Computer Aided Process Planning and Control

Module : 2

- GT: 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

There are three methods that can be used to form part families:

- **Manual visual inspection**
- **Production flow analysis (PFA)**
- **Classification and coding**

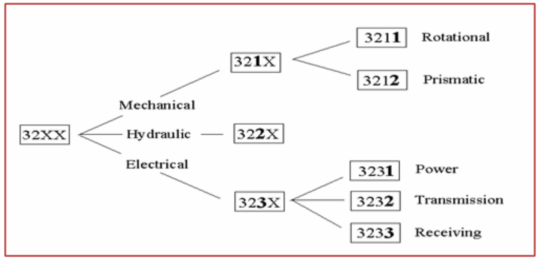
Coding refers to the process of assigning symbols to the parts

The ***symbols*** represent ***design attributes*** of parts or ***manufacturing features*** of part families

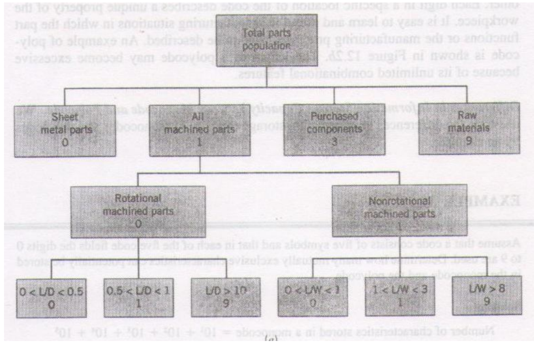
Coding Scheme Structures

1. Hierarchical structure (monocode)
   - Interpretation of each successive digit depends on the value of the preceding digit
2. Chain-type structure (polycode)
   - Interpretation of each symbol is always the same
   - No dependence on previous digits
3. Mixed-code structure(Hybrid)
   - Combination of hierarchical and chain-type structures

Hierarchical structure (monocode)



Monocode cont..

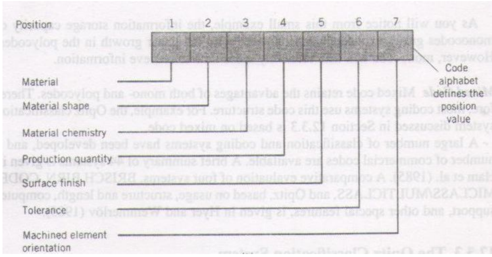


Chain-type structure (polycode)

Digit position	1	2	3	4
Class of feature	External shape	Internal shape	Holes	
Possible value 1	Shape 1	Shape 1	Axial	
2	Shape 2	Shape 2	Cross	
3	Shape 3	Shape 3	Axial and cross	
4				

Fig. 1.17. Chain structure.

Polycode Cont..



Hybrid or Mixed code

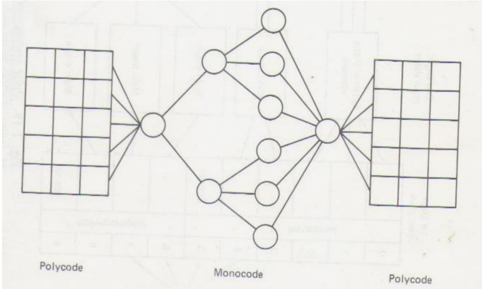


Fig. 1.18. Hybrid structure.

Opitz Coding System

MICLASS Coding Systems

Opitz Classification System

- Mixed Code
- One of the first published classification and coding schemes for mechanical parts
- Can be applied to machined parts, non machined parts and purchased parts
- Considers both design and manufacturing Information

Opitz Classification System

- Basic code = nine (9) digits
  - Digits 1 through 5 = FORM CODE – primary shape and design attributes (hierarchical structure)
  - Digits 6 through 9 = SUPPLEMENTARY CODE – attributes that are useful in manufacturing (e.g., dimensions, starting material)
  - Digits 10 through 13 = SECONDARY CODE – production operation type and sequence

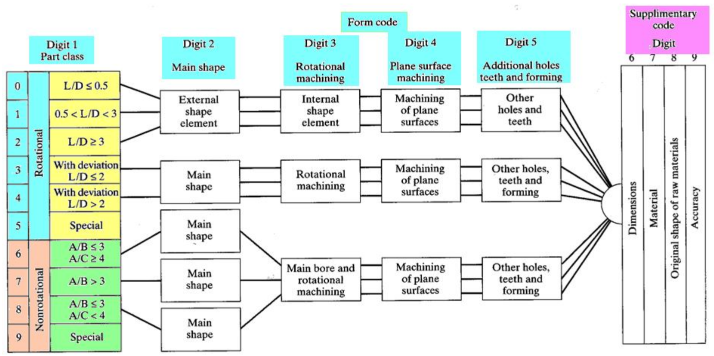
The Opitz coding system consists of three groups of digits

OPITZ CODE												
FORM CODE					SUPPLEMENTARY CODE				SECONDARY CODE			
1	2	3	4	5	6	7	8	9	A	B	C	D
for design attributes					*for manufacturing attributes*				for production operation type & sequence			

It is intended for machined parts and uses the above digits sequence

Opitz Classification and Coding System

- Form Code 1 2 3 4 5 *for design attributes*
- Supplementary Code 6 7 8 9 *for manufacturing attributes*
- Secondary Code A B C D for production operation type & sequence



FORM CODE

DIGIT 1 PART CLASS	Rotational or not
DIGIT 2 MAIN SHAPE	External Shape
DIGIT 3 ROTATIONAL MACHINING	Internal Shape
DIGIT 4 PLANE SURFACE MACHINING	Internal Or External Curved Surfaces, Slots Etc
DIGIT 5 ADDITIONAL HOLES AND TEETH	Auxiliary Holes And Gear Teeth

Digit 1 Part class

0	Rotational	$L/D \le 0.5$
1	Rotational	$0.5 < L/D < 3$
2	Rotational	$L/D \ge 3$
3	Rotational	With deviation $L/D \le 2$
4	Rotational	With deviation $L/D > 2$
5	Rotational	Special
6	Nonrotational	$A/B \le 3$, $A/C \ge 4$
7	Nonrotational	$A/B > 3$
8	Nonrotational	$A/B \le 3$, $A/C < 4$
9	Nonrotational	Special

First Digit :

- makes the difference between Rotational and Non Rotational Parts
- A dimensional ratio is used to evaluate the geometry of the shape
- Rotational : L/D ratio
- Non Rotational : edge length of the part in decreasing order of Magnitude (A,B,C)

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 the 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

For Rotational Parts

Code	DIGIT 2: MAIN FORM		DIGIT 3: Main bore and rotational machining	DIGIT 4: Machining of plane surfaces	DIGIT 5: Other holes, teeth and forming		
0	Plane/flat	Rectangular plane	No features	Without surface machining	Without features		
1	Plane/flat	Right-angled triangle plane	One smooth bore	Chamfers	Without transformation /without gearing		One bore direction
2	Plane/flat	Angularly	One bore multiple ascending	A flat surface	Without transformation /without gearing		Several bore directions
3	Plane/flat	Circular and rectangular	One main bore with all form elements	Stepped surface	Without transformation /without gearing	With hole	One bore direction
4	Plane/flat	Other	Two main bores parallels	Stepped surface vertically inclined and/or opposed	Without transformation /without gearing	With hole	Several bore directions
5	Flat part rectangular or orthogonal with small deviations		More than two main bores paralells	Groove and/or slot	Tranformation /without gearing		Formed without drilling
6	Flat part round or any other shape with small deviations		Many main bored perpendicular	Groove and/or slot and 4	Tranformation /without gearing		Formed with drilling
7	Flat part with regularly arched form		Ring groove machining surfaces	Curved surface	Gearing		
8	Flat part with irregularly arched form		7 + main bore	Guided surface	Gearing with hole		
9	Other		Other	Other	Other		

Figure 18: Attributes of the digits that classify non-rotational flat parts [Opit68]

When Digit 1 is 6

A/B ≤ **3**
A/C ≥ **4**

Code	DIGIT 2: MAIN FORM			DIGIT 3: Main bore and rotational machining	DIGIT 4: Machining of plane surfaces	DIGIT 5: Other holes, teeth and forming		
0	Straight form	Same cross-section	Rectangular cross-section	No features	Without surface machining	Without features		
1	Straight form	Same cross-section	Ortogonal cross-section	One smooth bore	Chamfers	Without transformation /without gearing		One bore direction
2	Straight form	Same cross-section	Any cross-section	One bore multiple ascending	A flat surface	Without transformation /without gearing		Several bore directions
3	Straight form		Rectangular cross-section	One main bore with all form elements	Stepped surface	Without transformation /without gearing	With hole	One bore direction
4	Straight form		Rectangular and ortogonal cross-section	Two main bores parallels	Stepped surface vertically inclined and/or opposed	Without transformation /without gearing	With hole	Several bore directions
5	Straight form		Other	More than two main bores paralells	Groove and/or slot	Tranformation /without gearing		Formed without drilling
6	Straight form		Rectangular, angular arbitrary cross-section	Many main bored perpendicular	Groove and/or slot and 4	Tranformation /without gearing		Formed with drilling
7	Curved form		Shaped part	Ring groove machining surfaces	Curved surface	Gearing		
8	Curved form		Shaped part with deviations in the axis	7 + main bore	Guided surface	Gearing with hole		
9			Other	Other	Other	Other		

Figure 19: Attributes of the digits that classify non-rotational long parts [Opit68]

When Digit 1 is 7

A/B > **3**

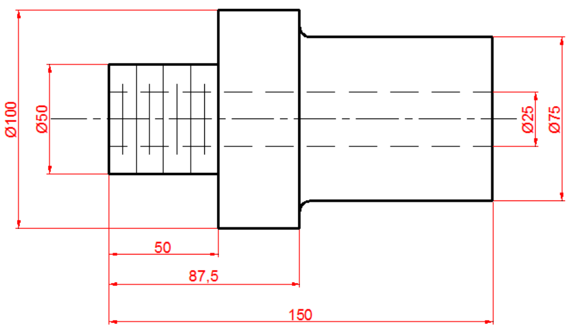
Code	DIGIT 2: MAIN FORM			DIGIT 3: Main bore and rotational machining	DIGIT 4: Machining of plane surfaces	DIGIT 5: Other holes, teeth and forming		
0			Cuboid	No features	Without surface machining	Without features		
1	Block-like parts		Ortogonal parts	One smooth bore	Chamfers	Without transformation /without gearing		One bore direction
2	Block-like parts		Composite parallelepiped	One bore multiple ascending	A flat surface	Without transformation /without gearing		Several bore directions
3	Block-like parts		Parts mit mounting surfaces and main bore	One main bore with all form elements	Stepped surface	Without transformation /without gearing	With hole pattern	One bore direction
4	Block-like parts		Parts with mounting surfaces and main bore with distribution area	Two main bores parallels	Stepped surface vertically inclined and/or opposed	Without transformation /without gearing	With hole pattern	Several bore directions
5	Block-like parts		Other	More than two main bores paralells	Groove and/or slot	Tranformation /without gearing		Formed without drilling
6	Case-like parts	Not shared case		Many main bored perpendicular	Groove and/or slot and 4	Tranformation /without gearing		Formed with drilling
7	Case-like parts	Not shared case	Any form	Ring groove machining surfaces	Curved surface	Gearing		
8	Case-like parts	Shared case		7 + main bore	Guided surface	Gearing with hole		
9	Case-like parts	Shared case	Any form	Other	Other	Other		

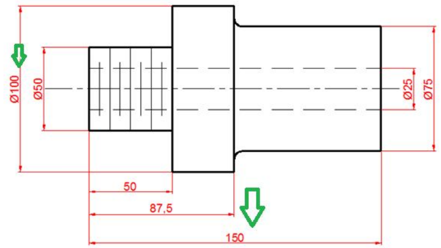
Figure 20: Attributes of the digits that classify non-rotational cubic parts [Opit68]

When Digit 1 is 8

A/B ≤ **3**
A/C < **4**

Example 1. Give the OPITZ code for the part shown below





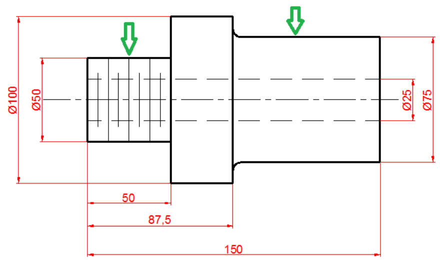
FORM CODE

Digit 1
Part class

0	Rotational	$L/D \leq 0.5$
1		$0.5 < L/D < 3$
2		$L/D \geq 3$
3		With deviation $L/D \leq 2$
4		With deviation $L/D > 2$
5		Special
6	Nonrotational	$A/B \leq 3$ $A/C \geq 4$
7		$A/B > 3$
8		$A/B \leq 3$ $A/C < 4$
9		Special

Here Length to diameter ratio = 150/100 = **1.5**

Digit 1 of OPITZ Code = 1



FORM CODE

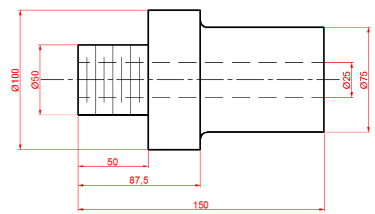
Digit 2

	External shape, external shape elements	
0		Smooth, no shape elements
1	Stepped to one end or smooth	No shape elements
2		Thread
3		Functional groove
4	Stepped to both ends	No shape elements
5		Thread
6		Functional groove
7		Functional cone
8		Operating thread
9		All others

External Shape : Both ends stepped with Screw thread on one end

Digit 2 of OPITZ Code = 5

FORM CODE



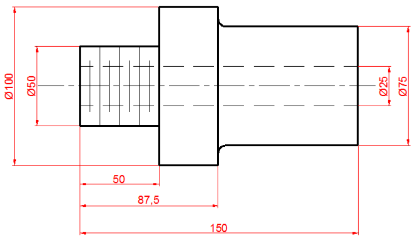
Digit 3

	Internal shape, internal shape elements	
0		No hole, no breakthrough
1	Smooth or stepped to one end	No shape elements
2		Thread
3		Functional groove
4	Stepped to both ends	No shape elements
5		Thread
6		Functional groove
7		Functional cone
8		Operating thread
9		All others

Internal Shape : Part Contains a through Hole

Digit 3 of OPITZ Code = 1

FORM CODE



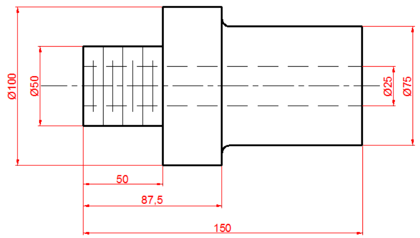
Digit 4

	Plane surface machining
0	No surface machining
1	Surface plane and/or curved in one direction, external
2	External plane surface related by graduation around the circle
3	External groove and/or slot
4	External spline (polygon)
5	External plane surface and/or slot, external spline
6	Internal plane surface and/or slot
7	Internal spline (polygon)
8	Internal and external polygon, groove and/or slot
9	All others

Plane Surface Machining : None

Digit 4 of OPITZ Code = 0

FORM CODE

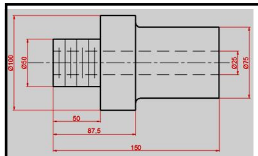


Digit 5

		Auxiliary holes and gear teeth
0		No auxiliary hole
1	No gear teeth	Axial, not on pitch circle diameter
2	No gear teeth	Axial on pitch circle diameter
3	No gear teeth	Radial, not on pitch circle diameter
4	No gear teeth	Axial and/or radial and/or other direction
5	No gear teeth	Axial and/or radial on PCD and/or other directions
6	With gear teeth	Spur gear teeth
7	With gear teeth	Bevel gear teeth
8	With gear teeth	Other gear teeth
9	With gear teeth	All others

Auxiliary Holes, Gear Teeth etc : None

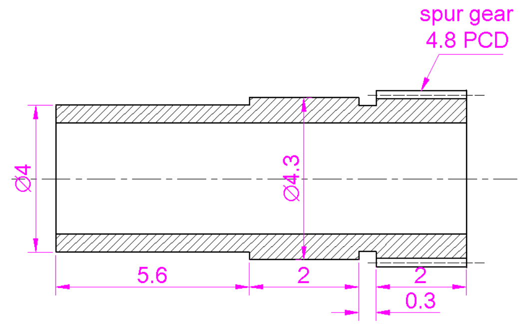
Digit 5 of OPITZ Code = 0



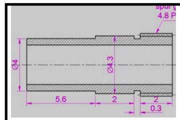
OPITZ Code = 15100

	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 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 the circle	No gear teeth: Axial on pitch circle diameter
3		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		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		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

Example 2. Give the Opitz form code for the following part



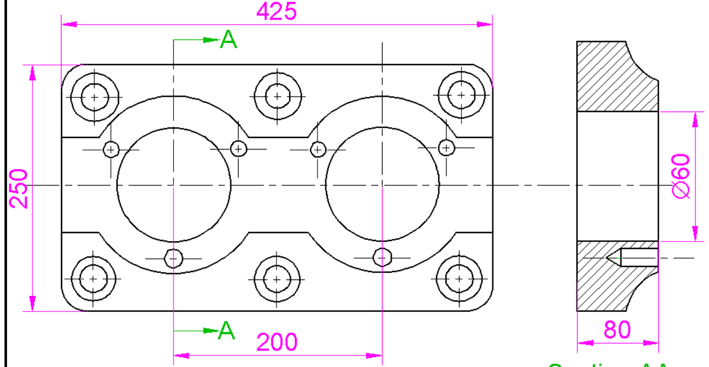
Rotational : L/D ratio = 9.9/4.8
= 2.06



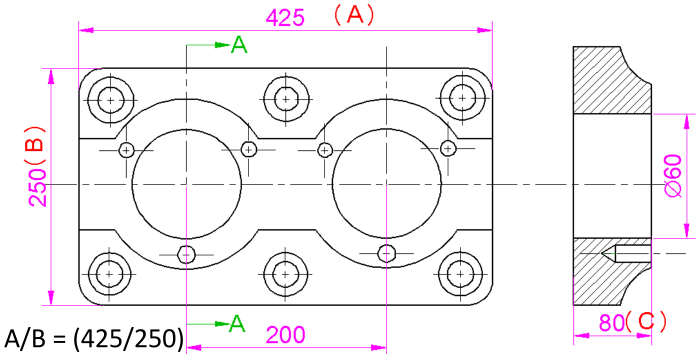
Digit 1		Digit 2		Digit 3		Digit 4		Digit 5	
Part class		External shape, external shape elements		Internal shape, internal shape elements		Plane surface machining		Auxiliary holes and gear teeth	
0	Rotational parts: L/D ≤ 0.5	0	Smooth, no shape elements	0	No hole, no breakthrough	0	No surface machining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

OPITZ Code = 13106

Example 3. Give the Opitz form code for the following part



Find A, B, C, Evaluate : A/B and A/C



A/B = (425/250)
= 1.7 ≤ **3**

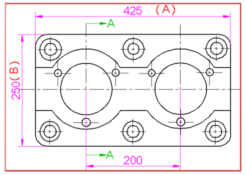
A/C = (425/80)
= 5.31 > **4**

Digit 1 Part class		
6	Nonrotational	A/B ≤ 3, A/C ≥ 4
7	Nonrotational	A/B > 3
8	Nonrotational	A/B ≤ 3, A/C < 4
9	Nonrotational	Special

A/B ≤ **3**

A/C = **4**

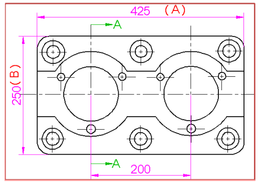
Opitz Code Digit 1 = 6



External feature: Flat rectangular with small deviation

DIGIT 2 MAIN FORM			DIGIT 3 Main bore and rotational machining	
0	Plane/flat	Rectangular plane	0	No features
1		Right-angled triangle plane	1	One smooth bore
2		Angularly	2	One bore multiple ascending
3		Circular and rectangular	3	One main bore with all form elements
4		Other	4	Two main bores parallels
5	Flat part rectangular or orthogonal with small deviations		5	More than two main bores paralells
6	Flat part round or any other shape with small deviations		6	Many main bored perpendicular
7	Flat part with regularly arched form		7	Ring groove machining surfaces
8	Flat part with irregularly arched form		8	7 + main bore
9	Other		9	Other

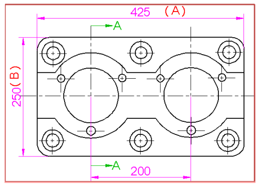
Opitz Code Digit 2 = 5



Internal feature: Two main bores parallel

DIGIT 2 MAIN FORM			DIGIT 3 Main bore and rotational machining	
0	Plane/flat	Rectangular plane	0	No features
1		Right-angled triangle plane	1	One smooth bore
2		Angularly	2	One bore multiple ascending
3		Circular and rectangular	3	One main bore with all form elements
4		Other	4	Two main bores parallels
5	Flat part rectangular or orthogonal with small deviations		5	More than two main bores paralells
6	Flat part round or any other shape with small deviations		6	Many main bored perpendicular
7	Flat part with regularly arched form		7	Ring groove machining surfaces
8	Flat part with irregularly arched form		8	7 + main bore
9	Other		9	Other

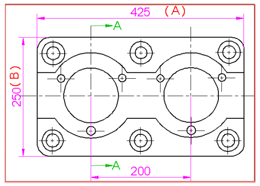
Opitz Code Digit 3 = 4



Stepped Surface

DIGIT 4 Machining of plane surfaces		DIGIT 5 Other holes, teeths and forming			
0	Without surface machining	0	Without features		
1	Chamfers	1	Without transformation /without gearing		One bore direction
2	A flat surface	2			Several bore directions
3	Stepped surface	3		With hole	One bore direction
4	Stepped surface vertically inclined and/or opposed	4			Several bore directions
5	Groove and/or slot	5	Tranformation /without gearing		Formed without drilling
6	Groove and/or slot and 4	6			Formed with drilling
7	Curved surface	7	Gearing		
8	Guided surface	8	Gearing with hole		
9	Other	9	Other		

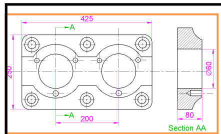
Opitz Code Digit 4 = 4



Auxiliary holes : with hole in one direction

DIGIT 4 Machining of plane surfaces		DIGIT 5 Other holes, teeths and forming			
0	Without surface machining	0	Without features		
1	Chamfers	1	Without transformation /without gearing		One bore direction
2	A flat surface	2			Several bore directions
3	Stepped surface	3		With hole	One bore direction
4	Stepped surface vertically inclined and/or opposed	4			Several bore directions
5	Groove and/or slot	5	Tranformation /without gearing		Formed without drilling
6	Groove and/or slot and 4	6			Formed with drilling
7	Curved surface	7	Gearing		
8	Guided surface	8	Gearing with hole		
9	Other	9	Other		

Opitz Code Digit 5 = 3



Opitz Code = 65443

Digit 1 Part class		
0	Rotational	L/D ≤ 0.5
1	Rotational	0.5 < L/D < 3
2	Rotational	L/D ≥ 3
3	Rotational	With deviation L/D ≤ 2
4	Rotational	With deviation L/D > 2
5	Rotational	Special
6	Nonrotational	A/B ≤ 3 A/C ≥ 4
7	Nonrotational	A/B > 3
8	Nonrotational	A/B ≤ 3 A/C < 4
9	Nonrotational	Special

	DIGIT 2 MAIN FORM	DIGIT 3 Main bore and rotational machining	DIGIT 4 Machining of plane surfaces	DIGIT 5 Other holes, teeths and forming
0	Plane/flat: Rectangular plane	No features	Without surface machining	Without features
1	Plane/flat: Right-angled triangle plane	One smooth bore	Chamfers	Without transformation /without gearing: One bore direction
2	Plane/flat: Angularly	One bore multiple ascending	A flat surface	Without transformation /without gearing: Several bore directions
3	Plane/flat: Circular and rectangular	One main bore with all form elements	Stepped surface	Without transformation /without gearing, With hole: One bore direction
4	Plane/flat: Other	Two main bores parallels	Stepped surface vertically inclined and/or opposed	Without transformation /without gearing, With hole: Several bore directions
5	Flat part rectangular or orthogonal with small deviations	More than two main bores paralells	Groove and/or slot	Tranformation /without gearing: Formed without drilling
6	Flat part round or any other shape with small deviations	Many main bored perpendicular	Groove and/or slot and 4	Tranformation /without gearing: Formed with drilling
7	Flat part with regularly arched form	Ring groove machining surfaces	Curved surface	Gearing
8	Flat part with irregularly arched form	7 + main bore	Guided surface	Gearing with hole
9	Other	Other	Other	Other

Figure 18: Attributes of the digits that classify non-rotational flat parts [Opit68]

MICLASS

- The name MICLASS stands for **Metal Institute Classification System**, and was developed by the Netherlands Organization for Applied Scientific Research (TNO) of Holland
- Includes both design and Manufacturing Information

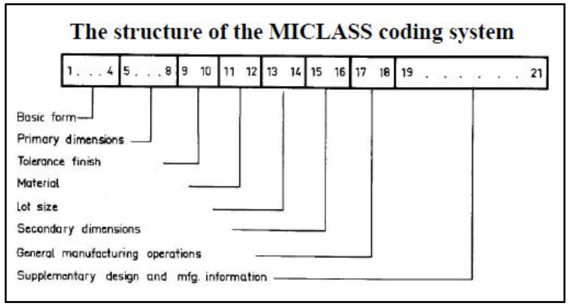
- The total number of digits used in MICLASS classification system may vary from 12 to 30 digits. The digits can be divided into two. The first twelve digits are a universal nature and can be applied to any work part.
- The other 18 digits which is called supplemental codes can be used for data that are specific to the particular company. Those supplemental digits provide a flexibility to accommodate broad applications. Such as lot size, cost data, and operation sequence

MICLASS Code Structure

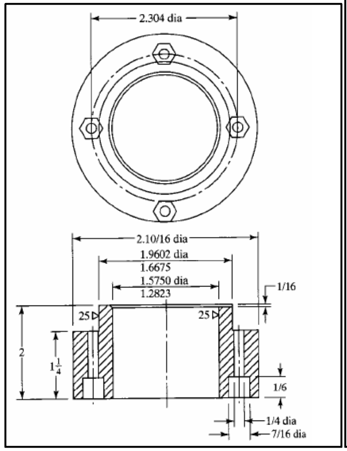
Code Position	Item
1	Main Shape
2	Shape Elements
3	
4	Position of Shape elements
5	Main Dimension
6	
7	Dimension Ratio
8	Auxiliary Dimension
9	Tolerance Codes
10	
11	Material Codes
12	

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.)*



MICLASS



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

Experience Based Process Planning

Relay on one's experience. Most frequently this is the way industry operates.

Drawbacks

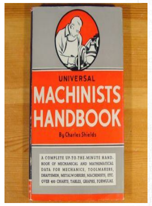
- Requires a **significant period** to accumulate
- Represents only **approximate**, not exact **Knowledge**
- Is **not Directly applicable** to **new** processes

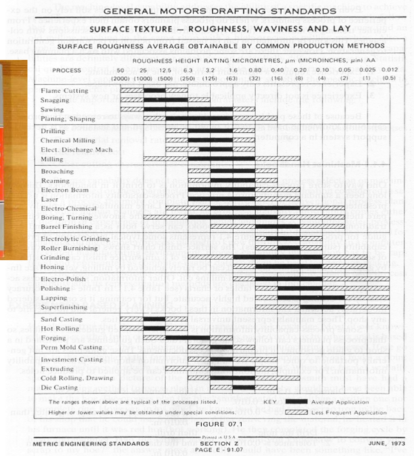
Need to automate.

MACHINIST HANDBOOKS

- Storing process capability information Represented in figures, tables or guidelines.
- Serve as reference and as guide for process selection

SURFACE FINISH CHART

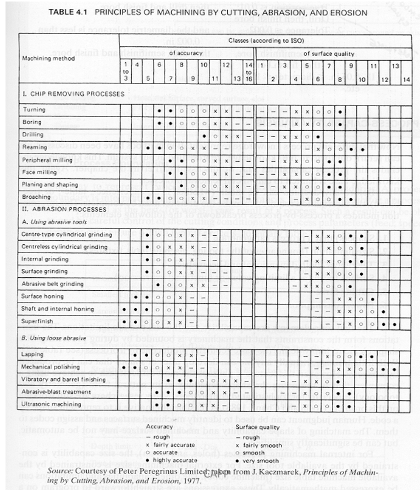




figure

Table

Dimensional accuracies for Process Planning



Hole Making Knowledge

Guidelines

I. Dia ≤ 0.5"

A. True position > 0.010"

1. Tolerance > 0.010"

Drill the hole.

2. Tolerance ≤ 0.010"

Drill and ream the hole.

B. True position ≤ 0.010"

1. Tolerance ≤ 0.010"

Drill, then finish bore the hole.

2. Tolerance ≤ 0.002"

Drill, semi-finish bore, then finish bore the hole.

II. 0.05" < dia ≤ 1.00"

MACHINIST HANDBOOKS

e.g. Surface-finish chart - limiting extremes of process

8 μ in - use grinding, polishing, lapping

Usually not with milling, however, finish milling may achieve the specification.

The information is general. It does not mean every machine or shop can achieve that accuracy.

Turning limit (6.3 - 0.4 μm or 250 - 16 μ inch)

Diamond turning at Lawrence Livermore Lab

(12.5 nm or 0.47 μ inch)

Decision Tables and Decision Trees

- Tools to assist in Decision making
- Are methods of describing the various actions associated with combination of input (conditions)

Decision rules must cover all possible situations so for using it in process planning these rules must be well though out.

Decision Tables

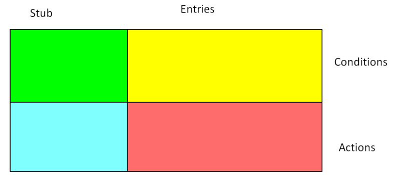
To computerize the decision making, one simple way is to use decision tables.

If the conditions set in an entry are satisfied, the actions in the entry are executed.

The stub contains the condition or action statements.

Entries mark which conditions or actions are applicable.

Each entry contain one rule.



Terminology

Stub	Rule 1	Rule 2	Rules 3,4	Rule 5	Rule 6	Rules 7,8
c1	T	T	T	F	F	F
c2	T	T	F	T	T	F
c3	T	F	-	T	F	-
a1	X	X		X		
a2	X				X	
a3		X		X		
a4			X			X

condition stubs	condition entries
action stubs	action entries

- To express the program logic we can use a limited-entry decision table consisting of 4 areas called the *condition stub*, *condition entry*, *action stub* and the *action entry*:

		Rule1	Rule2	Rule3	Rule4
		Condition entry			
Condition stub	Condition1	Yes	Yes	No	No
	Condition2	Yes	X	No	X
	Condition3	No	Yes	No	X
	Condition4	No	Yes	No	Yes
Action stub	Action1	Yes	Yes	No	No
	Action2	No	No	Yes	No
	Action3	No	No	No	Yes
		Action Entry			

• Each condition corresponds to a variable, relation or predicate
• Possible values for conditions are listed among the condition alternatives
  • Boolean values (True / False) – Limited Entry Decision Tables
  • Several values – Extended Entry Decision Tables

• Each action is a procedure or operation to perform
• The entries specify whether (or in what order) the action is to be performed

Decision Tables Classifications

Based on the rule representation

1. Limited Entry Decision tables
2. Extended Entry Decision Tables
3. Mixed Entry Decision Tables

Limited Entry Decision tables

Condition stub specifies exactly what the conditions are , entries can only be T, F or Do not Care

Raining	T	F	F
Hot		T	F
Go to arcade	X		
Go to beach		X	
Go to picnic			X

Extended Entry Decision tables

Condition stub specifies the identification of the condition not the value. Values are specified in the condition entries

Temperature		$\geq$ 80	< 80
Weather	Raining	Not raining	Not raining
Go to arcade	X		
Go to beach		x	
Go to picnic			x

Mixed Entry Decision Tables

Sequenced and unsequenced actions can be identified

True position > 0.01	T	T	
True position $\leq$ 0.01			
Dimensional tolerance > 0.1	T		
Dimensional tolerance $\leq$ 0.1		T	
Drill	X	1	
Ream		2	
Bore			

Factors to be considered while constructing Decision tables

- Completeness
- Accuracy
- Redundancy
- Consistency
- Loops
- Size

Redundant Rules

Occurs when two rules have the same actions

		A	B	C
Condition	1	T	T	T
	2			
	3	T	T	
	4		F	
Action	1	X	X	
Action	2			X
Action	3			X

Endless loop

	A	B	C	D
True Position > 0.01	T			
Tolerance > 0.01	T	F	F	
SF $\geq$ 60		T		
Dia = 0	F	F	F	T
Drill	X			
Ream		X		
Bore			X	
Dia = 0	X			
SF = 60			X	
Terminate				X

SF = 40 µin, Dia : 2in, Tol 0.005in

Merging

	A	B	C
Condition 1	T		F
Condition 2		F	
Condition 3	F	T	F
Condition 4	F	F	F
Action 1	X		X
Action 2		X	
Action 3		X	

Merge A,C

	A'	B
Condition 1		
Condition 2		F
Condition 3	F	T
Condition 4	F	T
Action 1	X	
Action 2		X
Action 3		X

Splitting and Parsing

	A	B	C	D	E
Condition 1	T	T	F	F	F
2	F	T			
3			T	F	F
4				T	F
Action 1	X		X		
2		X	X		X
3				X	X

Split (A,B) (C,D,E)

Condition 1	T	F
Table 1	X	
2		x

	A	B
Condition 2	F	T
Action 1	X	
2		X

	C	D	E
Condition 3	T	F	F
4		T	F
Action 1	X		
2	X		X
3		X	X

Decision Table - Example

Conditions	Printer does not print	Y	Y	Y	Y	N	N	N	N
	A red light is flashing	Y	Y	N	N	Y	Y	N	N
	Printer is unrecognized	Y	N	Y	N	Y	N	Y	N
Actions	Heck the power cable			X					
	Check the printer-computer cable	X		X					
	Ensure printer software is installed	X		X		X		X	
	Check/replace ink	X	X			X	X		
	Check for paper jam		X		X				

Printer Troubleshooting

Example Decision Table

CONDITIONS	Dia ≤ 0.5	X	X	X	X			
	0.5≤ D ≤ 1.0					X	X	X
	T.P ≤ 0.010	X	X					
	T.P ≥ 0.01			X	X			
	Tol > 0.010	X						
	0.002<Tol ≤ 0.010		X	X				
	Tol ≤ 0.002				X			
ACTIONS	Drill	X	X	X	X			
	Ream		X					
	Semi finish bore				X			
	Finish bore			X	X			

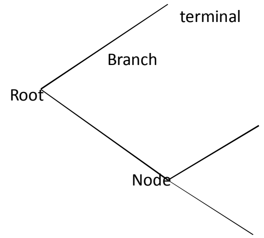
Decision Table Development Methodology

1. Determine conditions and values
2. Determine maximum number of rules
3. Determine actions
4. Encode possible rules
5. Encode the appropriate actions for each rule
6. Verify the policy
7. Simplify the rules (reduce if possible the number of columns)

DECISION TREES

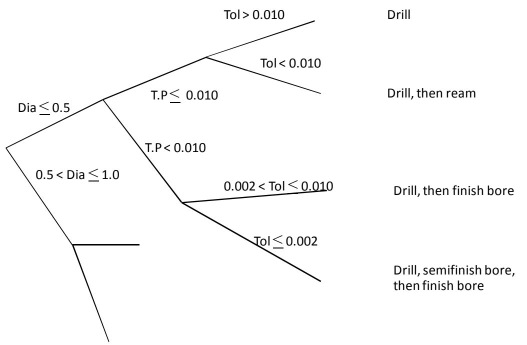
To computerize the decision making, one simple way is to use decision trees.

Decision tree is a graph with a single root and branches originating from the root. Each branch has a condition statement associate with it. Actions are written at the terminal. Probabilities may be assigned to the branches..

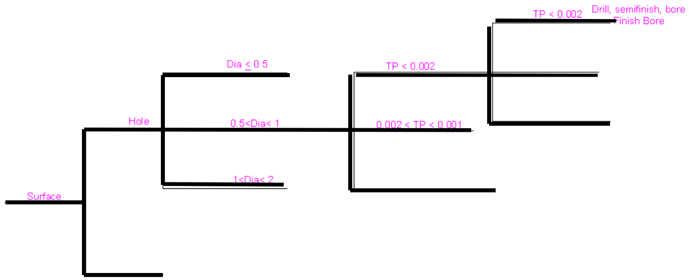


The node may be "AND" nodes or "OR" nodes.

EXAMPLE DECISION TREE



- Root is source of the tree
- Each tree have only one root
- Roots and Nodes are having branches originating from them.
- Nodes : Mutually Excursive and Non Mutually Excursive
- Branches can have only two logical statement True of False



Decision for Process Selection