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Heating Compression of Italian Poplar (*Populus euramericana*) Wood*1
- Dimensional Stability Against Moisture -

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ABSTRACT

This study was carried out to estimate the property of dimensional stability of heat compression of italian poplar wood with low density. Firstly, two levels of pressure conditions were applied using the closed and open-press system. The thermal treatment temperatures were 180°C and 200°C, respectively. Water absorption tests were conducted in water bath at 25°C and 100°C for 35 hours and 1 hour, respectively. The compression rates of wood were 47 percent, 60 percent, and 73 percent, respectively. From these tests, it was found that the dimensional stability of the closed-press system was superior to that of the open-press system. Furthermore, the dimensional stability of compressed wood in the closed-press system was better at 200°C than 180°C. In compression rate, dimensional stability of 73 percent compression rate was the best result. Considering these results, the best conditions for the dimensional stability of compressed wood were those of the closed-compressing system at high temperatures above 200°C and larger compression rate. Therefore, it was concluded that the dimensional stability of wood is improved at higher temperature and larger deformation.

Keywords: dimensional stability, compression wood, thermal treatment, closed and open-press system

1. INTRODUCTION

It is commonly recognized that compressed wood is perfectly recovered by soaking in water, because the wood is composed of cellulose and hemicelluloses with hydrophilic group, such as the hydroxyl group.

Therefore, to improve the dimensional stability of wood, the hydrophilic group has to be removed or replaced. Generally, it is known that steaming treatment of wood at temperatures above 160°C improves dimensional stability (Dwianto *et al.*, 1998, Eiji *et al.*, 1997, Norimoto *et al.*, 1993). Closed-heating compression treatment is well known to enhance dimensional stability because the permeability is very good and compressed wood's density is improved (Dwianto *et al.* 1999). Therefore, if it was

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possible to utilize these two methods at the same time, it could be the best method for improving the dimensional stability of wood. Korai *et al.* (1999) reported that dimensional stability and strength of particleboard which was produced in the closed-press system was improved.

In a closed-press system, the internal bonding strength was improved and there was less swelling than in an open-press system.

Therefore, the objective of this study was to estimate the dimensional stability of closed-heating compressed wood.

2. PROCEDURES

2.1. Materials

The specimens for this experiment were italian poplar wood (*Populus euramericana*) from Book-An Myun, Young-chun, Kyungpook Province, Korea. The specimens were air-conditioned at 20°C and 65% relative humidity for about 6 months. The dimensions of the specimens were 30(T)×30(L)×15 mm(R) and eight specimens for each experimented condition were prepared respectively. The total number of specimen were forty eight.

2.2. Apparatus for Experiment

A square plate with iron was made for this experiment (Fig. 1). Its dimensions were 170×170×30 (mm, thickness) inside and 220×220×30 (mm, thickness) outside. A thermometer, pressure gauge, and air leak valve were attached to this instrument. Heatproof rubber was also installed for the air closed-system. Therefore, the closed-press system was air tight condition and the open-press system was opening condition by leak valve.

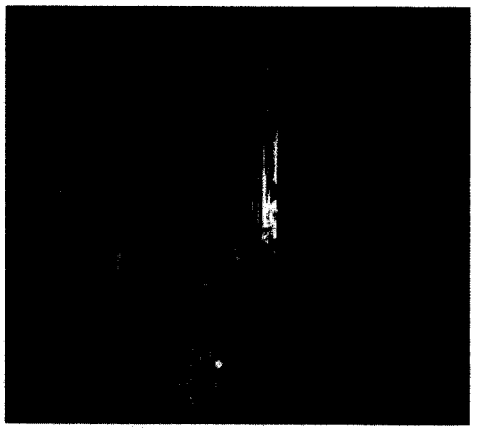

Fig. 1. Apparatus for experiment.

2.3. Control of Moisture Content

After water absorption (about 80~100 percent moisture content), to control moisture content for the fiber saturation point (F.S.P), thermal treatment was performed by microwave heating system (2,450 MHz, 700W) for 90 seconds.

2.4. Press Schedule

The thermal treatment temperatures were 180°C and 200°C respectively. The compression rates of wood were 47 percent, 60 percent, and 73 percent for used of iron stopper with different thickness. Compression pressure was 50 kgf/cm^2. The pressing time was every 20 minutes for heating compression and discharge on two different systems respectively.

2.5. Boiling Test

In the boiling water for one hour, volume swelling and the mass of specimens were measured. The equations for swelling, shrinkage, and dimensional recovery were as follows:

$$\text{Swelling } (\beta) = \frac{V_b - V_p}{V_p} \times 100 \qquad (1)$$

$$\text{Shrinkage } (\alpha) = \frac{V_b - V_d}{V_d} \times 100 \quad (2)$$

$$\text{Dimensional recovery } (\gamma) = \frac{V_d - V_p}{V_0 - V_p} \times 100 \quad (3)$$

V_b: Volume after boiling
V_p: Volume after compression
V_0: Volume before compression
V_d: Oven-drying volume after boiling.

2.6. Water Absorption Test

Water absorption test was conducted at constant temperature of 25°C in a water-bath for 35 hours. The measurement time were 30 minutes at the beginning and then 4 times at interval of 2 hours, and the last 8 times at interval of 3 hours. After the water absorption test, swelling, shrinkage, weight increase, and dimensional recovery were measured respectively. The equations were as follows:

$$\text{Swelling } (\lambda) = \frac{V_{cp} - V_P}{V_P} \times 100 \quad (4)$$

$$\text{Weight increase } (\eta) = \frac{W_{cp} - W_p}{W_p} \times 100 \quad (5)$$

$$\text{Shrinkage } (\varepsilon) = \frac{V_{ep} - V_d}{V_d} \times 100 \quad (6)$$

$$\text{Recovery } (\mu) = \frac{V_d - V_p}{V_0 - V_p} \times 100 \quad (7)$$

V_{cp} : volume of checking point
W_{cp} : weight of checking point
V_{ep} : Volume of final checking point

3. RESULT and DISCUSSION

3.1. Boiling Test

3.1.1. Coefficients of Boiling Swelling and Shrinkage

The both conditions of the open- and closed-press systems, there were low swelling values at lower compression rates of wood. In the case of the closed-press system, this phenomenon was similar to 47 percent and 73 percent compression rates of wood. These results indicate stress removal of the cell wall by steaming treatment and composition degradation by higher compression rate and water vapor at high temperatures in the closed-press system. At two temperatures, the coefficients of boiling swelling at higher temperatures were lower at 47 percent and 60 percent compression rates of wood. At 73 percent compression rate of wood, it was observed that the void volume of compressed wood did not exist at all. This compression condition was a critical point of the compression rate of the wood specimens. In this condition, it was considered that the difference of swelling was due to the difference of press methods in the open- and closed-press systems.

In the closed-press system, it was considered that the treatment with high temperature steam was very useful method for dimensional stabilization of compressed wood. From the results of the boiling test, it was found that the effective factor for lower swelling was not the treatment temperature but the compression rate. Shrinkage of compressed wood in the open-press system was increased by compression rate of wood. The value of shrinkage was larger at higher temperatures. Shrinkage in the closed-press system was about 20 percent, did not changed the compression rate of the wood, suggesting that there existed some restraint mechanism of volume swelling and shrinkage by hydrophobic

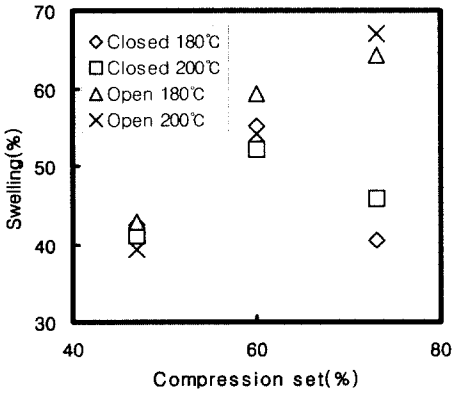

Fig. 2. Volume swelling by boiling.

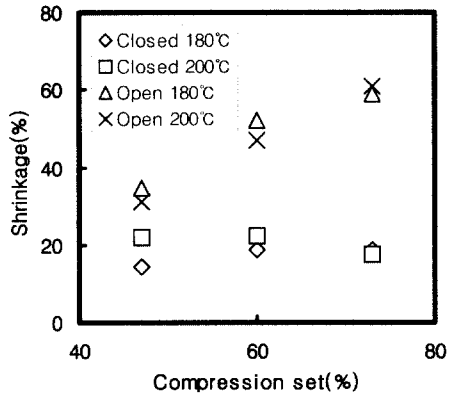

Fig. 3. Shrinkage after boiling.

bonding in the hot pressing process.

3.1.2. Dimensional Recovery

Dimensional recovery was measured to determine the recovery rate in the boiling test of compression wood. In Fig. 4, the amount of recovery below 60 percent compression rates of wood was affected by temperature conditions rather than press systems. However, recovery at 73 percent compression rates of wood was more affected by press system than press temperatures. In critical point of ultimate compression set of wood, it was considered that dimensional recovery in boiling conditions was greatly

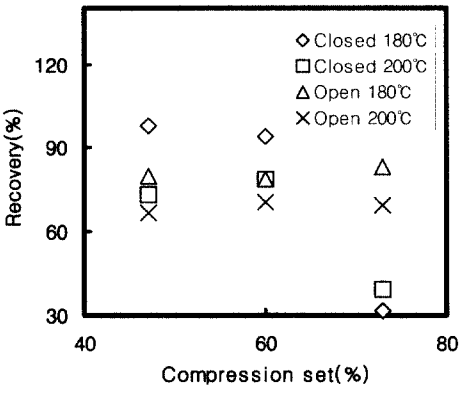

Fig. 4. Recovery by water absorption.

changed by the existent and the non-existent void volume of compression wood. In boiling water, the void volume of compressed wood acts on water absorption or diffusion space for swelling. Furthermore, compression treatment of wood in the closed system generates many small void volumes by degradation of the composition of the cell wall. Therefore, it is concluded that recovery below 60 percent compression set of wood in the closed-press system was larger than that of the open-press system.

3.2. Water Absorption Test

3.2.1. Swelling and Weight Increase

In Fig. 5, the large deviation of swelling with compression rate of wood in the closed-press system was found. In this condition, the coefficient of swelling at higher temperatures was small. The coefficients of swelling at 73 percent, 180°C and 60 percent, compression rate of wood and heat temperatures were exponentially increased in the closed system. Swelling at 180 °C and 60 percent compression was the largest value in the closed-press system. Therefore, it was concluded that treatment temperatures affect swelling in the closed-press system. On the other hand, coefficients of swelling in the

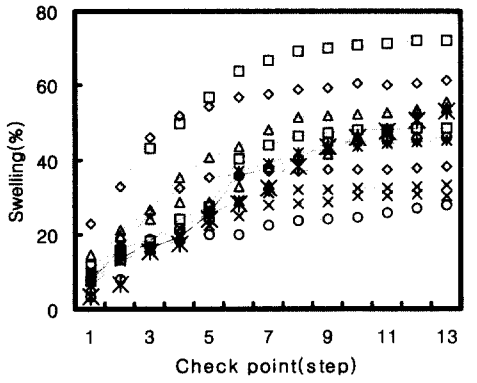

Fig. 5. Volume swelling on absorption.
Legend) -- closed-state, — open-state. ◇: 47% (180°C), □: 60% (180°C), △: 73% (180°C), ×: 47% (200°C), *: 60% (200°C), ○: 73% (200°C).

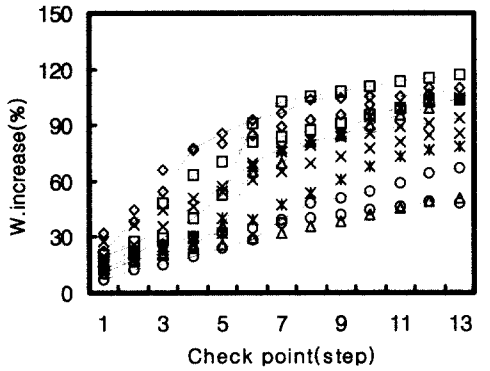

Fig. 6. Weight increase on absorption.
Legend) -- closed-state, — open-state. ◇: 47% (180°C), □: 60% (180°C), △: 73% (180°C), ×: 47% (200°C), *: 60% (200°C), ○: 73% (200°C).

open-press system appeared between 30 percent and 50 percent swelling. Weight increase with water absorption was largest at 180°C and 47 percent, at 200°C, and 60 percent for compression rate of wood in the closed-press system.

3.2.2. Shrinkage and Dimensional Recovery

Coefficient of shrinkage in water absorption

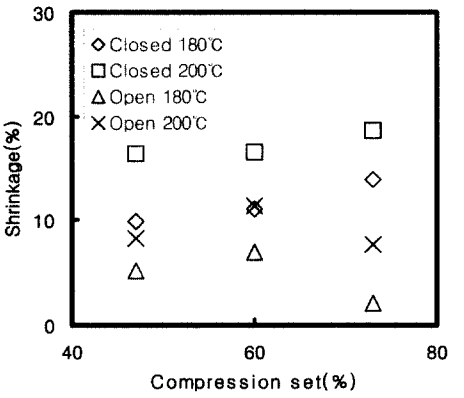

Fig. 7. Shrinkage by oven-drying.

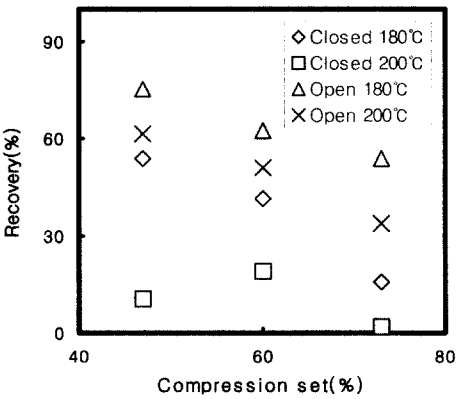

Fig. 8. Recovery by water absorption.

was 20 percent lower than in boiling. Shrinkage in the open-press system was lower than in the closed-press system. In the closed-press system, shrinkage of compressed wood was increased by compression set of wood. The value at 200 °C in the closed-press system was about 19 percent. However, shrinkage at 180°C in the open-press system was very small. At high temperatures, large compression of wood in the closed-press system may generate new absorption sites and many small void volumes involved in small cracks by degradation of lignin and hemicelluloses in the cell wall.

Therefore, shrinkage at high temperatures in the closed- press system showed the largest

value in cold-water absorption. However, in cold-water, what happened to compressed wood by water absorption was unclear. The reason for this phenomenon is not clear yet. As Fig. 8, recovery sets generally decreased with compression set of wood in all conditions. The recovery amount was smaller at higher temperatures and larger compression set. Furthermore, the recovery value in the closed-press system was smaller than in the open-press system.

Therefore, it was concluded that the dimensional stability of compressed wood is improved at higher temperature and deformation up to critical point.

4. CONCLUSION

This study investigated the properties of the dimensional stability of heat compressed italian poplar wood. It was found that the dimensional stability of the closed-press system was better than that of open-press system. Considering the results, the best conditions for the dimensional stability of compressed wood were the closed compressing system at high temperatures about 200°C and large compression. Therefore, it was concluded that the dimensional stability of wood is improved for higher temperature and larger compression in the closed-press system.

REFERENCES

1. Eiji U. and T. Furuno. 1997. Heat compression of Sugi(*Cryptomeria japonica*). *Mokuzai Gakkaishi* 44(3): 218-222.
2. Dwianto W., Morooka T., Norimoto M., Tanaka F., Inou M., and Y. Leu. 1998. Radial compression of sugi wood(*Cyptomeria japonica* D. Don). *Holz als Roh-und Werkstoff* 56: 403-410.
3. Dwianto W., Morooka T., and M. Norimoto. 1999. Method for measuring viscoelastic properties of wood under high temperature and high pressure steam conditions. *J. Wood Sci.* 45: 373-377.
4. Norimoto M. Tanahashi M., and Roger M. Rowell. 1993. Steam or heat fixation of compressed wood. *Wood and Fiber science* 25(3): 226-234.
5. Norimoto M., Ota C., Akrrsu H., and T. Yamada. 1993. Permanent fixation of bending deformation in wood by heat treatment. *Wood Research* 79: 23-33.
6. Korai H., Uemura K., and T. Esashi. 1999. Dimensional stability and strength properties of particleboard produced by a closed-press system. *J. Wood Sci.* 45: 408-410.