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# Application of Pressurized Carbon Dioxide to Drying Process of Wood

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A new process using pressurized carbon dioxide was investigated in order to minimize the carrying cost of wood. This process was performed using the following steps: (1)Firstly, woods were placed in a pressure vessel, (2) Secondly, the vessel was pressurized with carbon dioxide, (3) Thirdly, the pressurized state was held for a certain period and the pressure was then released suddenly.

Experimental results obtained from this study were as follows;

The carbon dioxide drying process could easily reduce one half of the moisture content ratio of woods. The higher pressure of carbon dioxide gave the more effective drying of woods.

[Carbon Dioxide, Drying Process, Wood]

## 1. Introduction

Heating methods are conventional and common processing routes for drying wood. A direct furnace heating method in a drying box, a high-frequency induction heating method, an evaporation method in a pressure vessel, and a combined method of these routes are used in the conventional routes [1]. However these methods require large-scale heating facilities, which make difficult to dry wood at the felling area in forest.

There are huge forest resources in Japan, though we are importing them from overseas. The costs of felling, carrying, and drying for woods are very expensive in Japan. If these costs are reduced, woods in Japan will be used more effectively.

We studied to develop the new drying method with small-scale equipment in use of carbon dioxide based on the new concept of wood drying. Practical wood drying process was investigated to reduce the carrying cost.

## 2. Experimental Procedure

### Raw materials

The wood used in the experiment was *Sugi*, a Japanese cedar, produced at *Reihoku, Kochi Prefecture*. The wood was 30 years old. The average annual ring size was 6.9mm in heartwood and 4.2mm in sapwood.

After the heartwood and sapwood portions were separated, the woods were placed in a water basin to keep the wet condition. Before testing, each specimen was machined into the following dimensions; fiber grain: 100 or 300mm, flat grain: 30mm, and edge grain: 30mm. All of the specimens tested were prepared from the same wood and more the same destination of fiber grain.

### Drying Method

The schematic diagram of drying wood is shown in Fig.1. The procedures of drying process are as follows;

1. Woods were put into a vessel.
2. The vessel was pressurized using carbon dioxide.
3. The pressurized state was held for a certain period.
4. The state was broken suddenly by releasing the pressure in order to liberate the including water from the woods.

The pressure of carbon dioxide, the holding time, the cycle of process, and the fiber grain size were varied changing in the amount of liberated water. Then the drying condition was optimized to obtain the largest amount of water. The drying conditions examined in this study are summarized in Table 1. Fig.2 shows the aspect of the liberation of water from wood in this process.

### Evaluation of wood drying

The effect of drying on each condition was estimated by the *WATER/VOID* ratio. Here, the *WATER/VOID* ratio is defined as follows:

*WATER/VOID* = (amount of remained water in specimen after the cycle, m*ℓ*) / (total volume of void contained in specimen, m*ℓ*)

*VOID* is calculated from the following equation.

$$VOID = V - \frac{W_0}{1.50}$$

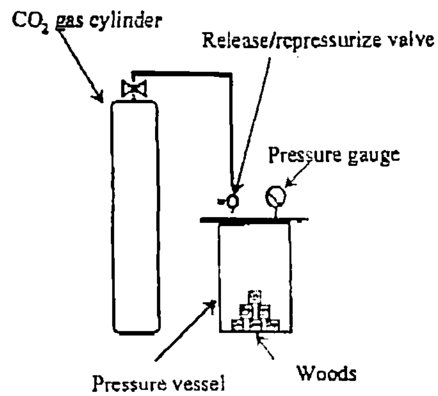


Fig.1. Schematic diagram of drying wood.

Table 1. Drying conditions examined in this study.

| Test No. | Gas | Portion in wood | Pressure [MPa] | Holding time [hr] | Length [mm] |
|---|---|---|---|---|---|
| 1 | Carbon dioxide | Sapwood | 1.08 | 0.5 | 100 |
| 2 | Carbon dioxide | Heartwood | 1.08 | 0.5 | 100 |
| 3 | Nitrogen | Sapwood | 1.08 | 0.5 | 100 |
| 4 | Nitrogen | Heartwood | 1.08 | 0.5 | 100 |
| 5 | Carbon dioxide | Sapwood | 1.08 | 24 | 100 |
| 6 | Carbon dioxide | Heartwood | 1.08 | 24 | 100 |
| 7 | Carbon dioxide | Sapwood | 1.08 | 24 | 300 |
| 8 | Carbon dioxide | Heartwood | 1.08 | 24 | 300 |
| 9 | Carbon dioxide | Sapwood | 1.57 | 24 | 300 |
| 10 | Carbon dioxide | Heartwood | 1.57 | 24 | 300 |

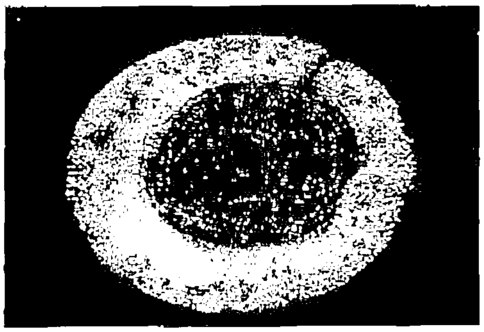

Fig.2. Aspect of water liberation from wood in this process.

Here, $V$ is the specimen's volume (cm$^3$), $W_0$ is the specimen's dried weight (g), and 1.50 is the true specific gravity of *Sugi* (g/cm$^3$) [2].

## 3. Results and Discussion

Gas

Fig.3 shows the effect of the gas species on drying wood. Carbon dioxide gave lower *WATER/VOID* ratios for both heartwood and sapwood as compared with nitrogen.

This is explained by the difference in solubility between carbon dioxide and nitrogen for water. According to Hodgman's measurement, the solubility of carbon dioxide is about 50 times larger than that of nitrogen at 298K and the atmospheric pressure [3]. This means that the gas with large solubility in water proceeds the process more effective.

Holding time

Fig.4 shows the effect of the holding time on drying wood. When the holding time was 0.5 hour, the *WATER/VOID* ratio decreased with the cycles. The *WATER/VOID* ratio decreased more rapidly when the holding time was changed from 0.5 to 24.hours. Less change of the *WATER/VOID* ratio was observed after 3 or 4 cycles

This indicates that it takes a certain time for carbon dioxide to diffuse into water in wood, because there are many failures in wood. Thus, when the holding time is not long enough, the

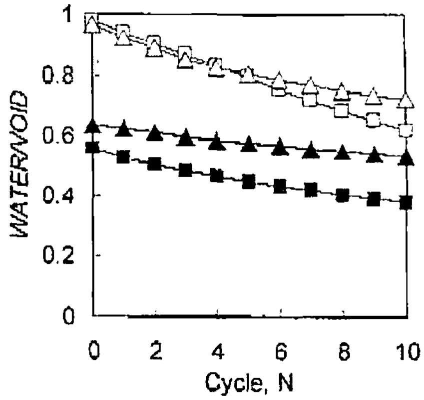


Fig.3. Effect of gas on the *WATER/VOID* ratio.

Drying conditions are summarized in the Table 1. Where, □ is No.1, ■ is No.2, △ is No.3, and ▲ is No.4.

amount of carbon dioxide dissolved in wood is less.

On the other hand, the amount of dissolved carbon dioxide in water caused the amount of liberated water. So the *WATER/VOID* ratio decreases rapidly in the initial stage of the treatment cycle.

Carbon dioxide pressure

Fig.5 shows the effect of carbon dioxide pressure on drying wood. From Fig.5, it is clear that a decrement of the *WATER/VOID* ratio of sapwood is more rapid than that of heartwood. Because the sapwood is more porous than the heartwood, it is considered that the water permeation in the sapwood was higher than that in the heartwood during the pressurizing process. Thus, when the pressure is higher, the final *WATER/VOID* ratio becomes lower.

Length of the specimen

From Fig.4 and Fig.5 (test No.5, 6, 7, and 8), another factor for the effect on drying wood is considered. Compare the decrement of the *WATER/VOID* ratio of test No.5 and 7, the behavior of them are very similarly. On the other hand, compare test No.6 and 8, decrement behavior are also similar to each other, otherwise the first stage of the *WATER/VOID* ratio is differ from.

These similarities show that there is no effect of length of the specimen on drying wood except the portion difference of wood.

## 4. Concluding Remarks

The mechanism in the wood drying process can be considered as follows: (1) Carbon dioxide is dissolved into the water in wood during the pressurization process, (2) The dissolved carbon dioxide is in turn evaporated and expanded at the reduced pressure during the release process, and (3) The evaporation of carbon dioxide induces high pressure in the specimen, facilitating the squeeze of the water from the specimen.

The evaporation of carbon dioxide can successfully reduce the amount of water contained in the wood. Therefore, this new

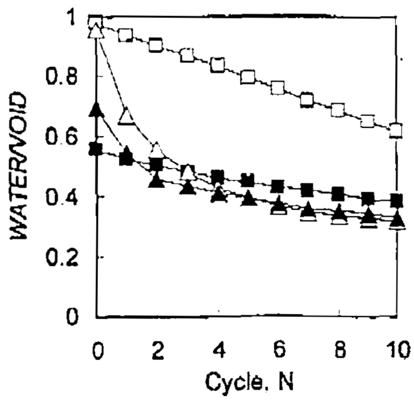


Fig.4. Effect of the holding time on the *WATER/VOID* ratio.

Drying conditions are summarized in the Table 1. Where, □ is No.1, ■ is No.2, △ is No.5, and ▲ is No.6.

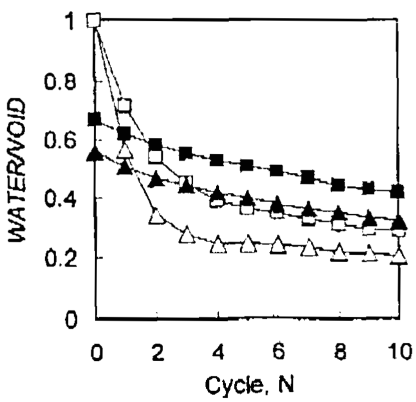


Fig.5. Effect of carbon dioxide pressure on the *WATER/VOID* ratio.

Drying conditions are summarized in the Table 1. Where, □ is No.7, ■ is No.8, △ is No.9, and ▲ is No.10.

drying process without heating is available for drying wood.

On the other hand, there is a great concern in the reduction of wood weight because the transportation cost now is drastically increasing. Thus, it is advantageous if this drying method can be developed.

**References**


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[2] C. D. Hodgman, *Handbook of Chemistry and Physics*, 44$^{th}$ ED., The Chemical Rubber Publishing Co. (1962-63)

[3] Kitahara K., *Mokuzaibuturi*, 24, 1967