Validation of auto-generated material removal volume for regular form milling part

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Abstract. Feature recognition is the primary objective to be achieved for the attainment of generative CAPP system. The feature recognition works performed so far have been successful in recognizing and generating material removal volume for regular form features of regular form parts. These material removal volumes provide detailed information about the amount of material to be machined in each process thereby eliminating the detailed designing stage employed in conventional machining process. But the generated material removal volume (MRV) were not validated by real time mill machining, so an effort is made to validate the feature recognition works by real time mill machining using the material removal volume. From the real time mill machining it can be said that there is zero wastage of material and part obtained is of accurate dimensions.

1. Introduction

The integration of computer-aided design (CAD) and computer-aided manufacturing (CAM) has led the production industries into a new era of manufacturing, but still there are real time mill machining problems faced in manufacturing. The further integration of computer-aided process planning (CAPP) into CAD/CAM will be vital to perform process planning, process selection, tool selection [1,2] and achieve an efficient manufacturing process. The idea generation, design of part model, CAPP, CAM and CNC all together forms a CAPP system. The CAPP system can be of two types (i) variant type; (ii) generative type. The variant CAPP needs human intervention to perform part input and necessary modifications in retrieved process plans, and in generative CAPP very little human intervention is required to generate process plans [3]. Machining feature recognition, machining operation type selection, and process optimization are the functions of generative CAPP system [4]. The feature recognition has been the primary method being applied to recognize features [5] and feature based CAPP works have been widely performed to produce material removal volume to be input to CAM software for numerical code generation. The geometrical shape of B-rep parts were studied and cone faces having a hole feature in them were identified [6]. The chamfer, fillet, hole and pocket features present on symmetrical and non-symmetrical parts were also identified [7,8]. The features of regular form B-rep parts were recognized using feature recognition method and material removal volume data were generated in .SAT file format [9–11]. In the feature recognition of regular form B-rep parts conducted so far, there is a need for real time mill machining in order to validate the stock model volume and material removal volume generated by recognition work. In this paper an effort is made to perform real time mill machining so as to validate the feature recognition works performed so far.

2. Methodology

The following flow chart (Figure 1) has been adopted to perform real time mill machining of regular form milling part.
2.1. Material and CNC machine selection

The material used for machining can be of aluminium or any other material based on the user requirements and the CNC milling machine can be 3 axis or 4 axis or 5 axis based on the complex shape of the part to be produced. In this work, aluminium material and 3-axis CNC milling machine are considered for machining of regular form part.

2.2. Input of MRV to generate numerical codes

In this section, an opener CAD part model (Figure 2) is considered for validation. The opener CAD part model is input to the algorithm developed by Kataraki and Abu Mansor [9] and material removal volume for various machining processes such as roughing and finishing were obtained (Figure 4). Figure 2 illustrates the CAD part model of opener. Figure 4 illustrates the material removal volume for roughing process and finishing process. These material removal volume data are input to AUTODESK FUSION 360 (free version for education purpose) software to generate numerical codes.

Figure 1. Flow chart.

Figure 2. CAD part model of an opener.
The flat end mill tool is selected to mill the material removal volume for roughing and finishing process as shown in generated N codes-1 .TXT file format of Figure 3. The flat end mill tool is also selected to mill material removal volume for pocket (shown in N codes – 2 .TXT file of figure 3).

Figure 3. Illustrates the MRV data for roughing and finishing process, and their Numerical codes.
2.3. Machining

As per the stock model details generated by the algorithm [9] the stock model volume required for opener CAD part model is 18190.3 mm$^3$ (Figure 5). The .SAT files of machining processes are converted to .IGES format to be input to AUTODESK FUSION 360 (free version for education purpose) software so as to generate NC codes. The work piece of aluminium material is machined in 3-axis CNC milling machine. The end milling process is done to remove bottom and top layers of MRV for roughing and finishing. Then the pocketing is performed (Figure 4) to obtain pocket feature and produce opener.

3. Results

Based on the suggested stock model volume, the aluminium material volume is taken and milled in 3-axis CNC milling machine using the numerical codes generated from material removal volume. The produced opener is shown in Figure 5. The dimensions of the opener were measured to be 68mm length, 50mm width and 3mm thickness. The dimensions of CAD part model of opener input to algorithm to generate material removal volume are shown in Table 1. The dimensions of stock model generated by algorithm are also shown in Table 1.

Table 1. Illustrates the dimensions of opener CAD part model, stock model, and final product opener.

| Models                     | Dimensions (mm)               |
|----------------------------|-------------------------------|
| Opener CAD part model      | 68mm length × 50mm width × 3mm thick |
| Stock model                | 71.35mm length × 51mm width × 5mm thick |
| Final product opener       | 68mm length × 50mm width × 3mm thick |
4. Conclusion

The time taken to generate MRV data is approximately 12 s and the machining time to produce opener is approximately 10 min, so the overall time taken to produce an opener is less than 30 min. The results show dimensions (68mm length × 50mm width × 3mm thick) of opener produced by milling are same as its CAD model input to the algorithm to obtain stock model and material removal volume. Hence, it can be concluded that the regular form part can be produced as per the required volumetric dimensions by using auto-generated material removal volume. Thus eliminating the detailed designing stage which is adopted in conventional machining.

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