Analysis of Heat and Moisture Transfer in a Center-Bored Timber whose Outer Surface is Sealed

Jun-Ho Park[1]– Yonggun Park[1]– Yeonjung Han[1]– Joon-Weon Choi[2]–

In-Gyu Choi[2]– Jun-Jae Lee[2]– Hwanmyeong Yeo[3]*

[1] Graduate Student, Dept. of Forest Sciences, CALS, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul – South Korea.
[2] Research Institute for Agriculture and Life Sciences, Professor, Dept. of Forest Sciences, CALS, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul – South Korea.
[3] Research Institute for Agriculture and Life Sciences, Associate Professor, Dept. of Forest Sciences, CALS, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul – South Korea
* *Corresponding author*
hyeo@snu.ac.kr

Abstract

A lot of time and energy are required for drying green timber that has a large cross section. This type of wood also has a high possibility of drying check occurrence due to evolving internal drying stress resulting from long-lasting big internal moisture gradients. Meanwhile, efforts to produce fast water emission by using a low temperature and moisture gradient in wood have been continued for drying wood without drying defects. We figured out a way to rapidly dry green timber that has a large cross section so that it does not make cracks and uses a small amount of thermal energy for drying. We applied a center-boring process, drilled a hole along the central longitudinal axis, and the outer surface of the timber was sealed. The center-boring reduces the heat and the moisture movement distance inside the wood and the outer-surface sealing changes the direction of drying stress. Through this center-bored timber drying process, drying-check free large solid structural timber can be manufactured as well as high grade wood flour, raw material of wood-based panel and woody biomass without extra cost. Because the check-free center-bored timber is light and has a uniform moisture profile, it is good for the beam and column construction. Also, its boring part can be used for hiding electrical wire line which is exposed in ordinary beam and column structures.

***Keywords*:** center-bored timber, MC variation, drying, pitch pine, sealed outer surface, heat transfer, moisture movement

Introduction

It should be applied to an appropriate process to dry wood to recommended low moisture content for efficient use of wood. Usually drying for large cross-sectional timber takes a long time and creates a lot of drying defects. To solve these problems, many drying methods such as high temperature/humidity drying and high-frequency drying, have been proposed. In this study, we developed the outer-surface sealed center-bored timber drying, drying after boring central part of timber along longitudinal axis and sealing the outer surface, which increases the drying rate by reduction of heat and moisture moving distance and prevents occurrence of drying checks. It also has the advantage that byproduct, high grade wood flour, from boring process can be acquired without extra cost. In this study, pitch pine tree needed species regeneration is used. The afforestation area of pitch pine in Korea is approximately 0.4 million ha. Most of these trees have been used for manufacturing wood composite not solid wood.

Materials and Methods

Materials. The species used in the experiments was pitch pine. Center-bored round wood with an outer diameter of 140mm, inner diameter of 80mm was prepared. The length of the specimens was 1.2m. Average initial MC was 30%.

Methods. Pitch pine tree was cut in length of 3m. Pitch pine tree was manufactured as round wood with an outer diameter of 140mm. The round timber was center bored by drilling bit with diameter of 80mm. The center-bored timber was cut in length of 1.4m. Before sealing the outer surface of the center-bored timber, initial MC content specimens with 0.1m (100mm) thickness were cut from both end of the 1.4m center-bored timber. Outer surface of 1.2m center-bored timber was sealed. And center-bored timber was dried at 95℃ for 48 hours according to temperature and humidity conditions of Figure 2. The outside size of dryer is 2,300 mm (length) × 1360mm (width) × 1080mm (height).And inside size is 1,570 mm (length) × 1,200 mm (width) × 640mm (height). Temperature and humidity was controlled by hot-wires located at the bottom of the dryer and steam heater. Wind velocity of longitudinal direction of wood was maintained by air blower on the side of the dryer. The wind velocity measured by anemometer (8386A, TSI Inc.) was at a speed of about 3 m/s.
To measure the internal temperature change during drying, thermocouples were inserted into the wood. Temperature was measured and recorded using data logger (CR1000, Campbell Scientific Inc.) for analyzing heat transfer. And To determining average internal moisture content of wood, the weight of the specimens was measured during drying. In addition, to analyzing moisture transfer, outer, center, and inner part (Figure 1) specimens were cut and weighed at 8 hour intervals during drying

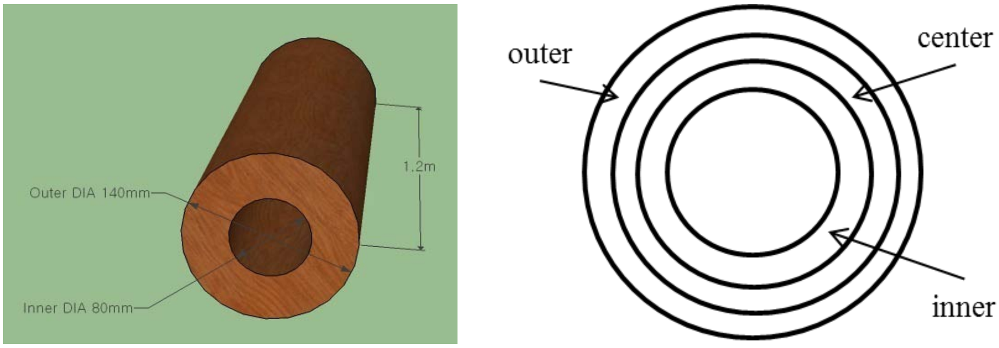

Figure 1. Dimension of center-bored timber and measuring part of MC (outer, center, inner)

Results and Discussion

In this study, heat and moisture transfers in and/or on the outer-surface sealed center-bored timber (sealing wood) and seal-free center bored timber (control wood) were analyzed. The change of MC of sealing wood and control wood during pitch pine center-bored timber drying is shown in Figure 2. MC decrement of sealing wood was a little bit slow compared with control wood, but it is not different significantly. The final MC after 48 hours was about 5%.

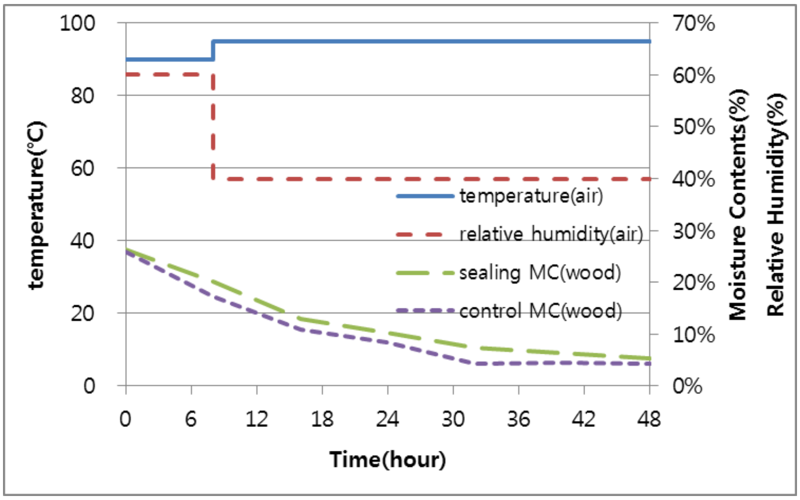

Figure 2. MC variation of sealing wood and control wood by drying schedule

Temperature changes of sealing wood and control wood during drying were shown in Figure 3 and 4. Wood temperature was increased during approximately 3 hours to reach around the setting temperature. In the case of control wood, temperature difference between surface and inner part of control wood was maintained with about 10℃ during 18 hours after beginning of drying. Whereas, temperature difference between surface and inner part of sealing wood was maintained within 5℃ during 18 hours after beginning of drying. It means that heat transfer into outer surface sealing wood very quickly. Because space between outer surface and sealing material was filled with a high temperature steam, it seems that the heat transfer rate in outer surface sealing wood is higher.

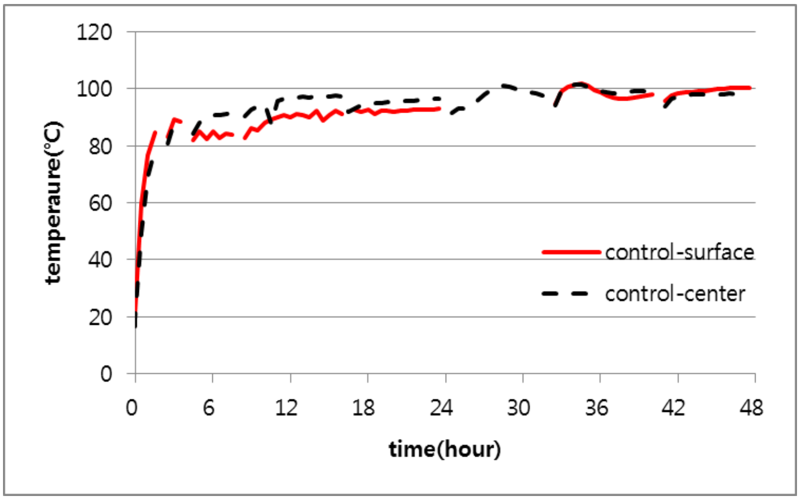

Figure 3. temperature change of control wood during drying

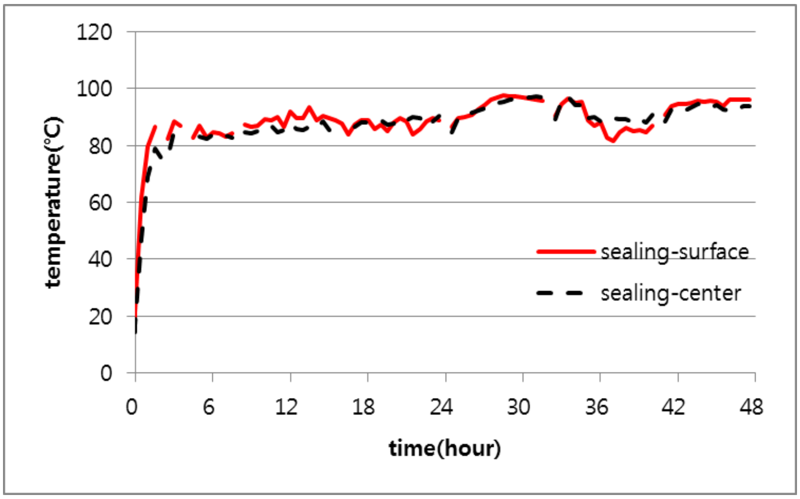

Figure 4. temperature change of sealing wood during drying

Changes of MCs of each part in center-bored timber during drying are shown in Figure 5, 6. Drying time of sealing wood was considerably shorter than expected. Compared to control wood, the moving distances of water molecules in outer-surface sealing wood are much longer. However, the actual drying time of the sealing wood was not increased significantly.

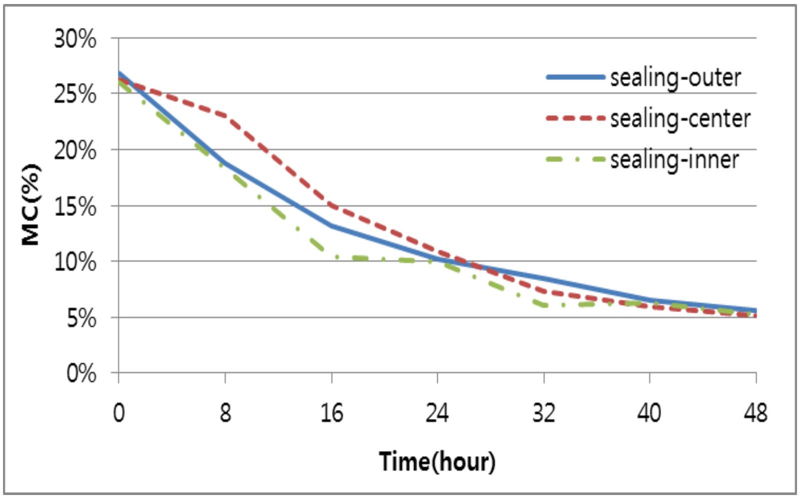

Figure 5. Partial MC variation during drying of sealing wood

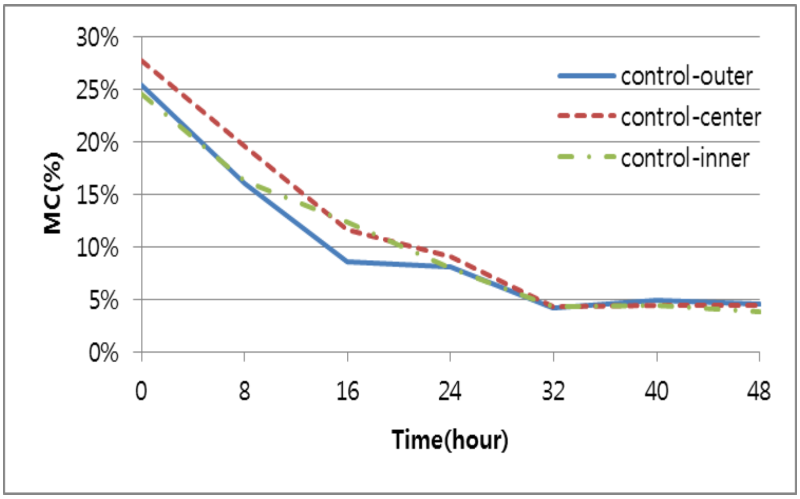

Figure 6. Partial MC variation during drying of control wood

In case of control wood, MCs of outer surface and inner surface are lower than MC of center part of wood prior to drying. And this tendency was maintained during drying and to ending the drying process. However, in case of sealing wood, drying rate of outer surface is lower than center part and inner surface.
This slower drying of outer part prevents the occurrence of tension stress on the outer surface. Also the tension stress occurred on inner surface part could not affect to cause drying check due to geometric characteristics of center-bored timber. Concave and closed curve shape of the hole in the cross section of timber dose not allowed increasing a gap between wood tissues. 6 surface drying checks were found on the outer surface of control wood. The length of surface check was 103.4±55.8mm. Whereas outer-surface sealed center-bored timber (sealing wood) was dried without drying check.
In this study, center-boring, sealing, and drying method and process was developed. Drying after sealing the outer surface of the timber was applied to manufactured defect-free center-bored timber. Also, MC measurement method using NIR during drying

center-bored timber was developed to control the drying process and determine when the drying process should be finished.

References

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