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Feature recognition and volume generation of uncut regions for electrical discharge machining

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ABSTRACT

Feature techniques have played an important role in CAD/CAM integration. These techniques need to be developed for each type of manufacturing process owing to its unique characteristics. Therefore, an approach is proposed in this paper to extract the machining feature of region containing internal sharp points for the process preparation of electrical discharge machining (EDM). The hint feature points are innovatively defined and classified into three types: internal sharp points, cutting-into points and interacting points. Based on this, our approach firstly identifies the faces and the type of the region. Secondly, the interacting region is decomposed into isolated regions through reconstructing the topological structure of the region. Thirdly, the reconstructed faces and original faces are stitched together to form a closed surface, and the CAD models of volumetric features are constructed. Finally, the position and dimension parameters are extracted and saved. The shape and parametric information extracted can be used for subsequent procession preparation, so as to promote the CAD/CAM integration of EDM.

1. Introduction

In mold machining, typical machining process consists of milling (roughing and finishing) and a number of subsequent EDM operations [1]. Since EDM is inefficient and needs extra design of electrodes, machining assistants tend to adopt milling technology. With the wide use of multi-axis machining equipment and ball-end milling cutter, milling has been applied in machining the majority of part surfaces [2–4]. However, milling process cannot machine the region containing internal sharp corners, as shown in Fig. 1, because of the restriction of cutter diameter and feeding direction. EDM is still the only effective technology for such region [5–11].

As non-traditional machining method, EDM needs extra electrode design and meanwhile the setting of its technological parameters is complicated. Recognizing machining feature is the prelude to these process preparations. The researches [5–7] have presented the criteria of characterizing the EDM region. The criteria are in the form of high-level description, and the feature recognition is not considered. Mahajan et al. [8] presented the basic rules for automatic electrode design. But these rules were implemented by machining assistants. Ding et al. [9] developed an algorithm of detecting sharp corner regions for electrode design by calculating the surface angles at their common edges. As the interaction of machining volume was not considered, the machinability of the electrode cannot be ensured. Lee and Li [10] developed an intelligent tool for electrode generation. With the tool, the automaticity of electrode design was improved by at least 50%. However, the machining region was partly recognized through the interactive selection. Zhou and Zhang [11] proposed a volume decomposition-based algorithm to generate the electrode CAD model. But their method assumed that the machining features had been identified. In summary, the related researches have not achieved the recognition of EDM machining feature.

The research work reported in this paper is motivated by the above observation. The work focuses on developing an algorithm for the recognition of EDM regions and the generation of their volumetric features. The remainder of this paper is organized as follows. Section 2 presents the literature review on feature recognition. Section 3 introduces technical definitions. Section 4 outlines the approach proposed here. Section 5–7 details the approach. Section 8 illustrates the algorithm analysis and experiment results, and, finally, Section 9 concludes this paper and discusses future work.

2. Literature review

Feature technology has been widely used in computer aided designing and manufacturing (CAD/CAM). [12–14] Recognition of

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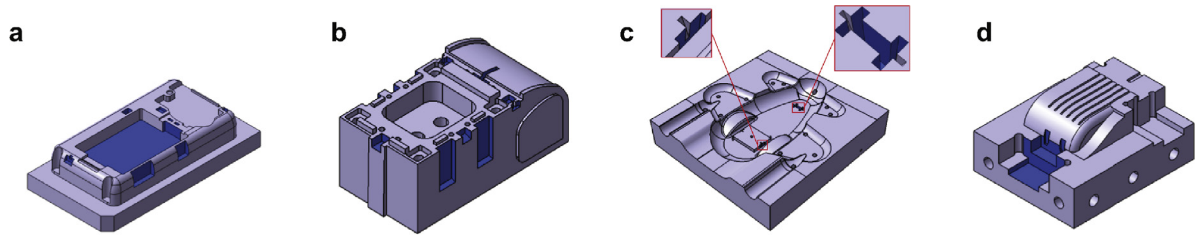

Fig. 1. Uncut regions: (a) phone cover mold, (b) distributor box mold, (c) toy plane mold and (d) shaver cover mold.

machining feature focuses on the design and implement of the algorithm to extract the required information from the part CAD model for the integration of CAD/CAM. Comprehensive review of various feature recognition techniques has been reported in the literature [15–18]. A key issue in feature recognition is to handle feature interactions [19–24].

The Attributed Adjacency Graph (AAG) proposed by Joshi and Chang [25] formed the basis for many subsequent approaches known as graph-based methods. These methods can effectively recognize non-interacting features, but have difficulties in recognizing interacting features because of the missed arcs caused by feature interaction. There were some attempts to restore the missed arcs [26,27], but recovering the missed arcs is still a difficulty for interacting features. The volume decomposition approach proposed by Woo and Sakurai [28] decompose interacting features into smaller volumetric units by extending the faces or edges. Features are considered as aggregation of these smaller volumes. This method sometimes generates unreasonably large number of small features and thus it is computationally expensive. Vandenbrande and Requicha [29] initiated hint-based approach to recognize interacting features. The authors supposed that no matter how features interacted, a machining feature would certainly leave a trace in the part boundary. So the hint-based approaches are more successful in recognizing interacting features than other existing approaches.

Recently, hybrid approaches, which combine the advantages of the above approaches, have been concerned by a growing number of researchers. Gao and Shah [19] proposed a hybrid method using graph and hint based approaches. In their method, Minimal Condition Sub-Graphs (MCSG) are used as feature hints. All MCSGs are generated by graph decomposition and completed by restoring its missed links. The missed links are restored by extensive geometric reasoning. Rahmani and Arezoo [20] proposed a hybrid of graph and hint based approach to extract interacting features from solid models. Here the graph-based hints are implemented and represented in concave graph forms helping the recognition of interacting feature with less computational effort. The interacting features are extracted based on the properties of concave graphs or its nodes. Sunil et al. [21] presented a graph and rule based approach for recognizing the interacting feature from B-rep CAD models of prismatic parts. Feature Face Adjacency Graphs (FFAGs) are constructed through decomposing Part Face Adjacency Graphs (FAG). Based on the structure of the explicit feature graphs, the interacting features are recognized by using geometric reasoning rules.

Review of related literature reveals that the existing approaches cannot handle the interacting EDM region. So the current work proposes a hint-based approach to generate the volumetric feature of EDM region in honor of automatic process preparations such as technological parameter setting and electrode design.

3. Technical definitions

Handling interacting region is a key issue of our approach in this paper. The associated definitions are introduced as follows.

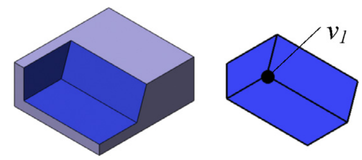

Fig. 2. Internal sharp point.

3.1. Hint feature point

The topological, geometrical and heuristic information about the part can be used as the hints for the presence of a certain feature, and the choice and utilization of the hint is a key and difficult problem in handling interacting machining feature [17]. The topological vertex is generated via multiple machining operations. The vertex has several adjacent edges, and their convex–concave configuration contains substantial information on the process planning. Therefore, the vertex is innovatively used as the hint in this paper. The vertices of region containing internal sharp points are termed as *hint feature points*, which are classified into three types: internal sharp points, cutting-into points and interacting points.

3.1.1. The internal sharp point

The internal sharp point is the hint for extracting the region faces. If the vertex meets the following conditions, it is termed as *the internal sharp point*.

- It has at least three adjacent concave edges and no adjacent convex edge.
- The two adjacent edges on any topological face are not continuously differentiable (C1).

For example, in Fig. 2, the vertex v_1 is the internal sharp point.

3.1.2. The cutting-into point

The cutting-into point suggests the cutter wedging, and it is one of the hints to handle the interacting regions. If the vertex meets the following conditions, it is termed as *the cutting-into point*.

- It has two adjacent convex edges and one or more than one adjacent concave edges.
- The other endpoint of all the adjacent concave edge is the internal sharp point.
- The two adjacent edges on any topological face are not continuously differentiable (C1).

As the adjacent convex edges of the cutting-into point are formed by the cutter wedging, the edges are termed as *the cutting-into edges*. For example, in Fig. 3, the vertices v_1–v_3 are the cutting-into points, and their adjacent convex edges, e_1–e_6, are the cutting-into edges.

3.1.3. The interacting point

The interacting point is formed by the interaction of machining operations, and its adjacent edges are the face boundary of different regions. So if the vertex meets the following conditions, it is termed as *the interacting point*.