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Machining of Woodceramics by High Laser Beams

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Applicability of laser machining to the porous carbon materials has experimentally been investigated with a special reference to woodceramics.The results are summarized as follows:
1.The degree of carbonization of WCS made by impregnating WDF with phenol resin can presume from the relationship between degree of WCS carbonization and burning temperature.
2.The degree of carbonization and the surface roughness of the cut section decrease as the machining speed increases.
3.WCS can be processed without cracking when the laser beam machine is used in PW mode.

1. Introduction

Environment-friendly materials are attracting much attention and the development of such materials is anticipated. Various ways to use materials and potential scenarios are being investigated in order to ensure the sustainable existence of humankind. In line with this philosophy, porous carbon woodceramic materials made from wood(a vegetable material) and phenol resin have been developed in the Industrial Research Institute of Aomori Prefecture.1)

Whether materials are used for structure or function, they should satisfy certain conditions such as form, dimensions, surface roughness and physical properties. Even if materials with superior functional characteristics are developed, they cannot be used effectively and much of their industrial value is lost unless an effective way of processing them is developed.2)

In this research, we investigated removal machining with a laser beam as a way to process porous carbon woodceramics (WCS) material. Laser beam machining is characterized as follows:

- Materials can be processed finely.
- The processed surface is burned.
- The machining produces dust.

In laser beam removal machining, optical energy, which is specific to laser beam machining, is converted to thermal energy. We researched how this thermal energy affects the cut surface in order to investigate the applicability of laser beam machining to WCS. Many studies have been done on the use of laser beams for vegetable materials3,4,5,6) which have shown that when wood is processed by laser beam machining, the cut surface is scorched. Therefore, we investigated the following three items:

1) Relationship between degree of WCS carbonization and burning temperature
2) Laser beam machining of WCS before phenol resin application and sintering
3) Laser beam machining of WCS

2. Test Method

2.1 Relationship between degree of WCS carbonization and burning temperature

We impregnated phenol resin in medium-density fiberboard (MDF; air-dried density: 0.66; moisture content: 8.5%) made from *Pinus radiata*, and burning the MDF at temperatures ranging from 300 to 2800℃.

We selected MDF to prevent the influence of aeolotropy specific to wood. We used an energy-dispersion X-ray analysis device (manufactured by Nihon Electronics) as an SEM/EDS analyzer to qualitatively analyze the surfaces of WCS specimens sintered at each temperature.

2.2 Laser beam machining of WCS before phenol resin impregnation

We cut MDF (air-dried density: 0.66; moisture content: 8.5%) made from *Pinus radiata* to 120 x 50 x 12 mm specimens, and used a CO_2 laser beam machine (1.2 kW, manufactured by Toshiba) to cut the specimens under various conditions, such as CW mode, 1000-W output, and machining speed from 100 to 1500 mm/min. We then used the energy-dispersion X-ray analysis device to quantitatively analyze the cut section. We also used a surface roughness measuring instrument (Surfcom 470A, manufactured by Tokyo Seimitsu) to investigate how the laser beam incidence affects the cut section by comparing upper, central, and lower layers of the section. We also used a scanning electron microscope (SEM) to observe the porous structure.

2.3 Laser beam machining of WCS

We cut WCS specimens (120 x 70 x 8 mm), which we fabricated by impregnating Pinus radiata MDF with phenol resin and sintering at 650℃, across the width using either a CO_2 laser beam machine (1.2 kW, CW oscillation (CW), manufactured by Toshiba, hereafter called 'Type 1') or a different CO_2 laser beam machine (single mode: 1.5 kW, multimode 3.0 kW; pulse oscillation (PW), manufactured by Mitsubishi, hereafter called 'Type 2') under two types of conditions listed in Table 1.

Table 1.Machining Conditions

Machine	TYPE 1	TYPE 2
Mode	CW	PW
Power(w)	1000	1000
Feed(mm/min)	500	300
Assist Gas	N2	N2
Frequency(HZ)	200	300
Duty(%)	100	36

3. Results and Discussion

3.1 Relationship between carbonization degree and burning temperature

Figure 1 shows how the carbon concentration and oxygen concentration change depending on burning temperature. Carbon increases as the burning temperature increases, and the concentration reaches 100% at 2000°C. Oxygen decreases as the burning temperature increases and the concentration is almost 0 at and above 2000℃. Hydrogen is also present, but we ignored it because its weight percentage is small compared to those of carbon and oxygen.

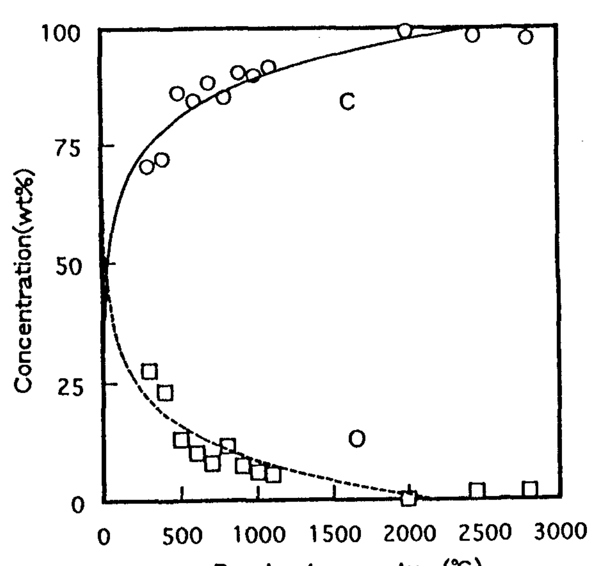

Fig.1 Concentration of carbon and oxygen as a function of burning temperature.

3.2 Carbonization degree of cut section when MDF without phenol resin impregnation is cut with laser beam

Figure 2 shows how a section cut with a laser beam is carbonized depending on the machining speed. The degree of carbonization decreases as the machining speed increases. We drew a line between the upper, central and lower layers based on the entry of the incident beam, and compared the degree of carbonization among the three layers. The upper layer was carbonized least, as shown in this figure.

The same results were obtained for all machining speeds. We conjecture that this is because the thermal conductivity of the MDF is low (0.09 to 0.11 Kcal/mhr$_o$ C) and the heat is used inside the material. The beam focus position, assist gas pressure height, and focal length of the lens appear to be related. The laser beam attenuates in the thickness direction, and we conjecture that the assist gas pressure height also reduces with the attenuation of the laser beam.

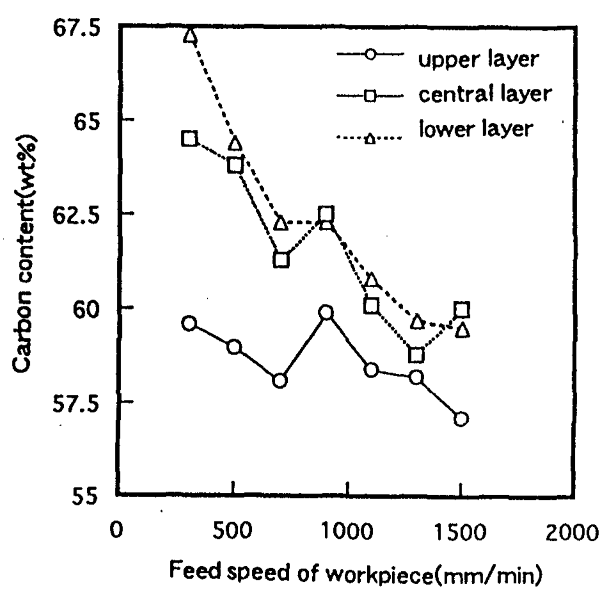

Fig.2 Relation between carbon content and feed speed of workpiece.

Next, we evaluated the properties of the cut section based on the surface roughness. We obtained roughness (center line mean roughness: Ra) of the upper, central and lower layers classified in the same way as above. Figure 3 shows the result; the upper layer is the smoothest. We believe that this is related to the degree of carbonization caused by the laser beam. The figure shows that the surface roughness of each layer increases as the machining speed decreases. This corresponds to the dependence of the degree of carbonization on the machining speed. Both the total degree of carbonization and the total surface roughness of the cut section decrease as the machining speed increases. This result for the whole cut section indicates that the heat effect of laser beam machining reduces as the machining speed increases.

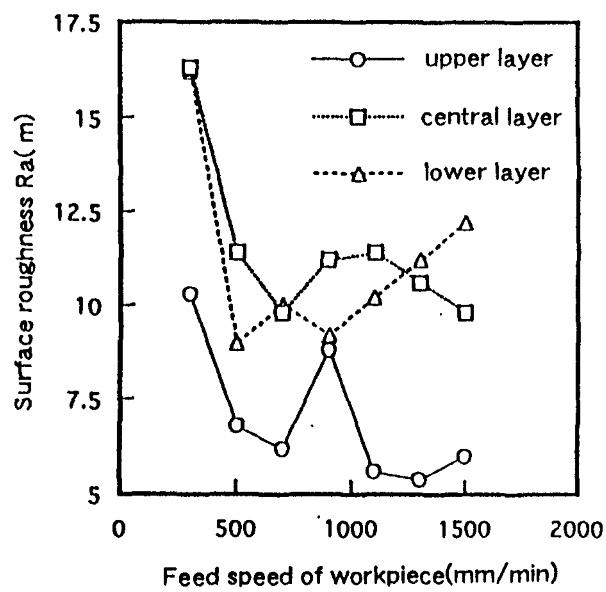

Fig.3 Relation between surface roughness and feed speed of workpiece.

3.3 Laser beam machining of WCS

WCS is a brittle material like a ceramic, so laser beam machining is often used to process it.7,8) Figures 4 and 5 show the structure of the section cut under the conditions listed in Table 1. Under the litions for Type 1 (Figure 4), the input heat tity is large because CW mode is used. As a lt, the temperature gradient becomes sharp and ks are caused by thermal stress.

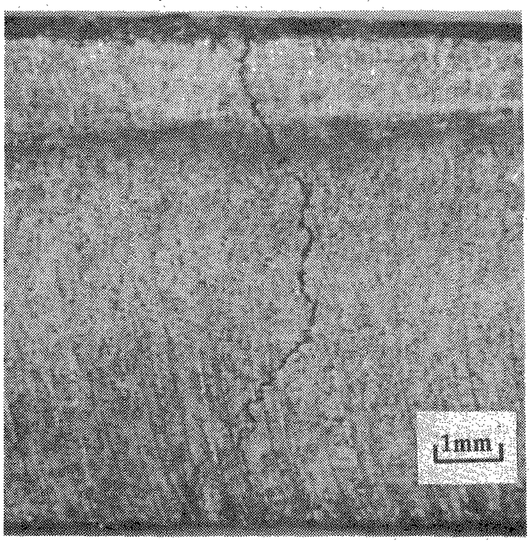

Fig.4 Structure of machined section in WC.

nder the conditions for Type 2 (Figure 5), the t heat quantity is minimized because PW mode is , and the laser beam is incident only mittently. Machining conditions to suppress the ation of cracks have been devised for brittle rials.9) In our research, the effect of heat was less r Type 2 conditions than under Type 1 litions, and a cut surface without cracks was ined in PW mode at the specified power and uency (pulse width: 1.2ms; peak output: 2.8kw).

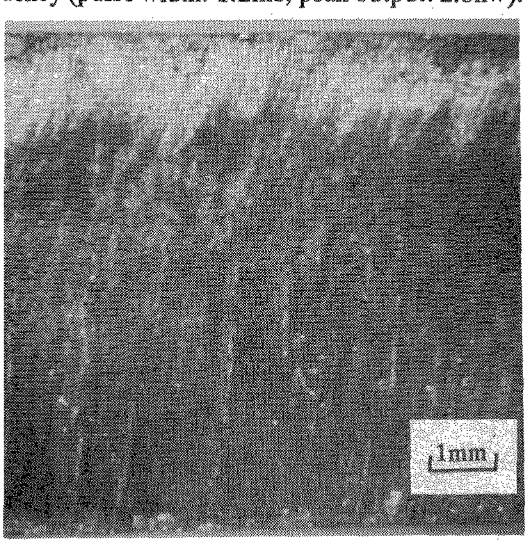

Fig.5 Structure of machined section in WC

4. Conclusions

We experimentally investigated the applicabilit laser beam machining to MDF made from Pi radiata and WCS made from the MDF, and obta the following results:

1. The degree of carbonization of WCS made impregnating MDF with phenol resin and burnin increases with burning temperature increase. WCS is carbonized almost completely at about 2000
2. On a section of MDF without phenol r impregnation cut by a laser beam, the central lower layers are carbonized more severely than upper layer. The degree of carbonization and surface roughness of the cut section decrease as machining speed increases.
3. WCS can be processed without cracking w the laser beam machine is used in PW mode.

5.REFERENCES

1)T.Okabe:a docteral thesis,New Porous Carbon Material "Woodceramics",Univ.of Tokyo,(19

2)Investigation and Research Subcommittee on Precision Work of Precision Socity Solid and Brittle Materials:Fine Ceramics,25,(1984)

3)N.Hattori,A.Ide,S,Kitayama and M,Noguchi: Mokuzai Gakkaishi,Vol.37,8,766-768,(1991)

4)N.Hattori,T.Matano,H.Okamoto,K and Okam Mokuzai Gakkaishi,Vol.34,5,417-422,(1988)

5)T.Arai and D.Hayashi:Mokuzai Gakkaishi,Vo ,4,350-356,(1992)

6)T.Arai and D.Hayashi:Mokuzai Gakkaishi,Vo ,5,497-503,(1994)

7)H.Imanaka,et al:Ceramics Work Handbook,R of Construction Industries,385-405,(1987)

8)H.Kawasumi,etal:Generalization of New Lase Machining Technology,Service Centerof Indus Technology,80-95,(1994)

9)S.Hiramoto,Yosetsu Gakkaishi,61,678,(1992