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Effect of Carbonization Temperature on the Water Proof Property of Woodceramics

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The effect of carbonization temperature on the water proof property of woodceramics was studied by soaking in water the specimens of woodceramics carbonized at several temperatures from 650℃ to 800℃. By measuring each value of compressive strength and comparing them, one can notice that the higher the carbonization temperature was, the higher the compressive strength was. However, the value of compressive strength decreased as the number of times of soaking augmented. Also, in 40% numbers of the specimens carbonized at 650℃, macroscopic cracks were observed after freezing. Thus, it is recommended to use the woodceramics carbonized at the temperature over 700℃ for an underground snow-melting heater.

Key words: woodceramics, porous materials, carbonization temperature, water proof, crack

1. INTRODUCTION

Woodceramics is a porous carbon material, which is fabricated by carbonizing after impregnating phenolic resin into wood products. It is such eco-material that can utilize wastepaper, sawdust and scrap wood as its raw material, so that it can be adapted to a future environment that will be polluted and flooded with wastes. Furthermore, woodceramics is lightweight, has electro-magnetic wave shielding property, emission property of far-infrared radiation, ohmic-resistance controllable property by changing the carbonization temperature, and holds a good number of potentials [1]. Practical experiments have been carried out nowadays, for example, for the snow-melting heater or the food heater. However, it is reported that woodceramics suffers from cracks in its internal structure with contact to water. Considering this characteristic, it is thus impossible for woodceramics to be in contact with water; namely, to use it for a snow-melting heater. And then we guessed ahead that the difficulty can be gotten rid of by carbonizing wood-ceramics at high temperature. Consequently, the effect of carbonization temperature on the water proof property of woodceramics was researched by comparing their strength after soaking the specimens into water.

2. EXPERIMENTAL METHOD

2.1 Specimen

In this research, woodceramics was fabricated the following method. First resole type phenolic resin (PX-1600: Honen Corporation) was impregnated into MDF (LD-21: Noda) under reducing pressure with adding ultrasonic waves. Next, the phenolic resin impregnated MDF specimens were carbonized at 650℃,700℃,750℃ and 800℃, then cut into tetragonal shape pieces of $9\times9\times18mm^3$. Moreover, MDF boards, which were prepared by pressing after combining lauan material with scrap wood and melamine resin powder, were carbonized at 750℃ without impregnating phenolic resin and cut into the specimens of $9\times9\times12mm^3$.

2.2 Soaking Test

2.2.1 Repeated Soaking Test

A soaking test was carried out in purified water for 2 hours under atmospheric pressure and room temperature.

A stainless-steel mesh was used to keep these specimens in the water. After that, these specimens were heated at the rate of 0.5℃/min, picked up from the water and held for 1 hour at 130℃. Then they were cooled down naturally in the furnace. Such processes were repeated 40 times. After repeated soaking processes, compression tests were carried out with an Instron-type testing machine at the initial velocity of $1\times10^{-3}sec^{-1}$. Ten pieces were used for each condition, and afterwards compared each value of compression strength σ.

2.2.2 Moisture Test and Freezing Test

Practical application of woodceramics has been carried out as the snow-melting heater. In that case, woodceramics must be laid underground and used under cold conditions. Therefore, compression tests were carried out in the moist condition. We soaked the specimens into water repeatedly for 24 hours -- longer than the above. The process made it possible for the internal structure of specimens to be well impregnated with water. In this case, the compression tests were carried out not in dry condition but in wet condition.

In the situation below freezing temperature, the same procedure as the previous test was performed -- soaked for 24 hours, and then the specimens were frozen at -20℃ for 1 hour. Afterward the drying process was carried out -- the same as the Repeated Soaking Test. Finally the compression tests were done and values were obtained and compared.

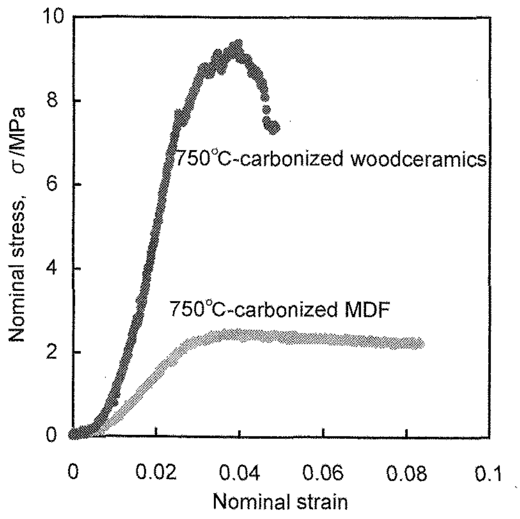

Fig.1 Nominal stress - nominal strain curves of woodceramics and MDF carbonized at 750℃

2.3. Observation of longitudinal-sections

In order to compare longitudinal-sections of woodceramics, observations were carried out with SEM.

3. RESULTS AND DISCUSSION

Figure 1 shows nominal stress - nominal strain curves of woodceramics and MDF which carbonized at 750℃. Differences between their behaviors were shown obviously. Woodceramics is hard and brittle due to the existence of vitreous carbon from phenolic resin, and so it flies in all directions after subsidiary fracture. Since effective cross-sections which receive compressive loads decrease, thereby, its stress sharply decreases. Meanwhile in the case of carbonized MDF, it shrinks because of its resilience for a while, after that, it was busted up with

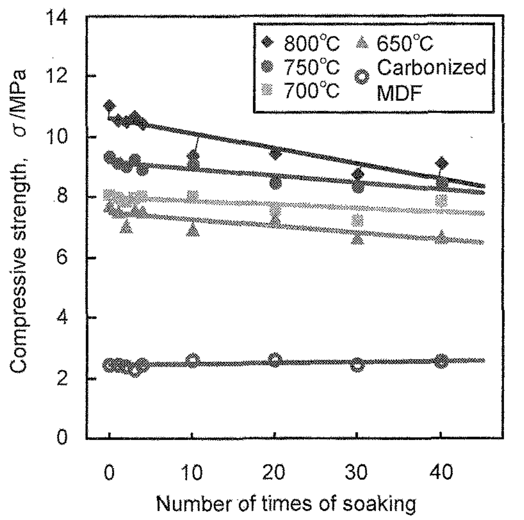

Fig.2 Compressive strength of each woodceramics and carbonized MDF

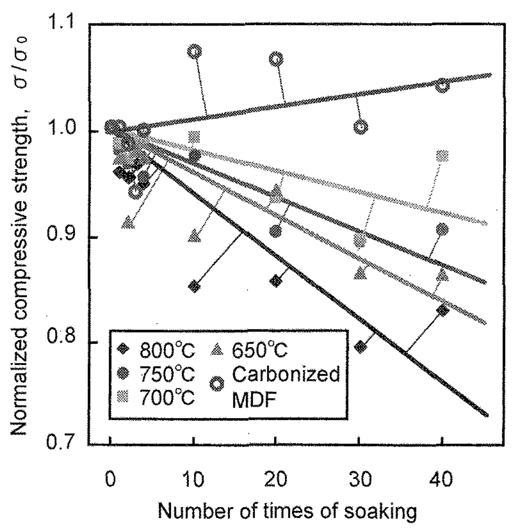

Fig.3 Normalized compressive strength of each woodceramics and carbonized MDF

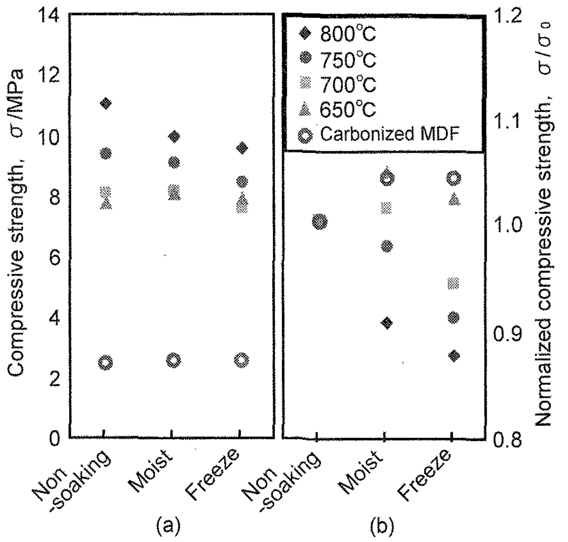

Fig.4 (a) Compressive strength of Moist Test and Freeze Test (b) Normalized compressive strength of Moist Test and Freeze Test

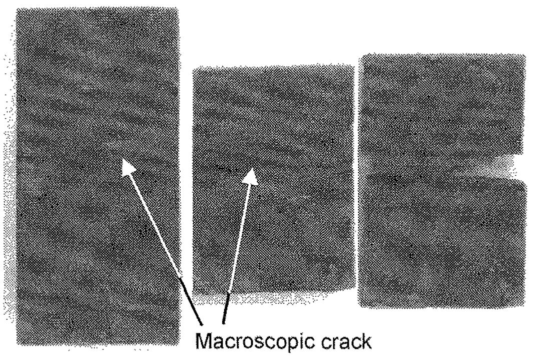

Fig.5 Cracked along its tissue in the Freeze Test
(a) Woodceramics carbonized at 650℃
(b) MDF carbonized at 750℃

dissipating its fine powdered fragment and its stress decreased gradually.

Figure 2 shows the relations between the numbers of soaking and the values of compressive strength of the woodceramics and the MDF after repeated soaking. Figure 3 shows each normalized compressive strength which was obtained by dividing the compressive strengths after repeated soaking σ by σ_0, the compressive strength of the woodceramics and carbonized MDF which were not soaked. From those graphs, the following two results can be obtained. (1) The woodceramics carbonized at higher temperature showed the higher compressive strength. (2) The woodceramics carbonized at 750℃ was 3-5 times stronger than the MDF carbonized at 750℃. Above results suggest that the strength of woodceramics depends on the number of times of soaking and its phenolic resin content. Any woodceramics' strength was likely to be on the decline as the number of times of soaking augmented, while in the case of the carbonized MDF, it scarcely changed by repeated soaking. The decrease in strength of the woodceramics carbonized at 800℃ largest, so that it can be estimated that the augmentation of the number of times of soaking will make its strength lower than that of woodceramics carbonized at 750℃.

Figure 4 (a) shows the values of compressive strength obtained from the Moist Test and the Freezing Test. Also, Fig.4 (b) shows each normalized compressive strength which was obtained by dividing each value of compressive strength σ by σ_0, the compressive strength of the woodceramics and carbonized MDF which were not subjected to soaking. From Fig.4, the similer results as those of the Repeated Soaking Tests were observed. The higher the carbonization temperature was, the higher the compressive strength was; but, at the same time, the larger the degradation in normalized compressive strength under moist and freezing conditions was. About the carbonized MDF, its strength varied slightly regardless of the conditions as same as it did in the Repeated Soaking Test.

Figure 5 (a) shows that 40% numbers of the woodceramics carbonized at 650℃ were cracked along its tissue in the Freezing Test. On the other hand, Fig.5 (b) shows that 60% numbers of the carbonized MDF cracked and was split into two pieces during the drying process. This could probably be explained by the fact that they couldn't bear the volume expansion of freezing water. Thus, when woodceramics is adapted to the snow-melting heater, it will need to be carbonized at the temperature over 700℃.

Figure 6 shows the structures of the longitudinal-section of woodceramics carbonized at 650℃, 700℃, 750℃ and 800℃. In the inside of the woodceramics, internal pores which originated from the raw material were observed. The average diameter of these pores were 15.6 μm in the woodceramics carbonized at 650℃, 9.0 μm at 700℃, 10.7 μm at 750℃ and 6.5 μm at 800℃, respectively. The higher the carbonized temperature, the smaller the internal holes, except for those at 700℃. The results suggest a rise of the percentage of contraction of phenolic resin and raw wood accompanying with an increase of carbonized temperature.

Since cellulose and hemicellulose, the materials from which wood is constructed, have vast amount of hydroxyl in their structures, they have a strong hydrophilic nature and may swell due to absorption of water [2]. It can be thought that hydroxyl groups remained in carbonized MDF swelled the volume of the specimen by 11.2% due to soaking into water. By the same idea, the woodceramics swelled from 0.3 to 0.9% -- this value was observed to be quite different from the carbonized MDF's. Meanwhile, phenolic resin has an upraise of hardness property and a volume shrinkage property, additionally, it doesn't absorb water because hydroxyl groups were eliminated from phenolic resin by the carbonization at higher temperature [3]. Woodceramics is the composite material of MDF and phenolic resin; therefore, it can be thought that specimens were burst as a result of inner stress which occurred between both sides due to the absorption of water, thus resulting in the decrease of strength. Especially, it can be thought that because the shrinkage of phenolic resin and its hardening of the woodceramics carbonized at higher temperature are larger, the swelling of wood charcoal by the absorption of water could not be performed and further the specimens burst; thereby, such occasion resulted in the sharp strength decrease in the woodceramics carbonized at higher temperature.

In the case of woodceramics carbonized at 650℃, whose strength increased in the wet condition, the swelling of wood charcoal can be comparatively easier because of its hardness of phenolic resin is comparatively lower than those carbonized at higher temperature.

Finally, the cause of the woodceramics increase in the strength of the carbonized at 650℃ in the compression test after freezing and thawing should be clarified accounted for in future studies.

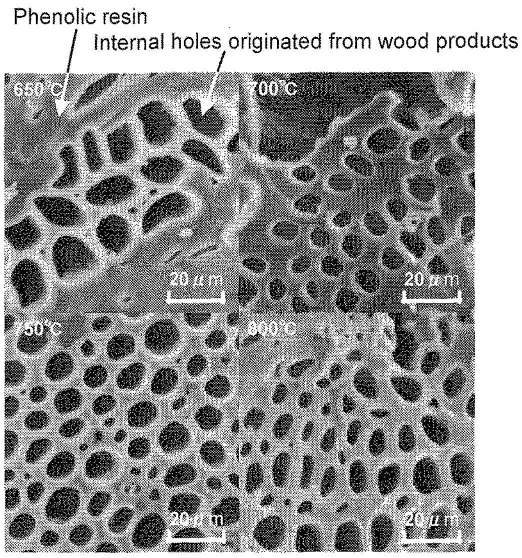

Fig.6 Longitudinal-sections of woodceramics carbonized at various temperatures

4. CONCLUSIONS

1) The strength of the woodceramics carbonized at high temperature was higher than that of ones carbonized at lower temperatures.
2) In the Repeated Soaking Test, the Moist Test and the Freezing Test, the decreasing rate in strength of the woodceramics carbonized at low temperature is lower, compared with that of those carbonized at higher temperature.
3) In the Freezing Test, 40% numbers of the specimens of the woodceramics carbonized at 650 ℃ showed macroscopic cracks. Thus if woodceramics will be adapted to the snow-melting heater, these woodceramics should be carbonized at the temperatures over 700℃.

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