5-axis Control Ultraprcision Micromilling by Means of a Developed CAPP/CAM System

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Abstract

The study deals with the development of a fundamental CAPP/CAM system for 5-axis control micromilling. The system consists of four stages; the decision of the workpiece fixing direction and the generation of NC data for very roughing, roughing and finishing. The effectiveness of the system is confirmed by a machining experiment of a microimpeller.

1 Introduction

Complicated 3-D microparts can be created by the development of 5-axis control ultraprecision machining center. 5-axis control machining has several advantages, i.e., to be able to use short tools and to machine without remounting of workpieces. 3-D CAD/CAM systems for 5-axis control micromachining are also developed to save time and labour in preparing NC data [1]. However, operators consume a long time in process planning since there are few computer systems that help process planning for micromachining. Therefore, operators have to make the process plan, based on empirical knowledge and intuition. In the near future, the demand for microparts will grow further, and the reduction in machining lead-time will be requested, too. It is vital to develop CAPP (Computer Aided Process Planning) system for 3-D ultraprecision micromachining in response to these demands.

The study deals with the development of a fundamental CAPP/CAM system for 5-axis control 3-D micromachining. Miniaturization of cutting tools causes the stiffness degradation, thus resulting in the unstable machining. In place of operators, the system developed in the study can decide the workpiece fixing direction and generate NC data for very roughing, roughing and finishing, considering the tool posture for stable 5-axis control machining, the collision-free machining and so on.

2 Outline of developed CAPP/CAM system

The CAPP/CAM system developed in the study consists of four stages, as shown in Figure 1. The input data to the system is 3-D CAD models of a blank material and a shape to be created. The output is NC data from very roughing to finishing.

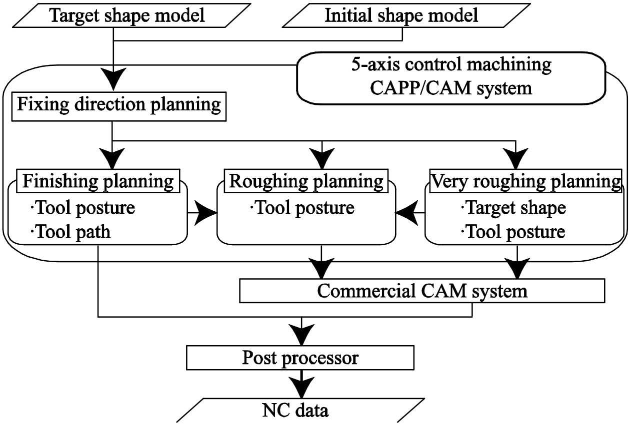


Figure 1: Outline of developed CAPP/CAM system

In the first stage, the system plans the workpiece fixing direction against the table of a 5-axis control ultraprecision machining center on the basis of the sight direction vector, by reference to the input data. The workpiece fixing direction is selected so that the number of the visible triangles from the sight direction can be the largest, as shown in Figure 2.

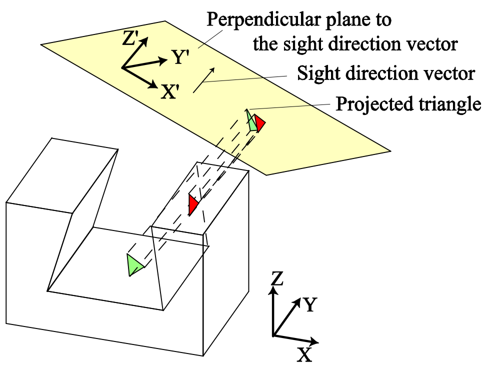
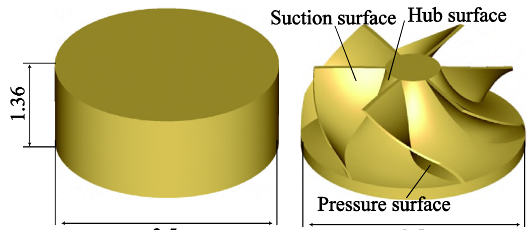


Figure 2: Judgement of visible triangle

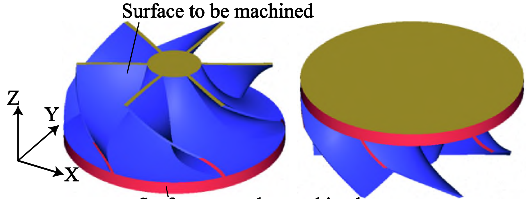
In the second stage, the finishing tool path and tool posture are planed on the basis of the information of the workpiece fixing direction. At the time, the tool collision between the tool and the workpiece must be avoided. In addition, the system aims at reducing the rapid tool posture change in 5-axis control machining since the accuracy of rotational axes affects the machining accuracy. Here, the important thing is to use a shorter tool. In 5-axis control machining, it is more difficult to estimate the tool length than 3-axis control machining since various tool postures are allowed. The use of short and high stiffness tools enables the stable machining.

In the third stage, the system plans rough machining on the basis of the tool posture determined in the finishing machining. The roughing tool path is determined by use of multi-stage decision process [2]. The rough machining is performed by 3+2-axis control.



(a) Initial shape model (b) Target shape model

Figure 3: Workpiece model



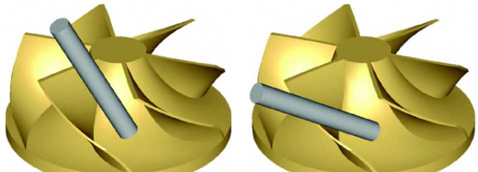
(a) Candidate 1 (b) Candidate 2

Figure 4: Fixing direction plan

In the fourth stage, the system plans very rough machining by 3+2-axis control, which means the process to roughly remove the excessive part before rough machining. Of course, the actual machining begins with very roughing.

3 Application to creation of microimpeller

The potential of CAPP/CAM system developed for micromachining is confirmed by a machining experiment, using a model of an impeller shown in Figure 3. The candidate of the workpiece fixing direction obtained by the system is shown in Figure 4. The plan 1 is selected due to the large visible area. The suitable tool postures of roughing and very roughing are shown in Figure 5 and 6 respectively.



(a) B=28.39327° C=196.35627° (b) B=57.68313° C=201.23459°

Figure 5: Index angle for roughing hub surface

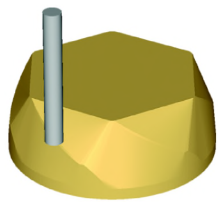


Figure 6: Convex envelop solid for very roughing

A brass impeller of 3.5 mm in diameter was created from a cylindrical material with the same diameter by use of an ultraprecision machining center and a carbide ball-end mill of 0.15 mm in radius. Machining arrangement is shown in Figure 7. The machined microimpeller is shown in Figure 8, together with the machining condition in Table 1. The total time from very rough machining to finishing is 58 hours.

Table 1: Machining conditions

Workpiece material	C3604
Tool	R0.15 carbide ball end mill WXL-LN-EBD (OSG CORPORATION)
Spindle speed	35000 rpm
Feed rate	20 mm/min
Depth of cut	0.02 mm
Pick feed	0.01 mm
Cutting fluid	METAL WORK HS (Nippon Oil Corporation)

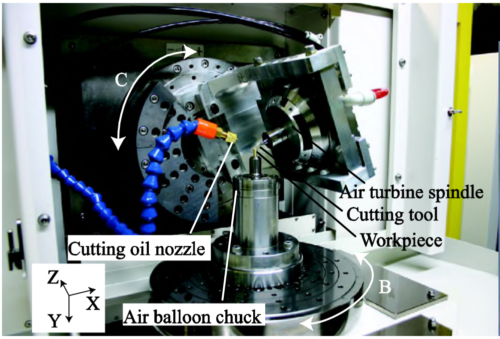


Figure 7: Machining arrangement

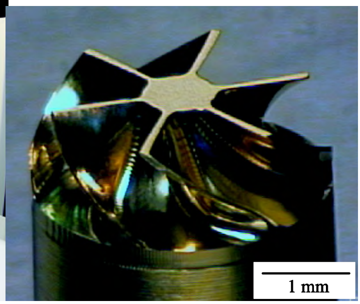


Figure 8: Machined impeller

4 Conclusion

From the experimental result of creating a micro impeller effectively, it is found that the CAPP/CAM system developed in the study has the potential of 5-axis control micromachining.

References:

[1] Y. Takeuchi, H. Yonekura, K. Sawada: Creation of 3-D Tiny Statue by 5-Axis Control Ultraprecision Machining, Computer-Aided Design, Elsevier, Vol.35, No.4 (2003) 403-409

[2] T. Umehara, K. Teramoto, T. Ishida, Y. Takeuchi: Tool Posture Determination for 5-Axis Control Machining by Are Division Method, JSME Int. Journal, Series C, Vol.49, No.1 (2006) 35-42