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Optimisation of Process Planning System for Prismatic Parts

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Abstract
This study includes process planning of prismatic parts by means of expert system. On the computer controlled machine tools, operation methods and mostly used process types in manufacture are drawn with solid modelling. Feature recognition process is achieved with "B-Rreb" modelling method to give vectorel direction knowledge and adjacent relationships of surface using STEP standard interface program. Furthermore, operation type and sequence of operation are defined for the prismatic parts by using the databases achieved from the feature recognition module. This developed method was prepared on an IBM compatible PC by using C++ programming language is used for this purpose and explained with a sample.

Key Words: Process Planning System, Prismatic Parts

Introduction

Now a days, the use of computers and communication technologies in the manufacturing industries is rapidly being widespread in order to increase production, reduce costs and produce better quality products in design and manufacturing sectors. It is now compulsory to use CAD/CAM Systems to produce qualificated product with a cheaper cost for cheap & good quality products in manufacturing.

Although, it seems that CAD and CAM are independent modules, in fact they are directly integrated with CAPP (Computer Aided Process Planning). As it is, the starting point and first station of CAD/CAM integration, design is the main feature of CIM (Computer Integrated Manufacturing). With the help of CAD activities, a model can be designed and presented to the production line with a minimum time, and effort Dereli and Filiz (1996). Process planning is a plan that decides how to manufacture a work part according to its design properties and find the parameters and necessary production methods in order to transform raw material into product Kayacan and Celik (1997). It is now on the agenda to use the expert system approach for improvement and high-levelled evaluation of CAPP system.

The developed software has huge databases including knowledge, which is based on expertness. In general, prolog and lisp languages are used in improving this type of process planning systems Chris and Jimmie (1993). In expert system, it is possible to add, delete or change the rules of the database without affecting the structure of the software Chang and other (1991). Expert systems provide perfect results in automation and deciding stage of planning.

In CAPP, data of parts drawn with CAD, "database is used one of the graphic interface standards such as DXF, IGES, VDA, FS, CAD*I, SET, PDES, STEP. Since there is no data such as necessary geometric data for CAPP, edge points and surface particles, In DXF and IGES graphic interfaces use actuality in process planning is diminishing. PDES (Product Data Exchange Specification) and STEP (Start for the Exchange of Product Data), the last proposed graphic interfaces, are preferred by researches of CAPP lately as they include necessary topological - geometric data for CAPP, tolerance and information about surface relations and features.

In order to achieve CAPP, first of all data are formed firstly by using one of standard graphics interface programs that includes geometric and topological features of a part which are designed by CAD in the first stage of CAPP, (B-Rep, Constructive Solid Geometry). Features on the product are recognised which to be used in database and process planning by using geometric and topological data formed with one of the modelling techniques. Feature is a geometric figure or parts having process function on any part.

In the CAPP particles, Determination of sequence of operation and operation type, selection of cutting tool and the module for cutting parameters are directly related to each other. Data formed by the result of recognition of process part by the computer to determine the operation type and sequence and cutting parameters data files are used for determining cutting parameters together with the selection of cutting tool and holder. Kusiak (1991) made arrangement and decomposition of workable capacities to find the process sequence by using the specified restrictions in his database.

In order to achieve operation type and sequence of operation, feature recognition data, operation type and sequence operation data; tool holder selection and cutting parameters data files are used, respectively. However CNC part program generation and simulation of operations are performed by using constructed data files which are derived from part program generation and simulation modules use these data base, respectively. If one of these modules is absent or functions insufficiently, it will be prepared by hand using. In this case main aim of the CAD/CAM integration will be collapsed. For full integration of CAD/CAM; all modules should be determined automatically by computer aids.

Up to today, operation sequence and operation types were investigated by a number of different researchers. Some of these studies are summarised in following sentences; Joshi and other (1988), developed a process planning system which puts the operation type and sequence in order for prismatic parts. Operation sequence and operation types are put in order according to its priority by using intelligent system. Each operation on the prismatic part is obtained by examining the characteristic factors, which are specified by researches Filiz and other (1996). Rho and other (1992) studied optimisation sequence of operation according to the technical and economical criteria by using developed matrix method, which is developed to determine process sequence. Minimisation of total cutting cost for the sequence of operation is studied by Lin and Wang (1993). Constructed database, which is used by examining the specified restrictions, is used for obtaining sequence of operation Gülesin and Joses (1993). Barkocy and Zdeblick (1984) studied economics of cutting condition by using referred cutting, parameters by manufacturer catalogues. According to all of the studies were summarised above standard features on prismatic parts were introduced.

In this study standard and non-standard features on the prismatic parts were introduced by developed process planning methods. This process planning method includes free feature introduction, determining process sequence, determine process type and selection of cutting and holding tools.

Feature Recognition: Features are divided into two groups which are standard and inclined features. Each group is examined separately. The groups were classified into two groups according to widely used milling operations and machinabilities of operation. The first group consists of standart features such as; closed pocket, flat canal, step, semi step, side pocket. The second group includes non-standart features such as inclined closed pocket, inclined step, inclined semi step inclined side pocket, V-slot, inverse V-slot, closed V-slot, open V-slot. In the feature recognition by computer aids, the developed Base Surface Method has been used. The method uses neighbouring relations of surface, Base-Referance-Surface, Base surface, direction knowledge of surface unit vectors which were obtained from STEP outputs of model part. The extraction of these knowledge from data base is explained in the following paragraphs.

Base-Surface-Relation Method (BSR): STEP standard includes corner points, line, surface, shell, closed surface loop and direction knowledge of a part. Surface knowledge of the parts is found in the STEP data file in an untidy and complex structure. These knowledges are extracted from data file by using developed Based-Surface-Relation method and they are arranged systematically.

Part analyze is made by using selection of base-reference-surface, relation of surfaces and determining direction of surface which were obtained from step standard by using the developed method.

a. Selection of Base-Reference Surface: In this method, base is accepted as the basic surface and all relationships are constructed according to this surface. The lowest base surface and lower left corner of prismatic parts are accepted as Base-Reference-Surface and reference point of part, respectively.

The surfaces on the part are analyzed on their coordinate surface so 3-D parts can be analyzed easily and surface reference point is determined in advance. Lines, which enclose the surface according to the selected reference point, are sorted around the clockwise direction. The "U" shaped surface is selected as an example as shown in Fig.1. Corner point, which has coordinates value, is assumed as a Surface Reference Point (SRP). After boundary lines of the surface are sorted around the clockwise direction and used for extraction of surface knowledge. One of the important parameter of the examined surface is coordinate plane. If at least two of the coordinates of plane are equal to each other, the different two sides are perpendicular to each other.

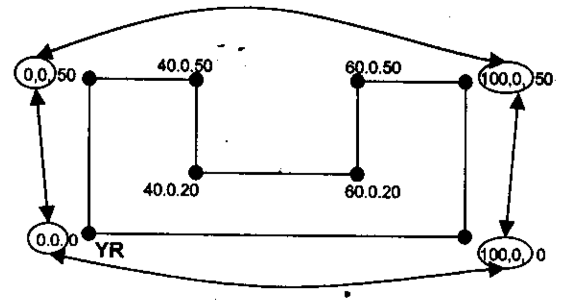


Fig.1: Side Knowledge of Surface

The surfaces of the part can exist on coordinate surface as given in Fig.2. The coordinate system is divided into three different surfaces (xy, yz, yz) and surfaces are explained by given 0 and 1 values to x, y, z directions of a surface.

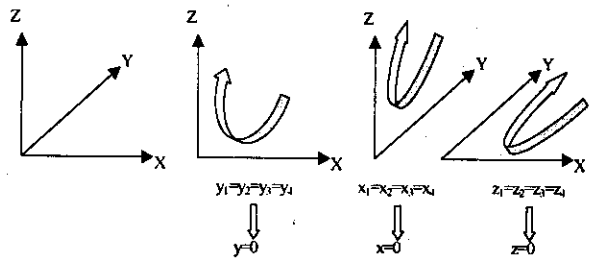


Fig. 2: Planes and Direction Vector of Co-ordinate System

If the co-ordinate axis is perpendicular to the surface, its value will be "0" and if it is on the surface, its value will be "1". Their rules are arranged in the knowledge base. Each surface of the part is classified according to its coordinate plane. Surfaces of the each coordinate plane are arranged from the lowest x, y, z coordinate to the highest x, y, z coordinate. Base surface of the feature is determined by comparing knowledge base and database knowledge of feature. Every horizontal surface can be base surface but a feature has one Base surface (Bs). Fetuses are examined individually. Surfaces, which can be the base surface are determined for each feature by taking the planes into consideration. In the Fig. 3, R is part reference point, E represents base surface of step feature.

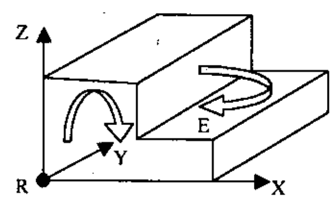


Fig. 3: Step Feature

b. Determining the Surface Direction: Part feature recognition system needs definition of corner points, sides and vectorel direction of surface. Three types of unit vector direction of coordinate plane were defined by taking structure of prismatic parts into consideration.

Sample part is given in the Fig.4. All surfaces of this part are perpendicular to each other and the direction vector for all surface are defined acordin to the coordinate of surface. By taking Machinability of feature into consideration, parallel surface to the base plane is assumed as the part reference surface. Unit vector of ABCD surface in the Fig 4a is f(x)yz. If a surface is inclined according to the base reference surface, the plane, which the surface in on, surface coordinate will be inclined and will have two vectorel components. EFGH surface is inclined to the defined reference plane and f(x, z) unit vectors' direction for this plane has an angle with $(y,z)_x$, and $(x,y)_z$ planes as shown in Fig.4b. 3-D surface of IJKL (Fig.4c) is analysed same as the other surface. Unit vector direction values of surfaces of coordinate plane are defined with x(0), y(1), z(2) and -x(0), -y(-1), -z(-2). If the analysed plane exist on two different planes, it has different characteristics from the ones that define mono-vector direction values as it is defined by single-componental unit vector. Unit vector direction values plane is summarised in Table.1.

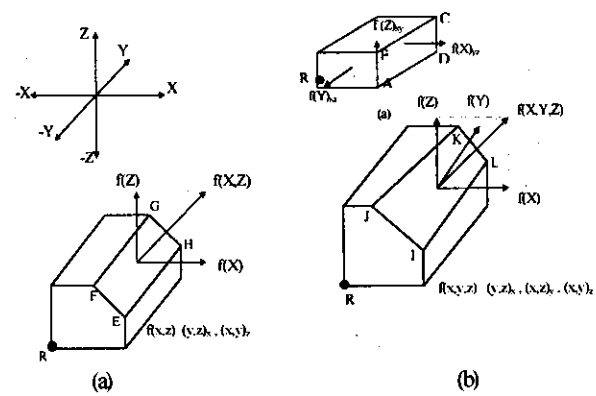


Fig. 4: Surface Types of Prismatic Parts

c. Neighbourly Deed Relation of Surfaces

Neighbourly deed relations of the features are examined by aid of knowledge base defined by BSR method. Neighbourly deed relation is divided into two groups such as concave and convex. A corner defines at least one surface except itself and determines and neighbourly deed relation of surfaces. The coordinate of two neighbouring surfaces according to each other is determined by convex or concave neighbouring relationships. Concave and convex relations of the surface are given in Fig.5. Neighbourly deed relations of the all surfaces are determined by examining the surfaces from part reference surface to the all of other surfaces. In this study machining features have been divided into two main categories "such as, standard and inclined features" according to the machinability of features. Standard features of the prismatic part have been called closed pocked, straight slat, step, side pocked, semi-step and hole are given in Fig. 6.

Neighbourly deed relations of the surface, base reference surface co-ordinate plane and unit vector values are given in Table 2. As the selected basic features are on xy co-ordinate, x and y values on BSR co-ordinate plane are 1 and z is 0.

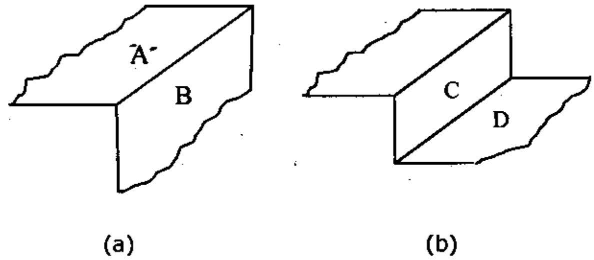


Fig.5: Neighbourly deed relation of surface

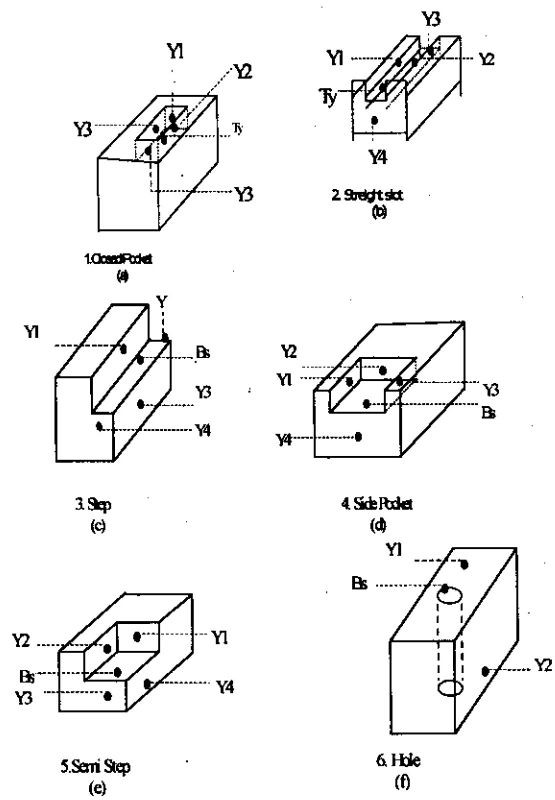
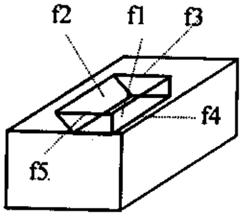


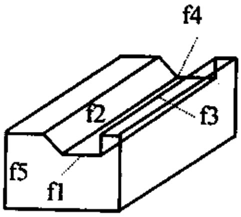
Fig. 6: Standard Prismatic features

The BSR of standard features have the same unit vector. On the neighbourly deed columns, Bs column has "0" and "-1" values "-1" means feature has no base surface. On the other columns (like y1, y2, y3 and y4), "-1" defines concave relation and "1" defines convex relation. Second group features consist of inclined closed pocket, angular slot, inclined slot, inclined side step, closed v slot, inclined side pocket and v slot as shown in Fig.7. The symbols f1, f2, f3, f4 and f5 represent both unit vector and neighbourly deed relation. f1 defines base surface (BS), and f2, f3, f4, f5 specifies neighbour surfaces y2, y3, y4, y5 respectively. The inclined slot is selected as an example features drawn Fig.7. f1 is on the +z direction and BRS is neighbour to the surface f2 so that f2(x,z) has the different co-ordinate plane like that $(y,z)_x$, $(x,y)_z$. Therefore, $f_2(xz)$ is defined by directions $f_3(-x)$, $f_4(+y)$ and $f_5(-y)$ angular with plane $(yz)_x$ and $(xy)_z$. It is also defined by f3(-x), f4(+y) and f5(-y). Base Surface Relation knowledge base is given in Table.3 for



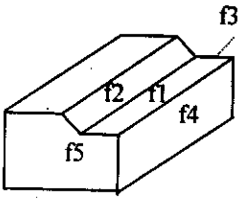
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(-y)$	$(x,z)_{-y}$
$f_4(-x)$	$(y,z)_{-x}$
$f_5(y)$	$(x,z)_y$

1.Inclined Closed Pocked



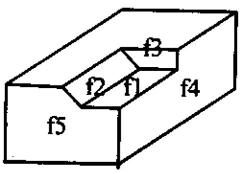
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(-x)$	$(y,z)_{-x}$
$f_4(y)$	$(x,z)_y$
$f_5(-y)$	$(x,z)_{-y}$

2. Inclined Slot



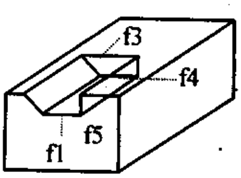
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(y)$	$(x,z)_y$
$f_4(x)$	$(y,z)_x$
$f_5(-y)$	$(x,z)_{-y}$

3. Inlined Step



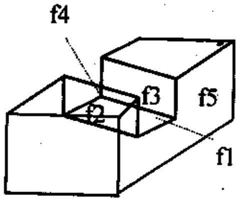
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(-y)$	$(x,z)_{-y}$
$f_4(x)$	$(y,z)_x$
$f_5(-y)$	$(x,z)_{-y}$

4. Inclined Semi Step



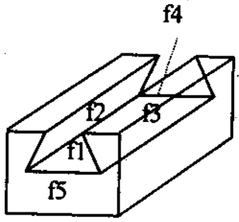
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(-y)$	$(x,z)_{-y}$
$f_4(-x)$	$(y,z)_{-x}$
$f_5(-y)$	$(x,z)_{-y}$

5 Inclined Side Pocket



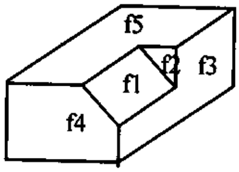
$f_1(z)$	$(x,y)_z$
$f_2(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_3(-x,-z)$	$(y,z)_{-x}$, $(x,y)_{-z}$
$f_4(-x)$	$(y,z)_{-x}$
$f_5(x)$	$(y,z)_x$

6. Angular Slot



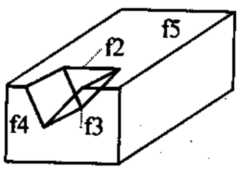
$f_1(z)$	$(x,y)_z$
$f_2(x,-z)$	$(y,z)_x$, $(x,y)_{-z}$
$f_3(-x,-z)$	$(y,z)_{-x}$, $(x,y)_{-z}$
$f_4(y)$	$(x,z)_y$
$f_5(-y)$	$(x,z)_{-y}$

7. Inverse "V" Slot



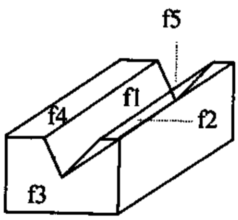
$f_1(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_2(-y)$	$(x,z)_{-y}$
$f_3(x)$	$(y,z)_x$
$f_4(-y)$	$(x,z)_{-y}$
$f_5(z)$	$(x,y)_z$

8. Inclined Surface



$f_1(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_2(-y)$	$(x,z)_{-y}$
$f_3(-x,z)$	$(y,z)_{-x}$, $(x,y)_z$
$f_4(-y)$	$(x,z)_{-y}$
$f_5(z)$	$(x,y)_z$

9. Closed " V" Slot



$f_1(x,z)$	$(y,z)_x$, $(x,y)_z$
$f_2(-x,z)$	$(y,z)_{-x}$, $(x,y)_z$
$f_3(-y)$	$(x,z)_{-y}$
$f_4(z)$	$(x,y)_z$
$f_5(y)$	$(x,z)_y$

10. " V" Slot

Fig. 7: Selected inclined Prismatic Part

Table 1: Direction Vectors of Unit Vector on the Co-ordinate Plane

Direction Knowledge of the Unit Vectors of the Inclined Surfaces											
XY	XZ	YZ	-XY	-XZ	-YZ	X-Y	X-Z	Y-Z	-X-Y	-X-Z	-Y-Z
001	010	100	110	101	011	-001	-010	-100	-110	-101	-011

Table 2: BSR Database for First Group Feature Types

Feature Type	Neighborly Deed Relation				BSR Coordinate Plane Operations of Directions							
	Bs	y1	y2	y3	y4	X	Y	Z	f2y	f3y	f4y	f5y
1	0	-1	-1	-1	-1	1	1	0	-1	-0	1	0
2	0	-1	1	-1	1	1	1	0	0	1	-0	-1
3	0	-1	1	1	1	1	1	0	0	1	0	-1
4	0	-1	-1	-1	1	1	1	0	0	-1	-0	-1
5	0	-1	-1	1	1	1	1	0	0	-1	0	-1
6	-1	0	0	-	-	1	1	0	2	-2	-	-

Table 3: BSR Inclined Feature Type Database for Second Group of Feature Ttypes

Feature Ttype		Neighborly Deed Relation				BSR Coordinate Plane			Operations of Directions			
	Bs	y2	y3	y4	y5	X	Y	Z	f2y	f3y	f4y	f5y
1	0	-2	-1	-1	-1	1	1	0	010	-1	-0	1
2	0	-2	-1	1	1	1	1	0	010	-0	1	-1
3	0	-2	1	1	1	1	1	0	010	1	0	-1
4	0	-2	-1	1	1	1	1	0	010	-1	0	-1
5	0	-2	-1	-1	1	1	1	0	010	-1	-0	-1
6	0	-2	-2	1	1	1	1	0	001	-110	-0	0
7	0	-2	-2	1	1	1	1	0	-010	-101	1	-1
8	0	-1	1	1	1	2	0	2	-1	1	-1	2
9	0	-1	-2	1	1	2	0	2	-1	1	-1	2
10	0	-2	1	1	1	2	0	2	101	-1	2	1

Table 4: Total Self factors of Feature Types which are on (+z) Plane

Feature Type	Self Factor	Feature Factor	Total Factor
1.Closed_Pocked	600	30	630
2.Straiht_Slot	600	25	625
3.Step	600	20	620
4.Side_Step	600	15	615
5.Semi_Step	600	10	610
6.Hole	600	5	605

Table 5: Knowledge Base for Sample Part

Operation No	Feature Type	Reference Coordinate of Feature			Feature Dimension		Operation Direction		Cutting Direction
		X	Y	Z	D	G	B		
1	Step	65	0	60	20	100	135	+Y,-Y,-X	+Y,-Y
2	Closed_Pocked (3)	155	35	60	20	30	30	-Z	+X, +Y
3	Closed_Pocked (4)	160	40	40	20	20	20	-Z	+X,+Y
4	Slot	65	0	40	40	100	75	-Y,+Y,-Z	+Y
5	Closed_Pocked (2)	90	35	20	20	30	30	-Z	+X,+Y
6	Closed_Pocked (1)	20	35	60	20	30	30	-Z	+X,+Y
7	Closed_Pocked (5)	165	45	20	20	10	10	-Z	+X,+Y
8	Hole (1)	35	50	60	6	60	0	-Z	-Z
9	Hole (2)	105	50	20	6	20	0	-Z	-Z
10	Hole (3)	170	50	20	6	20	0	-Z	-Z

second group features. According to table first column defines features type. On the neighbourly deed relation columns; BS base surface at the y2, y3, y4, y5 columns (1, 2) defines convex relation, (-1, -1) defines concave relations. Base Reference Surface columns defines the position of the BRS on the co-ordinate plane, surface direction columns defines surface direction to the BRS.

Determining Operation Type and Sequence of Operation : After features of **CAD** parts are described to computer, operation type and sequence of operation are determined by considering feature characteristics and the plane, which the feature exists. The prismatic parts consist of six different surfaces such as bottom, left side surface, right side surface, top, front and back surfaces as shown in Fig.8. Machinability, set-up of prismatic part on table and approach direction of cutting tool to the prismatic part is taken into consideration for defining sell factor. The specified self-factor of the surfaces are listed below.

Top 600
Front 500
Right side 400
Left side 300
Back side 200
Bottom 100

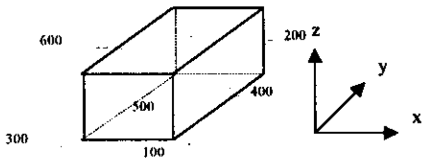
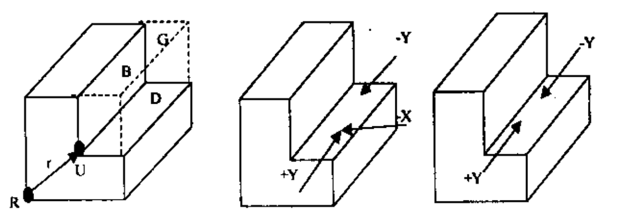


Fig. 8: Priority of Prismatic Part Surfaces According to Machinability

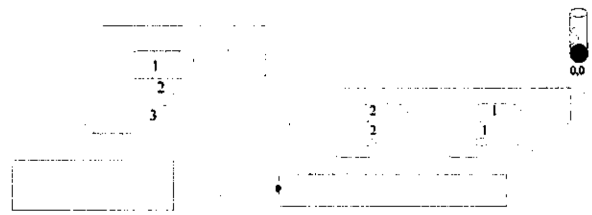
The surface, which includes maximum machining operation, is setted on (+Z) co-ordinate direction and The second maximum machining surface is coupled on (-Y) direction.
Instead of self-factor of surfaces, self factor for each feature is also specified. Feature type, dimensions of the feature, position according to the part reference point, direction of machining and cutting directions are taken into consideration for self factor determination of feature. Total factor of each feature is calculated by summing self-factor of surface and sub-group of self feature factor. Total self-factors are listed in the Table.4. Operation types are selected automatically according to feature types, cutting tool and holder properties by computer aid. Dimensions of operation (width, length and high) must be determined from prismatic part. Firstly base surface is selected for a feature as shown in Fig.9. The difference between maximum and minimum values of base surface (x2-x1=x) represents with on x-axis, the difference of maximum and minimum y values (y2-y1=y) represent length of feature on y-axis and z represents depth on z-axis.
Closest distance from base surface co-ordinate to part reference point is defined as feature reference point and it defined the position of feature. Possible alternative operation directions are given in Fig.9.b (in -y +y and -x directions). Feasible possible machining directions of step features are -y and +y as shown in Fig.9c.



(a) (b) (c)

Fig.9: Sample Step Features

There can be some special conditions in manufacturing of prismatic parts. For example, some operations of manufacturing can be sub-set of another operation group. Total self-factor of that feature is equal to the sum of all feature factors and self-factor. Sequence for sub-operations are determined in the same way. In Fig.10.a, as first operation (closed pocked) is on the top, it includes the other two operations (2 and 3) and has the highest total factor. If there are equal self-factors for different operation groups, new total factor will be determined by adding 10 points to the self-factor of feature which is closest to the 0 point of the cutting tool.



(a) (b)

Fig.10: Part Sample, which Have Similar Operation Types and Self-Factor

Application: Selected sample prismatic part which is given in Fig.11, has 10 different operations. The features of closed pocket (C) and hole (D), which were selected by Base Sure Relation (BSR) method, saved in the feature recognition data file.
Starting point and, dimensions (width, length and height) of each feature on the part is obtained from prepared data file. Besides those properties, cutting direction, and possible machining directions are also determined. Properties of the features on the part are listed in Table 5.

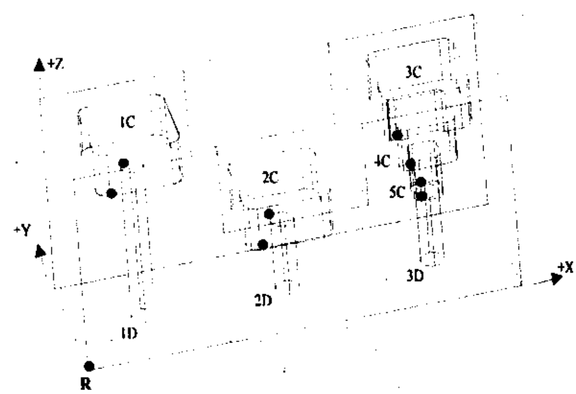


Fig.11: Sample Part

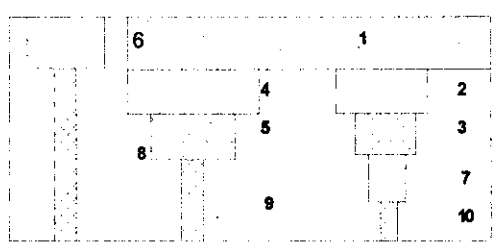


Fig. 12: Operation Sequence for Sample Part

Table.6 Factors that Affect Features on Sample Part

Feature Type	Total Factor	Pocket	Slot	Hole Factor	Correction Factor	Total Operation	Sequence of Operation
Closed_Pocked (1)	630			605	10	1245	6
Closed_Pocked (2)	630			605	20	1255	5
Closed_Pocked (3)	630	630/2		605		2495	2
Closed_Pocked (4)	630	630/1		605		1865	3
Closed_Pocked (5)	630			605		1235	7
Slot	625	630		605		1860	4
Step	620	630/4	625	605/2		4975	1
Hole (1)	605			20	625	8	
Hole (2)	605			10	615	9	
Hole (3)	605				605	10	

Table.7 Operation Sequence and Type for Ssample Ppart

Operation No	Total Factor	Feature Type	Operation Type
1	4975	Step	Step_Milling
2	2495	Closed Pocket (3)	Pocket_Milling
3	1865	Closed Pocket (4)	Pocket_Milling
4	1860	Slot	Slot_Milling
5	1255	Closed Pocket (2)	Pocket_Milling
6	1245	Closed Pocket (1)	Pocket_Milling
7	1235	Closed Pocket (5)	Pocket_Milling
8	605	Hole (1)	Drilling
9	605	Hole (2)	Drilling
10	605	Hole (3)	Drilling

Table.8 Selected Cutting Tool and Tool Holder for Selected Part

Operation No	Feature Type	Operation Type	Cutting Tool	Tool Holder
1	Step	Step_Milling	SEAN 1303AFTN-M15	R217.33-3250.3-12
2	Closed Pocket (3)	Pocket_Milling	CCMX 060204T-MD06	R217.19-1612.3-06
3	Closed Pocket (4)	Pocket_Milling	CCMX 060204T-MD06	R217.19-1612.3-06
4	Slot	Slot_Milling	SEAN 1303AFTN-M15	R217.33-3250.3-12
5	Closed Pocket (2)	Pocket_Milling	CCMX 060204T-MD06	R217.19-1612.3-06
6	Closed Pocket (1)	Pocket_Milling	CCMX 060204T-MD06	R217.19-1612.3-06
7	Closed Pocket (5)	Pocket_Milling	RPKX 2006MOT-M15	R217.29.3205.3-10
8	Hole (1)	Drilling	-	R216.13-0060
9	Hole (2)	Drilling	-	R216.13-0060
10	Hole (3)	Drilling	-	R216.13-0060

According to the table, first column defines sequence of operation. Second column shows name of features and the number in the brackets identify sequence of operation between same types of operations. In the column 3 and 4, starting point co-ordinate of feature and dimensions of feature are given. For the hole feature, H and W identify Diameter of feature and height of feature, respectively. The last two columns represent machining and cutting direction.

Calculated factors and surface position factors for ten features on the sample part are listed in Table.6. In the Table 6, column one defines type of the feature. At the second column total self-factors for all features are given. The column 3, 4 and 5 represents number of same features and their self-factor values. The last column includes sequence of operation. At the correction column closed pocket (2) and hole (1) has value of 20 as a correction factors. If two or more features have the same total factors, the new total factor can be obtained by taking the last position of cutting tool and machinability into consideration. The correction factor is calculated with adding the nearest feature to the cutting tool to the results of equation (1) as a correction factor.

$$\text{Correction Factor} = (n - 1) * 10 \qquad (1)$$

In the equation, n represent number of features, which have the same total factor. The operations are resorted according to the values of total factors. The operation, which has the maximum self- factor, will be the first and the one, which has the minimum self-factor, will be the last. Machining area of the sample part is defined in Fig.12. Sorted sequence of operation is given in Table.7. According to the defined feature and operation type, cutting tool and tool holder knowledge are selected as given in Table.8 by using SECO catalogue.

Conclusion

In this study, coupling module of Computer Aided Design and Computer Aided Manufacturing for prismatic part is designed and constructed.

The developed BSR method knowledge base and unit vector operation is applicable for all prismatic parts. All required knowledge could be obtained with developed method.

All modules (feature recognition, sequence of operation, cutting tool selection and tool holder selection) are integrated between each other. Inanition to this, the modules can operates individually.

Cutting parameters and NC part program can easily be constructed by using obtained data file. Because, it requires all necessary knowledge.

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