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Processing characteristics of woodceramics during vibration cutting

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Woodceramics are generic term for porous carbon material produced by impregnating wood materials with thermosetting phenolic resin and then carbonating it under anoxic and depressurized conditions. In this experiment, cutting operation of woodceramics was conducted by peripheral turning using a STGC (Super Tough Grooving Chip) cutting tool and the relation between processing and hardness in cutting resistance as well as the effectiveness of vibration cutting were studied. The hardness of woodceramics increased with rising carbonating temperature from 600℃ to 1200℃. The cutting resistance of woodceramics increased with increasing hardness and woodcramics with higher hardness had higher accuracy of surface finishing. The cutting resistance of woodceramics was found to be reduced by ultrasonic vibration cutting.

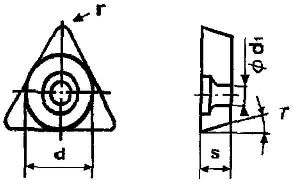
Keyword: woodceramics, carbonating temperature, cutting resistance, hardness, vibration cutting

1. INTRODUCTION

Woodceramics are porous carbon materials produced by impregnating wood or sawdust with thermosetting phenolic resin and then carbonating it under anoxic and depressurized conditions. And pyroligneous acid which is a by-product of woodceramics , can be used for soil improvement. In addition, woodceramics can be recycled, and activated chararcoal can be made from crushed woodceramics.[1] Woodceramics can be endowed with various functions by changing the carbonating temperature, and the uses as a humidity / ammonia sensor[2,3,4], electromagnetic shield [5, 6], and a heating medium [7, 8] have been expected. In the application of woodceramics to them, the forming process of woodceramics needs to be conducted before and after carbonating. However, since woodceramics contract and their shapes change during carbonating, cutting must be done after carbonating to get a precise shape. For processing of hard and brittle woodceramics, grinding using mechanical energy- cutoff by bound abrasive coating (cutoff by cutting wheel), cutoff by free abrasive grain (water jet cutting), and grinding using optical energy-laser cutoff have been studied [9]. But until now, few studies have been conducted on cutting. For the production of woodceramics, establishing a more effective processing method is a pressing issue. Therefore, in this study, possible cutting operations for processing woodceramics were investigated by using conventional prosess cutting methods. Moreover, woodceramics different characteristics depending on the carbonating temperature, impregnatied phenolic resin content, and the carbonating time. Current processing characteristics of woodceramics are mostly compared by carbonating temperature, but processing characteristics can differ even at the same caebonating temperature if another condition is changed. In this study, we assumed that processing characteristics can be judged not only from the carbonating temperature, but also from hardness, so a correlation between hardness and cutting resistance was examined. For hard but brittle material, vibration cutting is generally conducted. Advantages of vibration cutting are lubricating ability, cooling capability, and discharge of sawdust, minimizing edge defects and cracks, which often occur in the processing of woodceramics. For this reason, this study was focused on processing by ultrasonic cutting.

2. EXPERIMENTAL PROCEDURE

We measured the surface roughness, hardness, and cutting force, so that the characteristic of processing at each carbonization temperature of woodceramics might be examined. Moreover, we verified the effectiveness of the ultrasonic vibration cutting at the same time.Woodceramics were made by carbonating a medium density fiberboard (abbreviated as MDF hereafter). Woodceramics made from MDF are the most common. Equipment used for this experiment were a STGC shaped cutting tool (for turning processing), with a super tough chip. Conventional cutting operation was conducted with it. For cutting work, an ultrasonic vibration cutting machine by FUJI Ultrasonic



Inscribed circle	Thickness	Nose radius	Hole diameter
d	s	r	d1
6.35(mm)	2.38(mm)	0.4(mm)	2.8(mm)

Fig. 1 Tool shape.

Engineering Co., Ltd. was used. Figure 1 shows the shape of the byte.

2.1 Comparison of hardness

Peripheral turning of woodceramics disk was conducted using woodceramics carbonated at 1000℃. Turning conditions were as follows: Feed per revolution= 0.16 nm/rev, infeed= 1.0 mm, rotational speed= 380 rpm. The principal force, feed force and thrust force were measured by using a dynamometer as shown in Figure 2. In order to compare hardness of woodceramics made under different carbonating temperature conditions, a 3.2mm diameter bearing was attached to the dynamometer and was pressed into the woodceramics carbonated at 400℃ (board thickness of 21mm, density of 0.73Mg/m^3), at 600 ℃ (board thickness of 13.5mm, density of 0.82Mg/m^3), at 800℃ (board thickness of 17mm, density of 0.88Mg/m^3), at 1000 ℃ (board thickness of 16.6mm density of 0.78Mg/m^3) and at 1200℃ (board thickness of 10mm density of 0.79Mg/m^3) as in Figure 2. Pressing was set to 0.10mm and the pressing force value per area of part where bearing was pushed, was used for comparison. In addition, woodceramics tended to have uneven impregnation of phenolic resin when treated with phenolic resin before carbonating. Therefore, differences in the physical parameters occurred between the surface and the interior. Because of this issue, comparison was also done between the surface part 1.6mm from edge and the central part.

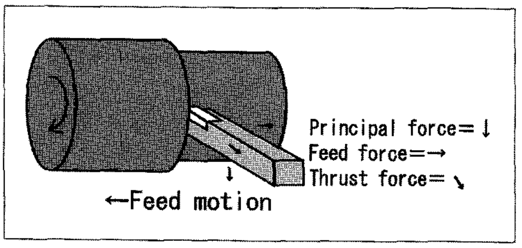


Fig. 2 Measurement of cutting resistance.

2.2 Relation between cutting resistance and surface roughness

The influence of cutting resistance on surface roughness was studied. Woodceramics were carbonated at several temperatures- 400℃, 600℃, 800℃, 1000℃ and 1200℃, and the turning conditions were as follows: Feed per revolution= 0.16mm/rev, infeed= 1.0mm, rotational speed= 390rpm. Surface roughness was measured by using a sensing shape analyzer and average roughness Ra was determined. Additionally, the measurement was conducted for the surface and the central parts and their differences were also compared.

2.3 Comparison of cutting resistance with / without vibration

The reduction in cutting resistance by conducting vibration cutting, which is said to be effective for hard but brittle material, was estimated. Woodceramics carbonated at 400℃ and 1000℃ was used. When vibration was used, vibration amplitude was set to 19□m and turning conditions were set as follows: Feed per revolution= 0.16 nm/rev, infeed= 0.3 mm, rotational speed= 150 rpm, cutting speed= 20-21m/min.

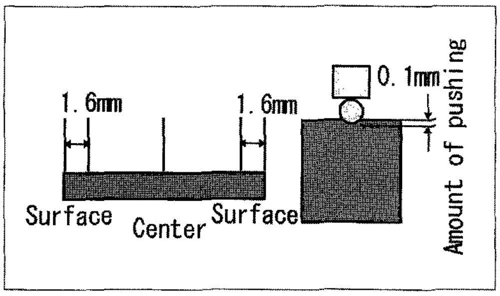


Fig. 3 Outline chart of measurement of hardness.

2.4 Effect of vibration on surface roughness

The influence of vibration cutting on surface roughness was compared. Turning conditions were set as follows: Feed per revolution= 0.16mm/rev, rotational speed= 150 rpm, infeed= 0.3 mm, vibration amplitude= 19□m, vibration oscillation= 26970Hz. Woodceramics carbonated at 400℃ and 1000℃ was used. Then surface roughness with and without vibration was measured. For surface roughness, the average roughness Ra was measured by using a sensing shape analyzer.

3. RESULTS AND DISCUSSION

3.1 Effect of hardness

Figure 4 shows the results of disk of cutting resistance obtained by conducting peripheral turning of the woodceramics carbonated at 1000℃. All 3 component forces showed two peaks at the beginning and at the end of turning and they were higher than the component forces in the middle. Even when turning was stopped midway and then re-started, the results obtained regarding resistance during cutting were the same. From both results, it is assumed that higher resistance at the beginning and at the end was not due to hasty contact of a cutting tool edge, but due to the difference in hardness between the surface and center parts. Also the measurements showed that thrust force had the greatest influence among the 3 component forces. It was considered that sufficient abrasion to woodceramics during cutting was achieved. Figure 5 shows pressing hardness at the surface and interior of woodceramics carbonated under each temperature condition. The hardness tended to be proportional to carbonating temperature. And results similar to those in Figure 4 confirmed that the interior was softer than the surface part for each carbonating temperature.

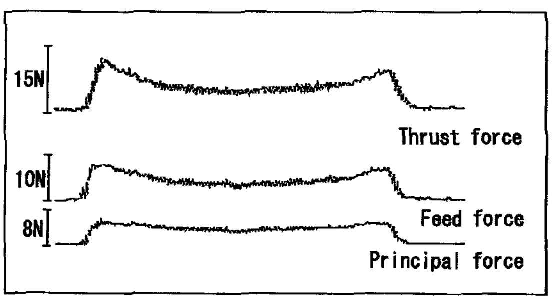


Fig. 4 Cutting force of woodceramics.

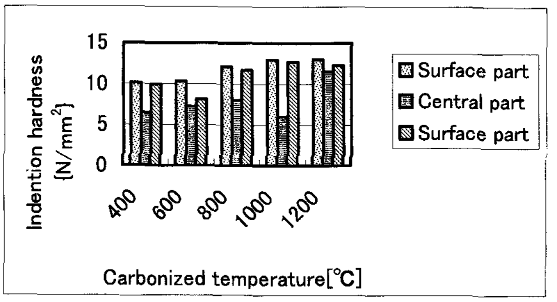


Fig. 5 Comparison of hardness of woodceramics carbonated at different temperatures. (Amount of pushing 0.1mm)

Figure 6 is a diagram showing relation between the cutting resistance and measured pressing hardness at each carbonating temperature. Although some randomness was shown, harder material carbonated at higher carbonating temperature gave higher cutting resistance. It was found that cutting resistance could be predicted by checking hardness.

3.2 Relation between cutting resistance and surface roughness

Figure 7 shows difference in surface roughness between the surface and the center parts at different carbonating temperatures. Surface roughness was inversely proportional to carbonating temperature. Therefore, the average roughness Ra decreased when harder material was cut. This can be understood because sawdust generated in harder material was powdery and thus the surface area was flat. Additionally, generation of chip off (negative burr), which was formed by impact of the cutting tool contact, is thought to be responsible for such a wide variation of data. Material carbonated at 1200℃ did not show such tendency. This can be considered to be due to that the thickness of the material was thinner than other materials and thus the surface shape became almost even.

3.3 Comparison of resistance with / without vibration

Figures 8 and 9 show the reduction profile of cutting resistance of woodceramics by vibration cutting, which is considered to be effective for hard but brittle material. When carbonating temperature was set to 1000℃, cutting resistances could be reduced by setting the vibration at 3 components of force according to results compared with or without vibration. High reduction of feed force is thought to be due to the cutting influence of front rake angle. For carbonating at 400℃, resistance could be reduced for all 3 component forces by applying vibration as in carbonating at 1000℃. When the vibrations amplitude of both 400℃ and 1000℃ were compared, the reduction value of both amplitudes was almost the same. From this result, it can be considered that ultrasonic vibration is effective for woodceramics, independent of their hardness, which is derived from different carbonating temperatures.

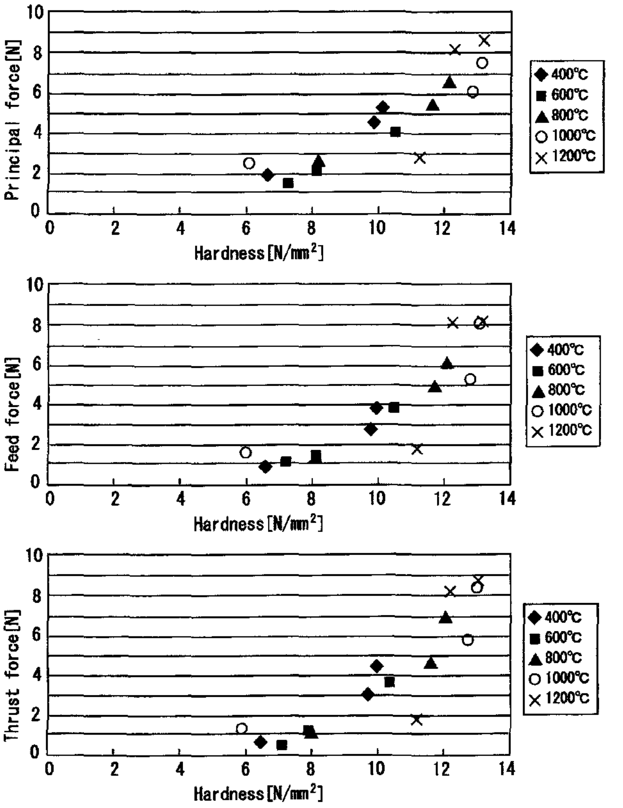


Fig.6 Relation between cutting force and hardness. (Amount of pushing 0.10mm)

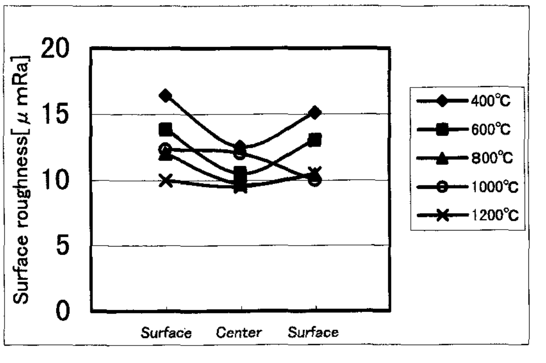


Fig.7 Difference in surface roughness between center part and surface at different carbonating temperatures.

3.4 Effect of vibration on surface roughness

Figure10 shows the effect of vibration on the surface roughness. When 400℃ and 1000℃ were compared, it was confirmed that processing a flatter surface was possible for woodceramics carbonated at higher temperature. There was little difference in surface roughness between the cuttings with and without vibration.

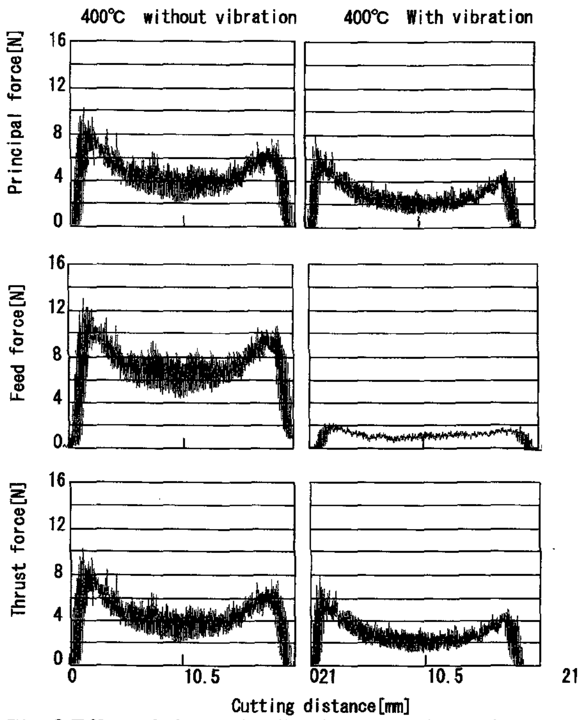


Fig. 8 Effect of ultrasonic vibration on cutting resistance (400℃) .

Feed per revolution 0.16mm/rev, Rotational speed 150rpm, Cutting speed 20~21m/min, Infeed 0.3mm

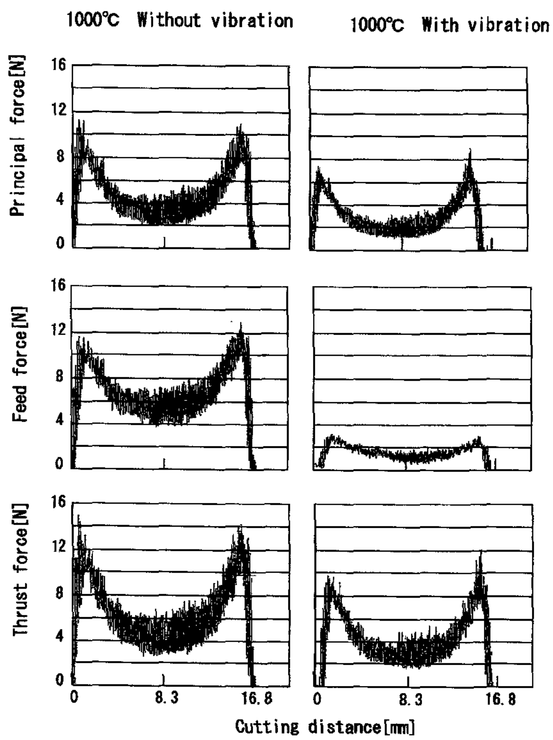


Fig.9 Effect of ultrasonic vibration on cutting resistance (1000℃).

Feed per revolution 0.16mm/rev, Rotational speed 150rpm, Cutting speed 20~21m/min, Infeed 0.3mm

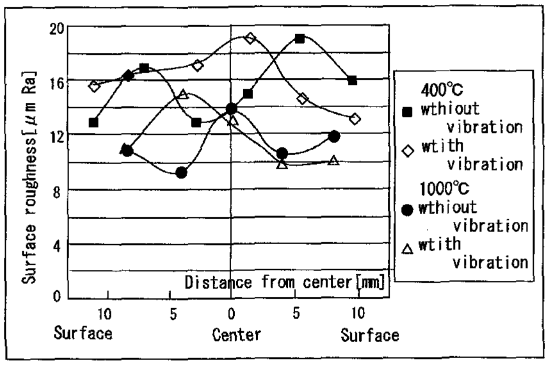


Fig.10 Effect of vibration on surface roughness

4. CONCLUSIONS

Through the study of processing possibilities of woodceramics, the following results were obtained by examining the relation between the cutting resistance and the hardness of woodceramics as well as processing by vibration cutting.

Woodceramics had different hardnesses between the surface and the center parts due to production. Hardness of woodceramics was proportional to carbonating temperature.

The cutting resistance of woodceramics increased with increasing hardness. Wodceramics with higher hardness had higher accuracy of surface finishing. However, there was littile difference in finished surface between the surface and the center parts. Ultrasonic vibration cutting could reduce the cutting resistance of all 3 component forces for woodceramics carbonated at any temperature. Under the cutting conditions used in this study, the influence of ultrasonic vibration cutting on surface roughness was hardly observed for woodceramics carbonated at any temperature.

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