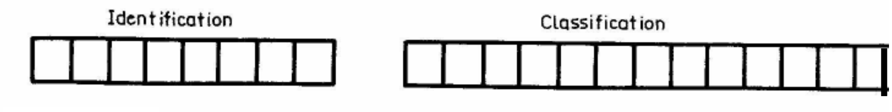
I. Engineering
- Reduction of number of similar parts
- Elimination of duplication parts
- Identification of expensive parts
- Reduction of drafting efforts
- Easy retrieval of similar functional parts
- Identification of substitute parts

II. Equipment Specification and Facility Planning
- Flow line layout of production equipment
- Location of bottlenecks
- Location underutilized machine tools
- Reduction of part transportation times
- Improvement of facility planning

III. Process Planning
- Reduction of number of machining operations
- Shortening of production cycles
- Improvement of machine loading operation
- Easier prediction of tool wear and tool changes

IV. Others

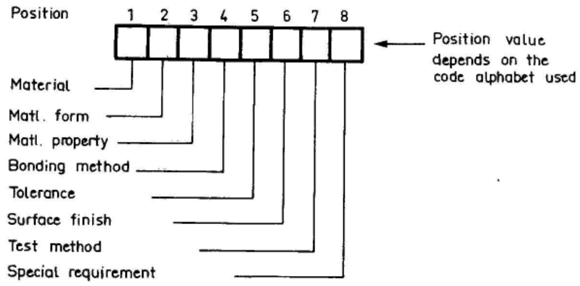
Code Number System:



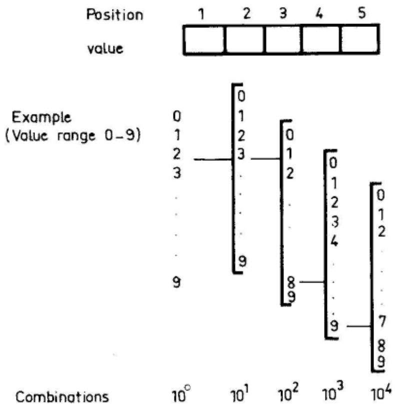
Typical structure of a part number.

3 basic code structure used in GT applications

1. Chain-Type Code Structure (Polycode)



2. Hierarchical Code Structure (Monocode and Tree Structure)



3. Hybrid Code Structure

Some of the important systems

- Opitz classification system – the University of Aachen in Germany, nonproprietary, Chain type.
- Brisch System – (Brisch-Birn Inc.)
- CODE (Manufacturing Data System, Inc.)
- CUTPLAN (Metcut Associates)
- DCLASS (Brigham Young University)
- MultiClass (OIR: Organization for Industrial Research), hierarchical or decision-tree coding structure
- Part Analog System (Lovelace, Lawrence & Co., Inc.)

Basic Structure of the Opitz Parts Classification and Coding System

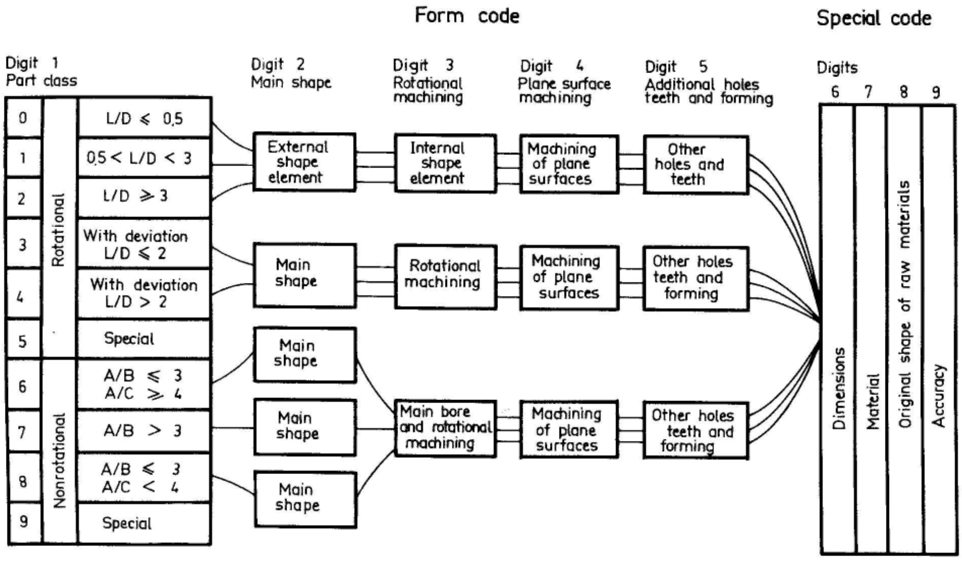
Digit	Description
1	Part shape class: rotation versus nonrotational Rotational parts are classified by length-to-diameter ratio. Nonrotational parts by length, width, and thickness.
2	External shape features; various types are distinguished.
3	Rotational machining. This digit applies to internal shape features (e.g., holes, threads) on rotational parts, and general rotational shape features for nonrotational parts.
4	Plane machined surfaces (e.g., flats, slots).
5	Auxiliary holes, gear teeth, and other features.
6	Dimensions—overall size.
7	Work material (e.g., steel, cast iron, aluminum).
8	Original shape of raw material.
9	Accuracy requirements.

1. **The Opitz Classification System** (Developed by the Technical University of Aachen): the code number has a maximum of 13 positions. Each position may assume 10 different values (attributes).

Basic structure of the Opitz system

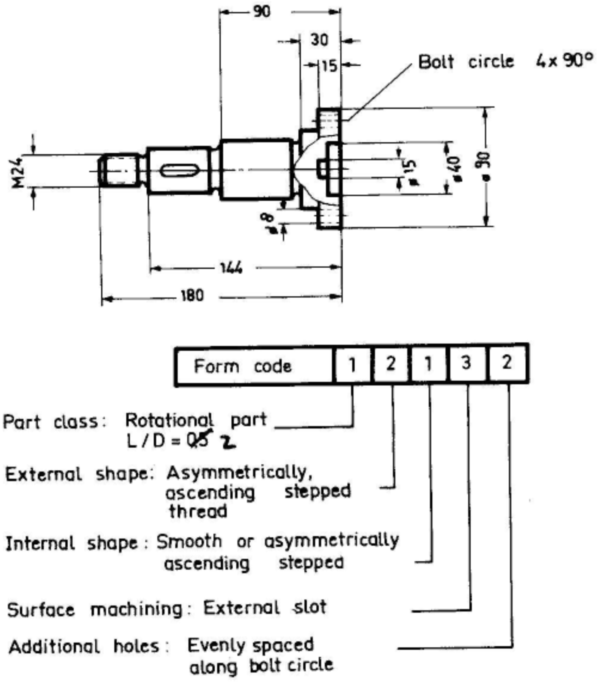
1 2 3 4 5	6 7 8 9	A B C D
Form Code	Supplementary Code	Secondary Code

- Form code: describes the primary design attributes of a part
- Supplementary code: describes manufacturing related attributes
- Secondary code: more detail of manufacturing attributes

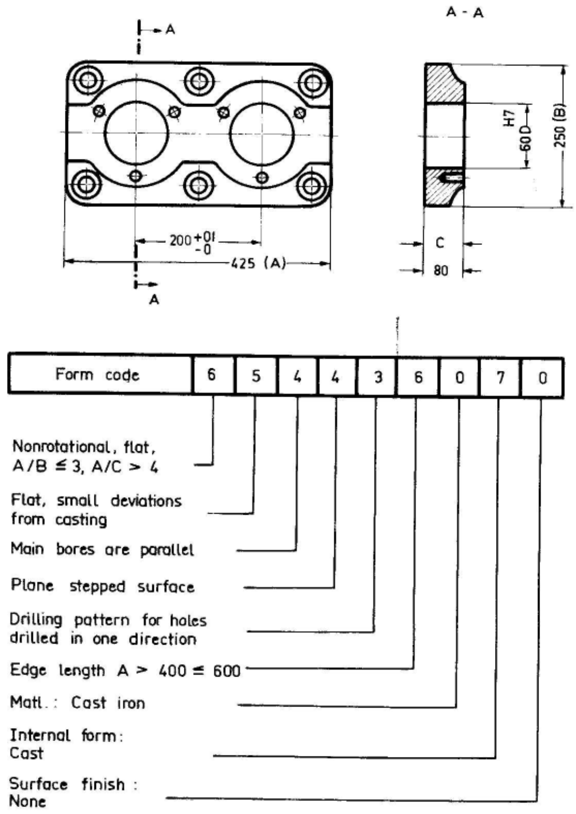


Code	Digit 1: Part class		Digit 2: External shape, external shape elements		Digit 3: Internal shape, internal shape elements		Digit 4: Plane surface machining	Digit 5: Auxiliary holes and gear teeth	
0	Rotational parts	L/D ≤ 0.5		Smooth, no shape elements		No hole, no breakthrough	No surface machining	No gear teeth	No auxiliary hole
1	Rotational parts	0.5 < L/D < 3	Stepped to one end or smooth	No shape elements	Smooth or stepped to one end	No shape elements	Surface plane and/or curved in one direction, external	No gear teeth	Axial, not on pitch circle diameter
2	Rotational parts	L/D ≥ 3	Stepped to one end or smooth	Thread	Smooth or stepped to one end	Thread	External plane surface related by graduation around a circle	No gear teeth	Axial on pitch circle diameter
3	Rotational parts		Stepped to one end or smooth	Functional groove	Smooth or stepped to one end	Functional groove	External groove and / or slot	No gear teeth	Radial, not on pitch circle diameter
4	Rotational parts		Stepped to both ends	No shape elements	Stepped to both ends	No shape elements	External spline (polygon)	No gear teeth	Axial and/or radial and/or other direction
5	Rotational parts		Stepped to both ends	Thread	Stepped to both ends	Thread	External plane surface and / or slot, external spline	No gear teeth	Axial and/or radial on PCD and/or other directions
6	Nonrotational parts		Stepped to both ends	Functional groove	Stepped to both ends	Functional groove	Internal plane surface and/or slot	With gear teeth	Spur gear teeth
7	Nonrotational parts			Functional cone		Functional cone	Internal spline (polygon)	With gear teeth	Bevel gear teeth
8	Nonrotational parts			Operating thread		Operating thread	Internal and external polygon, groove and or slot	With gear teeth	Other gear teeth
9	Nonrotational parts			All others		All others	All others	With gear teeth	All others

Form code for rotational parts of the Opitz system

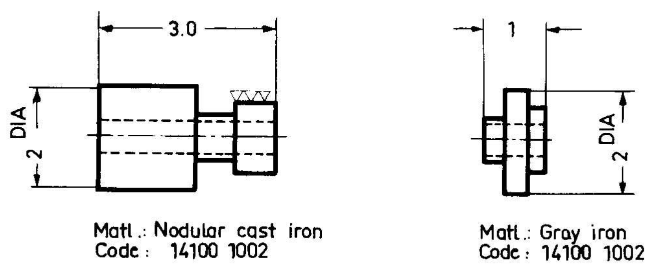


Example of Classification of a rotational part

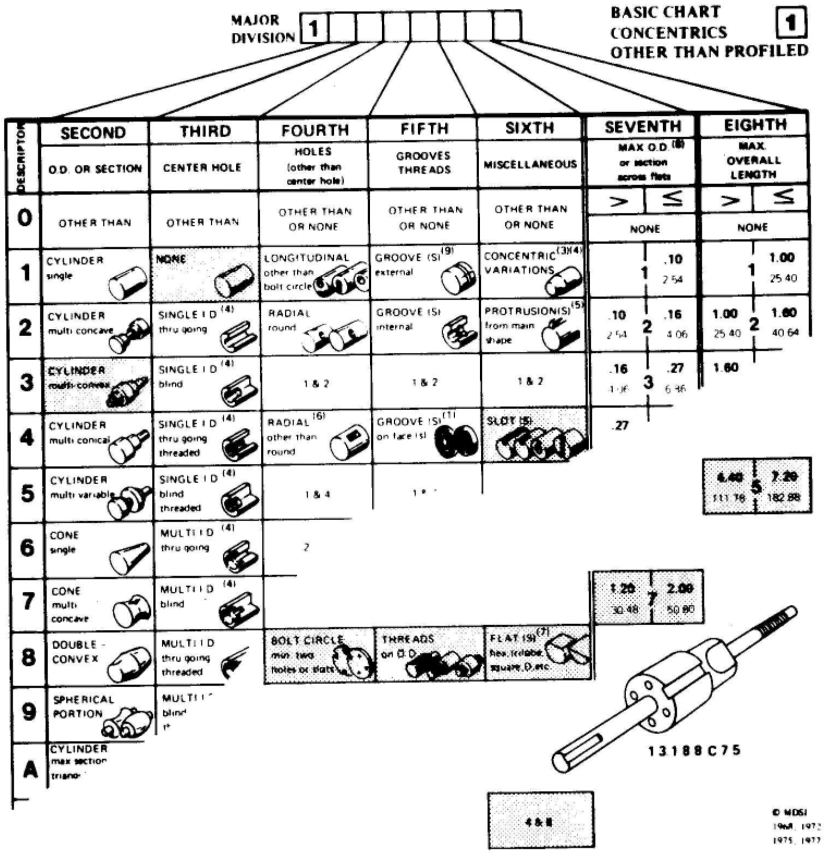


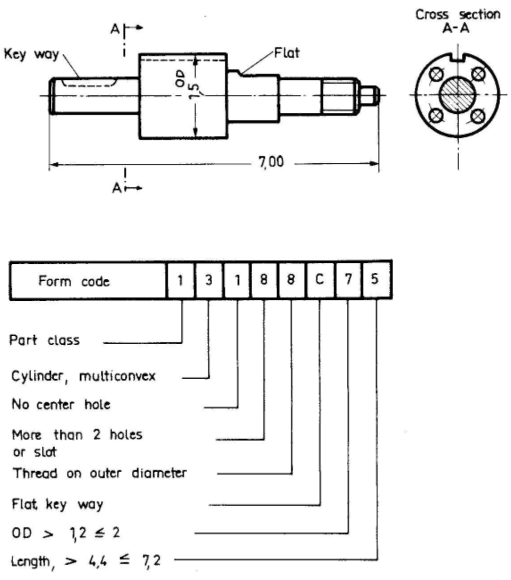
Example of Classification of a square cast-iron flange classified by the Opitz system

Possible ambiguity with a coding system



2. CODE System (Developed by industry and is marketed by Manufacturing Data System Inc.)





Example of a workpiece coded by the CODE system

3. MICLASS System (Developed in the Netherlands): the abbreviation is derived from the name Metal Institute Classification System.

Developed to help automate & standardize a number of design, production and management function.

These include:

- Standardization of engineering drawings
- Retrieval of drawings according to classification
- Standardization of process routing
- Automated process planning
- Selection of parts processing on particular group of machine tools

- Machine tool investment analysis etc.

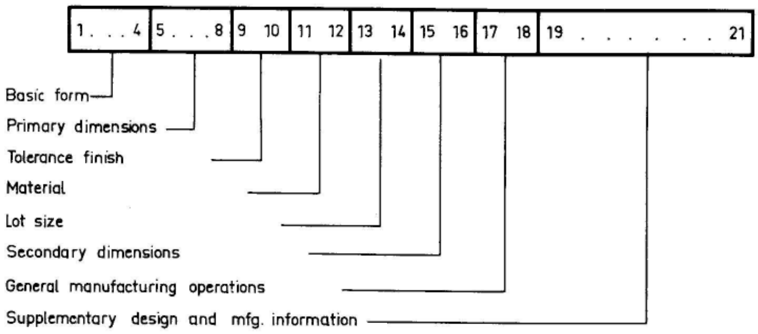
The System consists of 30 digits (maximum)

1 2 3 4 ..... 12 13 14 15 30

Universal Code — *(for any part)*

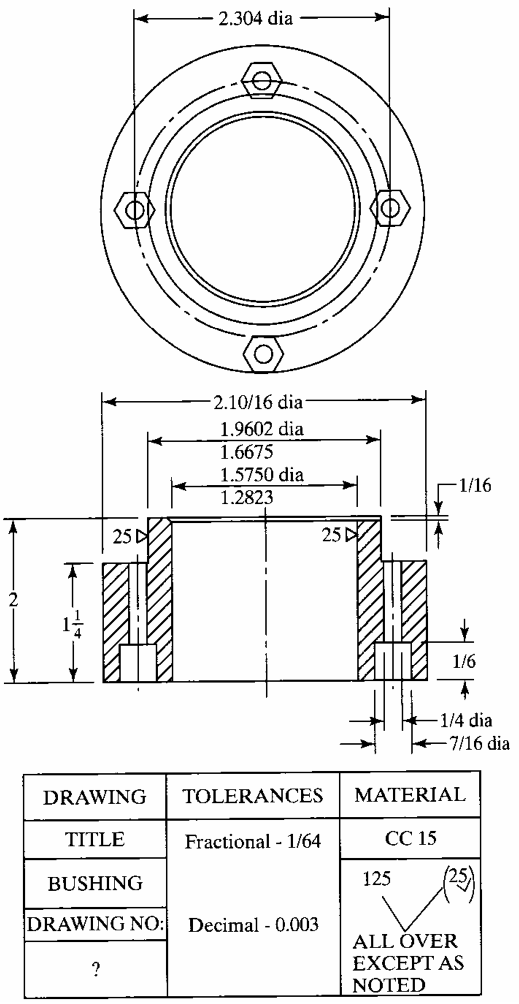
Special Code — *(for any company or industry including lot size, cost data, time, operation sequence, etc.)*

The structure of the MICLASS coding system



- Basic form: Basic shape (1), Shape element (2 & 3), Location of the shape element (4)
- Supplementary design and mfg. information: Number of outside diameters (19), Number of inside diameters or specific shape (20), Rotational grooves or knurls (21), Close tolerance diameters (22), Splines (23), Gears (24), Sprockets (25), Pitch diameter/diameter pitch (26), Number of teeth (27)

An example of coding a part using the MICLASS system


ENTER THE CLASSIFICATION ROUTE (1 TO 9) •1

3 MAIN DIMENSIONS (WHEN ROT. FART D,L AND 0) :2.9375,2,0 DEVIATION OF ROTATIONAL FORM ,NO

CONCENTRIC SPIRAL GROOVES :• NO

TURNING ON OUTERCONTOUR (EXCEPT ENDFACES) -YES

SPECIAL GROOVES OR CONE(S) OR PROFILE(S) ON OUTERCONTOUR ..::NO

ALL MACH. EXT. BEAM. AND ROT. FACES VISIBLE FROM ONE END (EXC. ENDFACES + GROOVES) :=YES

TURNING ON INNERCONTOUR ::YES

INTERNAL SPECIAL GROOVES OR CONE(S) OR PROFILE(S) •NO

ALL INT.DIA. + R0T.FACES VISIBLE FROM 1 END(EXC. GROOVES)YES ALL

D1A. + ROT.FACES VISIBLE FROM ONE END (EXCL. ENDFACES :?YES ECC.

HOLING AND/OR FACING AND/OR SLOTTING :AYES

ON INNERFORM AND/OR FACES (INC. ENDFACES) YES ON OUTERFORM NO

ONLY ENCLOSE[, INTERNAL SLOTS •NO ECC. MACHINING ONLY ONE SENSE :Y

ONLY HOLES ON A BOLTCIRCLE (AT LEAST 3 HOLES) ::YES FORM-OF

THREADING TOLERANCE .,NO

DIAM. OR ROT. FACE ROUGHNESS LESS THAN 33 RU (MICRO-INCHES) .,YES

SMALLEST

CLASS .NR.= 1271 3231 3100 0000 0000 0000 0000 00

xxxx*xxx*x*xxx***x*x*x*xxxxxx***x**x*xxx**xx*xxx*

DIGIT TO CHANGE >

CONTINUE (Y/N)>N

TTO – STOP

>

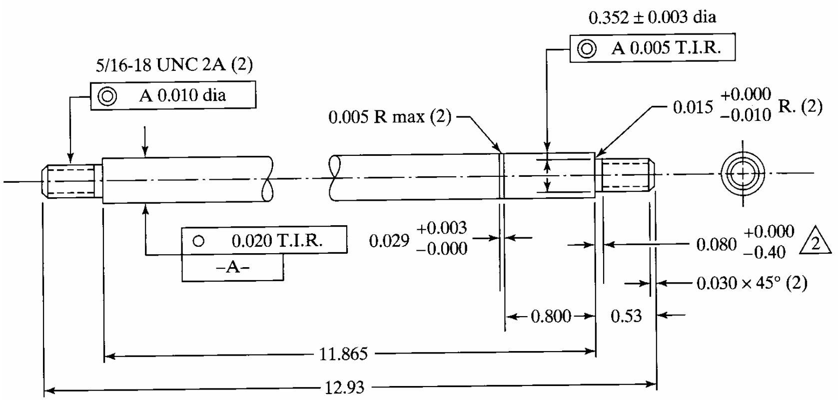
DRAWING	TOLERANCES	MATERIAL
TITLE	Fractional - 1/64	CC 15
BUSHING		125 (25)
DRAWING NO:	Decimal - 0.003	ALL OVER EXCEPT AS NOTED
?		

4. MultiClass – developed by the Organization for Industrial Research (OIR)

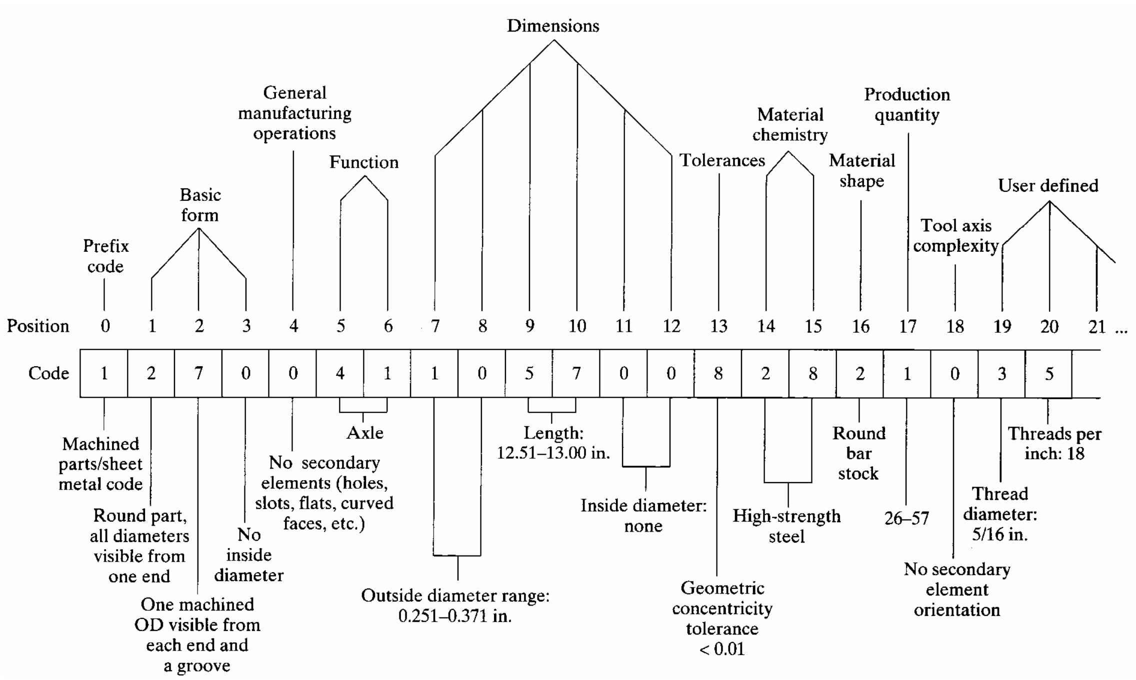
First 18 digits of the Multiclass Classification and Coding System

Digit	Function
0	Code system prefix
1	Main shape category
2, 3	External and internal configuration
4	Machined secondary elements
5, 6	Functional descriptors
7–12	Dimensional data (length, diameter, etc.)
13	Tolerances
14, 15	Material chemistry
16	Raw material shape
17	Production quantity
18	Machined element orientation

MultiClass Coding System example – the rotational part design

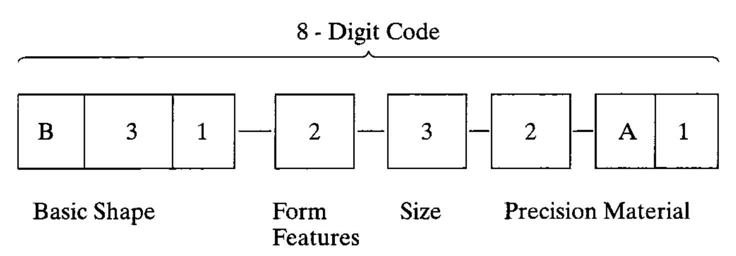


MultiClass code number for the rotational part



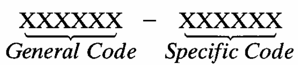
5. DCLASS System

- It is a decision-making and classification system.
- It is a tree-structured system that generates codes for components, material, processes, machines, and tools. Each branch of the system represents a condition in which a code is formed at the junction of each branch.
- The complete code is obtained by taking multiple passes in the decision tree.
- Sample of DCLASS code representation



General Code (AA BC DD)

- The code is a numerical code of constant length and is divided into two groups of six digits each:



- The first digit (AA) has 10 possible values, the second and third digits (B and C) are combined to give 99 possible subclasses of each item classified, and the last digit (DD) in the general code has 10 possible values.
- The general code gives a general description of the part, the type of operation it performs, and other specifications that uniquely identify the product.

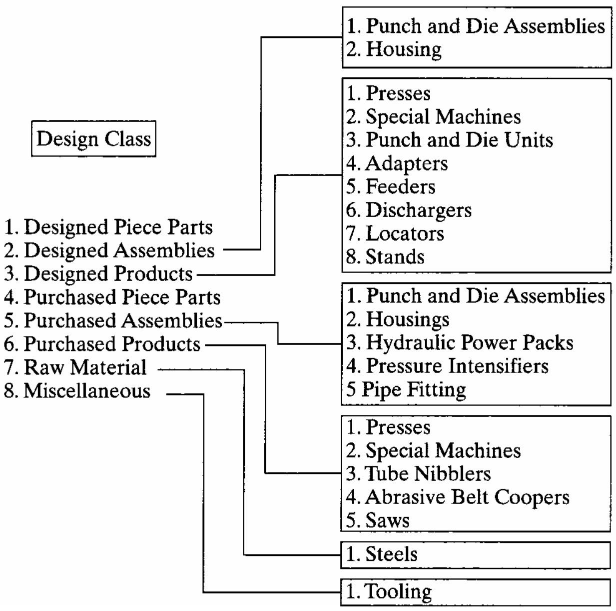
Specific Code (XX X X X X)

- The specific code gives us a more detailed description about a part by classifying it into subclasses.
- Some parts do not need all 12 digits. The extra digits are reserved for possible future expansion of the company of the company line of products.

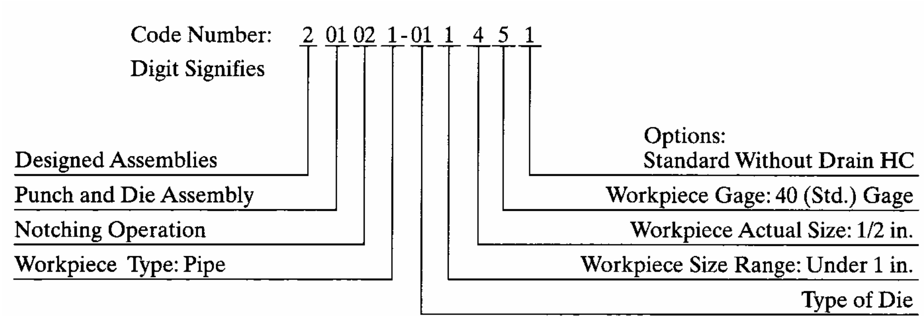
Method Used for the Proposed Classification System

- The first step taken in designing the proposed classification system is to break down all of the company's components or parts into eight major design classes as following:
  1. Designed piece parts
  2. Designed assemblies
  3. Designed products
  4. Purchased piece parts
  5. Purchased assemblies
  6. Purchased products
  7. Raw material
  8. Miscellaneous

Division of a design class into subclasses



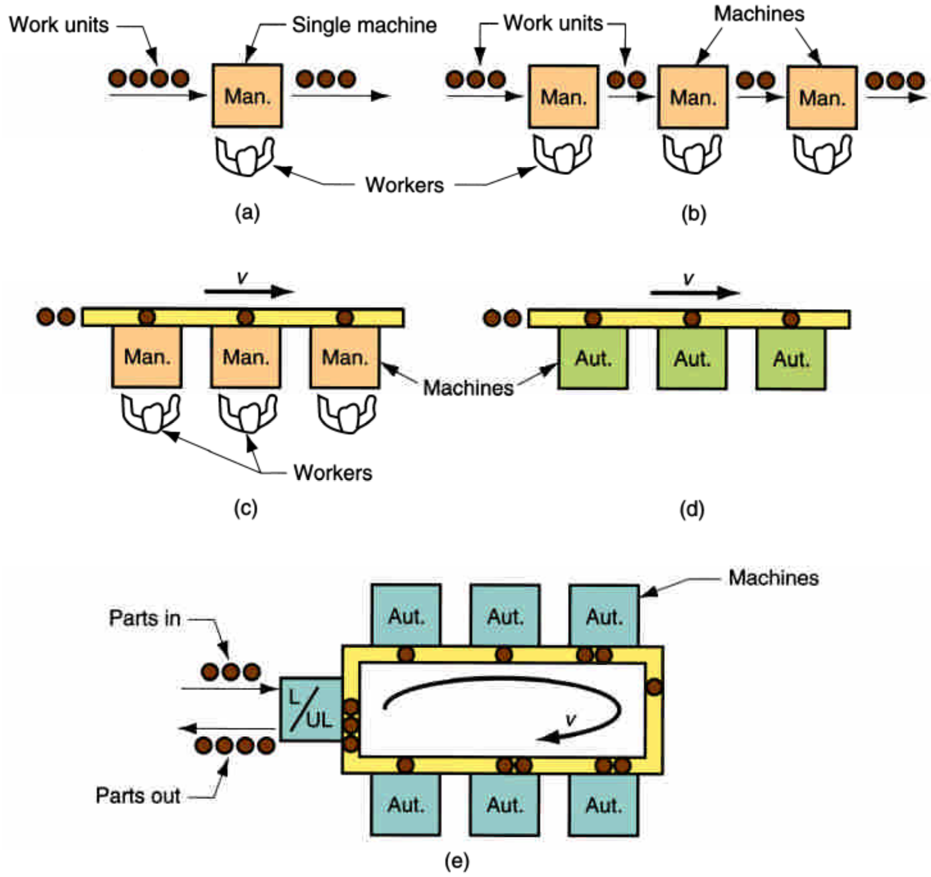
Construction of a proposed code



Benefits of a Well-Designed Classification and Coding System

- Facilitates formation of part families
- Permits quick retrieval of part design drawings
- Reduces design duplication
- Promotes design standardization
- Improves cost estimating and cost accounting
- Facilitates NC part programming by allowing new parts to use the same part program as existing parts in the same family
- Computer-aided process planning (CAPP) becomes feasible

Types of GT cells



(a) Single machine
(b) Multiple machines with manual handling
(c) Multiple machines with mechanized handling
(d) Flexible manufacturing cell
(e) Flexible manufacturing system

Factory Flow Analysis

-The parts are assigned to groups that require the same routing through the machine shop. This implies that parts may be of different design; however, they must be made by the same sequence of processes.
-If the group technology and factory flow analysis are combined during the plant layout, efficient manufacturing routes can be established and maintained, as long as there is no change in the part spectrum or the design of the part.
-This method also requires a very through knowledge of the part spectrum which can be grouped together, and the available processes.
-The use of the algorithm will have to be done with the help of a computer, and shown with the help of following figures.

PART NO.	MACHINE NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	m
1		x								x	x	x				4
2			x		x			x					x		x	5
3	x					x			x					x		4
4	x			x					x					x		4
5			x		x			x					x		x	5
6	x			x		x			x					x		5
7		x					x			x	x	x				5
8			x		x			x					x		x	5
9				x		x			x					x		4
10		x					x			x	x	x				5
n	3	3	3	3	3	3	2	3	4	3	3	3	3	4	3	

Unsorted factory flow matrix.

1. Count the number of entries x in each column. Record these numbers. Count the number of entries x in each row. Rearrange the matrix with columns in decreasing order of m and rows in increasing order of n, respectively.
2. Take the first column of the new matrix and move all rows that have an entry x in this column to the top. Repeat this procedure with succeeding columns until all rows are rearranged.
3. If the current matrix an the one that preceded it are identical, go to 6; otherwise, go to 4.
4. Take the first row of the matrix and move all columns that have an entry x in this row to the leftmost position. Repeat this procedure with all succeeding rows until all columns are rearranged.
5. If the current matrix and the one that preceded it are identical go to 6; otherwise go to 2.
6. Stop

PART NO.	MACHINE NO 14	9	15	13	12	11	10	8	6	5	4	3	2	1	7	m
9	x	x							x		x					4
4	x	x									x			x		4
3	x	x							x					x		4
1					x	x	x						x			4
10					x	x	x						x		x	5
8			x	x				x		x		x				5
7					x	x	x						x		x	5
6	x	x							x		x			x		5
5			x	x				x		x		x				5
2			x	x				x		x		x				5
n	4	4	3	3	3	3	3	3	3	3	3	3	3	3	2	

Result of the first grouping.

PART NO.	MACHINE NO. 14	9	15	13	12	11	10	8	6	5	4	3	8	1	7
9	x	x							x		x				
4	x	x									x			x	
3	x	x							x					x	
6	x	x							x		x			x	
8			x	x				x		x		x			
5			x	x				x		x		x			
2			x	x				x		x		x			
1					x	x	x						x		
10					x	x	x						x		x
7					x	x	x						x		x

Result of the second grouping.

PART NO.	MACHINE NO. 14	9	6	4	1	15	13	8	5	3	12	11	10	2	7
9	x	x	x	x											
4	x	x		x	x										
3	x	x	x		x										
6	x	x	x	x	x										
8						x	x	x	x	x					
5						x	x	x	x	x					
2						x	x	x	x	x					
1											x	x	x	x	
10											x	x	x	x	x
7											x	x	x	x	x

Result of the final grouping.