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Effect of a stepped flank face tool on polycarbonate cutting

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Abstract
In the cutting process of resin, the tool flank face and the finished surface are always kept in contact in a wide range due to the influence of elastic deformation of the workpiece. This leads to an increase in cutting force and frictional heat, causing deterioration of the finished surface properties such as dullness and melting, accuracy of dimensional and roughness. In this study, a cutting tool with a step on the tool flank by laser process was attempted to improve these problems. As the result, it was observed that the depth of the step influences the cutting force, whereas the width of the step influences the cutting temperature. In conclusion, the cutting force and the cutting temperature were the most reduced using the stepped tool with a width of 25 μm and a depth of 100 μm.

Polycarbonate, Resin cutting, Elastic deformation, Stepped flank face tool

1. Introduction

Resin is widely used as an industrial material due to its lightness, high transparency, high corrosion resistance and impact resistance. Especially in recent years, resin is used for touch panels, display panels and protective films instead of glass which is easily broken. In order to produce these products, resin in thin plate shape with high flatness is required. However, it is difficult to achieve this required accuracy by conventional molding process because of the influence of thermal deformation. Therefore, cutting of rolled resin sheet by end mill is carried out. however, since the melting point of resin is generally low, it tends to lead to processing defects such as melting and cloudiness during cutting. Thus, the authors have been studying toward the optimization of cutting conditions and elucidation of cutting phenomenon for polycarbonate by changing cutting conditions (cutting speed, etc.) and tool shapes (tool edge sharpness and rake angle)[1]. However, changing cutting conditions and tool shapes did not reduce melting and cloudiness. Since polycarbonate has highly ductility, the unperformed chip thickness becomes lower than the designated value, and the elastic deformation of the workpiece causes the tool flank and the workpiece to come into constant contact over a wide area. This is thought to increase the temperature through friction, deteriorating the properties of the finished surface. Therefore, if the contact area of the tool flank face and the finished surface can be reduced, the above problem may be able to be solved. Based on these facts, In this study, a cutting tool with a step on the tool flank made by a ultra-short pulse laser process was fabricated and its effect was investigated.

2. Experimental apparatus and methods

2.1 Experimental apparatus and methods

In the experiment, an manually controlled lathe (Okuma Corporation LS type) was used and cut a disk-shaped workpiece in radial direction (Fig. 1) to perform orthogonal- cutting. Polycarbonate was used as the workpiece. Cutting force and thrust force were measured by a Quartz 4-Component Dynamometer (Kistler 9272). A thermal camera (CHINO CPA-SC620) was used to measure the cutting temperature. To measure the tool edge sharpness, laser scanning microscope (KEYENCE VK-X200) was used.

2.2 Flank tool with steps

laser processing was performed on the flank of the cemented carbide tool by using ultra-short pulsed laser shown in Fig. 2, and prepared tools with various steps (25–100 μm) in the width and depth directions (Fig. 3). Laser conditions was set to wave length of 1064nm, pulse width 15ps, pulse repetition rate 10kHz, advantage output power 0.5W. All tools used for the experiment were prepared with an edge sharpness of approximately 1 μm (Fig. 4). The cutting conditions and tool shapes used for the experiment are shown in Table 1.

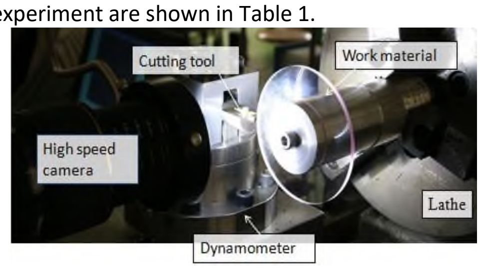

Fig.1. Experimental setup

Fig.2. Laser cutting machine

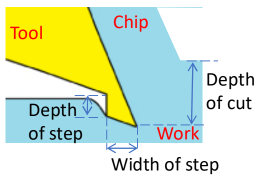

Fig.3. Definition of step tool geometry

Table 1 Cutting conditions

Cutting speed [m/min]	75
Feed [mm/rev]	0.065
Rake angle [deg]	20
Relief angle[deg]	0
Width of workpiece [mm]	3
Tool material	Carbide (K10)
Width of step [μm]	0,25,50,100
Depth of step [μm]	0,25,50,100

3. Experimental results and discussions

Fig. 5 shows the cutting force when the relief angle of the tool is changed. When the width/depth in the figures is 0 μm, this refers to a tool without a step prepared as a control (hereafter, a normal tool). In general, to avoid contact between the flank of the tool and the workpiece, the relief angle of the tool should be increased by a significant degree; however, as shown in the figure, even if the relief angle is increased to 20 degrees, there is little change in the cutting force. As such, when cutting of resin, even if the relief angle is made significantly larger, the properties of the finished surface cannot be improved upon.

Fig. 6 and Fig. 7 show measurement results for the cutting force when cutting with a stepped flank tool. The figures show that, with tools with steps, cutting force and thurust force were lower than normal tools under all conditions. Furthermore, even when the width of the steps was changed, there was little change in the cutting force; however, when the depth of the steps was changed, the cutting force was reduced. This is thought to be because, by making the steps deeper, the contact area of the elastically deformed workpiece and the flank of tool was reduced. It has possibility that this change in the contact area affects the cutting temperature. Therefore, the cutting temperature near the cutting point was measured by a thermal imaging camera. Regarding the cutting temperature, the maximum temperatures of the tool were determined from the temperature distribution images taken by the camera. Measurement was performed the temperature of the side of the tool 10 seconds after starting to cut. Fig. 8 shows the measurement result of cutting temperature. As shown in the figure, similar to the results of cutting force, all tools with steps had a lower cutting temperature compared to the normal tool; however, a clear temperature reducing effect can not be confirmed by increasing the depth of steps where the cutting force was reduced. In contrast, the cutting temperature decreased as the width decreased. The tool flank face (the interval between the cutting edge and the step) is under an extremely high stress, and violent friction conditions; thus, the reduced width led to a reduced frictional heating. As shown in Fig. 9, Scratches on the finished surface was found in both the cutting and horizontal directions with the normal tool, but it can be seen that this is improved upon with the stepped tool.

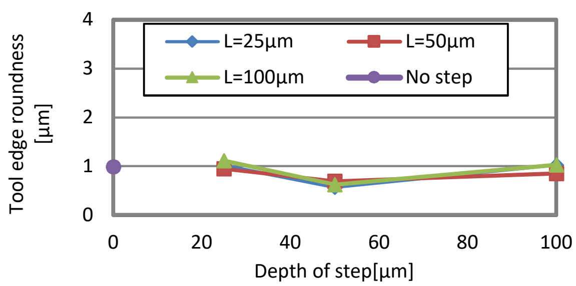

Fig.4. Tool edge sharpness of manufactured step tool (v100m/min, f0.05mm/rev, α20deg)

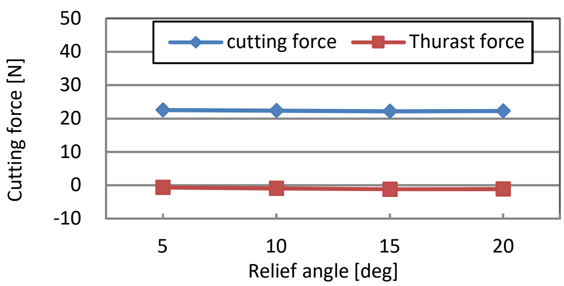

Fig. 5. Relationship between relief angle and cutting force

4. Conclusions

In this study, effects of stepped flank face tool on resin cutting were investigated and the following results were obtained.

1. With the tool with steps, the cutting force, cutting temperature, and roughness of the finished surface can be improved.
2. The depth of the steps contributes to a reduction in the cutting force, while the width of the steps contributes to a reduction in the cutting temperature.
3. Under the present experimental conditions, the most reductions in the cutting force and temperature were observed with a tool with steps with a width of 25 μm and a depth of 100 μm

References

[1] Hiroo Shizuka, Katsuhiko Sakai, Akikazu Matsuda, Yuki Kurita and Fumihiro Uchiyama "Basic research on the precision cutting characteristics of polycarbonate -Effects of cutting conditionas and rake angle on cutting" Proceedings of the 15th international conference of the European society for precision engineering an nanotechnology, pp. 375-376, 2015

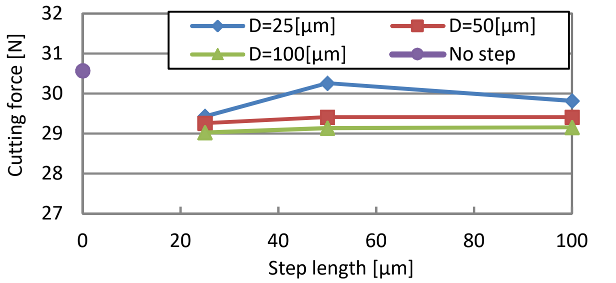

Fig.6. Cutting force and step geometry

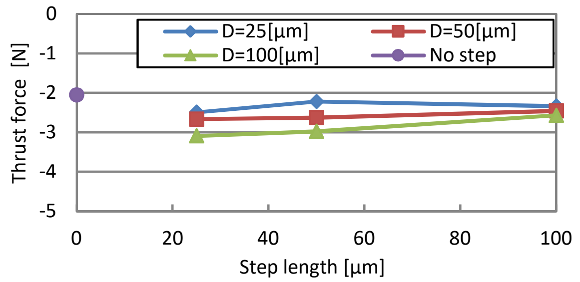

Fig.7. Thrust force and step geometry

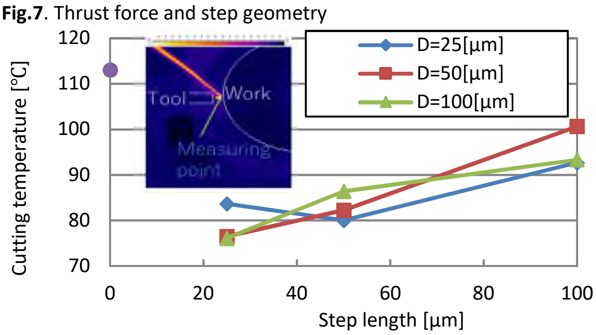

Fig.8. Cutting temperature

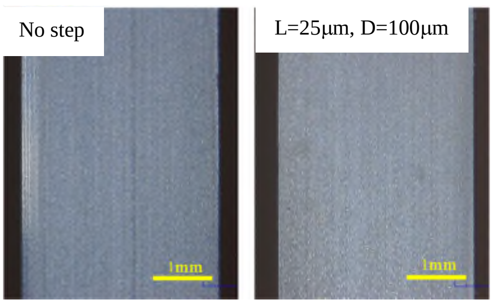

Fig.9. Microscopic image of finished sureface