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Manufacturing Characteristics of Woodceramics from Thinned Small Logs (II)*1

- Dimensional Change, Weight Change and Compressive Strength -

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ABSTRACT

A new porous carbon material "woodceramics" was developed by carbonizing wood or woody materials impregnated with thermosetting resin. Steamed board and non-steamed board were made from thinned small log of Aomori Hiba (*Thujopsis dolabrata* S. *et*. Z. var. *hondae* M.). They were impregnated with phenol resin and sintered in a vacuum furnace at 650°C. In this paper, the manufacturing method of woodceramics and changes of dimension, weight and compressive strength were investigated. The changes of dimension, weight and compressive strength depend on the types of board and density.

Keywords : Woodceramics, resin impregnation rate, Aomori Hiba, compressive strength

1. INTRODUCTION

Many carbon materials have been developed and used for various purpose. Specially, the use of charcoal has a very long history. Its has been widely used for domestic fuel and heating, soil conditioner and absorbent as a raw material. But it has been limited to these kinds of application. Because the quality is variable, depends on many factors such as kind of wood, moisture content, temperature and craftsman's skill and they have fissure, warp occurs easily. Therefore, Okabe *et al*. (1995a, 1995b, 1996a) have developed woodceramics as light and hard carbon materials. Woodceramics is a new porous carbon materials obtained by carbonizing wood and woody materials impregnated with thermosetting resin such as phenol resin in a vacuum furnace (Hokkirigawa *et al*., 1995; Okabe *et al*., 1995b). They can be positioned between traditional industrial materials such as charcoal and more modern high-technology materials such as carbon fiber and graphite materials (Okabe *et al*., 1996a). The research on the woodceramics have been done for the application in various fields (Hokkirigawa *et al*., 1996b; Okabe & Saito, 1995a). Some of the properties of woodceramics have been reported previously (Hokkirigawa *et al*., 1995, 1996a; Kano *et al*., 1996; Kasai *et al*., 1996; Okabe & Saito 1995b; Okabe *et al*.,

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1995a, 1995b; Shibata *et al.*, 1997). However, the research of woodceramics made from thinned small logs is little investigated. Even though thinned small logs have been produced in a great amount, it was limited to be used as a support wood in building construction or pulp wood. Therefore, it is recommended to be utilized in an industrial way such as woodceramics. And understanding of their mechanical properties is necessary for industrial use. This paper describes the manufacturing method of woodceramics and compressive strength, changes of dimension and weight were tested according to the types of board from thinned small logs of Aomori HIBA to get some basic information and investigate the application of woodceramics.

2. EXPERIMENTAL PROCEDURE

2. 1 Specimen

Two types of board were made from thinned small logs of Aomori HIBA (*Thujopsis dolabrata* S. *et*. Z. var. *hondae* M.) according to the density. To make a board, it was cut into small section with chipper and refiner (Toyo press Co., Ltd.) and mixed with powder phenol resin (BRP 5933, Showa Highpolymer Co., Ltd.) in a ratio of 10:1 by weight. In previous paper, the board manufacturing conditions were reported (Oh *et al.*, 2000). After the board was manufactured, it was impregnated with liquid phenol resin (PX-1600, Honen Corporation) using an ultrasonic impregnation system descried in the previous reports (Okabe *et al.*, 1995, 1996a, 1996b). And the characteristics of phenol resin were reported by Okabe *et al.* (1996a). The impregnated boards were dried and hardened in high temperature for 8 hours at 60° C, 6 hours at 135°C and burned to make a woodceramics at 650°C using the indirect heating charcoal kiln (Okabe & Satio, 1995a; Okabe *et al.*, 1995, 1996a, 1996b). The temperature in the furnace was increased by 5°C/min, kept at 730°C for 2 hours and decreased gradually at the rate of 0.5°C/min (Shibata *et al.*, 1997).

2.2 Measuring the changes of dimension and weight

Effect of the process on dimension and weight were investigated after making woodceramics from thinned small logs of Aomori HIBA. The dimensions and weights of 50 samples were measured using a digital vernier calipers (Mitutoyo, Co., Ltd.) and electric balance (ER-120, A&D Co., Ltd.) according to the board type and density, respectively.

2.3 Test of compressive strength

Compressive strength was tested using an universal testing machine (Autograph, AGS-10KNG, Shimadzu) in a constant temperature and humidity chamber. The size was 1.5 cm × 1.5 cm × 1.5 cm and cross-head speed was 0.5 mm/min.

3. RESULTS and DISCUSSION

3.1 Changse of dimension and weight

The weight changed according to the board type and density. The relationship between density and rate of weight reduction after making woodceramics was shown in Figure 1. After making woodceramics, the rate of weight reduction increased and the density increased. The rate of weight reduction ranged from 57.1 to 62.0% in

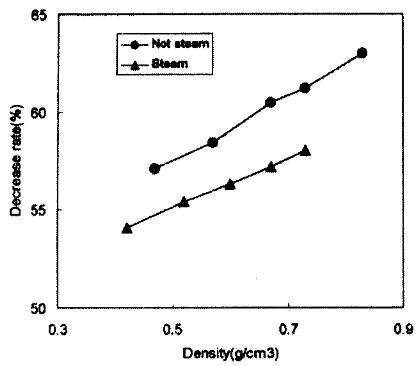

Fig. 1. Relationship between density and decrease rate of weight after making Woodceramics.

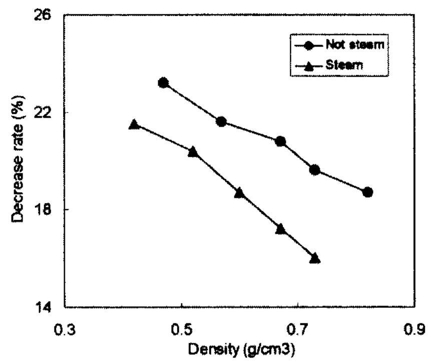

Fig. 2. Relationship between density and decrease rate of length after making Woodceramics.

non-steamed board and from 54.1 to 58.0% in steamed board according to the density of board. Because the board consists of fiber layers, the changes in length and thickness are different. The relationships between density, rates of length and thickness reduction after making woodceramics were shown in Figures 2 and 3. The rates of length and thickness reduction decreased and the density increased. The rate of length reduction ranged from 23.2 to 18.7% in non-steamed board and from 21.5 to 16.0% in steamed board according to the density of board. The rate of thickness reduction ranged from 27.1 to 22.2% in non-steamed board and from 25.5 to 20.6% in steamed board according to the density of board. The rates of length and thickness reduction in non-steamed board were slightly higher than those of steamed board. This value is close to that reported for MDF woodceramics (Okabe *et al.*, 1996b). For these results, burning at 400°C reduced the length and width by 8% and thickness by 14%. The thickness reduction of samples burned at 600°C and 1000°C were 18% and 22%, respectively. The reduction rate is consistent enough that the raw material can be manufactured to suit the dimensions of the finished product. Overall, the rate of thickness reduction is

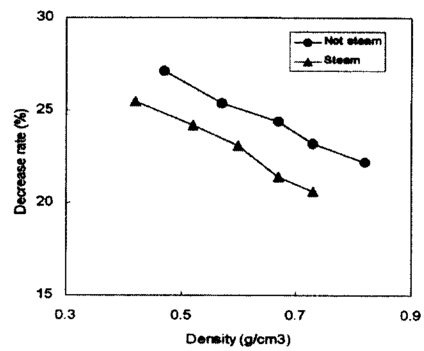

Fig. 3. Relationship between density and decrease rate of thickness after making Woodceramics.

5% greater than the rate of length reduction. The change of dimensions and weight at high temperature, were caused mainly by structural change of wood and resin during the carbonization. Because woodceramics is carbonized wood-phenol resin material, it is believed that the marked reduction in dimensions at 650°C is due to an elimination reaction of structural elements. The changes of dimensions and weight were similar to that reported by Okabe *et al.* (1996a).

3.2 Compressive strength

In order to be used as industrial materials, the compressive strength of woodceramics was tested. Figure 4 shows the relationship between resin impregnation rate and compressive strength of woodceramics. The compressive strength had a tendency to increase, while the resin impregnation rate increased. This is similar to the tendency of beech woodceramics where as increasing of densities, compressive strength was increased as reported by Okabe *et al.* (1996). From these results, the compressive strength of beech woodceramics is 4.5 times, 3.4 times, 2.0 times as larger as that of charcoal, respectively in longitudinal, radial and tangental direction. The strength anisotropy observed here is similar to that reported for natural beech wood (Gibson *et al.*, 1988). The compressive strength of woodceramics ranged from 27 to 36 MPa in non-steamed board and from 24 to 32 MPa in steamed board according to the resin impregnation rate. The compressive strength of woodceramics in non-steamed board was higher than that of steamed board. This may be the reason that the density profile of non-steamed board was higher than that of steamed board. Then the phenol resin of middle layer in non-steamed board was changed the volume fraction of glassy carbon formed during the carbonization (Okabe & Satio, 1995a; Okabe *et al.*, 1996a). It means that the phenol resin has entered cell wall and has been transformed into glassy carbon, thereby reinforcing the cell wall.

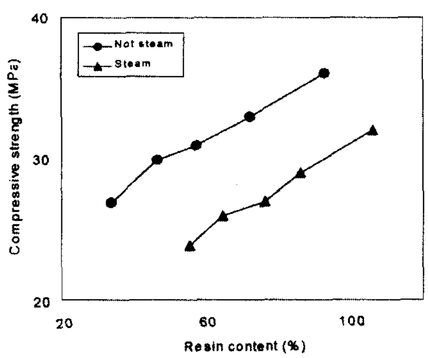

Fig. 4. Relationship between resin coutent and compressive strength of woodceramics.

4. CONCLUSION

The manufacturing method, changes of dimension, weight and compressive strength of woodceramics which was made from thinned small logs of Aomori HIBA were examined according to the board type and density. The rate of weight reduction increased as the density increased. The rates of length and thickness reduction were decreased as the density increased. The rate of thickness reduction was about 5% greater than the rate of length reduction. The rates of weight and dimensions reduction in non-steamed board were slightly higher than those of steamed board. The compressive strength had a tendency to increase, while the resin impregnation rate increased. The compressive strength of woodceramics in non-steamed board was higher than that of steamed board.

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