Microgrooving with Flat-ends for Hard Materials

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Abstract

High performance and miniaturization are strongly demanded for optical elements and precision parts, where microgrooves play an important role. A non-rotational cutting tool is one of machining means to create such microgrooves. However, even non-rotational cutting tool forms slopes at the cutting start and end points, which deteriorates the optical performance. In optical elements and precision parts, the creation of microgrooves with two flat-ends at their start and end points, is expected, where flat-ends microgrooves mean microgrooves having no slopes at the cutting start or end point. The method to create two flat-ends microgrooves has already been devised and applied for soft materials in our previous reports, not for hard materials. In the study, a new method is proposed to create straight and curved microgrooves with two flat-ends for hard materials by indenting and feeding a non-rotational diamond cutting tool mounted to a 5-axis control ultraprecision machining center. From experimental results, it is found that the proposed method has the potential of creating two flat-ends microgrooves for hard materials.

1 Introduction

The machining method of two flat-ends microgrooves by use of non-rotational cutting tool is one of the microgroove cutting technologies, which can machine accurate shape so that cutting tool shape and path are transcribed. Figure 1 shows a flat-ends microgroove. Flat-end microgrooves have vertical walls at end points. Flat-end microgrooves are expected for air conduction grooves on air bearing which is made from low-thermal expansion ceramics. In the

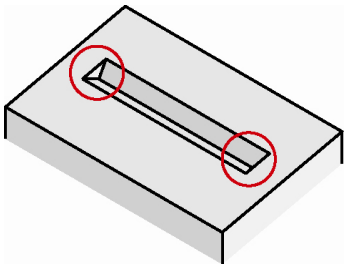


Figure 1: Microgroove with two flat-ends

previous research [1], two cutting methods with a non-rotational cutting tool were devised so that the microgrooves with two flat-ends could be created. These methods were successfully applied for soft materials. However, these methods can not apply for hard-brittle materials like low-thermal expansion ceramics because of a possibility that the cutting tool is broken. Thus, a new cutting method with a non-rotational cutting tool for hard-brittle materials is essential so that the microgrooves with two flat-ends can be created.

2 Preparation of microgroove creation

A 5-axis control ultraprecision machining center used in the research is ROBOnano Ui made by FANUC Ltd., which is equipped with three translational axes (X, Y, Z) and two rotational axes (B, C). A cutting tool needs the hardness and wear resistance to cut hard materials. In the research, the non-rotational cutting tool made of a single crystal diamond with the angle of 90 degree is used. Figure 2 shows the dimension of tool tip. The rake angle of this cutting tool is 0 degree, and the relief angle is 8 degree. As shown in Figure 3, the workpiece and a cutting tool are fixed on B-table and C-table respectively, by use of jigs. In this research, two kinds of workpiece materials are used as hard ones, i.e. Ni-P plating and NEXCERA. The latter is zero thermal expansion ceramics, which is expected for an application of the precision fields [2].

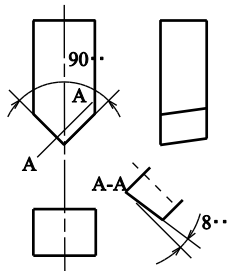


Figure 2: Non-rotational diamond cutting tool

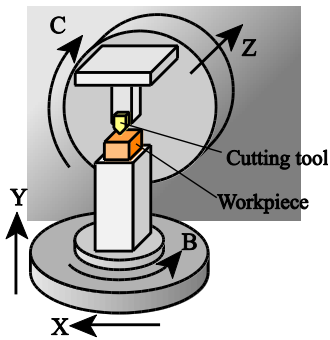
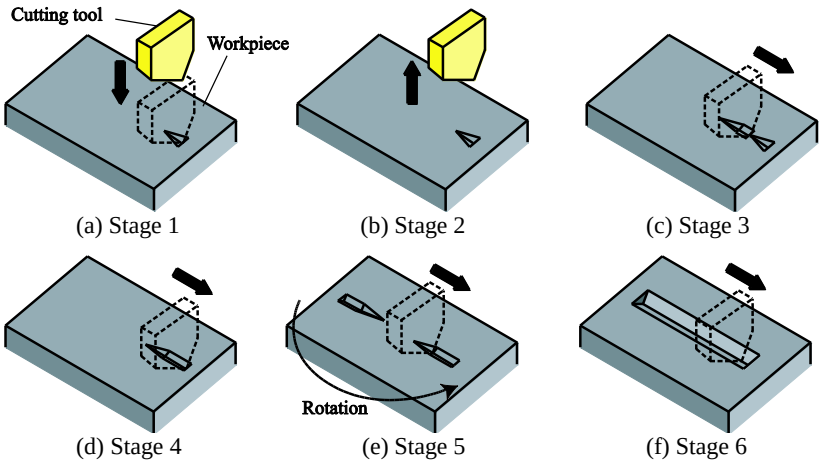


Figure 3: Arrangement of cutting tool and workpiece

3 New method of creating microgrooves with two flat-ends

The new machining method is applied to create a microgroove with two flat-ends. The machining method utilizes two microgrooves with single flat-end, as shown in Figure 4. At first, a microgroove with single flat-end is machined by the same method

and the same non-rotational cutting tool as before, as illustrated in (a), (b), (c) and (d). Then, B table is rotated by 180 degrees, and another microgroove with single flat-end is machined, as illustrated in (e). Finally, two microgrooves with single flat-end are connected, as illustrated in (f). By using this machining method, two flat-ends microgrooves with arbitrary depth can be created.



(a) Stage 1 (b) Stage 2 (c) Stage 3

(d) Stage 4 (e) Stage 5 (f) Stage 6

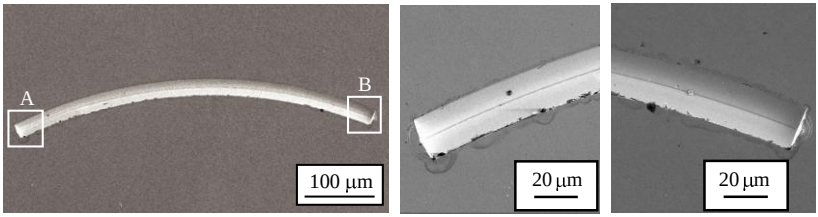
Figure 4: Machining method of two flat ends microgroove

4 Machined microgrooves with two flat-ends

Each machining condition is listed in Table 1. Kerosene is sprayed during machining. Figures 5 and 6 show SEM micrographs of machined curved micro grooves of Ni-P plating and NEXCERA, together with the enlarged profile of groove end. With regard to the linear microgroove with two flat-ends, they are well created. From these figures, it is found that the microgroove with two flat-ends is successfully machined, while suppressing the brittle fracture.

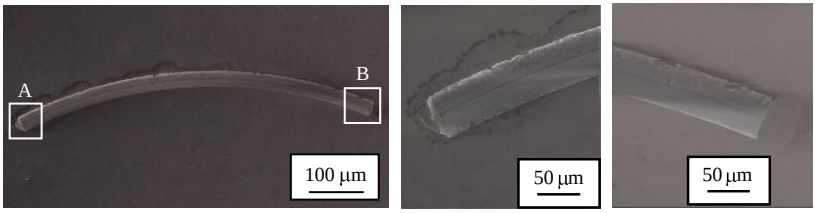
Table1: Machining condition

	Ni-P plating	NEXCERA
Total depth μm	12	12
Depth of one indentation μm	0.5	0.1
Depth of cut μm	0.5	0.1
Indentation feed rate μm/min	5	5
Feed rate μm/min	10	10



(a) Whole view (b) Enlarged view of A (c) Enlarged view of B

Figure 5: Machined two plat ends curved microgroove of Ni-P plating



(a) Whole view (b) Enlarged view of A (c) Enlarged view of B

Figure 6: Machined two plat ends curved microgroove of NEXCERA

Judging from the above experiments, it is confirmed that new cutting method can sharply create two flat-ends curved microgrooves on hard-brittle materials under appropriate machining conditions.

5 Conclusion

A new machining method of microgrooves with two flat-ends on hard-brittle materials is proposed by repeating an indentation method to make a single flat-end. As the result of machining, it is confirmed that the new machining method can be applicable to create two flat-end microgrooves on such materials as Ni-P plating and zero thermal expansion ceramics.

References:

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