**Research Paper**

# A Prismatic Part Machining and Simulation for Computer Aided Process Planning System

## Engineering

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## ABSTRACT

*The global competition between the manufacturing industries has increased the demands to reduce production times and increase quality of the product. The attempt to automate processing of geometric data and reduce the manual effort for handling complex and huge geometries has been persistently pursued over the last two decades. This pursuit has resulted in a drastic improvement in CAD systems that allow the designers to easily build complex geometries into the models. This paper presents the algorithm of tool generation of prismatic part. A case study of prismatic part has been done and the various parameters such as machining time, machining power is determined by using Creo/proe design software. This paper also shows the simulation results of prismatic part using Depth1 See NC-Mill software.*

## INTRODUCTION

A part is created by removing material from a large block with a rotating tool. The trajectory followed by the tool to remove material is called toolpath [1]. The toolpath for a particular feature can be determined based on its geometry and topology coupled with some additional toolparameters. In order to plan the toolpath, the prismatic part is studied to determine number of orientation and its accessibility relative to two axis [25]. First, it should be analyzed whether all surfaces of the solid model can be machined by a tool rotating about a selected axis. If all features of the prismatic part cannot be accessed by a tool, ro tating about fixed axes, then the part may have to be oriented and redesigned to machine all the features [26]. The prismatic part can be machined in one or two passes using a flat end mill tool. The number of passes depends on the tool radius. However, larger tools exert higher forces and require larger machines [2]. The larger tools also leave lots of material in the corners. In order to avoid this, the toolpaths are normally planned with tools having smaller radius [23]. The radius is determined by the acceptable radius of the corners. Two main approaches are commonly used in planning, a toolpath once the part has been oriented relative to the tool axis and jigged onto the machine table [27]. The toolpath can be constructed using either a Cartesian or a parametric method. In the Cartesian method, the coordinate system determines the machine tool movements in the orthogonal coordinate system used to define the path [3]. The Cartesian coordinate system is specified relative to one point called the origin. Any other point is specified in terms of its distance from the original along three orthogonal axes. The toolpath is specified as the trajectory of a point on the tool typically the center of key geometry on the cutter. The key geometry for a ball nosed cutter is the center of a sphere. The trajectory of this point is specified in terms of the destination point and interpolation scheme. The interpolation scheme is of three types: linear, circular and un-coordinated [4]. Linear interpolation moves the key point from its current location to the destination along a straight line; the circular interpolation takes the key point along a circular path to the destination point and in un-coordinated interpolation, the tool moves from the current point to the destination at full specified speed and with all axis moving independently [24]. The toolpath comprises of two distinct types of toolpath segments are point to point movement and continuous path movement [21]. The point to point path movement takes the tool from one activity atone point to the next point. The path generation system is used to locate accurately on the part specific features for operations such as drilling, reaming, boring and punching, etc. And continuous path movements are used to machine surface features such as pockets, edges and faces etc. [22]. In the parametric method the basic idea of the parametric-plane-based toolpath generation is for the toolpaths be parallel straight lines on the parameter plane [5]. The parametric-plane-based method is the popular method for sculptured surface machining because the parametric surface data can be directly utilized in the toolpath generation.

## 2. LITERATURE ON TOOL PATH PLANNING:

Shah et al [5], presented a method for generating interference free-toolpaths from parametric compound surfaces. This method was able to obtain toolpaths from a surface modela in a shorttime. In this method toolpaths are generated in two steps, first points are obtained from a compound surface by converting it into a triangular polyhedron from which toolpaths are generated. In that algorithm, an efficient method was used in the calculation of cutter location data and planar toolpaths to make it suitable for metalcutting [20]. Kao et al [10] proposed that the tool paths can be also generated by offsetting the 3D constant Z-height contours on parametric surfaces. This method allows the iterative calculation of interference free 3D offset-contours and it is independent of reference frame used to define the surface. The main elements of that method are the iterative offset of flo ops and parametric segments, with the corresponding trimming and connection process.

Bedi et al [7] developed an automatic web-based toolpath planning for machining sculptured surfaces as is found in wooden plaques using 3-Axis CNC machines. This work has integrated a web-based CAD system with web-based toolpath planning system to automatically generate toolpaths using an optimal cutter with desired tolerances [19]. In his method, the toolpath planning was divided into cutter contact path and tool positioning. It is developed by taking a projection of the CAD model on the foot print surface. After generating footprint, it is discredited into several equally spaced points and cutter position at each point is found. The maximum depth at which the cutter can penetrate without gousing the surface is calculated. The toolpath is constructed by moving the tool linearly between two consecutive points on the toolpath foot print.

Kayacan [13] proposes an approach of process planning of prismatic parts. The feature recognition process is achieved with the B-rep modeling method in order to identify the vector direction and adjacent surface relationships using the STEP interface. The database achieved from the feature recognition module is used to define the operation type and sequence of operation for prismatic parts. The work proposed by Han [16] also integrates the two activities such as feature recognition and process planning of prismatic parts. That work presents the efforts done towards feature recognition-for manufacturability and setup minimization, feature dependency construction and generation of an optimal feature based machining sequence.

## 3. TOOLPATH GENERATION AND ALGORITHM ADOPTED IN PRISMATIC PART:

Toolpath generation begins with selection of geometric entities to be machined [17]. The machine used to determine the tool path generation and features, operations by prismatic part shown in fig 1 and tool path generation is shown in fig. 2 along

with specification of machine in table 1. The entities may def ineaslot,aboss,apatch,aholeetc.Thistaskistypically donemanually.Oncethe entitieshavebeendefined,atoolpathstrategyisselected.Thetoolpathstrategydescribes theshapeof the toolpath. Somepopulartoolpathstrategiesarezig-zag,toandfro,radial offset etc. [6]. Once the tool path strategy is defined, the tool is selected along with tool parameterssuchasemersion,RPMetc. Nextthetoolapproach,toolentry andtoolexit strategies aredefined [7]. Once these data have beenchosen,thetoolpathtomachine the specificentitiescan beproduced.Similartoolpathsare createdforthegrouping ofentities untilthe whole parthasbeenmachined. Ina tool path generation,the toolmovesalongan offsetofthegeometricentities.Forsomesimple entitiesitispossibletoensurethat thetool doesnotmachineany entityotherthanthegeneratingentities.The toolpathgenerationmethodsareclassified into Cutter Contact-based method or Cutter location-based method.



**Fig.1 Machine on which operation performedModel VMC-400 M**



**Fig. 2 Tool Path generation on prismatic part**

**TABLE 1: SPECIFICATIONS OF MACHINE MODEL VMC -400 M**

| S.N | Capacity | Specification |
|---|---|---|
| 1 | Table clamping surface | 650 x 400 mm |
| 2 | Max, Weigh on the table | 300 kg |
| 3 | Table tops from floor | 950 mm |
| 4 | Longitudinal axes travel X -Axis | 420 mm |
| 5 | Cross axes travel Y -Axis | 400 mm |
| 6 | Vertical axes travel Z -Axis | 420 mm |
| 7 | Feed rate (X, Y, Z) Axis | 0-6000 mm/min |
| 8 | Rapid Feed | 10 mm/min |
| 9 | Spindle power | 3.7 /5.5 KW |
| 10 | Spindle Taper | BT-40 |
| 11 | Spindle face from Table top | 200mm /620 mm |
| 12 | Tool capacity | 12 mm |
| 13 | Max. tool length | 200 mm |
| 14 | Max. tool weight | 6 kg |
| 15 | Overall Dimensions | 1500 x 2715 x 2800 mm |

### 3.1CUTTER CONTACT-BASED METHOD

Thecuttercontactbasedmethodgeneratestoolpathby dividingthepartsurfaceintoa sequenceofcuttercontactpointswhich isthenconvertedintotheconventionaltoolpath generationwhichisbasedoncutterlocationpoints [8].The cuttercontactbasedmethodcan be further classified asguideplanemethod, parametric method and drive surfacemethod. TheGuideplanemethodinitiallygeneratestoolpathona2.5 Dplaneintheformofeitherline orcontoursandthenprojectsitonthedesignsurface.Theguideplanein3-axismachiningis theplaneperpendiculartothetoolaxis [9]. Themainadvantageofthismethodisthatthefeature shapeorthepartsurfacetobemachinedcanbetakenintoaccountduringtoolpathplanning ontheguideplane.TheParametricmethodgeneratesthetoolpathbyextractingthesurfaceparametersatfiniteintervalsand bysequencing thecorrespondingcoordinatesonthesurface [10]. TheDrivesurfacemethodgeneratestoolpathsbycreatingaseriesofplanesalongthe surface,andbyidentifyingtheintersectionbetweentheplanesandsurface [15].Theintersection ofsurfaceandplanesresultinintersectingcurve,whichareusedtogeneratetoolpaths [16].This method which creates parallel intersecting planes for machining isknown as iso-planar machining [18]. This methodcan handlecomplexsurfaces easilyand is robust and reliable.

### 3.2 CUTTERLOCATION METHOD

Thecutterlocationmethodsgeneratetoolpaths;by creating acutterlocationsurfacerelative tothedesignsurface [11].The cutterlocationsurfaceisusedtogeneratethetoolpathsegments whichareconnectedtobuildthetoolpath.Thecutterlocationsurfaceiscreatedbyoffsetting the surfacewith an interval distancetypicallyequal to the tool radius.

### 3.3 OFFSET SURFACE METHOD

Theoffsetsurfacemethodgeneratestoolpathbyadoptingoffsetondesignsurfaceandalso to avoid the accuracyofsurface finish [12].It is divided into two steps such as discretization of surface, this method will help to take certainresolutionondesignsurfaceby assigningz- coordinatevaluesalongwithx,yco-ordinates.Undervarying surface,theintersecting planeisusedtogetinitialcurvesonsurfaceandtheseintersecting planesmustbe vertical and parallel to each other at constant arclength. Secondly is the inverse

tool offset, this method is usedtogenerate theoffsetsurfacean-dithelpsininverseof toolinZ-direction, withthe center ofinverted toolon designsurface.

## FLOW CHART FOR PROPOSED ALGORITHM
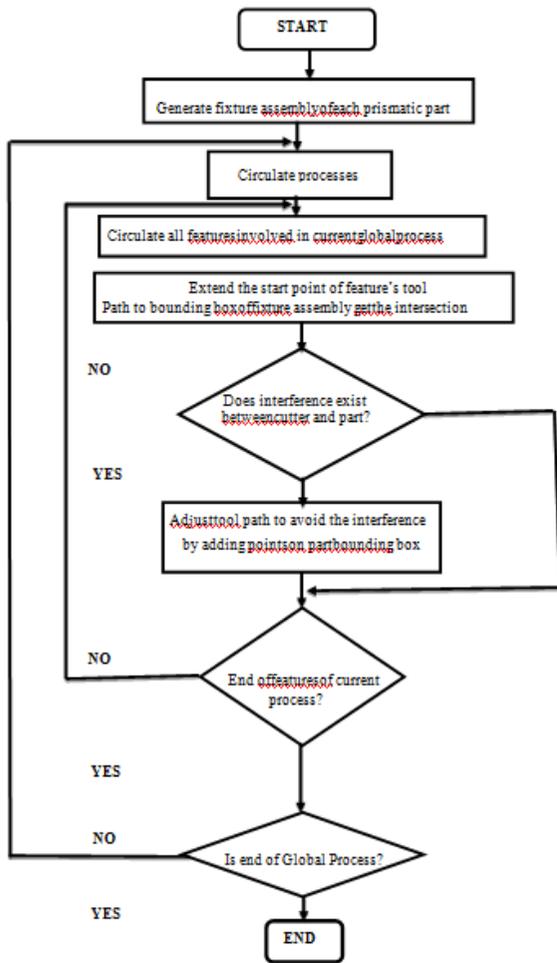


## 4. AN ILLUSTRATIVE EXAMPLE OF PRISMATIC PART:
Consider a prismatic part have the dimensionslength = 157 mm , W=106 mm, H=8 mmThe different features and operations such as machining time, machining rate and machining power are determinedwith tool CIM software from table 2 -5



**Figure 3 Prismatic part**

Dimensions of prismatic part = L= 157, W=106, H=8 mm

## TABLE 2 MACHINING FEATURES LIST FOR PRISMATIC PART

| S.no | feature Name | Feature size | Location | orientation |
|---|---|---|---|---|
| 1 | Drill hole | D= 30, L=15 | x=62,y=62, z=31 | XY-top |
| 2 | Drill hole | D= 20, L=12 | x=62,y=138, z=31 | XY-top |
| 3 | Drill hole | D= 16, L=8 | x=189,y=138, z=31 | XY-top |
| 5 | Milling slot | L=130, W=12, h=5 | x=122,y=98, z=31 | XY-top |
| 6 | Milling slot | L=27, W=12, h=4 | x=123,y=74, z=31 | XY-top |
| 7 | Square slot | L=25, W=12, h=4 | x=123,y=122, z=31 | XY-top |
| 8 | Edge round | L=4, R=10 | x=50,y=50, z=31 | YZ-right |
| 9 | Edge round | L=4, R=10 | x=50,y=148, z=31 | YZ-right |
| 10 | Edge round | L=4, R=10 | x=197,y=148, z=31 | YZ-left |

## TABLE 3: MACHINING OPERATIONS FOR PRISMATIC PART

| S.N | Operation Name | Length mm | Width mm | Depth mm |
|---|---|---|---|---|
| 1 | Side Rough Milling | 19.27 | 7.95 | 3.01 |
| 2 | Side Rough Milling | 18.24 | 7.85 | 3.01 |
| 3 | Side Rough Milling | 18.24 | 7.85 | 3.01 |
| 4 | Side Rough Milling | 18.24 | 7.85 | 3.01 |
| 5 | Bottom and Side Rough Milling | 119 | 8 | 3 |
| 6 | Bottom and Side Rough Milling | 17 | 8 | 3 |
| 7 | Bottom and Side Rough Milling | 17 | 8 | 3 |
| 8 | Drilling | 30 | 15 | -- |
| 9 | Drilling | 20 | 12 | -- |
| 10 | Drilling | 16 | 8 | -- |
| 11 | Bottom and Side Finish Milling | 115 | 2 | 1 |
| 12 | Bottom and Side Finish Milling | 16 | 2 | 1 |

## TABLE 4: MACHINING PARAMETERS FOR PRISMATIC PART

| Sr.No | Operations | Cutting speed m/min | Feed rate mm/r | Feed speed mm/min | RPM | Machined Time min | Removal Rate mm³/min | Machining Power KW |
|---|---|---|---|---|---|---|---|---|
| 1 | Side Rough Milling | 38.48 | 0.255 | 212.51 | 119 | 0.09 | 4,978.01 | 0.299 |
| 2 | Side Rough Milling | 38.48 | 0.255 | 212.51 | 119 | 0.09 | 4,978.01 | 0.299 |
| 3 | Side Rough Milling | 38.48 | 0.255 | 212.51 | 119 | 0.09 | 4,978.01 | 0.299 |
| 4 | Side Rough Milling | 38.48 | 0.255 | 212.51 | 119 | 0.09 | 4,978.01 | 0.299 |
| 5 | Bottom and Side Rough Milling | 20.65 | 0.056 | 137.31 | 822 | 0.87 | 3,295.47 | 0.198 |
| 6 | Bottom and Side Rough Milling | 20.65 | 0.056 | 137.31 | 822 | 0.12 | 3,295.47 | 0.198 |
| 7 | Bottom and Side Rough Milling | 20.65 | 0.056 | 137.31 | 822 | 0.12 | 3,295.47 | 0.198 |

| 8 | Drilling | 18.03 | 0.107 | 153.75 | 435 | 0.07 | 1,932.08 | 0.116 |
| 9 | Drilling | 18.03 | 0.107 | 153.75 | 435 | 0.07 | 1,932.08 | 0.116 |
| 10 | Drilling | 18.03 | 0.107 | 153.75 | 435 | 0.07 | 1,932.08 | 0.116 |
| 11 | Bottom and Side Finish Milling | 18.03 | 0.107 | 153.75 | 435 | 0.07 | 1,932.08 | 0.116 |
| 12 | Bottom and Side Finish Milling | 21.70 | 0.056 | 109.75 | 657 | 1.07 | 219.5 | 0.013 |

**TABLE5: CUTTING TOOLS FOR PRISMATIC PART**

| S.N | Tool Name | Tool Diameter mm | Flute length mm | Tool Material |
|-----|-----------|------------------|-----------------|---------------|
| 1 | Rounding Corner Mill | 105 | 0 | HSS |
| 2 | Rounding Corner Mill | 105 | 0 | HSS |
| 3 | End Mill | 10 | 69 | HSS |
| 4 | End Mill | 10 | 72 | HSS |
| 5 | Twist Drill | 26 | 128 | HSS |
| 6 | Twist Drill | 26 | 128 | HSS |
| 7 | Twist Drill | 26 | 128 | HSS |
| 8 | End Mill | 12 | 76 | HSS |
| 9 | End Mill | 12 | 76 | HSS |
| 10 | End Mill | 12 | 76 | HSS |

## 5. Simulation Results:

Thefeature-based tool path planning generates an accurate tool path for both roughing and finishing operation, which is simulated using a machining simulate or to verify the effectiveness of the manufacturing process and the tool path. Many manufacturing engineers use CNC simulators to verify the tool path before using in the CNC machine in order to reduce the cost and to minimize the errors that occurs during machining. In this work,the simulation process were carried out using a custom machining simulator. Creo/Proe5.0 was used to design and Depth1-SeeNC-Mill was used to simulate the machining process for the generated tool path.
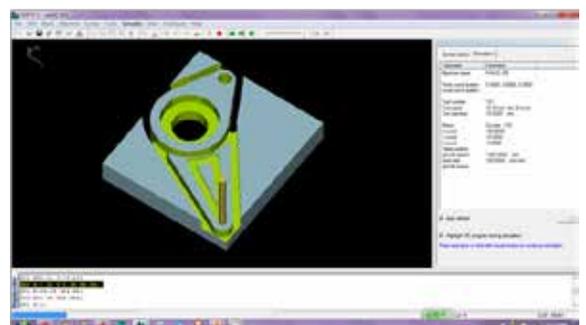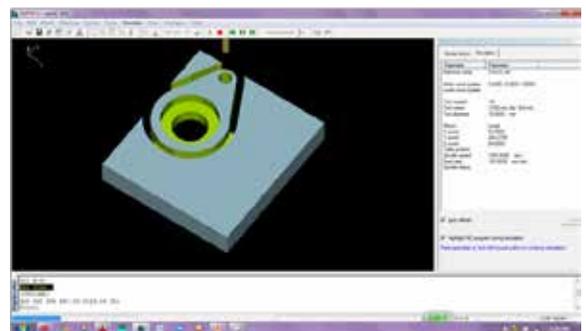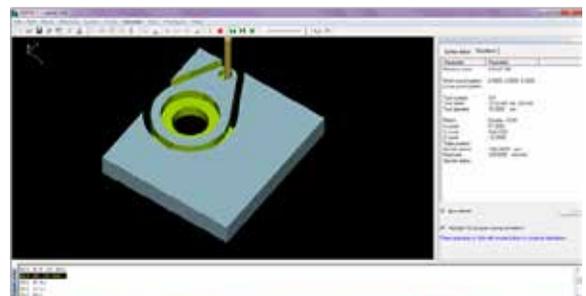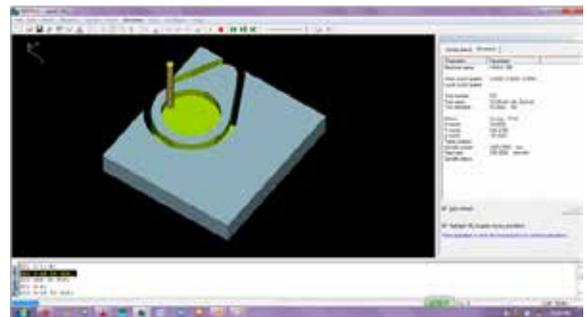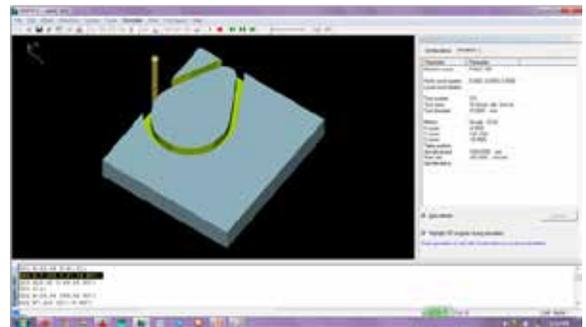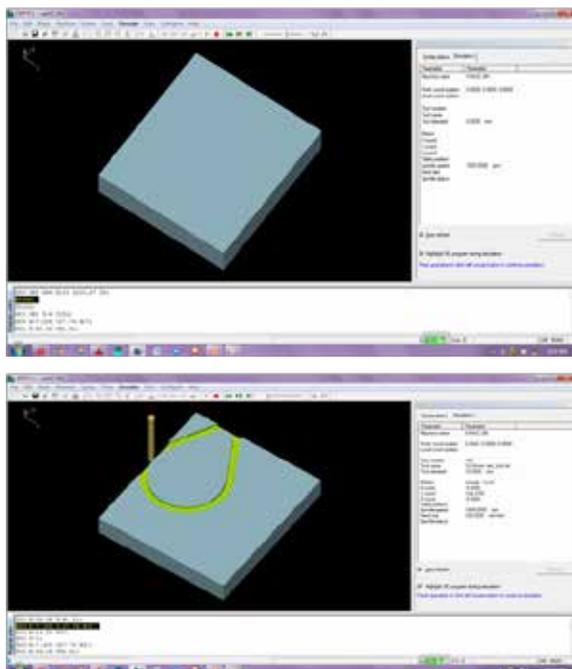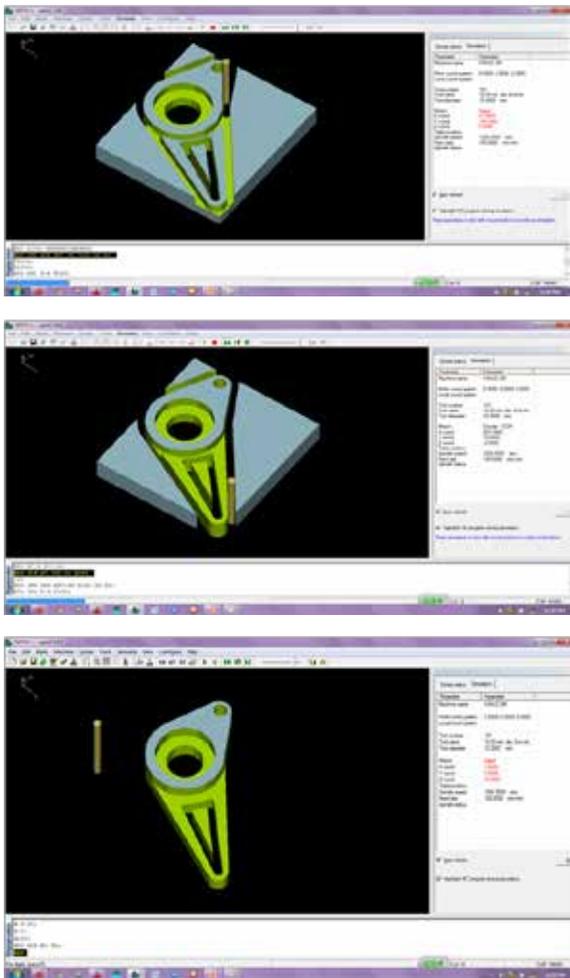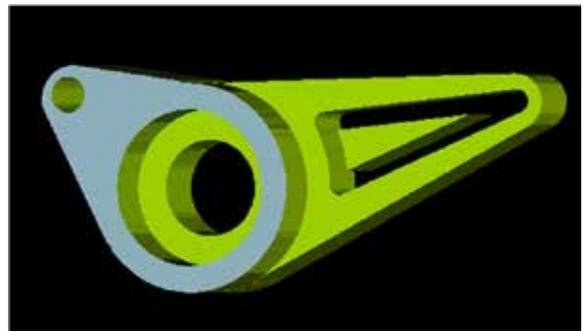
**Figure 5. Finished part simulation image**

## 6. DISCUSSIONS AND CONCLUSION

The main purpose of tool path simulation is to visually display the tool paths on the computer screen. Therefore, any error can be easily detected before actual machining. This ensures that the right profile of prismatic part is to be machined. Feature RecognitionandFeature-basedMachininghasbeenan active researcharea forpast few decades.Itplaysavitalrole inthe integrationof designand manufacturing process.Researchershaveused variousmethodsforFeatureRecognitionand Tool Path Planning. Allthese methodsworkon triangulated models.Theuse oftriangulated modelsamountstothrowingaway thetopologyandgeometry information toredinaB-rep model.Theparameter extractionforalgorithmicreasoning suchasintoolpathplanning andprocessplanningfrom thefeatureshasalsobecomeachallenging task.Planning machining sequenceisnoteasy unlessthefeatureparametersandtheirlocationsonthepartandgeometryareknown. Mostofthestudiesdiscussedintheliteratureonly presentinconceptmethodstointegrate designwithmachining.Some workshaveimplementedfeaturerecognitionconceptSimsoftware.Those who have implementedideashave focuseither infeature recognition or on tool pathplanning. The separation of focus between feature recognition and tool path planning hasmadeithardertodotoolpathplanning forprismatic partswhichhaveinteracting features and transition features like chamfers and fillets. In addition, mostof the research onautomatictoolpathplanning appliestotriangulated modelsonly.Overallthispaper showsthat features, operation performed, feed rate, cutting speed,depth of cut of the prismatic part by using Tool Sim software with simulation results.



**Figure 4. Images of machining simulation**

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