



COMPUTERIZED CLASSIFICATION AND CODING
FOR AUTOMATIC PROCESS PLANNING SYSTEMS

By

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ABSTRACT

The development of a computerized process planning system requires a comprehensive description of the workpiece in terms of geometry and form elements, so that a sufficiently detailed workpiece model is required. The classification code is the logical tool for breaking up the workpiece spectrum into input data to be analysed by digital computers.

The fulfillment of the complete automation of the process planning can be achieved through the computerization of all the involved activities. All the reviewed automated process planning systems are based on manual workpiece classification-and coding.

The work presented in this paper is concentrated on the development of a computer aided workpiece classification-and coding method which can be used in any automated process planning system.

INTRODUCTION

The system developed in the present work depends upon a generalized workpiece classification-and coding procedure which has been developed to be convenient for computerization. The full description of the workpiece which has to be given as input data is accomplished using the geometrical feature coding system (GFCS)/1/. A special logic algorithm has been developed in the present work to enable the computerization of the classification and coding activities for any component to be machined.

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In a careful analysis of most of the known workpiece classification-and coding systems it has been found out that none of these systems can be used in automated process planning due to the narrow specialization and inadequacies presented in the reviewed systems. A general workpiece classification-and coding system is essential for establishing computerized integrated manufacturing (CIM) systems.

GENERAL WORKPIECE CLASSIFICATION AND CODING

THE STRUCTURE OF THE SYSTEM:

The first step in developing a classification and coding system is to determine the system structure. The different code structures which are shown in Fig. 1, can be classified as follows:

- Hierarchical structure: In which each code position is evaluated by the preceding position.
- Chain structure: Each code position is completely independent of all other characters, where each character has a fixed significance. A certain digit in a specific position always represents the same feature.
- Hybrid structure: Which is a mixture of hierarchical and chain type structures.

Computerized process planning systems require a code structure which lends itself very well to computer analysis. In spite of the fact that monocodes with few code positions are able to contain a large amount of information, the computer analysis in this case will be a fairly complex task. Polycodes on the other hand, which require a large number of code positions for part description, can be easily analyzed by digital computers [2]. Since the development of a computerized process planning system depends essentially on computer analysis of the workpiece code, it was decided to use a polycode structure workpiece classification-and coding system.

INFORMATION CONTENT OF THE SYSTEM:

The general workpiece classification-and coding system GWCCS was developed to classify and code machined components, (both rotational and nonrotational), that are produced on conventional-and nonconventional machine tools. The system consists of eighteen positions that describe the part geometry (7 code positions), product quality (7 code positions), heat treatment, workpiece material and major part dimensions (4 positions). The arrangement of the information is logically sequenced to facilitate both computer sorting of the part code for product design purposes and computer analysis of the part code for automated process planning. The information content of the code positions is shown in Fig. (2).



Each position is able to take a numerical value from 0 to 9 and an alphabetical letter from A to Z, giving 36 possible values in each position. The values assigned to any code position can be modified to suit any user's specific requirements. The GWCCS code positions are described as given in tables (1) to (4).

PART GEOMETRY

The part geometry code positions cover the possible workpiece shapes mostly encountered in practice. The different geometrical features of the workpiece shape are classified into; External rotational (ER) and nonrotational (ENR) surfaces, Internal rotational (IR) and nonrotational (INR) surfaces, Auxiliary holes, Threads and Gears. Each workpiece shape is given a code number (0 to 9). Table 1 describes the code positions for the part geometry.

PRODUCT QUALITY

The service life and the performance of the workpiece to be machined depend to a great extent on its quality.

The quality of a machined product is characterized mainly by the surface roughness obtained in manufacturing processes and the dimensional and form accuracy.

Surface roughness: The roughness of a machined surface is the whole complex of irregularities (relatively finely spaced ridges and valleys), the height, width and direction of which establish the predominant surface pattern [3]. The average height R_z is frequently used as a measure of the surface roughness so that it will be considered as the surface roughness criterion in the present work.

Geometrical Tolerances: The types of geometrical errors encountered in practice and which will be considered in the present paper are: Out of Roundness-, Flatness-, Straightness-, Parallelism and Angularity errors.

DETERMINATION OF PRODUCT QUALITY CODES:

As the workpiece geometry has been classified into 7 features, there are also 7 corresponding positions for product quality of the different features. Position (8) is the quality code for the external rotational features identified in position (1) and so on. The determination of the quality code for any feature is carried out as follows:

- According to the least value of the surface roughness R_z of the feature, a number from 1 to 4 is denoted to the surface roughness as obtained from table (2).



Table (1) Code positions for the part geometry (positions 1 to 7)

Position	Code number	Description of the code
(1) External Rotational Features	0	- No external rotational
	1	- Uniform diameter.
	2	- Stepped in one direction without shape elements*.
	3	- Stepped in one direction with shape element(s).
	4	- Stepped in both directions without shape elements.
	5	- Stepped in both directions with shape element(s).
	6	- Nonuniform diameters without shape elements.
	7	- Nonuniform diameters with shape element(s).
(2) Internal Rotational Features	0	- No internal rotational features
	1	- Single diameter through bore, no shape elements.
	2	- Single diameter blind hole, no shape elements
	3	- Single diameter through hole with shape elements.
	4	- Single diameter blind hole, with shape element(s).
	5	- Multiple diameters through bore, no shape elements.
	6	- Multiple diameters blind hole, no shape elements.
	7	- Multiple diameters through bore with shape element(s).
8	- Multiple diameters blind holes with shape element(s).	
(3) External Nonrotational Features	0	- No external nonrotational features.
	1	- Flat surface(s).
	2	- External slot , key way or groove.
	3	- External spline.
	4	- Uniform box shape without shape elements.
	5	- Uniform box shape with shape element(s).
	6	- Stepped planes without shape elements.
	7	- Stepped planes with shape element(s)
8	- Special form	

*)The term "shape element" refers to functional features



Table (1): Continued

Position	Code number	Description of the code
(4) Internal Nonrotational Features	0	- No internal nonrotational features
	1	- Internal flat surface(s).
	2	- Internal slot or key-way or groove.
	3	- Internal spline.
	4	- Internal nonrotational cavity.
	5	- Through form.
	6	- Special form.
(5) Auxiliary Holes	0	- No auxiliary holes.
	1	- Round axial hole.
	2	- Round radial hole.
	3	- Round inclined hole.
	4	- Not round axial hole.
	5	- Not round radial hole.
(6) Threads	0	- No threads.
	1	- External thread.
	2	- Internal thread.
	3	- External-and internal thread in rotational.
	4	- Internal thread in auxiliary hole.
	5	- External-and internal thread in auxiliary hole.
	6	- Internal thread in rotational and auxiliary hole.
7	- External-and internal threads in rotational and threads in auxiliary hole.	
(7) Gears	0	- No gears.
	1	- External spur gear.
	2	- External helical or spiral gear.
	3	- External herringbone gear.
	4	- External Bevel gear.
	5	- External spiral bevel gear.
	6	- External worm gear.
	7	- Internal spur gear.
	8	- Internal helical gear.
9	- External rack.	



- Another value for the product quality is obtained from table (3) according to the tolerance values. The selected number corresponding to the tolerance ranges from 1 to 4 and will be based on the most critical tolerance value.
- The two position numbers are compared and the higher value represents the quality code of the feature.
- Procedure will be repeated for all the geometrical features of the workpiece one after the other.

The quality codes in the developed system occupy 7 code positions which is a very wide representation for the product quality. This is to enable the analysis of the workpiece code to generate, without any other input data, a complete process sequence plan, an advantage which could not be achieved before by other previous systems, [4, 5].

GEOMETRICAL FEATURES CODING SYSTEM "GFCS"

To achieve the full description of the workpiece, a special coding system GFCS has been developed in the present work to be used specifically for the description of the individual features of the geometry for automated process-and operation planning system. This code, rather than dealing with the entire part geometry as the GWCCS described previously, limits itself to the description of the individual geometrical features to serve as the necessary input data for the operation planning stage. This system also facilitates the application of the computer aided workpiece classification and coding. The information content of the system is shown in Fig. (3).

The code describes each geometrical feature in terms of the attributes required for computerized process-and operation planning. The coding system consists of 14 code positions. Due to the nature of the code, most of the code positions are value code positions for the description of the dimensions, tolerances, angles and surface roughness (Rz). The other code positions, which are not value code positions, are explained as given in table (5).

The GFCS code represents the only input data for the computer aided workpiece classification and coding system.

COMPUTER AIDED WORKPIECE CODING "CAWC"

In order to achieve the objective of the present work, a procedure has been developed for the computer aided workpiece coding. The procedure is based on the complete description of the workpiece using the GFCS developed in the present work. The procedure is shown in Fig. (4) and can be explained as follows:



Table (2) Code positions for product quality (Positions 8 to 14)
a-Surface roughness base

Code Number	ISO/R 1302	Range	Surface Roughness R_z (μm)				
			Classification groups				
			Rough	Normal	Precision	High precision	Super precision
1	N12 N11 N10	160 - 25	160	100	63	40	25
2	N9 N8 N7	40 - 6.3	40	25	16	10	6.3
3	N6 N5 N4	10 - 1.6	10	6.3	4	2.5	1.6
4	N3 N2 N1	2.5 - 0.4	2.5	1.6	1	0.63	0.4

Table (3) Code positions for product quality (Positions 8 to 14)
b- Tolerance value base

Code Number	Tolerance Value (mm)					
	Dimensional	Geometrical				
		Roundness	Flatness	Parallelism	Straightness	Angularity perpendicularity
1	0.05	0.1	0.03	0.04	0.07	0.03
2	0.05 - 0.03	0.03	0.02	0.02	0.03	0.02
3	0.03 - 0.001	0.01	0.01	0.01	0.01	0.01
4	0.001	0.005	0.001	0.002	0.001	0.005



Table (4) Code positions for workpiece material (positions 15 to 18)

Position	Code number	Description of the code	
(15) Heat Treatment	0	No heat treatment.	
	1	Hardening.	
	2	Case hardening.	
	3	Annealing.	
(16) Workpiece Material Group	0	Free machining steel.	
	1	Structural steel.	
	2	Carbon steel.	
	3	Alloy steel (cold work)	
	4	Alloy steel (hot work)	
	5	Stainless steel.	
	6	Cast iron.	
	7	Bronze.	
	8	Copper and copper alloys.	
9	Aluminum and aluminium alloys.		
(17) Raw Material Shape	0	Casted part.	
	1	Round bar	
	2	Square bar	
	3	Rolled sections.	
	4	Hexagonal bar.	
	5	Sheet.	
(18) Product Dimensions	0	- Not used	
	1	Round	$L/D < 0.5$
	2		$0.5 \leq L/D < 2$
	3		$2 \leq L/D < 4$
	4		$4 \leq L/D < 8$
	5		$L/D \geq 8$
	6	Not round	$L/W \leq 3, L/H \leq 3$
	7		$L/W \leq 3, L/H > 3$
	8		$L/W > 3, L/H \leq 3$
	9		$L/W > 3, L/H > 3$



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Table (5): Code positions for workpiece features.

Position	Code number	Description of the code
(1) Geometry	1	External rotational.
	2	Internal rotational.
	3	External nonrotational.
	4	Internal nonrotational.
	5	Auxiliary hole.
	6	Thread.
	7	Gear.
(2) Shape	1	Longitudinal
	2	Form
	3	Face (cross)
	4	Shape element.
(10) Type of Geometrical Deviation	1	Out of roundness
	2	Flatness error.
	3	Straightness error.
	4	Parallelism error.
	5	Angularity error.



- (1) A linear search about the first geometrical feature group (external rotational) has to be carried out.
- (2) If there is no feature of the type of the geometry group under consideration, the corresponding geometry code position will take zero and automatically the corresponding quality code position will take also zero. The procedure then will go to analyse the next group and so on.
- (3) If there is one or more features from the geometry group under consideration, the corresponding value of the geometry code position can be automatically selected in accordance with the table (1).
- (4) After the determination of the value of the geometry code position, the corresponding value of the quality code position will be determined according to tables (2) and (3) taking into consideration the surface roughness and the tolerances (dimensional and geometrical) of all features of the geometry group. The highest value will be selected.
- (5) The procedure will be repeated for all other geometrical feature groups.
- (6) The values of the code positions (15) to (17) are fed as input data. Fig. 5 shows an example for the application of the "CAWC".

CONCLUSION

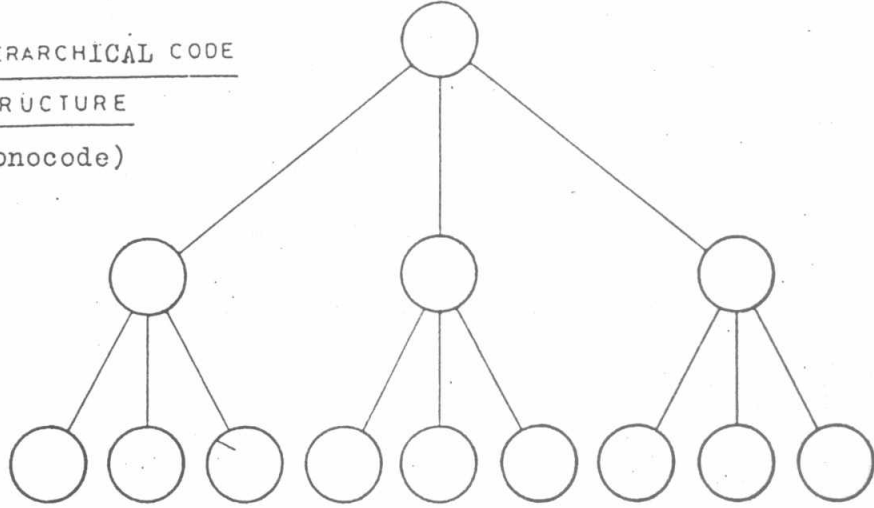
A computer aided classification and coding system (CAWC) has been developed in the present work. The system can be applied in any automated process planning system. The developed system represents an important part in integrated manufacturing systems.

REFERENCES

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HIERARCHICAL CODE
STRUCTURE
(Monocode)



CHAIN TYPE
CODE
STRUCTURE
(Polycode)

DIGIT	FEATURE	POSSIBLE VALUES			
		1	2	3	4
1	E . R .	SHAPE 1	SHAPE 2	SHAPE 3	—
2	I . R .	SHAPE 1	SHAPE 2	—	—
3	E . NR .	FLAT	—	—	—
4	I . NR .	SLOT	—	—	—
5	GEAR	—	—	—	—

HYBRID CODE
STRUCTURE

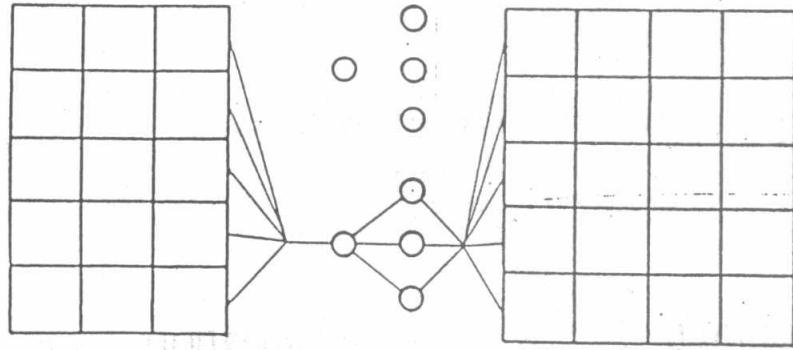


FIGURE (1) : CODE STRUCTURES



- 1 EXTERNAL ROTATIONAL FEATURES
- 2 INTERNAL ROTATIONAL FEATURES
- 3 EXTERNAL NONROTATIONAL FEATURES
- 4 INTERNAL NONROTATIONAL FEATURES
- 5 AUXILIARY HOLES
- 6 THREADS
- 7 GEAR TEETH
- 8 SURFACE QUALITY OF EXT. ROT. FEATURES
- 9 SURFACE QUALITY OF INT. ROT. FEATURES
- 10 SURFACE QUALITY OF EXT. NONROT. FEATURES
- 11 SURFACE QUALITY OF INT. NONROT. FEATURES
- 12 SURFACE QUALITY OF AUX. HOLES
- 13 SURFACE QUALITY OF THREADS
- 14 SURFACE QUALITY OF GEAR TEETH
- 15 HEAT TREATMENT
- 16 WORKPIECE MATERIAL GROUP
- 17 WORKPIECE MATERIAL FORM
- 18 MAJOR DIMENSIONS

FIGURE (2): POSITION INFORMATION CONTENT OF THE GWCC SYSTEM.

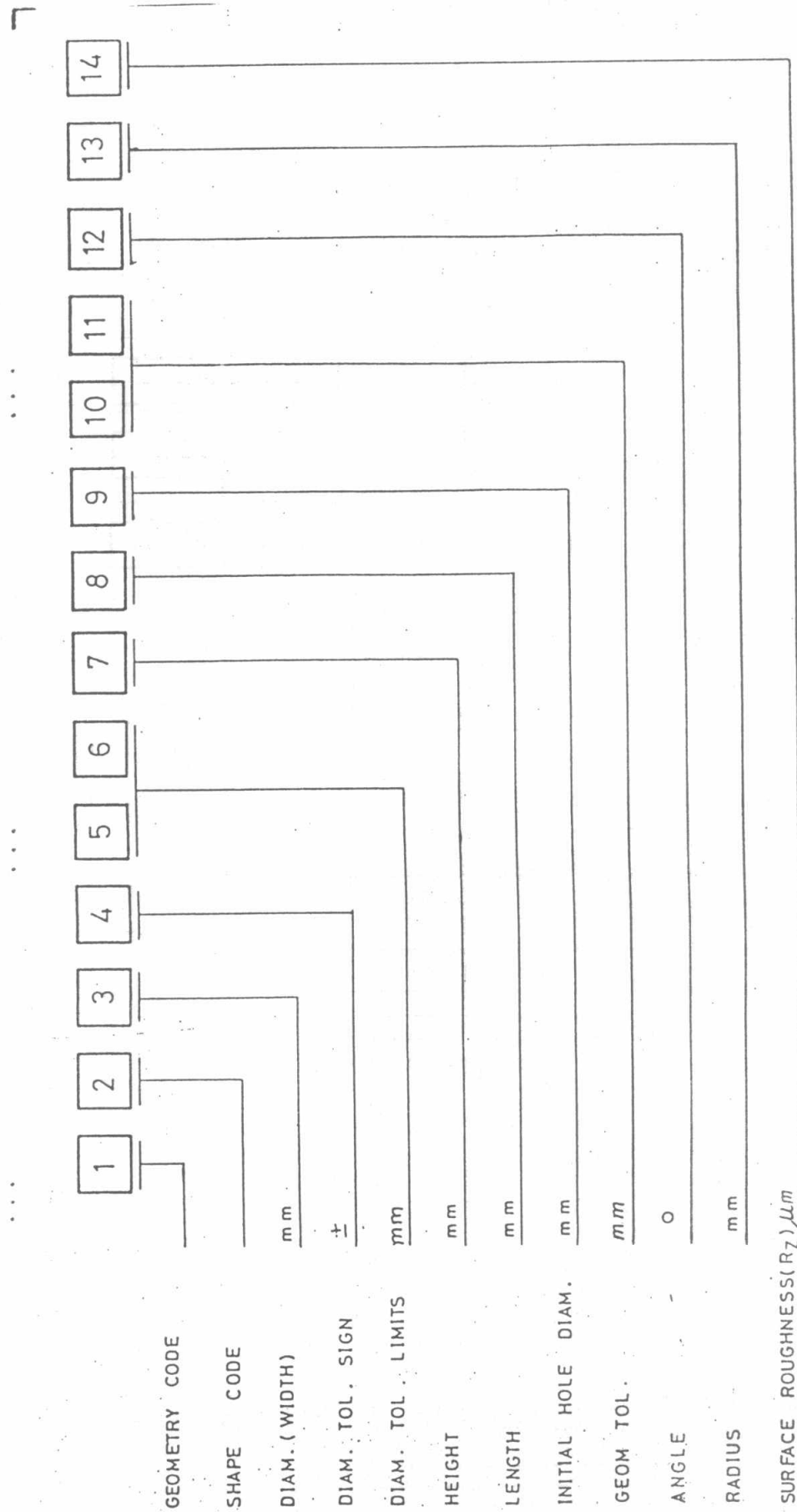


FIGURE (3) : INFORMATION CONTENT OF FEATURE CODE (GFCS)

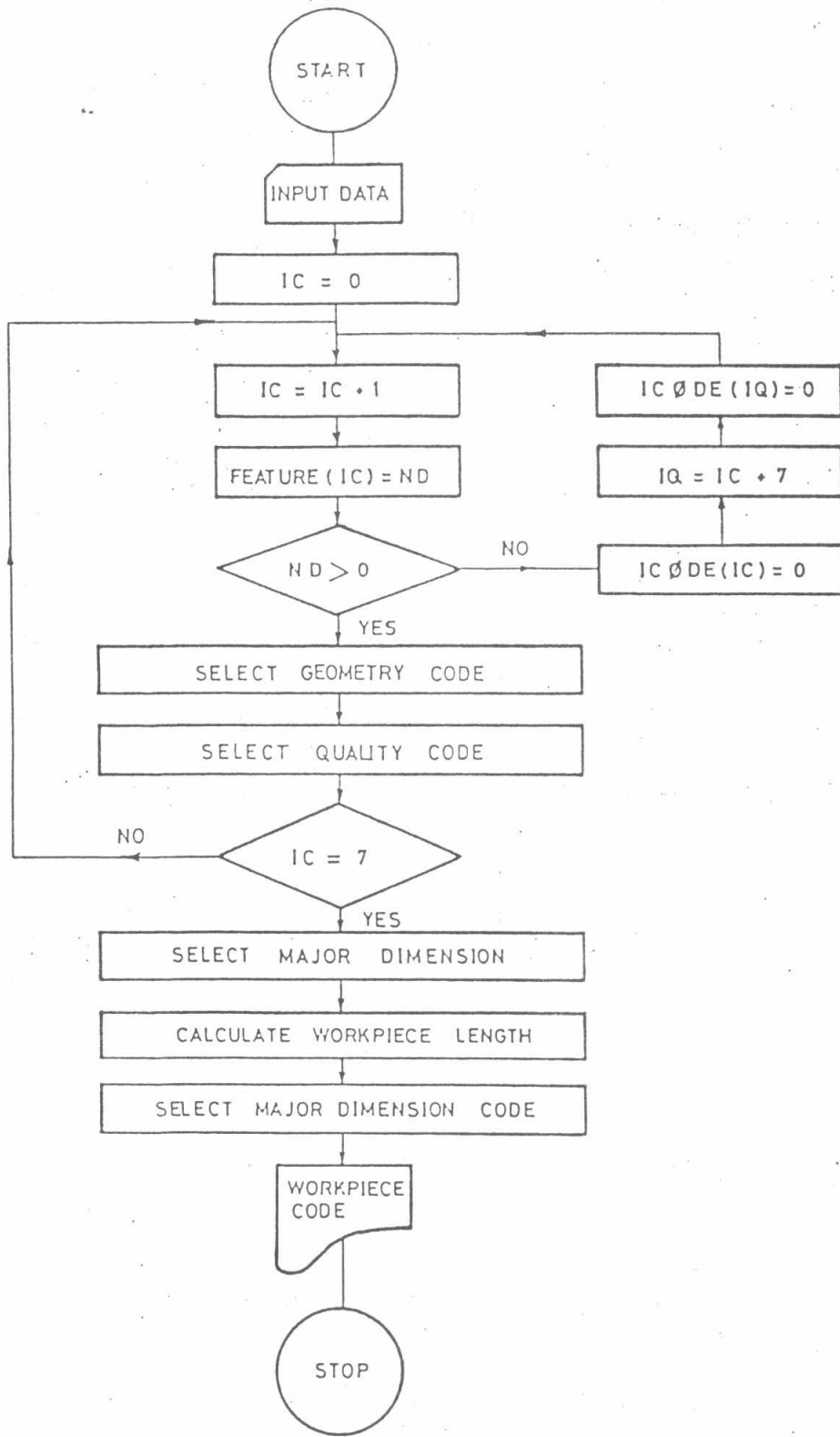


FIGURE (4) PROCEDURE FOR COMPUTER AIDED WORKPIECE CODING (CAWC)

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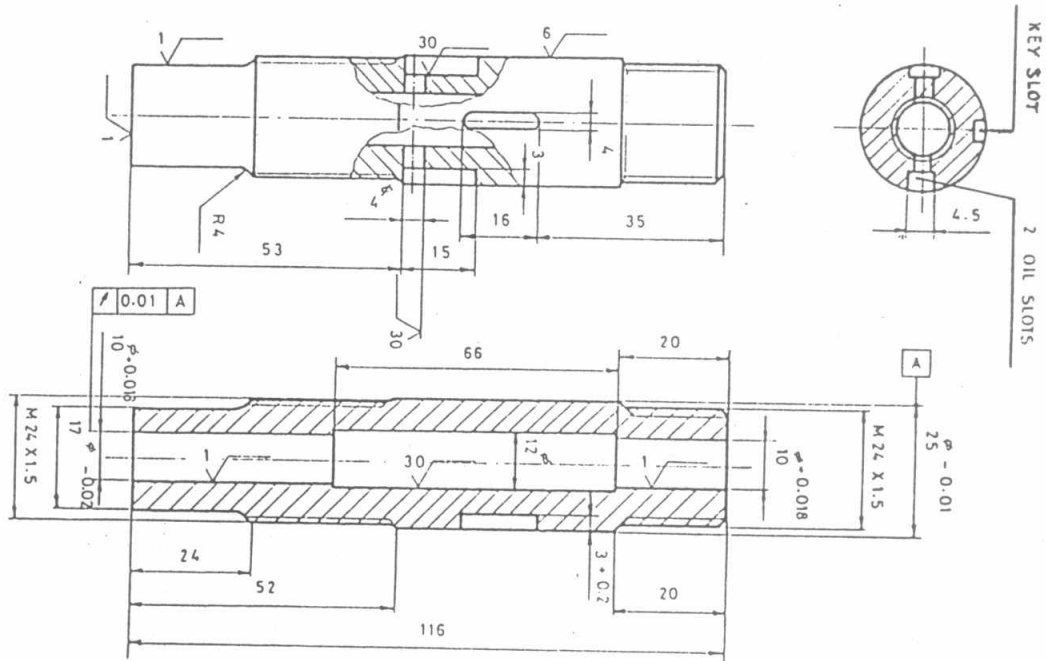


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HRC 62 - 64

68 (1, 6, 30)



INTERMEDIATE OUTPUT

ANALYSIS OF GEOMETRY:

WORKPIECE CODE:

4 5 2 0 2 1 0 4 4 2 0 2 1 0 1 3 1 4

EXT. ROT. : STEPPED IN BOTH DIR.

MULT. DIAM. THR. BORE NO SHAPE ELEM.

EXT. SLOT OR KEYWAY

NO INT. NONROT. FEATURES

AUX. RADIAL HOLE (ROUND)

EXT. THREAD

NO GEARS

FIGURE (5) THE SAMPLE WORKPIECE FOR THE PRACTICAL APPLICATION.

