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Machining feature recognition and tool-path generation for 3-axis CNC milling

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Abstract

This study develops an effective method for identifying machining features. While recognizing features, the workpiece is sliced at some assigned positions. The sectional curves of the workpiece faces and slicing plane constitute the feature profiles. Not only the isolated machining features but also the intersecting machining features can be identified by the information from these intersection profiles. Moreover, the recognized machining features can be employed for scheduling the manufacturing sequence. Different kinds of tool paths can be automatically generated for various machining features to improve the cutting efficiency.

Keywords: Machining feature; Tool path; Pocket; CAD/CAM; CNC

1. Introduction

Computer aided manufacture (CAM) has been being researched for over four decades and excellent results have been achieved, but computer automatic manufacture continues to make little progress. Although variable elaborate machining methods have been developed in CAM software, the assignments of different kinds of tool paths to variable features still depend on humans. The recognition of machining features (MF) is the cornerstone of automatic machining. MF differs from design features considering machining information. MF derives from delta volume, which is the volume obtained by subtracting workpiece from raw stock, as illustrated in Fig. 1(a). Decomposing delta volume can obtain MF [1–2]. All the volume of MF must be removed. However, all of the volume cannot be removed for design features such as bosses, which is contradicting the basic meaning of MF. The information of the faces of the boss is inadequate, and face machining may lead to overcut to its neighbor features.

The faces of MF are frequently divided into two sets: finished or overcut face. After the removal of MF, the finished faces must be precisely maintained but the overcut faces must be broken to prevent residual volume being left. But for design features, these machining information are often unknown. Some researches added extra volumes (often a half cylinder) to the overcut faces to change their attributes from overcut to finished, as shown in Fig. 1(c). This method may be useful for isolated features. However, for intersecting feature, it lacks generic and efficient. Taking MF 2 of Fig.1(b) as an example, it is tedious to add extra volume to the overcut faces of MF 2.

Feature recognition has been developed for two decades. Numerous feature recognition algorithms have contributed to intersecting feature. These algorithms produce multiple interpretations for intersecting features [3], but the multiple interpretations features do not always meet needs of machining. From the design perspective, the more features are decomposed from intersecting features, the more freedom of the design-change is permitted. However, from the machining perspective, burrs and machining time increase with more decomposed features. Burrs frequently occur on the mutual edge of two intersecting features following machining. The faces intersected by every other intersecting feature are cut twice, increasing the machining time. Consequently, specific development for MF is necessary.

Tyan submitted an algorithm for recognizing MF from 2D CAD files, but the submitted algorithm could not recognize intersecting MF [4]. Numerous works contributed to intersecting features, but these researches are often relevant to 2.5D features [5–6]. Moreover, Lee applied

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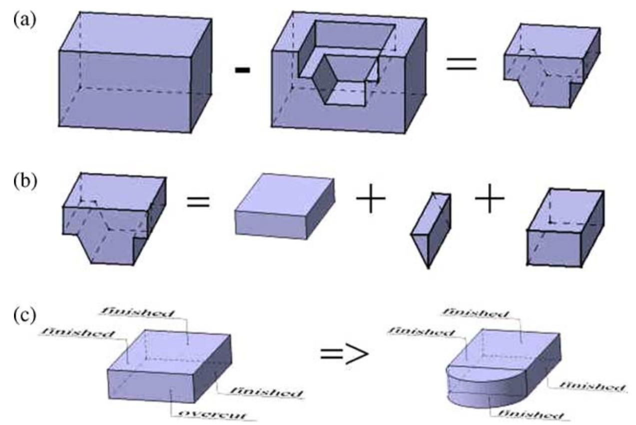

Fig. 1. Delta volume and machining features (MF). (a) Raw stock − workpiece = delta volume. (b) Decomposition: Delta volume = MF 1 + MF 2 + MF 3. (c) Adding extra volume to the overcut face of MF 1.

a feature-composition method to refine MF [7]. Additionally, Zulkifli used a Kohonen self-organizing feature map neural network to determine intersecting MF [8]. However, their algorithms are difficult to apply to 3D features. Furthermore, Woo presented a method of maximal features for recognizing MF, but described little machining information. Unlike these previous studies, this work applies a slicing technique for recognizing MF. MF is extracted using the intersection information of some selected slicing planes. From the machining perspective, it is not necessary to discriminate the differences of slots, steps, notches, and bosses. The only concern is the machining boundaries for 2.5D MF and the surface shapes for 3D MF. Hence, all 2.5D features can be shrunk to just one machining type- pocket. Every pocket possesses just one outer profile (called the pocket profile). Some profiles (called island profiles) may exist inside pockets, and are exploited as non-machining boundaries. The removable volume is located between the pocket profile and its island profiles.

This study classifies pockets into two types—virtual pockets with islands (VPI) and real pockets with islands (RPI). Fig. 2(a) illustrates the formation of VPI. A virtual boundary is automatically added to the workpiece. During workpiece slicing, the concrete portions intersect with the slicing plane to form four face(s). These faces comprise the non-machining region. Every face has an outer profile as its outer boundary. The face profiles and the virtual pocket profile form the top portion of VPI. From the design perspective, this workpiece possesses four bosses and a slot. It can also be viewed as a workpiece that contains two different slots. However, from the perspective of VPI, the workpiece is simply an island with multiple shapes. The island shapes and altitudes will be identified via several vital slices, which are introduced in Section 2.

Unlike VPI, needed adding a virtual pocket profile, the RPI owns its pocket profile as illustrated in Fig. 2(b)-2. Pocket with itself pocket profile is herein called RPI. Following slicing the workpiece, six faces and five inner profiles appear. The five inner profiles contribute to five pocket profiles of RPI. Meanwhile, five faces are located in two inner profiles. They serve as the islands of RPI. These island profiles are herein termed dependent outer profiles. If the depths of the five RPI are determined, their tool paths can be automatically generated.

Generating tool paths for features frequently involves two problems. The first problem involves the feature manufacturing sequence. Features with higher altitude should be machined first. Meanwhile, features such as boss, slot, step or notch should be machined before the closed pocket. These rules are easy to carry out using the forms of VPI and RPI. Design features such as slots, steps and notches are merged to form the islands of VPI in this study. The manufacturing sequence of 2.5D features can be simplified to just two rules: machining VPI before RPI and machining higher RPI before lower RPI.

The second problem that arises in tool-path generation regards the feature machining. The machining region for 2.5D MF is located between the profiles of the pocket and its islands. Gouging avoidance can be achieved using

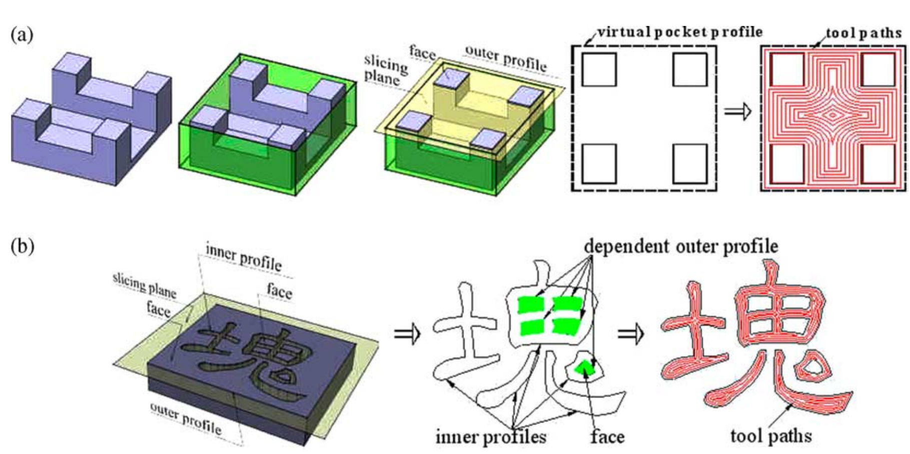

Fig. 2. Formation of VPI and RPI. (a)-1 The workpiece. (a)-2 The adding of virtual boundary. (a)-3 A slicing of VPI. (a)-4 The profiles of VPI and its tool paths. (b)-1 A slicing of RPI. (b)-2 The RPI and their tool paths.