Prediction and Simulation of Milling Burr Formation for Edge-Precision Process Planning

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Abstract— A milling burr prediction system is developed for edge-precision process planning. Workpiece edges are first classified into distinct categories according to experimental conditions; the corresponding experimental findings are then applied to predict burr types and burr locations, which are displayed graphically on the workpiece contours. This system assists process planners to reduce milling burr formation by adjusting tool paths, or change burr formation locations for easy deburring.

Introduction

Burr formation is a highly complicated behavior of material deformation. A number of factors are involved in the burr formation process, including material properties, workpiece geometry, surface treatment, tool geometry, tool path and cutting parameters. It would be very difficult to model burr formation in 3D oblique cutting such as milling and drilling. Most previous studies used experimental approaches, i.e. a series of experiments are conducted by changing different factors; the experimental results are then observed and analyzed to find how these factors affect burr formation both qualitatively and quantatively. Empirical equations have been obtained in this manner [1, 2]. More importantly, a few key controlling factors have been discovered, such as the in-plane exit angle [3] and the tool exit order [4]. Due to the particular experimental settings, each study can only be applied to very restricted machining conditions. Not surprisingly, this is the shortcoming of an experimental study. There is a lack of systematic methods that can effectively use those findings in real machining.

In order to use those experimental findings more effectively, a burr prediction and simulation system is developed in this study. This system classifies 2D workpiece edges according to particular experimental settings. Each classified edge is then predicted with the corresponding data analysis method. The prediction results include milling burr type (entry, secondary, primary and wavy) and its locations along the workpiece contours. Graphical outputs are also generated for burr formation simulation. This system utilizes the previous experimental studies in an integrated way, and offers effective tools for edge-precision process planning.

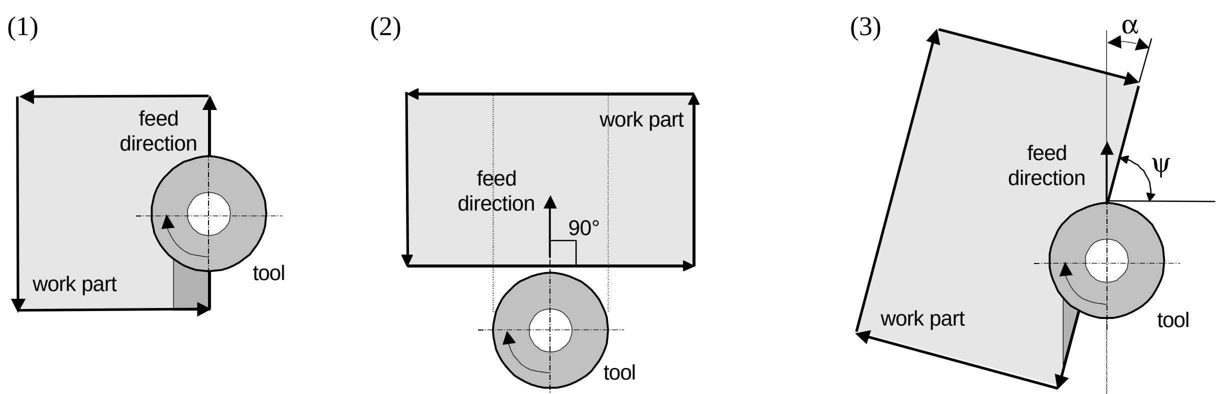

Figure 1 *Three distinct experimental settings for milling burr formation*

Experimental Findings

Three previous experimental studies and their corresponding results are used in this prediction system, shown in Figure 1: (1) the tool feed direction is precisely parallel to the workpiece edge, (2) the tool feed direction is precisely vertical to the workpiece edge, and (3) the tool feed direction is neither parallel nor vertical to the workpiece edges. Each case has its own corresponding rules for predicting burr type. In the first case, the *milling burr control chart* [1] has been established that predicts the occurrence of secondary, primary or wavy burrs in the face milling operation. The second case uses simple geometric rules to determine entry and exit burr formation. The in-plane exit angle and the in-plane exit angle gradient [5] are employed in the last case. Note that tool engagement is the crucial information for burr prediction for all three cases.

System Structure

Figure 2 illustrates the schematic structure of the prediction system. Input data includes tool geometry, 2D workpiece contours, cutting parameters and tool path. The tool path pattern can be single-direction or zigzag. Only burr formation induced by one single tool pass is considered. Next, the corresponding tool engagement information is computed; and then the inquiry is generated. Milling data base containing previous experimental findings will predict the burr type with the inquiry. The results are displayed graphically.

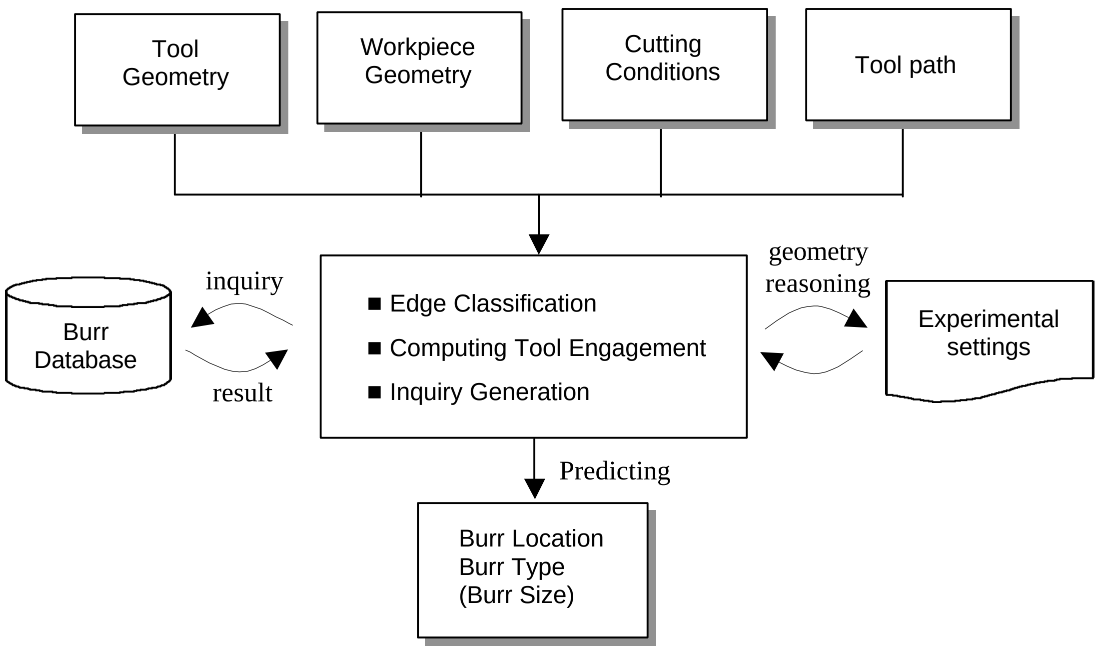

Figure 2 *Schematic structure of the burr prediction system*

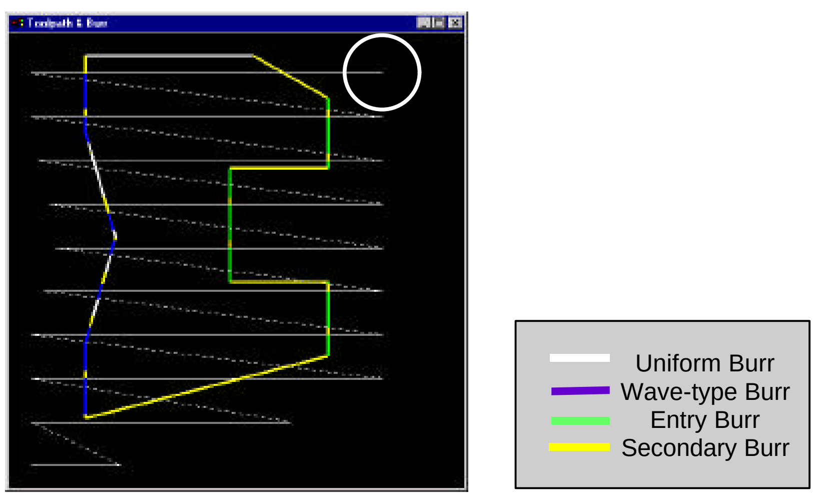

Figure 3 *Simulation result of burr prediction and simulation*

Result

The proposed burr prediction system has been implemented in C++ with ACIS as a geometric engine and OpenGL as the graphic library. Figure 3 shows a screen-shot of the burr prediction result. Note that the white circle represent the tool rotating clockwise. Single-direction tool path is used in this test example. Different colors indicate different burr types as shown in the figure. The burr prediction functionality can be further extended and integrated into other process planning modules for minimizing exit burr formation. For instance, Figure 4 shows the simulation result of the same example indicating how the total primary burr length varies with the depth of cut. The sudden drop in the figure represents the critical depth of cut. With this simulation result, process planners can easily select appropriate cutting parameters for edge-precision planning. Automatic process planning for enhancing edge quality can be thus achieved.

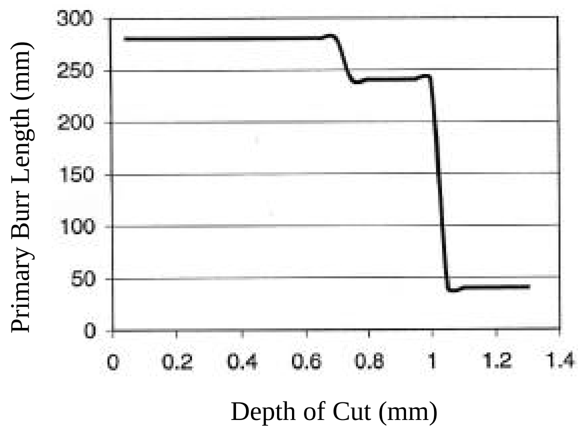

Figure 4 *Influence of the depth of cut on primary burr length*

Conclusion and Future Work

This study offers a solution to the difficulties encountered in using previous experimental findings in milling burr formation. It also shows the feasibility of using burr prediction and simulation for edge-precision process planning. However, the following issues need further investigations. First, more burr formation data can improve the prediction result. This requires a systematic approach for populating our burr database using other data sources. In addition, the link between this system and other process planning software modules needs to be established. Internet-access is another issue to be focused.

References

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