Research Paper

A 2.5 D Prismatic Part Machining for Computer Aided Process Planning

Engineering

KEYWORDS : Computer aided design, computer aided process planning, Feature Recognition, algorithms, computer aided manufacturing and geometric modeling.

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ABSTRACT

The geometric information from the given CAD file for a designed component, may not be able to useful directly for process planning. Different CAD or geometric modeling packages store the information related tothe design in their own databases. Then various optimized approaches are much needed to translate geometrical specification into machine cognize. The (B-Rep) Boundary Representation analyze the geometrical information of the part from CAD model into machining module by using a feature recognition system. In this paper a unique identification of Machining Feature discussed that is generated explicitly to extract the features from the geometrical information based on a Geometric Reasoning Approach [GRA] and Object Oriented Design [OOD] in C++. A feature recognition algorithm is used to recognize different features of the part such as step, holes, etc. Finally, a sample application as an illustrative example of 2.5D has been described and presented for demonstrative purpose along with simulation.

1. INTRODUCTION

The Computer Aided Design and Computer Aided Manufacturing technologies suggestively augmented for effectivenessin Computer Integrated Manufacturing environment. The individual growth of CAD, CAPP and CAM however, greatly effects the enlargement of global efficiency from end to end. To get effectiveness from design to manufacturing systems, the correlation between CAD and CAM is inevitable, but the bottleneck of CAD and CAM relation reduce the further improvement of productionefficiency. Therefore much efforts are required to discontinuity the remoteness of CAD and CAM systems was to reuse the product model designed in CAD systems in CAM systems [2].It made CAMsystems able to directly manipulate CAD models, either the wire frame or solid model. The current trend is feature-based systems. Features play a key role in the recent integration of CAD/CAM systems. Automatic feature recognition has been successful to a certain extent and applied to Computer Aided Process Planning (CAPP) systems. Feature based CAPP interprets the product model in terms of machining features and uses the features to generate manufacturing instructions to produce the product [7]. But the model given by CAD systems is only the product model of the final shape. With the help of automatic feature recognition, CAPP systems can recognize features directly from solid models created by CAD systems and generate process plans for the solid models. Automatic feature recognition from CAD solid systems highly impacts the level of integration. CAD files contain detailed geometric information of a part, which are not suitable for using in the downstream applications like process planning.Different CAD or geometric modeling packages store the information related to the design in their own databases. Structures of these databases are different from each other. Computer aided design and computer aided manufacturing applications of solid modeling have emerged such as feature and constraint based modeling, automatic mesh generation for finite element analysis, assembly planning including interference checking, higher dimensional modeling for robotics and collision avoidance, tolerance modeling, automation of process planning tasks, etc.[1].A group of application independent geometric tools and algorithms is provided which can be used to query/analyze the model to obtain unambiguous results. These tools can be used or combined with other application specific tools to perform the required task. The issues related to data structures and geometric algorithms, their efficiency, reliability and robustness also form an important aspect of solid modeling. The academic effort in solid modeling utilizes several disciplines in many applications. That is including algebraic geometry and topology, differential geometry and topology, combinatorial topology, computer science, and numerical analysis [2]. Field of data transfer between different CAD/CAM systems is a well-established one for a number of years and the paramount importance of CAD/CAM/CAE data transfer between manufacturers and their suppliers and subcontractors has become more apparent. In the early years of CAD/CAM industry, software packages were developed which were employed as direct translators between different systems. CAD/CAM system a vendor was increased, the impracticality of using direct translators becomes more apparent [5].

2. VARIOUS LITERATURE REVIEWS

The part design is introduced through CAD software and it is represented as a solid model by using CSG technique as a design tool [3]. The solidmodel of the part design consists of small and different solid primitives combined together to form the required part design [4]. The CAD software generates and provides the geometrical information of the part design in the form of an ASCII file (IGES) that is used as standard format which provides the proposed methodology the ability to communicate with the different CAD/CAM systems [8]. The boundary (B-rep) geometrical information of the part design is analyzed by a feature recognition program that is created specifically to extract the features from the geometrical information based on the geometric reasoning and object oriented approaches. The feature recognition program is able to recognize these features: slots (through, blind, and round corners), pockets (through, blind, and round corners), inclined surfaces, holes (blind and through) and steps (through, blind, and round corners), etc. These features are called manufacturing information that are mapped to process planning as an application for CAM [11].In order to have a good generic representation of the designed object for CAM applications especially for Computer Aided Process Planning (CAPP), the overall designed object description and its features need to be represented in a suitable structured database. An Object Oriented Representation (OOR) has been used in this paper. The first step toward automatic feature extraction will be achieved by extracting the geometric and topological information from the (IGES-(B-Rrep)) CAD file and redefining it as a new object oriented data structure as demonstrated in Figure 1. In this hierarchy, the highest level data class is the designed object (shell). An object consists of manufacturing features that can be classifies into form features which decomposed of either simple or compound intersecting features and the features are classified into concave or convex as attributes in the generic feature class [6]. Concave features consist of two or more concave faces, and convex features are decomposed of either one or more convex faces or the interaction between other features [8].

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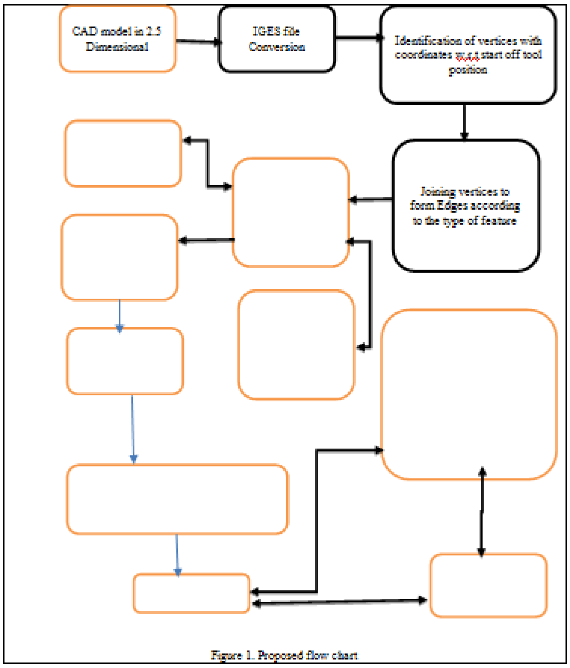
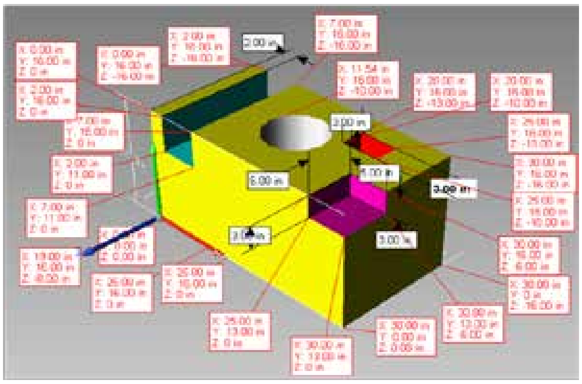


Figure 1. Proposed flow chart

3. PROPOSED METHODOLOGY
Figure 1. Proposed flow chart

4. ALGORITHMS FOR CASE STUDY
In accordance with Figure 2 and 3 some solid primitives as block raw material, slot, blind step, and through pocket and through hole. IGES file will be generated after designing a component.



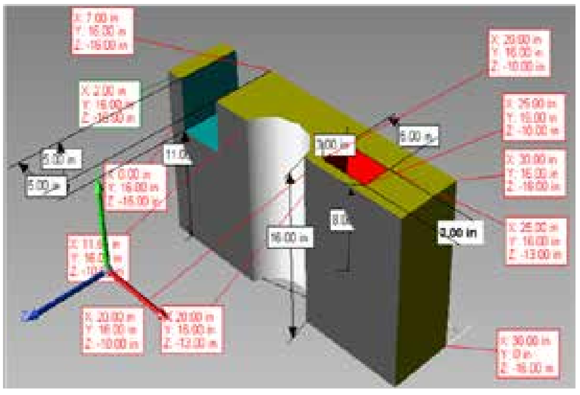


Figure 2. Illustrative Example
Figure 3.Sectional view of Illustrative Example
Identify the detailed features and extract the related feature geometry parameters by Number of vertices, edges, loops, frames, no surfaces, surface type [restraint to concave, convex and hybrid].The following are the algorithms used for extraction and machining of features.

Step 1: The IGESfile projects the various geometrical and topological specifications from given entity.
Step2: Amass all the vertices in an order of and record total vertices along with their coordinates with respect to origin [0, 0, and 0] as the reference point for each and every vertex.
Step 3. Stockpile the vertices concerned with the related feature and group the vertices in accordance with the feature contour.
Step4. Extracted geometrical topologies from entities in each and every basic surface, recognize and analyze its type,the results are obtained as follows.

Table1. Extraction of Edges

No.	Vertex I.D	Coordinates X Y Z
1	[1]	[20,13,16]
2	[2]	[19,8,0]
3	[3]	[11,8,0]
4	[4]	[11,8,16]
5	[5]	[25,13,8]
6	[6]	[25,10,8]
7	[7]	[25,13,8]
8	[8]	[25,10,8]
9	[9]	[20,10,16]
10	[10]	[25,10,16]
11	[11]	[20,13,16]
12	[12]	[20,13,16]
13	[13]	[30,6,10]
14	[14]	[30,0,10]
15	[15]	[25,6,10]
16	[16]	[25,0,10]
17	[17]	[25,6,16]
18	[18]	[25,0,16]
19	[19]	[30,6,16]
20	[20]	[30,0,0]
21	[21]	[30,16,0]
22	[22]	[30,16,16]
23	[23]	[7,6,11]
24	[24]	[7,0,11]
25	[25]	[2,16,11]
26	[26]	[2,0,11]
27	[27]	[2,16,11]
28	[28]	[2,0,11]
29	[29]	[7,0,16]
30	[30]	[7,16,16]
31	[31]	[0,0,16]
32	[32]	[0,0,0]
33	[33]	[0,16,16]
34	[34]	[0,0,16]

Table 2Extraction of Edges

Edge I.D	Edge Type	Coordinates Starting Point	Terminal Point	Centre	Length /Radius	Concavity
[1]	Line	[1]	[2]		14	Tangent
[2]	Cir. Arc	[3]	[1]	(15,8, 14)	4	
[3]	Line	[4]	[3]		14	Tangent
[4]	Cir. Arc	[2]	[4]	(15,8,0)	4	
[5]	Line	[5][6]			3	Concave
[6]	Line	[7][5]			5	Concave
[7]	Line	[8][7]			3	Concave
[8]	Line	[6]	[8]		5	Concave
[9]	Line	[9]	[8]		8	Concave
[10]	Line	[10]	[9]		5	Convex
[11]	Line	[10][6]			8	Concave
[12]	Line	[11]	[7]		8	Concave
[13]	Line	[9]	[11]		3	Convex
[14]	Line	[12]	[5]		8	Concave
[15]	Line	[11]	[12]		3	Convex
[16]	Line	[12]	[10]		3	Convex
[17]	Line	[4]	[2]	(15,8,0)	4	Convex
[18	Line	[1][3]		(15,8,16)	4	Convex
[19]	Line	[13][14]			5	Convex
[20]	Cir. Arc	[15][13]			6	Concave
[21]	Cir. Arc	[16][15]			5	Concave
[22]	Line	[14][16]			6	Concave
[23]	Line	[17][15]			6	Concave
[24]	Line	[18][17]			6	Concave
[25]	Line	[16][18]			6	Convex
[26]	Line	[19][23]			6	Convex
[27]	Line	[17][19]			5	Convex
[28]	Line	[14][20]			10	Convex
[29]	Line	[21][20]			16	Convex
[30]	Line	[22][21]			16	Convex
[31]	Line	[19][22]			10	Convex
[32]	Line	[23][24]			16	Concave
[33]	Line	[25][23]			5	Convex
[34]	Line	[24][26]			5	Concave
[35]	Line	[27][25]			5	Convex
[36]	Line	[28][27]			5	Convex
[37]	Line	[26][28]			16	Convex
[38]	Line	[28]	[24]		5	Convex
[39]	Line	[30]	[29]		5	Convex
[40]	Line	[23]	[30]		16	Convex
[41]	Line	[23]	[18]		5	Convex
[42]	Line	[29]	[28]		18	Convex
[43]	Line	[31]	[32]		2	Convex
[44]	Line	[31]	[32]		16	Convex
[45]	Line	[30]	[33]		30	Convex
[46]	Line	[27]	[29]		2	Convex
[47]	Line	[33]	[30]		16	Convex
[48]	Line	[22]	[34]		23	Convex
[49]	Line	[32]	[21]		16	Convex
[50]	Line	[22]	[23]		30	Convex
[51]	Line	[22]	[33]		18	Convex

Table:3 Extraction of loop

Loop I.D	Loop Type	Loop Category	Face I.D	Edge I.D
[1]	External	Hybrid	[1]	[1] [2] [5] [6]
[2]	External	Concave	[2]	[3] [4] [7] [8]
[3]	External	Concave	[3]	[9] [10] [11] [8]
[4]	External	Hybrid	[4]	[12] [13] [9] [7]
[5]	External	Hybrid	[5]	[14] [15] [12] [6]
[6]	External	Hybrid	[6]	[11] [16] [14] [15]
[7]	External	Hybrid	[7]	[1] [17] [3] [18]
[8]	External	Hybrid	[8]	[19] [20] [21] [22]
[9]	External	Hybrid	[9]	[23] [24] [25] [21]
[10]	External	Convex	[10]	[26] [27 [23] [30]
[11]	External	Hybrid	[11]	[26] [19] [28] [29] [30]
[12]	External	Hybrid	[12]	[32] [33] [34] [35]
[13]	External	Concave	[13]	[36] [37] [38] [30]
[14]	External	Hybrid	[13]	[39] [40] [41] [32]
[15]	External	Convex	[13]	[25] [42] [39] [32]
[16]	External	Convex	[14]	[37] [46] [39] [43]
[17]	External	Convex	[15]	[27] [31] [39] [40]
[18]	External	Convex	[16]	[10] [13] [15] [16]
[19]	External	Convex	[17]	[29] [45] [49] [50]
[20]	External	Convex	[18]	[51] [49] [44] [47]
[21]	External	Convex	[19]	[41] [48] [30] [50]

Table 4.Extraction of Faces

Face I.D	Surface Type	Normal Vector	Concavity	Number of loops	Loop I.D
[1]	Surface of Revolution	---	Concave	1	[1]
[2]	Plane Surface (parameterized)	0,0,1	Concave	1	[2]
[3]	Plane Surface (parameterized)	0,1,0	Concave	1	[3]
[4]	Plane Surface (parameterized)	0,0,-1	Concave	1	[4]
[5]	Plane Surface (parameterized)	0,-1,0	Concave	1	[5]
[6]	Plane Surface (parameterized)	-1,0,0	Concave	1	[6]
[7]	Surface of Revolution	--	Concave	1	[7]
[8]	Plane Surface (parameterized)	1,0,0	Concave	1	[8]
[9]	Plane Surface (parameterized)	0,1,0	Concave	1	[9]
[10]	Plane Surface (parameterized)	0,0,-1	Concave	1	[10]
[11]	Plane Surface (parameterized)	0,-1,0	Concave	1	[11]
[12]	Plane Surface (parameterized)	-1,0,0	Concave	1	[12]
[13]	Plane Surface (parameterized)	0,-1,0	Convex	1	[13]
[14]	Plane Surface (parameterized)	0,0,1	Convex	1	[14]
[15]	Plane Surface (parameterized)	0,0,-1	Convex	3	[15]

[16]	Plane Surface (parameterized)	-1,0,0	Convex	2	[16]
[17]	Plane Surface (parameterized)	0,-1,0	Convex	1	[19]
[18]	Plane Surface (parameterized)	0,1,0	Convex	1	[20]

Step5: Identify feature type by connecting each vertex to its vicinity vertex according to the contour of feature and condition is that should not enter the vertices of other feature. The feature existence is tested, conformed and analyzed with edges.

Step 6: By intersection of all edges of concern feature forms a frame structure. If in the frame structure the starting and ending vertex is same then consider as a loop.

Step 7: Fasten all loops or frames in an order according to the contour of selected feature

Step 8: The extraction of feature geometrical and dimensional parameters in order to identify the detailed features structure.

Step 9: The cutting tool path is restraint to the no of loops and coordinates of each vertex of the concerned feature. Then go to machining details.

Table 5. Extraction of Features

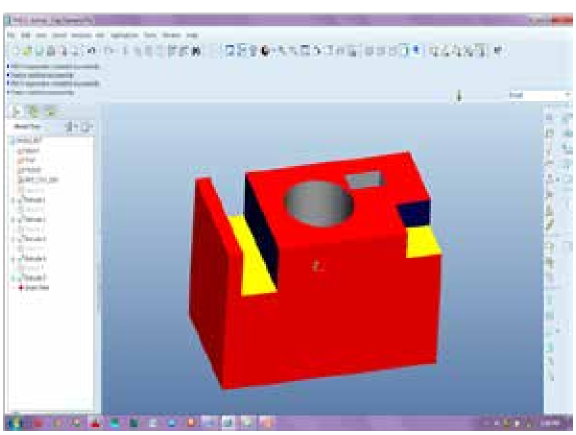
Feature I.D	Feature Type	Faces I.D	Edges I.D	Location	Feature Name	Dimension L W H R
[1]	prismatic	[11] [18] [20] [15] [19]	[29] [30] [37] [40] [39] [45] [47] [49] [50]	[32]= (0,0,0)	Raw Material	30,16,16
[2]	$FF_{exterior}$	[8[[10] [9]	[20] [21] [23]	[17]= (25,0,10)	Step - Blind	5 5 4
[3]	$FF_{exterior}$	[13] [12] [14]	[34] [32]	[26]= (2,0,11)	Slot - Through	15 4 4
[4]	$FF_{interior}$	[3] [4] [5] [6]	[5] [6] [7] [8] [9] [12] [14] [11]	[8]= (20,10,8)	Pocket -Blind	7 4 3
[5]	$FF_{interior}$	[1] [7]	[1] [2] [3] [4] [17] [18]	(15,8,0)	Hole -Through	4

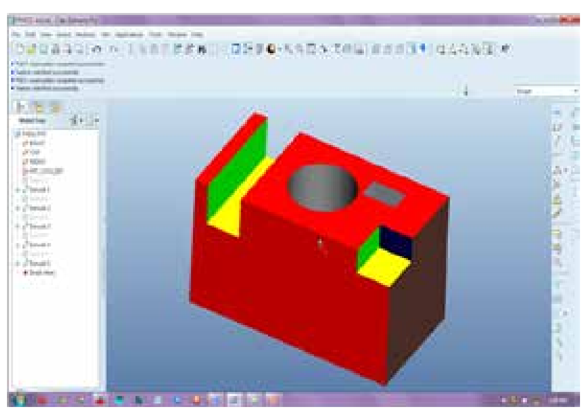
Step 10: in accordance with feature type, machining information for each feature determined. Analyze the operation sequence of the selected feature [along with volume] including the type of operation, on which machine, cutting tool approach and direction [clockwise or counter clockwise] and no of passes to finish the machining feature.

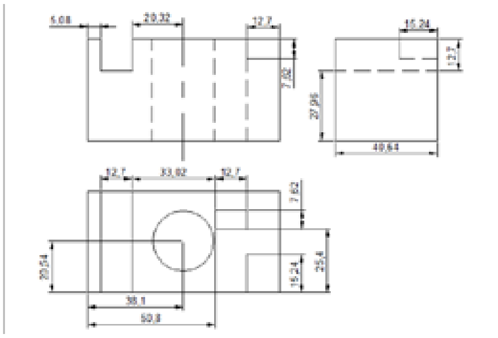
Table 6. Machining Information

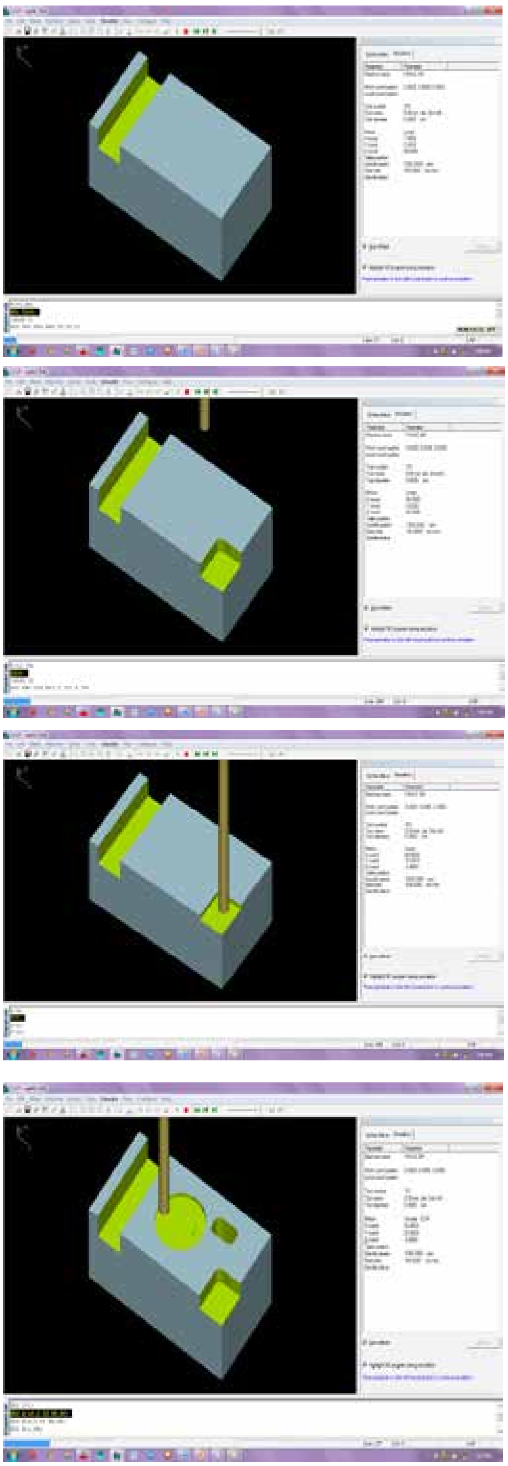
Operation Sequence	Feature I.D	Feature Type	Operation type	Machine	Cutting tool	Tool Approach	Removed Volume mm^3
1	[3]	Slot _Through	Slotting Milling	Milling	End Milling Cutter	[0,1,0]	398
2	[2]	Step_ Blind	Shoulder Milling	Milling	Side Milling Cutter	[-1,0,0]	176
3	[4]	Pocket_ Blind	Pocket Milling	Milling	End Milling Cutter	[0,0,-1]	116
4	[5]	Hole_Through	Drilling	Drilling	Twist Drill	[0,0,-1]	796

5. SIMULATION









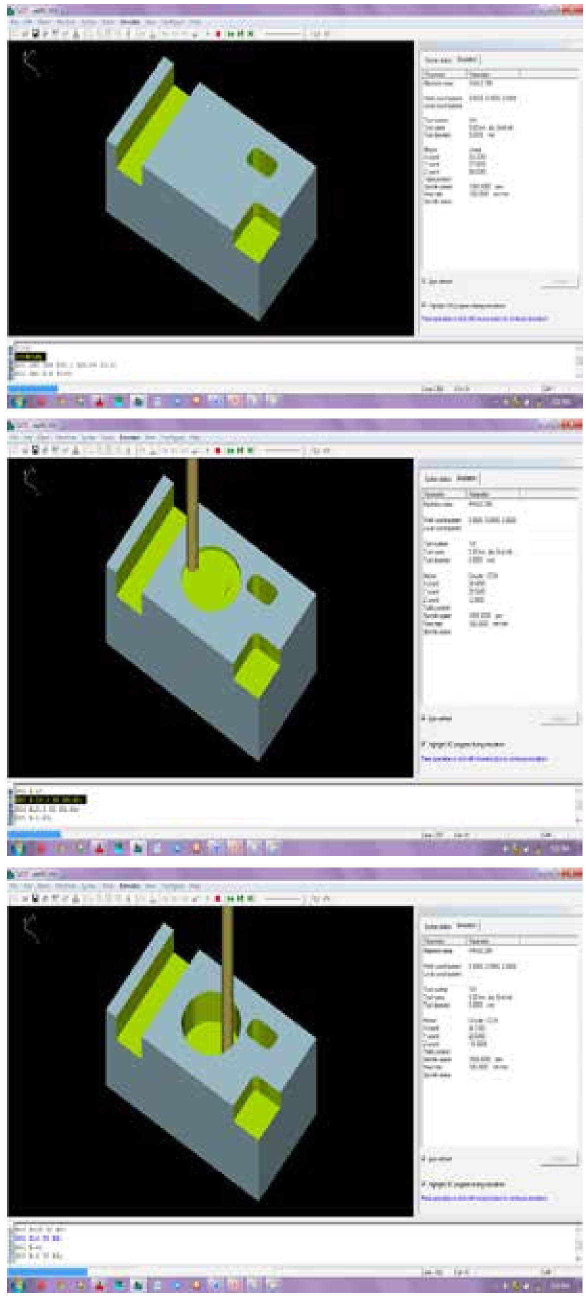


Figure 4. Images of machining simulation

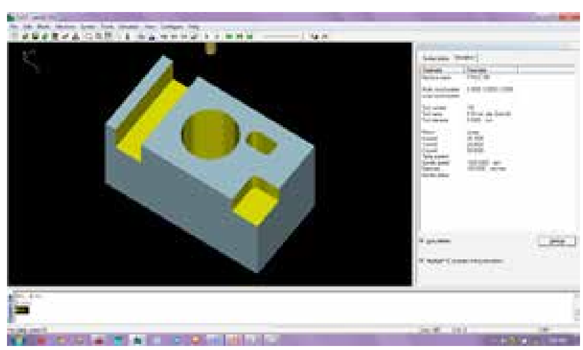


Figure 5. Finished part

6. CONCLUSION

Part design was introduced through CAD software and was represented as a solid model. The Design model engenders the same is used for geometrical evidence of the component in the form of an ASCII file (IGES). The geometrical evidence then used as standardized set-up. Further, the proposed methodology prepared to communicate with the different Computer Aided Design and Manufacturing systems. In order to extract the features from the geometrical information based on the Geometric Reasoning Approach [GRA], The B-rep geometrical information of the part design is analyzed using a Feature Recognition Programming Scheme [FRPS]. The proposed feature recognition program scheme is able to recognize the following features such as slots, pockets, holes, steps, counter bore holes, counter sink holes, etc. The manufacturing information, are mapped to process planning function as an application for CAM. The system is developed in C++ language on a PC-based system. Finally, a case study is used to illustrate the validity of the proposed methodologyalong with simulation.

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