DETERMINATION OF MACHINABLE VOLUME FOR FINISH CUTS IN CAPP

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Identification of machinable volume for finish cut is a complex task as it involves the details not only of the final product but also the intermediate part obtained from rough machining of the blank. A feature recognition technique that adopts a rule-based methodology is required for calculating this small, complex shaped finish cut volume. This paper presents the feature recognition module in a CAPP system that calculates the intermediate finish cut volume by adopting a rule based syntactic pattern recognition approach. In this module, the interfacer uses STEP AP203/214, a CAD neutral format, to trace the coordinate point information and to calculate the machinable volume. Two illustrative examples are given to explain the proposed syntactic pattern approach for prismatic parts.

1. INTRODUCTION

Computer Aided Process Planning (CAPP) has come to acquire an extremely important role in implementation of Computer Integrated Manufacturing (CIM) since it serves as the bridge between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). Mostly two approaches variant and generative are employed to accomplish this task. Variant approach uses the similarity among the components by means of classification and coding scheme as used in Group Technology (GT) to generate process plans. In the generative approach, knowledge of manufacturing is captured, encoded and supported by manufacturing database to create process plans. Human intervention is needed in the variant approach but the generative system creates process plans automatically. While developing a generative CAPP system for prismatic parts, recognition of machining features from a CAD model is the first and foremost task to plan further activities. To accomplish this task researchers have adopted various feature recognition techniques and CAD neutral formats. Derli and Filiz, 2002, recognized features and constructed a separate rough-cut machinable volume in a CAPP system. Dong and Vijayan, 1997, in their integrated geometric modeling system, have extracted machinable volumes that are required for 3-axis milling operations for prismatic parts. Feature relationship graph approach has been used to extract the application specific features known as high-level features from a CAD model (Fu et.al, 2003). Han and Requicha, 1997, adopted hint-based reasoning approach to recognize slot, step-groove etc in their feature recognizer named IF^2. Optimal volume segmentation approach is used to extract features and for removing the elementary volume (Huang and Hoi, 2002). Syntactic pattern recognition approach has been implemented to identify the machining features by using DXF format to calculate the size, location and shape of the prismatic part (Jain and Sharavan Kumar, 1998). Features are identified by adopting IGES format to translate into an object oriented data structure for creating process plans (Lee1 & Kim, 1998). Liu et.al, 1996, proposed an approach to identify the removable volume known as delta volume by comparing the final part with the original stock. Sandiford and Hinduja, 2001, adopted STEP AP203 protocol for identifying the features from prismatic parts by attributed adjacency relationship graphs using GT coding scheme. A feature recognition processor has also been developed to recognize manufacturing features from STEP AP224 format (Woo and Sakurai, 2002).

2. PROPOSED FEATURE RECOGNITION MODULE FOR FINISH CUTS

The feature recognition module for finish cut contains different phases as shown in figure 1. In the system, the prismatic part is designed by using a CAD package called Solid Works. Then, it is transformed into STEP AP203 or AP214 format by using the available STEP translator in Solid Works. This neutral format of STEP is used as an input to the feature recognition module in the CAPP system. The interfacer developed inside the feature recognition module, produces an output file of the prismatic part. The output file contains the coordinate information related to the model. Then, the feature recognizer identifies the features in the part model by syntactic pattern recognition technique and identifies the machinable volumes to be removed for the features obtained after rough cuts. The machinable volume for finish cuts is obtained by deducting the rough-cut feature from the final part input to the system. The identified machinable volume contains the details of all the parameters related to final machining of the part. A schematic representation of the volumes to be removed during the finish cuts is shown in the figure 2, which shows the machinable volumes, including the fillet and chamfer in the final part.

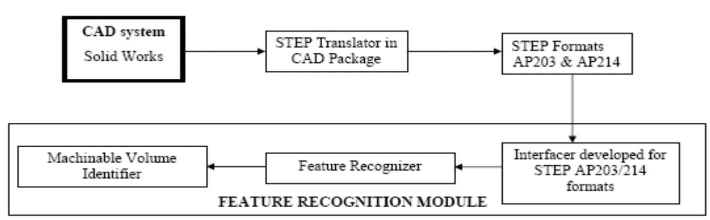


Figure 1 - Overview of the Proposed System

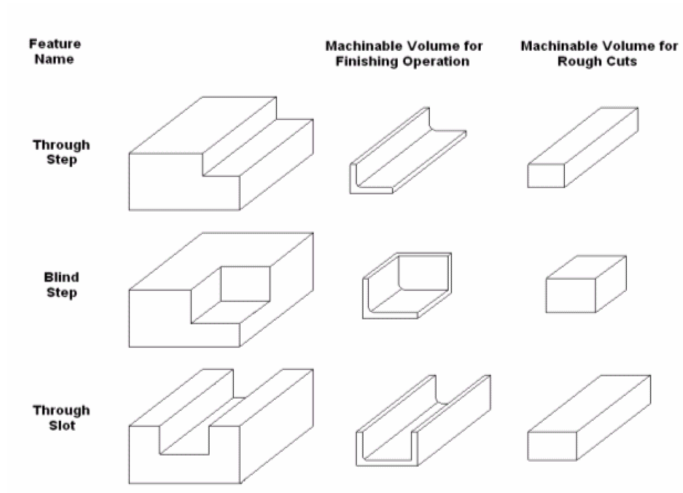


Figure 2 - Representation of machinable volumes

3. INTERPRETING THE NEUTRAL FORMAT

The first part in the feature recognition module is the interpretation of STEP AP203/214 format. The AP203/214 formats contain two sections (i) Header section (ii) Data Section. The header section starts with the specification of the type of format AP203/214 by a keyword FILE_DESCRIPTION, followed by another keyword FILE_NAME that gives the full details about the file name, person, and organization. The protocols "Configuration Controlled Design" or "Automotive Design" are identified in a key word FILE_SCHEMA inside the header section. The end of this section is denoted by a key word "END SEC". The next section i.e., data section is the core part of the STEP AP203/214 format. It contains all the informations, starting from the time when the part is created to the CAD model's coordinate point information. The data section is started by a key word "DATA". The representation of the part is given by the entity SHAPE_REPRESENTAION. The information about the CAD model starts from CLOSED_SHELL entity. The closed shell entity contains information about the consecutive lines indicated by their respective IDs such as '#123'etc. Each ID in the closed shell goes directly to another entity ADVANCED_FACE, which is a standard hierarchy in all STEPAP203/214 formats. The ID's in the advanced face are split into many entities depending on the CAD model. The details of entities and the hierarchy of the STEP AP203/214 formats to identify the correct coordinate point information's are different for different shapes.

4. STEPS FOLLOWED BY THE INTERFACER

The interfacer developed for the CAPP system uses the following steps to detect the feature and its coordinate informations. Figure 3 gives the tracing logic applied particularly for prismatic parts with filleted edges as referenced in step 10.

Step1: Read the lines up to semicolon.
Step2: Check for HEADER section
Step3: If HEADER section is found, check for FILE_SCHEMA for finding out the protocol of STEP used.
Step4: If it is Configuration Controlled Design – AP203 or Core data for Automotive Mechanical Design Processes - AP214 then proceed to step 6.
Step5: If it is not AP203/214 then mention the user to input AP203/214 file.
Step6: Check for DATA section
Step7: If DATA section is found, then check for CLOSED_SHELL entity.
Step8: If it is found then read the ID values inside it.
Step9: Now check for the ID's inside the DATA section up to End of File.
Step10: Implement the trace logic developed that suits for the Prismatic part taken as an input for the interfacer and
Step11: Write the appropriate "Cartesian Points" for the whole part and store the information of cylindrical surface or a filleted object separately.

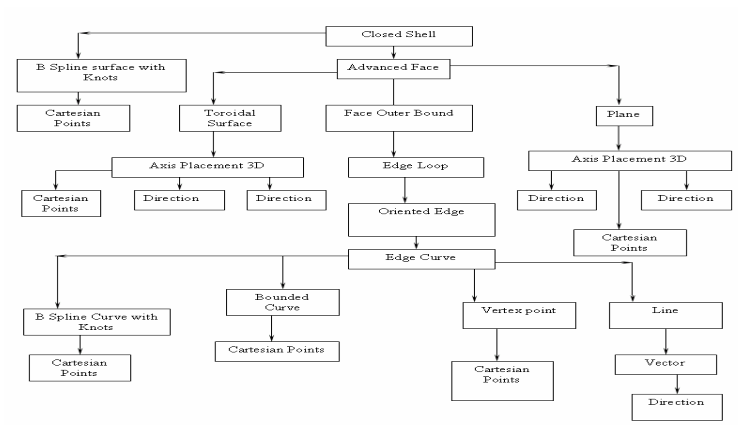


Figure 3 - Hierarchy tree for a prismatic part with filleted edges

5. CALCULATING THE INTERMEDIATE MACHINING VOLUME FOR FINISH CUTS

In this phase, the arranged points from the interfacer containing the details of all the surfaces present in the rough-cut prismatic part and the final part are used as input to the feature recognition module. Automatically the details of all the features with the edge loop information are taken out in the form of a separate file. In addition, the details regarding the tolerance information and surface finish information of the final part are also taken. After getting this information, the machinable volume identifier calculates appropriate finish cut volume for the features identified by the feature recognition system. Two example parts are discussed below to illustrate the approach to calculate the machinable volumes.

5.1 Illustrative Example: 1: When the Feature Is a Step

The edge loops (e1r, e2r, e3r, .etc.) are shown in figure 4 and the Coordinate Point information obtained from the feature recognizer are used to calculate the machinable volume. The different phases followed by the feature recognizer are given below.

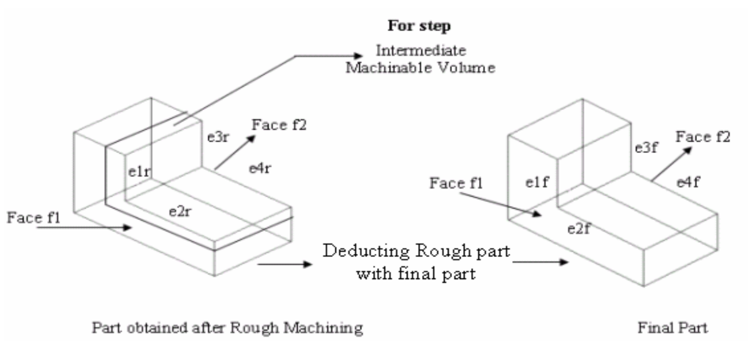
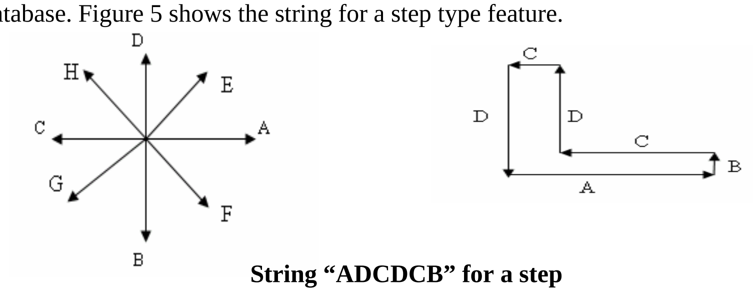


Figure 4 - Details of the edge loops for a step type feature

Phase1: Check whether the coordinate points follow the same string stored in the database. Figure 5 shows the string for a step type feature.



String "ADCDCB" for a step

Figure 5 - Syntactic Pattern Recognition approach developed for step

Phase2: If it is the same then intersect the edge loop of rough machined feature with the final feature
Phase 3: Calculate the difference in the values for e1r, e2r, e3r, e4r and e1f, e2f, e3f, e4f
Phase 4: Interpretation of results

The edge loops on face f1 and face f2 can be used to determine the thickness(g), length(l), width(w) and height(h) as follows :

(i) edge loops (e1r-e1f) (e2r-e2f) on face f1 and (e3r-e3f) (e4r-e4f) on face f2

$$\text{e1r-e1f} \begin{vmatrix} 10,20,0 & - & 8,20,0 \\ 10,15,0 & & 8,13,0 \end{vmatrix} \quad \text{and} \quad \text{e2r-e2f} \begin{vmatrix} 10,15,0 & - & 8,13,0 \\ 20,15,0 & & 18,13,0 \end{vmatrix}$$

On face f1

e1r-e1f | Dif.of.2mm in X axis, Dif.of.2mm in Y axis | and e2r-e2f | Dif.of.2mm in X axis, Dif.of.2mm in Y axis |

On face f2 for calculating the thickness (g)

e3r-e3f | 10,20,0 — 8,20,0 ; 10, 15,0 8,13,0 | and e4r-e4f | 10,15,0 — 8,13,0 ; 20,15,0 18,13,0 |

On face f2

e3r-e3f | Dif.of.2mm in X axis, Dif.of.2mm in Y axis | and e4r-e4f | Dif.of.2mm in X axis, Dif.of.2mm in Y axis |

Hence the material to be removed is having a uniform thickness of (g) =2 mm in both the XY plane on both the faces f1 & f2

(ii) The edge loops (e1r-e3r) & (e2r-e4r) and (e1f-e3f) & (e2f-e4f) on XZ plane provide dimensional value width (w) of the finish cut machinable volume

e1r-e3r | 10,20,0 — 10,20,50 ; 10,15,0 10,15,50 | and e2r-e4r | 10,15,0 10,15,50 ; 20,15,0 20,15,50 |

Calculating the thickness (w) in final part

e1f-e3f | 8,20,0 — 8,20,50 ; 8,13,0 8,13,50 | and e2f-e4f | 8,13,0 8,13,50 ; 18,13,0 18,13,50 |

Here a comparison is made for both the parts so that a common difference is obtained in Z-axis from both the rough and final part. Otherwise, the amount of material has to be calculated separately for face f1 and face f2. Here the width (w) is 50 mm.

(iii) The edge loops e2f & e4f on ZY plane provide dimensional value length (l) of the finish cut machinable volume

e2f → 8,13,0 ; 18,13,0 | the difference is 10 mm

e4f → 8,13,0 ; 18,13,0 | the difference is 10 mm

The calculated length (l) is 10 mm including the thickness 2mm

(iv) The edge loops e1f & e3f on XZ plane provide dimensional value length (l) of the finish cut machinable volume

e1f → 8,20,0 ; 8,13,0 | the difference is 7 mm

e3f → 8,20,50 ; 8,13,50 | the difference is 7 mm

The calculated height (h) is 7 mm including the thickness 2mm.

The schematic representation of the machinable volume is shown in figure 6.

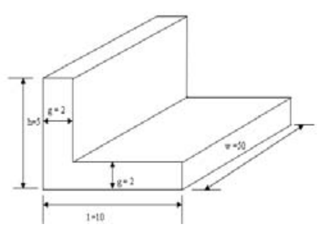


Figure 6 - Machinable volume for finish cut with dimensional values

5.2 Illustrative Example: 2: When the Feature Is a Slot

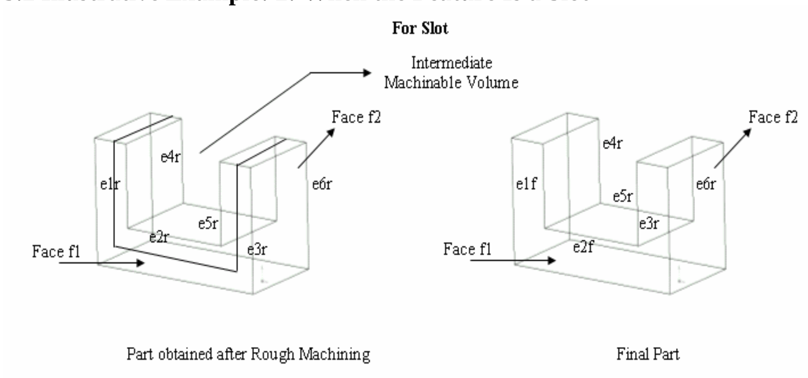


Figure 7 - Details of the edge loops for a slot type feature

The details of the Edge loops (e1r, e2r, e3r,.etc..) are shown in figure 7 and the Coordinate Point information obtained from the feature recognizer is given below.

Rough machined Part: Edge loop on face f1

e1r → 10,60,0	e2r → 10,40,0	e3r → 20,40,0
10,40,0	20,40,0	20, 60,0

Edge loop on face f2

e4r → 10,60,50	e5r → 10,40,50	e6r → 20,40,50
10, 40, 50	20, 40, 50	20, 40, 50

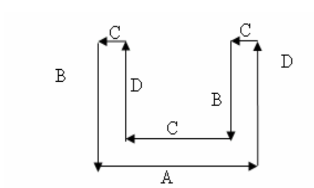
Final Part: Edge loop on face f1

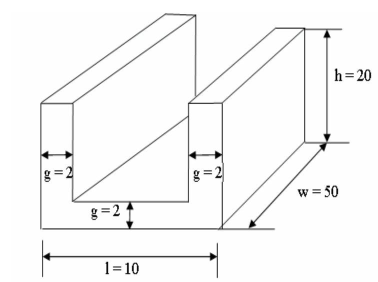
e1f → 8,60,0	e2f → 8,38,0	e3f → 18,38,0
8,38,0	18,38,0	18,60,0

Edge loop on face f2

e4f → 8, 60, 50	e5f → 8, 40, 50	e6f → 18, 40, 50
8, 40, 50	18, 40, 50	18, 60, 50

Phase1: Check whether the coordinate points follow the same string stored in the database. Figure 8 shows the string for a step feature.





String "ADCBCDCB" for a slot

Figure 8 - Syntactic Pattern Recognition approach developed for slot and Machinable volume for finish cut with dimensional values

Phase2: If it is the same then intersect the edge loop of rough machined feature with the final feature

Phase 3: Calculate the difference in the values for e1r, e2r, e3r, e4r and e1f, e2f, e3f, e4f

Phase 4: Interpretation of results

The procedure followed for the “step” type feature is applied for “slot” and the following dimensional values length (l) = 10 mm, width (w) = 50 mm, height (h) =20 mm, thickness (g) = 2 mm are calculated. The machinable volume is as shown in figure 8. The same methodology is followed also for features such as blind slot, blind step, hole, and pocket.

6. CONCLUSIONS

In this paper, a methodology is presented by adopting syntactic pattern recognition approach to calculate the finish cut machinable volume by deducting the rough-cut part from the final part. At present, the feature recognizer is capable of identifying the machinable volume for finish cut from STEP AP203/214 format for both primitive features such as slot, step, blind slot, blind step, pocket, hole and interacting features slot-slot-step, slot-pocket-step etc to make the recognition process complete. Feature volume details as extracted along with the user inputted surface finish and tolerance values are used for machining planning at the later stage.

References

1. Derli & Filiz, A note on the use of STEP for interfacing design to process planning, Computer Aided Design, 2002; 34: 1075-1085.
2. Dong & Vijayan, Manufacturing feature determination and extraction Part II: A heuristic approach, Computer aided Design, 1997; 6(29): 475-484.
3. Fu, Ong, Lu, Lee & Nee, , An approach to identify design & manufacturing features from a data exchange part model, Computer Aided Design, 2003; 35: 979-993.
4. Han & Requicha, Integration of feature based design and feature recognition, Computer Aided Design, 1997; 5(29):393-403.
5. Huang & Hoi, High-level feature recognition using feature relationship graphs, Computer Aided Design, 2002; 34:561-582.
6. Jain & Sharavan Kumar, Automatic feature extraction in PRIZCAPP, International Journal of Computer Integrated Manufacturing, 1998; 6(11): 500-512.
7. Lee1 & Kim, A feature-based approach to extracting machining features, Computer-Aided Design, 1998; 13(30):1019–1035
8. Liu, Gonzalez & Chen, Development of an automatic part feature extraction and classification system taking CAD data as input, Computers in Industry, 1996; 29: 137-150.
9. Sandiford & Hinduja, Construction of feature volumes using intersection of adjacent surfaces, Computer Aided Design, 2001; 33: 455-473.
10. Woo & Sakurai, Recognition of maximal features by volume decomposition, Computer Aided Design, 2002; 34: 195-207.