KFS Journal, Vol. 20(6), 2009: 599-604

Observation of Moisture Content in Wood at Non-Steady State

Sung Wook HWANG[1] and Won Hee LEE[†1]

ABSTRACT

For the search of unified law of moisture movement in wood, moisture distribution of Korean red pine at non-steady state was investigated. We assume that the equilibrium moisture content (EMC) in wood depends on only temperature and relative humidity, it can be control in temperature and humidity chamber. If temperature is constant and humidity or vapor pressure is changed with sin curve shape at adequate cycles, EMC in chamber can be changed as well with sin-curve shape. The setup condition of a non-steady state in humidity control chambers is a constant temperature at 20℃and 15+10 sin ωt percent EMC. It can be found that the distribution of moisture in the specimen with varying relative humidity are illustrated various types. Moisture in wood is complicated and vibrates with the moisture sorption process. Considering a unified law of moisture movement in wood, it is considered that the most important fact is to search the method of precise diffusion & transfer coefficients.

Key words: Non-steady state, Moisture Distribution, EMC, Diffusion & transfer coefficient.

1. INTRODUCTION

It is important to know of the behavior of moisture movement to control the moisture content of wood and wood products. In wood science, there are many studies on moisture transmission, and these researches have been applied to structural materials. The behavior of moisture transmission is vapor adsorption and desorption process between wood walls. This vapor transmission property is evaluated by vapor permeability and vapor transmission resistnace (Wantanabe 1978, Lee et al. 1991). In general, there are many researches on vapor permeability for wood materials using architectural wall panels (Kato 1987). The internal resistance is controlled by the diffusion of moisture (Choong, E.T. 1969), whereas the external resistance with a surface emission coefficient results from a convective effect in the air to the wood surface (Siau 1971).

A wood and wood product is continually exchanging moisture with its surrounding. Various physical properties and mechanical properties of wood as a hygroscopic material are affected by its moisture content(W. Lee 2008). Furthermore, a fungal attack occurs if the moisture content of wood is higher than about 20 percent (Griffin, D.M. 1977). It is very interest to have a good knowledge on the moisture distribution in wood, as well as the moisture content in relation to its environment. In previews study, it was reported the moisture distribution in wood of different thickness at a steady state in constant temperature and relative humidity chamber (A. Droin et al. 1988). The distribution of moisture content in wood can be illustrated by two straight lines intersecting at the point of nine percent moisture content. The shape of the distribution of moisture content is similar irrespective of

Received for publication: Jun 12, 2009 ; Reviewed: Jul 10, 2009 ; Accepted: Nov 19, 2009.
1) Department of Wood Science & Technology, Kyungpook National University, 702-701 KOREA.
† Corresponding author: Won Hee LEE (Email: leewh@knu.ac.kr).

the wood thickness. Therefore, it was reported that diffusion coefficients have two constant values at moisture contents below and above nine percent (W. Lee et al. 1991, 1991b). In unsteady state of moisture transmission, it can be analyzed as a unified law of moisture movement in wood if the diffusion coefficient and surface transfer coefficient at a steady state can be utilized.

This study is concerned with the study of the kinetics of adsorption and desorption of moisture by wood, in order to build an analytic model for these sorption processes. In the present work the interest was focused on moisture distribution during sorption process in wood. As a first step, in this study, it is mainly investigated the moisture distribution in wood of same thickness.

2. EXPERIMENTAL

2-1 Material

Korean red pine sapwood (*Pinus densiflora*) blocks are shaped like parallelepipedic samples of thickness 36 mm and other dimensions 80mm×80mm (tangential direction) for this study. Density and annual ring width of wood samples are 0.61 (0.05) g/cm^3 and 2.04 (0.55) mm, respectively. After equilibrating the wood specimens in air at 77 % RH at 20℃, the specimens have been prepared for this research. Vapor flow direction is tangential direction. Vapor sorption through two opposite radial faces of these wood samples has been observed by protecting the other faces from the water vapor with an impermeable paint. As a result, the moisture movement occurs by unidirectional diffusion through the wood specimen.

2-2 Apparatus and experiment

In practice, wood drying is unsteady-state diffusion in wood. Therefore, if the equilibrium moisture content (EMC) in wood depends on only temperature and relative humidity (RH), it can be control EMC in temperature and humidity chamber. In temperature and humidity chamber, for instance, if temperature is constant and humidity or vapor pressure is changed with sin curve shape at adequate cycles, EMC in chamber can be changed as well with sin-curve shape. Therefore, the wood specimens will be changed with sin-curve shape.

The setup condition of a non-steady state in humidity control chambers is a constant temperature at 20℃ and 15+10 sin ωt percent for EMC (left side in Fig.1). In this case, relative humidity in control chamber should be changed with EMC (right side in Fig.1).

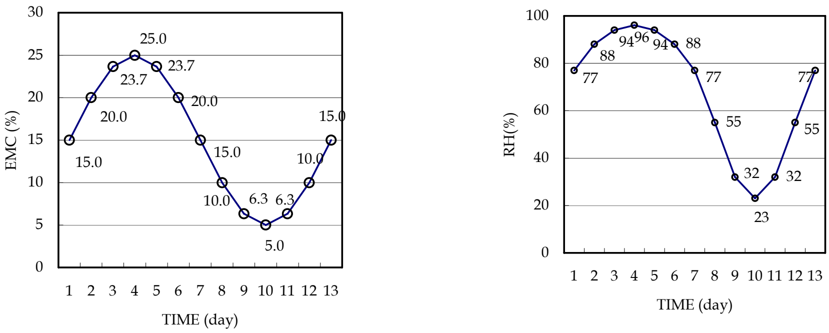

Fig. 1. Set up of relative humidity (RH, right) for equilibrium moisture content (EMC, left). The temperature is constant at 20℃. The period of one cycle is twelve days.

In sorption process, the variation in weight of the wood specimens has been measured at one-day intervals. When the variation with measured time was constant in the adsorption and desorption process, the moisture content distribution in wood has been measured at one-day intervals. In these procedures, the moisture distribution in wood to flow direction is determined by slicing method as rapidly as possible with a handy planner. The moisture content in each flake has been determined by the oven-dry weight method. The wood flakes were weighed to the precision of 0.1 mg.

3. RESULTS AND DISCUSSIONS

3- 1 Change of specimen's weight at non-steady state

Specimens' weight at non-steady state was changed as illustrated in Fig. 2. As shown in this Figure, it was observed that change of specimen's weight is approach a periodic steady state from the number of repetition of two cycles. This result was the same as that of the other eleven specimens. Therefore, we could conclude that investigation of moisture distribution in wood can be conducted after four cycles of repetition number. In this time, I was defined that is "steady state in non-steady state." This Figure was illustrated a cyclic phenomenon like as a harmonic function with phase lag.

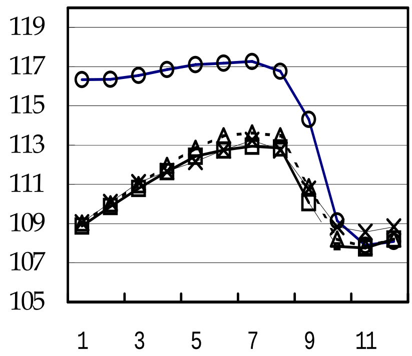

Fig. 2 Change of specimen's weight at non-steady state at 20℃. One cycle is twelve days. A cross axis is time (day) and vertical axis is arbitrary weight unit (g) in this figure. Legend) Symbols in figure is number of cycle. ○:1 cycle, □:2 cycle, +:3 cycle, ×:4 cycle.

3-2 Distribution of moisture content in wood

The distributions of moisture in wood along the vapor flow direction are shown in Figures 3(Time(1)~Time(12)). From these Figures, it can be found that the distribution of moisture in the specimen cannot be approximated by constant tendency. Distributions of observed moisture content in the wood with varying relative humidity are illustrated various types. Moisture in wood is complicated and vibrates when the moisture is adsorbed and desorbed.

These data may be analyzed by the use of the Fourier transformation. Moreover, the model is able to develop from the experimental results. Theoretical maximum EMC is the moisture content (MC) at 72hours (3 days) and minimum value is the MC at 216 hours (9 days). However, phase lag in this result is appeared for the slow velocity of moisture movement in wood. The reason of this phenomenon is the higher velocity of EMC change in atmosphere than that of wood. In fact, equilibrium on the wood surface is to be reached very slowly.

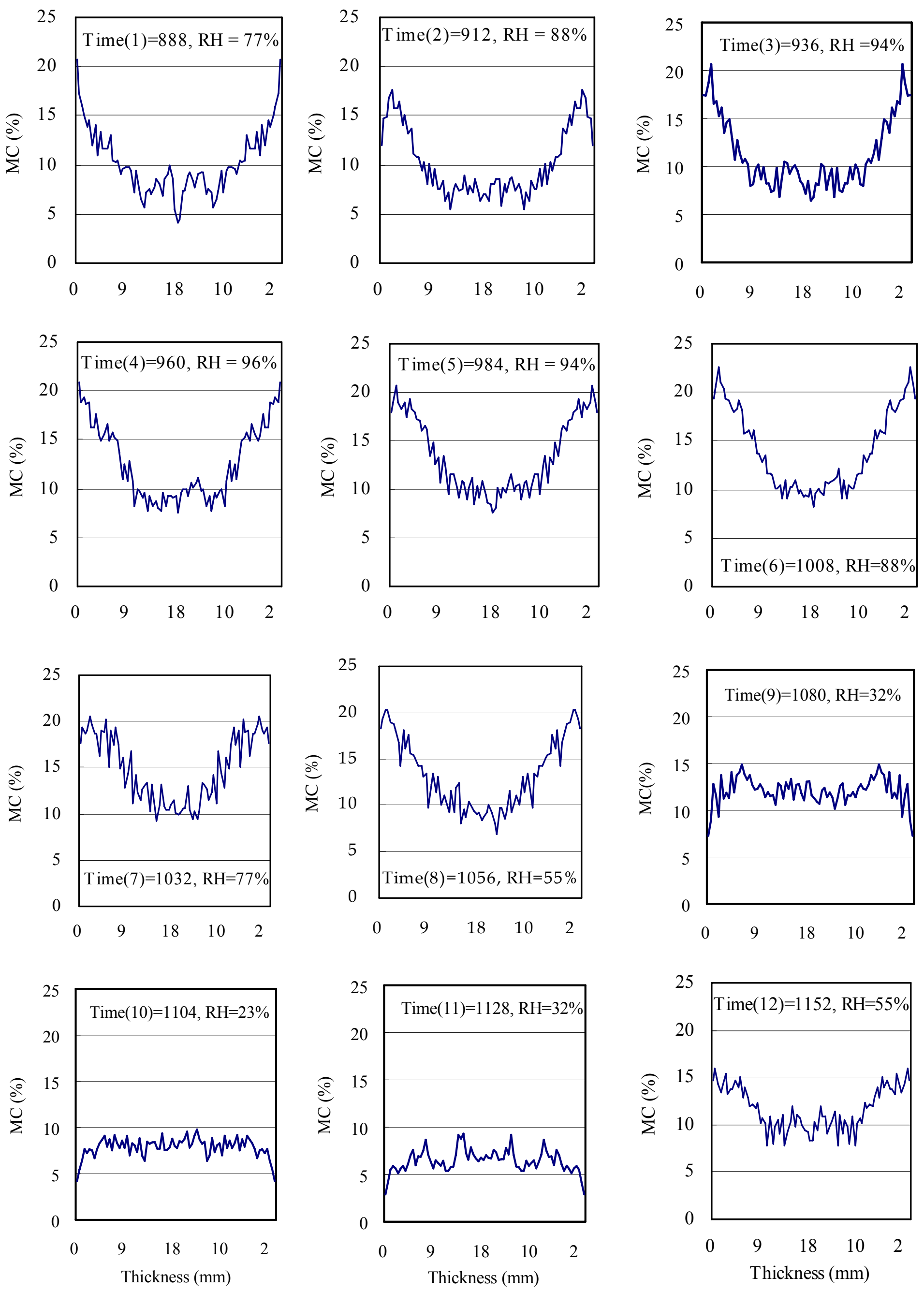

Fig. 3. Distributions of moisture content in the tangential direction. Thickness in cross axis is vapor flow direction. Time in Figure is elapsed time and the unit is hour. Number in brackets is the number of times for moisture measurement.

If the results from steady-state experiments can be applied in unsteady-state diffusion in wood, it may be solve the complicated problems such as the phenomenon of moisture movement in wood below fiber saturation point. In this research, the measurement of exact moisture content in wood and wood surface and amount of moisture

movement will be very important data for considering of the mechanism of moisture movement in wood. If possible, it can be expressed moisture distribution in wood by various methods. Irrespective of theoretical and numerical and experimental method, the most important problem is to know of exact diffusion coefficient.

Therefore, a unified precise measurement method of diffusion coefficient and transfer coefficient of each wood species is more important issues. But the most suitable decision method of these coefficients does not exist yet. The driving force of moisture movement in wood generally has been divided into three schools of thought from long ago. One is the MC gradient in wood. The others are the gradient of vapor pressure and chemical potential. Scientists are looking for a driving force yet, but they don’t know what because of the lack of a public response.

Comparing of this experiment results and various analytic solutions and numerical methods, we will be find the unified law in moisture movement in wood. Therefore, a more precise data collection under the various conditions will be necessary for an analysis of moisture sorption below fiber saturation point.

4. CONCLUSION

For the search of unified law of moisture movement in wood, moisture distribution of Korean red pine at non-steady state was investigated. The distribution of moisture in wood was illustrated a complicated style by phase lag and vibrations in wood. When the numerical modeling, some simple assumptions by scientists has been made, in order to describe the process and simplify the problem. Especially, it has been treated that moisture movement through the air-wood interface is very simple. Therefore we have to clear the air-wood interface equilibrium for exact analysis on moisture movement at non-steady state. The second, it has to find the constant diffusion coefficient or actual model to search the unified law with no relation to any experimental conditions. Therefore, considering a unified law of moisture movement in wood, it is considered that the most important fact is to search the method of precise diffusion and transfer coefficients.

5. REFERENCES

A.Droin, J.L. Taverdet, J.M. Vergnaud. 1988. Modeling the kinetics of moisture adsorption by wood. Wood Sci Technol. 22:11-20.

Choong, E.T., Skaar, C. 1969. Wood Sci. 1: 200-202.

Griffin, D.M. 1977. Water potential and wood decay fungi. Ann. Rev. Phytopathol. 15:319-329.

Kato, K. 1987. “Mokushitsu Kankyou no Kagaku (Wood-based Environmental Science)”, Yamada, T. ed., Kaiseisya, p.341-351(Japan)

Siau, J.F. 1971. “Flow in Wood”, Syracuse Univ Press.

Watanabe, K. 1978. Kenchiku Keikaku Genron Ⅲ (The principle of Construction Planning Ⅲ), Maruzen. P.136-141(Japan).

Weon Hee LEE, Takeshi OKANO, Masamitsu OHTA. 1991. Moisture Transmission in Wood. Moisture transfer and velocity of moisture transmission in a steady state. *Mokuzai Gakkaishi* 37(2):101-108.

Weon Hee LEE, Takeshi OKANO, Masamitsu OHTA. 1991b. Moisture Transmission in Wood. The amounts of moisture transmission calculated by diffusion coefficients of moisture transfer. *Mokuzai Gakkaishi* 37(4):291-296.
Won-Hee Lee. 2008. Vapor permeability and moisture gradient on a *Paulownia* Wood for inside material of furniture making. KFS Journal. Vol.19(6):447-451.