Effect of Production Conditions of Wood Powder on Bending Properties of Wood Powder Molding Material without Adhesive

Hiroshi IMANISHI**, Naho SOMA**, Osamu YAMASHITA***, Tsunehisa MIKI**** and Kozo KANAYAMA**

The effect of production conditions of wood powder on the bending properties of wood powder molding material was investigated. Wood powder was produced by milling wood into powder under conditions of different temperatures (25°C, 100°C) and moisture contents (0%MC, about 30%MC). Molding materials were produced from wood powder in stream atmosphere of high temperature and high pressure (175°C, 900 kPa) using self-bonding ability of the wood powder. Adhesives, such as a synthetic resin, were not used. To evaluate the bending properties of the molding materials, the modulus of elasticity and the bending strength were examined by static three-point bending test. As for the characteristic of wood particle, in case of wood particle produced by milling wood under a condition of high temperature and high moisture content (100°C and about 30%MC), tendencies for intercellular layer to be exposed on surface of a particle and for the aspect ratio of particles to be large were confirmed. And in that case, the molding material showed the highest value in modulus of elasticity and bending strength. It is highly probable that the improvement of the self-bonding ability of wood powder and the increase of the aspect ratio of wood particle take part in the improvement of strength properties of molding material.

Key Words: Wood Powder, Molding Material, Self-Bonding Ability, Aspect Ratio and Bending Property

1. Introduction

Considering the problem of exhaustion of natural resources and the environmental problem such as global warming, wood material is promising as alternate material for plastic made from oil. Because a wood grows up while fixing CO₂, which is greenhouse gas by photosynthesis, it is thought natural resources that can be used continuously.

Then, we started to develop processing technology of wood powder molding material that preserves characteristics of biodegradability etc. that wood possesses. Me-

* Received 25th May, 2005 (No. 05-4123)
** National Institute of Advanced Industrial Science and Technology, 2266–98 Anagahora, Shimoshidami, Moriyana-ku, Nagoya 463–8560, Japan. E-mail: h.imanishi@aist.go.jp
*** Graduate School of Bioagricultural Sciences, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464–8601, Japan
**** Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606–8585, Japan
molding material doesn’t have enough strength properties, it is necessary to improve them for practical use.

In the molding process, the self-bonding ability of wood caused by suitable hydrothermal treatment is very important. In addition, because lignin, which is one of the main composition elements of wood is deeply related to the self-bonding of wood\(^2\), it is thought that effective use of lignin leads to the improvement of strength properties of the molding material. A cell of wood has very long and slender spindle shape, and in case of softwood, the diameter is about 50 \(\mu m\). Lignin exists abundantly between the cells, and softens at about 80°C if water was contained enough, so when wood breakdown happens in hot water, the selective delamination fracture in an intercellular layer is caused easily\(^3\). Therefore, it is likely that the milling wood in the state of high temperature and high moisture content causes exposure of lignin to the surface of wood particle. Then the above-mentioned self-bonding ability appears more strongly, and the improvement effect to the strength properties of the molding material is expected. Moreover, the change in the shape of the wood particle is expected to take place by milling with the selective delamination fracture in an intercellular layer, and it is probable that the strength properties of the molding material receive some influence.

In this study, we produced wood powder under various conditions of temperature and moisture content, and investigated the relation between the production condition of wood powder and the strength properties of molding material of the wood powder.

2. Experimental Methods

2.1 Production of wood powder

The wood material used was air-dried Japanese cedar (\textit{Cryptomeria japonica} D.Don). The material was cut into thin fragments of about 3 mm in the longitudinal direction, and the fragments were made at a temperature of 25°C or 100°C and at a moisture content (MC) of 0% or about 30% (fiber saturation point). The fragments made at each temperature and MC were milled into powder by a mill. Table 1 shows the list of the production condition of wood powder. Then, the powder was classified in the air-dry
state by the sieve method.

2.2 Molding procedure and method of bending test

The procedure of making specimens for strength test was similar to that shown in Fig. 1. The wood powder of 1.5 g was put in a mold of 30 mm in the inside diameter, and steam treatment was applied for 30 min. Then, the wood powder was pressed for 5 min, and a stick specimen with circular section (3 mm in the section diameter and 30 mm in length) was molded. The steam temperature was 175°C, the steam pressure was 900 kPa, and molding pressure was 139 MPa. Adhesives, such as a synthetic resin, were not used.

Bending tests on the stick specimens by center concentrated load were conducted and the modulus of elasticity and the bending strength were examined.

3. Results and Discussion

3.1 Properties of wood powder

Figure 3 shows one example of mass base distribution of the obtained wood powder. It is the distribution of the wood powder produced under condition A (25°C and 0%MC). A peak of the distribution was in the particle size division of 53 – 90 µm, and wood powder produced under the other condition showed the same tendency.

Figure 4 shows the scanning electron microscopy (SEM) photographs of the wood particles produced under each condition of temperature and MC. Those photographs show the particles of 150 – 180 µm in particle diameter. Because wood is strongly orthotropic material, in all the production conditions, most of the particles were slender and the aspect ratios were large. Figure 5 shows the aspect ratios obtained from SEM photographs. About 250 particles of each wood powder were examined. The aspect ratio of wood particles of each powder was greatly different according to the difference of the production condition, for instance, the maximum value was 7.2 (in the case of condition D, 100°C and about 30%MC), and the minimum one was 3.9 (in the case of condition B, 100°C
Fig. 5  Aspect ratio of wood particles. Legend: Each error bar shows one standard deviation. Notes: Particle diameter: 150 – 180 µm. A, B, C, D: Production condition of wood powder (See Table 1).

Fig. 6  Photographs showing the surface of a wood particle produced under different condition of temperature and moisture content (MC). Note: A, D: Production condition of wood powder (See Table 1)

Fig. 7  Relationships between the production condition of wood powder and the bulk density, the bending properties of molding material. Legend: ○: Bulk density, ●: Modulus of elasticity, ■: Bending strength. Each error bar shows one standard deviation. Note: A, B, C, D: Production condition of wood powder (See Table 1)

about 30%MC). While fractures of cell wall were seen mostly in the former case, a lot of delamination fractures in an intercellular layer were caused in the latter case. It is clear that the temperature and the MC when wood powder was produced influenced the surface properties of wood particle. And in the latter case, it is possibly that lignin has been exposed on the surface of the wood particle.

3.2 Bending properties of molding material

Figure 7 shows the influences of the production condition of wood powder on the bulk density and the bending properties of wood powder molding material. The case of wood particle of 150 – 180 µm of particle diameter is shown here as an example. The influence of the production condition on the bulk density was small, and that of each molding material was about 1.1. Considering the specific density of wood substance is about 1.5, it is probable that voids that cause strength reduction exist considerably in the molding material.

However, for the bending properties of molding ma-
The influences of the production condition of wood powder were confirmed obviously. The molding material of the wood powder produced under condition D (100°C and about 30%MC) indicated the maximum values of both the modulus of elasticity and bending strength. From these results, it was clarified to be able to improve the strength properties of molding material only from wood powder by grind wood in the state of high temperature and high moisture content when wood powder is produced.

It is probable that the improvement of strength property was caused by the major two factors. One is the improvement of the self-bonding ability of wood powder by exposure of an intercellular layer that contains a lot of lignin to the surface of the wood particle. Another is an effect of reinforcement of the wood particle with a large aspect ratio. More precise investigations will be necessary in the future to clarify how those factors contribute to the improvement of strength property.

4. Conclusions

The influence of production conditions of wood powder on the bending properties of wood powder molding material was investigated. Wood powder was produced by milling wood into powder under conditions of different temperatures and moisture contents. Molding materials were produced from wood powder in steam atmosphere using self-bonding ability of the wood powder. The bending properties of the molding materials were examined with a static three-point bending test. The results are concluded as follows:

(1) The difference of wood particle in the surface properties and in the aspect ratio was caused by milling wood under different condition of temperature and moisture content. Especially, as to the wood particle of diameter 150 – 180 µm, in case of wood particle produced by milling wood under condition of high temperature and high moisture content (100°C and about 30%MC), an intercellular layer was exposed on surface of particle, and aspect ratio of particles was large.

References