Hole Feature on Conical Face Recognition for Turning Part Model

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Abstract. Computer Aided Process Planning (CAPP) is the bridge between CAD and CAM and pre-processing of the CAD data in the CAPP system is essential. For CNC turning part, conical faces of part model is inevitable to be recognised beside cylindrical and planar faces. As the sinus cosines of the cone radius structure differ according to different models, face identification in automatic feature recognition of the part model need special intention. This paper intends to focus hole on feature on conical faces that can be detected by CAD solid modeller ACIS via .SAT file. Detection algorithm of face topology were generated and compared. The study shows different faces setup for similar conical part models with different hole type features. Three types of holes were compared and different between merge faces and unmerge faces were studied.

Keywords: Automatic Feature Recognition, CAPP, lathe machining

1. Introduction

Computer Aided Process Planning (CAPP) nowadays is the solution in bridging Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) system. Process planning encompasses the activities and functions to plan detailed set of procedures and instructions to produce a part. The first step on generating the process plan is feature recognition. Recent studies show automatic feature recognition (AFR) is among the best methods [1]. In AFR, there are several methods that had been used by researchers and feature recognition via topological data is among the best [2]. Other methods include attribute based [3], artificial neural network [4,5] and genetic algorithm (GA) [6]. Previous works on turning part model feature recognition had been done in [7] and more works on volume recognition of mill-turn part models had also been done[8,9].

Conical part model consist of unique characteristic and some considerations need to be made to recognise it. This paper provides useful information of part model with conical faces with two type of face setting (merges and unmerges) and the effect of hole feature on its surface. The topological of the part model will become distinctive as the characteristics change.

2. Process Overview

2.1 Part Model Preparation
CAD part models were modelled in commercial CAD software and being imported into .SAT file. The part model was then being added with three types of hole and this altogether generate four types of samples to be study. The part model shapes consist of two different types of conical faces. Samples are shown in figure 1. Besides having a separate two faces of each cone feature, one sample is being tested with merge cone faces. This will develop a single cone face for each cone. The merge faces sample is using the same sample of sample (a). The characteristics of conical features are calculated by sinus and cosines of the angle of the cone expressed in Eqn. (1) and Figure 2.

\[ P(u, v) = C_{base} + \left(1 + \frac{s u s f_u}{R}\right) \vec{V} + c u s f_u \vec{n}_{base} \]  

(1)

Where \( C_{base} \) is ellipse’s base centre, \( s f_u \) is \( u \)-parameter scaling factor negative if reverse when \( u \) is TRUE, \( s \) is sine angle if cosine angle is non-negative, or –sine angle if cosine angle is negative, \( c \) is cosine angle if cosine angle is non-negative or –cosine angle if cosine angle is negative, \( \vec{V} \) is vector from the base ellipse centre to a point on the base ellipse for a given \( U \)-parameter value, \( R \) is length of the major axis of the base ellipse, and \( \vec{n}_{base} \) is base ellipse normal [10].

Figure 1: Sample of conical faces and its wireframe model; (a) no hole (b) with blind hole (c) with through hole and (d) with half-circle hole

Figure 2: Cone definition [10]
2.2 Process framework

The setup of the algorithm will be based on the objective to detect the face orientation and topological structure. To carefully detect faces and topological behaviour, first of all, the topological structure of all body will be examine to know the overall lump, body, faces, edges and vertex of the 3D CAD model. The volume of the 3D CAD part model is then calculated for the comparison. Finally, the algorithm will detect every single face of the 3D CAD part model. By the detection, users will know each faces separately. In CAD modeller software, normally cone faces are treated by two faces. To make it one, user has to merge it. By merging the cone faces, the overall quantity of faces will be less. This will help the recognition of respective faces. Besides doing merging, faces also can be recognized by their loop and face type. By using loop type, one can recognize certain faces by separation loop, hole loop and periphery loop. Faces can be recognised by CAD solid modeller either as an analytic face or a spline face. Analytic face consists of planar face, cone face, sphere, torus face while spline face consists of B-Spline face. Figure 3 shows the flow of the algorithm.

![Process flow of algorithm](image)

Figure 3: Process flow of algorithm

3. Results and Discussion

3.1 Topological data

Five samples are run through the algorithm. The volume of the part model sample was generated and faces were recognized. The calculation of the volume shows reduction if there is hole within the sample. As expected the volume of the through hole is greater than the blind hole. Table 1 shows the comparison of the volume and topological data of each sample. Sample 1 and Sample 6 shows the largest amount of volume as these samples had no hole. The differences of these two samples are the topological data of faces and edges. It is because the number of cone face had been reduced to half. Sample 5 shows three faces which are two cone faces and one planar face. Sample 1 shows five faces which are 4 cone faces and one planar face. Sample 2, sample 3 and Sample 4 show differences in volume as the types of hole are different. The samples with through hole (Sample 3 and Sample 4) show lesser volume compare to Sample 2 with blind hole. The number of faces of Sample 2 with blind hole is more than the through hole by the addition on one more face as the blind hole had another face at the bottom of the hole while through hole does not. This will reflect the number of edges and number of loop as well.
Table 1 Volume and topological data comparison

| Sample   | Volume (mm³) | Lump | Faces | Edges | Loop |
|----------|--------------|------|-------|-------|------|
| Sample 1 | 60038.7      | 1    | 5     | 8     | 5    |
| Sample 2 | 59360.4      | 1    | 8     | 15    | 8    |
| Sample 3 | 58683.9      | 1    | 7     | 16    | 7    |
| Sample 4 | 59360.4      | 1    | 7     | 16    | 7    |
| Sample 5 | 60038.7      | 1    | 3     | 3     | 5    |

3.2 Face Recognition

The topological data and every face of the CAD model were being analysed. This individualised each face. By having the segregation, cone face, planar face and face with hole were detected. The behaviour of the detection was then concluded. Figure 4 shows the patent of face sequence of every sample. As algorithm detected the faces in loop sequence, face from F_{n-1} to F_n were displayed in the output window. By knowing the characteristic of each faces i.e: having hole, face type and number of loop, user will easily identify the faces sequence. By knowing this patent of sequence, future work can be done.

Figure 4: Face detection (a) Sample 1, (b) Sample 2, (c) Sample 3, (d) Sample 4, (e) Sample 5
Figure 4 shows the front view illustration of face configuration detected by the algorithm. Fig. 4 (a) shows face structure of Sample 1, it shows five faces starting from F0 to F4. The sequence is according to clockwise sequence. The middle line appears as the cone face is split by CAD modeller. F2 is planar face. Figure 4(b) acts the same as figure 4(a) with the addition of three faces from the blind hole: two faces of cylindrical faces and one more planar face. Sample 3 in figure 4 (c) shows some differences as the hole feature is through hole and two additional faces were generated. Next in figure 4(c) and 4(d), the configuration is in the same orientation which is clockwise. While in figure 4(e), there are only 3 faces; this is because F0 and F1 were generated from the merge face of F0 with F4 and F1 with F3.

4. Conclusions

The algorithm for cone face detection generation is proven to detect cone faces of CAD part model. The sequences of faces detected are shown in clockwise direction sequence. The volume differences of CAD part model with hole and without hole also as expected. Using rule of number of loop in each face, hole can be detected. Although more major works need to be done, this simple technique can be used in feature recognition method that will be useful for process planning.

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