

Manufacture of woodceramics using liquefied wood

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A new processing to manufacture woodceramics which is impregnated with liquefied wood was introduced and some properties of this woodceramics were presented. The results indicated that carbonization temperature played an important role on the weight loss, dimension shrinkage, volume electrical resistivity, compressive strength and the surface area. The woodceramics impregnated with liquefied wood could possess relatively high compressive strength even though low phenolic compound concentration in liquefied wood. Further investigation on the environmental recycling circle of woodceramics manufacture is expected.

Key words: Woodceramics, liquefied wood, recycling circle

1. INTRODUCTION

Woodceramics are made of wood, or woody material, impregnated with phenol resin and carbonized in vacuum atmosphere at high temperatures, during which the wood or woody material changes into soft amorphous carbon and the impregnated phenol resin changes into hard glassy carbon. Pores, which originally exist in the wood and woody material, still remain in the woodceramics. Accordingly, woodceramics are porous amorphous carbon and glassy carbon composite materials. Useful characteristics of the woodceramics include stiffness, corrosion and friction resistance, and electromagnetic shielding ability [1-5]. At the present time, most of the woodceramics are manufactured with impregnation of phenol resin directly.

In the past several decades, considerable research on conversion into useful materials from the waste lignocellulosic resources such as waste wood, which

included techniques referred to as "wood liquefaction" due to the conversion of wood chemically or thermochemically into liquid material, were studied. H. Ono *et al.* described a simple wood liquefaction method where they used phenol in the presence of H₂SO₄ to obtain completely liquefied wood [6, 7]. In the manufacturing of woodceramics, the wood liquefaction using solvolysis is interesting technique because the amount of phenol compound used in the production of woodceramics will be consumed and the waste lignocellulosic resources could be used without remainder. Accordingly, the manufacture method and some properties of woodceramics impregnated with liquefied wood were presented in this work.

2. EXPERIMENTAL PROCEDURE

2.1. Material preparation

Fig. 1 shows the schematic illustration of the

synthesis of liquefied wood. Hinoki (*Chamaecyparis obtusa* Endl.) wood powder, which was not preformed any treatments such as coating and painting, and phenol compound are mixed and the sulfuric acid is added as catalyst at 150 °C.

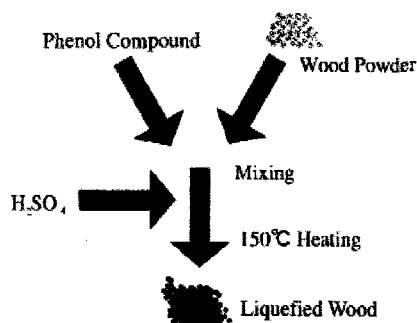


Figure 1 Schematic illustration of synthesis of liquefied wood

MDF (Medium Density Fiberboard), with the size of $20 \times 20 \times 15 \text{ mm}^3$ and with the original density of 0.58 g/m^3 , was impregnated with the liquefied wood diluted with ethanol (ratio 1: 1) under the vacuum atmosphere and then the MDF was carbonized in vacuum furnace at 400 °C, 500 °C, 650 °C and 800 °C.

2.2. Characterization

The dimension shrinkage and weight loss of woodceramics which impregnated with liquefied wood, were measured before and after carbonization, using digital slide calipers (Mitutoyo, CD-15CP Co., Ltd.) and electrical balance (Kensei, ER120-A Co., Ltd.), respectively. The compressive tests of woodceramics are carried out in Shimadzu material testing system, where the cross head speed is 1mm/minute, and the deflection is measured with a dial gauge. The volume electrical resistivity of woodceramics was measured with Mitsubishi MCP-PR02 resistivity system. The surface area measurements of woodceramics were carried out using Shimadzu Flowsorb II2300 by degassing at 250 °C for 1 hour, followed by N_2 adsorption at 77 K. The Brunauer-Emmett-Teller (BET) surface area was calculated from the BET adsorption isotherm.

3. RESULT AND DISCUSSION

Fig. 2 shows the carbonization temperature

dependence of the shrinkage ratio and weight loss. The dimension shrinkage along the length and width direction, of woodceramics carbonized at 400°C, 500°C, 650°C and 800°C are 14%, 18%, 22% and 25%, respectively, while shrinkage along the thickness direction of woodceramics are 25%, 28%, 34% and 36%, respectively. The results show that the dimension shrinkage increases as the carbonization temperature increases. The shrinkage rate is small enough so that the raw material can be manufactured to suit the dimensions of the final product. The shrinkage ratio along the thickness direction is 11% greater than that along the length and width direction because the shrinkage along horizontal direction depends on the decrease in the space of the MDF board as the woodceramics raw material, while the shrinkage along a parallel direction depends on the shrinkage of the wood fiber in MDF board. The weight loss follows a similar with curve those of the dimensional, which are 53%, 59%, 64% and 66% at the carbonization temperature 400 °C, 500 °C, 650 °C and 800 °C, respectively. It has the same tendency as the woodceramics impregnated with phenol resin directly.

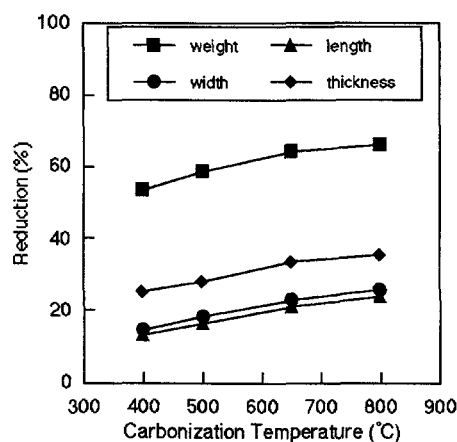


Figure 2 Effect of carbonization temperature on the weigh loss and dimension shrinkage of woodceramics impregnated with liquefied wood

Fig. 3 shows the relationship between carbonization temperature and the compressive strength of the woodceramics impregnated with liquefied wood. The compressive strength is almost constant at the temperatures between 400 °C and 500 °C and increases remarkably with increasing carbonization temperature above 500 °C. It is noteworthy that the compressive

strength of woodceramics with only 50% liquefied wood impregnation ratio (40% phenolic compounds were enclosed) is as same as that of the woodceramics with 50-70% phenol resin impregnation ratio. This result indicated that the woodceramics impregnated with liquefied wood with low phenolic compound concentration could possess relative high strength.

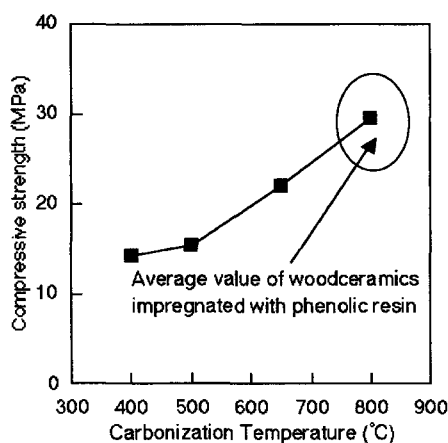


Figure 3 Effect of carbonization temperature on the compressive strength of woodceramics impregnated with liquefied wood

Fig. 4 showed the relationships between carbonization temperature and volume electrical resistivity of MDF charcoal, woodceramics impregnated directly with phenol resin and woodceramics impregnated with liquefied wood, where all the volume electrical resistivity had the same tendency; the volume electrical resistivity decreases with increasing the carbonization temperature. At every carbonization temperature, the electrical resistivities of these materials have the nearly same value.

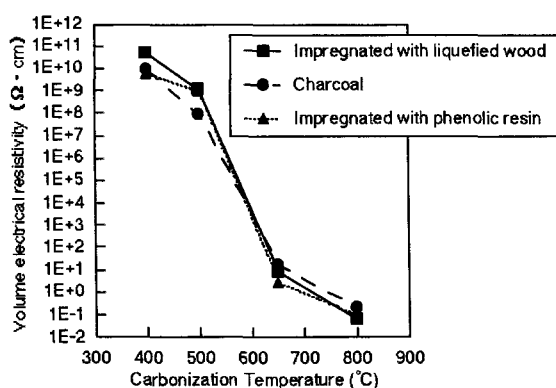


Figure 4 Effect of carbonization temperature on the volume electrical resistivity of woodceramics and MDF charcoal

Fig. 5 showed the effect of carbonization temperature on the surface area of MDF charcoal, woodceramics impregnated directly with phenol resin and woodceramics impregnated with liquefied wood. At the carbonization temperature below 650 °C, MDF charcoal possessed higher surface area than woodceramics impregnated with phenol resin and liquefied wood, but these materials possessed nearly same surface area above the carbonization temperature of 650°C. The surface area of woodceramics was attributed to the decomposition of cellulose, lignin and hemicellulose in woody material and the phenolic compound, because the decomposition of these components produces a lot of gas which extend the surface area and the pore size during the carbonization of woodceramics. It is known that, at the case of thermal decomposition of wood, the hydrocarbon structure forms by the dehydration and depolymerization of cellulose between 250 °C and 310 °C, and the condensation aromatic polynuclear structures starts to form above 400 °C and develops gradually above 500 °C [8]. For phenol compound, that depolymerization occurs between 300 °C and 400 °C, and that the aromatic polynuclear structure starts to form above 400 °C and develops above 500 °C [9]. Accordingly, when the woodceramics impregnated with phenol resin or liquefied wood were carbonized above 600 °C, both of them could possess wide surface area. It is important that woodceramics have higher strength and surface area than MDF charcoal.

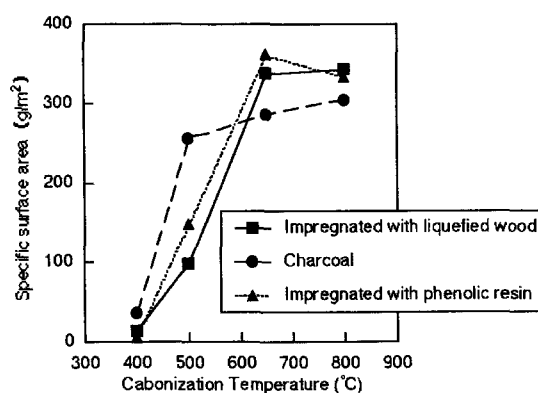


Figure 5 Effect of carbonization temperature on the surface area of woodceramics and MDF charcoal

4. SUMMARY AND THE FUTURE

In the present work, a new processing to manufacture woodceramics which is impregnated with

liquefied wood were introduced, the results showed that carbonization temperature played an important role on the weight loss, dimension shrinkage, volume electrical resistivity, compressive strength and the surface area. Compared with phenol resin, liquefied wood was attractive since the strength of woodceramics is high even though low phenolic compound concentration was enclosed in liquefied wood, and the liquefied wood could be synthesized using wood vinegar, wood tar during the manufacture of woody active carbon, woodceramics *etc.*. An interesting environment recycling circle of woodceramics manufacture shown in fig. 6 is expected.

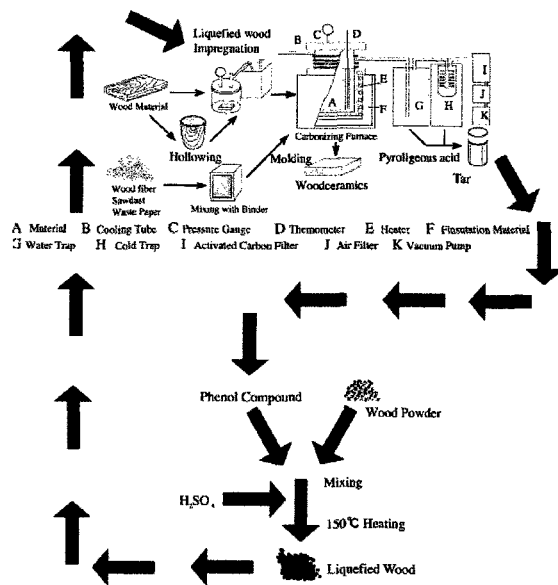


Figure 6 Schematic Illustration of environmental recycling circle of woodceramics manufacture

REFERENCE

1. T. OKABE and K. SAITO, *J. Porous Materials* 2 (1996) 215.
2. T. OKABE and K. SAITO, *IBID.* 2 (1996) 223.
3. K. HOKKIRIGAWA, T. OKABE and K. SAITO, *IBID.* 2 (1996) 229.
4. K. SHIBATA, K. KASAI, T. OKABE and K. SAITO, *J. Soc. Material Science* 44 (1995) 284.
5. T. OKABE, K. SAITO, H. TOGAWA and Y. KUMAGAI, *IBID.* 44 (1995) 284.
6. H. ONO and T. YAMADA, *J. Adhesive* .59 (1996) 135.
7. T. YAMADA and H. ONO, *Bioresource Technology*.70 (1999) 61.
8. K. FUNAHIKI, M. NAKAMURA and M. TSURITANE, *Thermosetting Resin* 2(1981) 220.
9. Y. YAMASHITA and K. OUCHI, *Carbon* 19 (1981) 89.

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