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Study of transfer process of moisture by wood below the fiber saturation point

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Abstract: *Wood is a hygroscopic material. It has the ability to absorb and release moisture naturally and achieve a state that corresponds to equilibrium with its surroundings. The purpose of this article is about the evolution of unidirectional absorption relative humidity of 76% at a constant temperature (20 ± 2) ° C in the course of time.*
The method used is to couple the experimental study with the theoretical study. The kinetics of moisture absorption and profiles of dialogue from every direction were determined.
Keywords: *humidité, transfère unidirectionnel, absorption, bois*

I. Introduction

The movement of moisture through wood is very complex process. Pieces of wood are exchanging moisture with the surrounding medium. Depending of the relative values of actual moisture content on the surface of the wood and the moisture content which is at equilibrium with the surrounding atmosphere, the moisture is absorbed by wood or absorbed.
When the surrounding atmosphere is air, the moisture content, the moisture content is below the fiber saturation point being attained when the relative humidity of air is 100%.
The main objective of this study is to describe the process of absorption of water, when the moisture content is below the fiber saturation point.
The second objective of this study is to build a mathematical model capable of describing the process of absorption of moisture below the fiber saturation point.

II. Theoretical and experimental part

The transfer of moisture through the wood is governed by transient diffusion in one-dimension;

$$\frac{\partial(\mathrm{MC})}{\partial \mathrm{t}} = \frac{\partial}{\partial \mathrm{x}}\left[\mathrm{D}.\frac{\partial(\mathrm{MC})}{\partial \mathrm{x}}\right]$$

Which becomes

$$\frac{\partial(\mathrm{MC})}{\partial \mathrm{t}} = \mathrm{D}.\frac{\partial^2(\mathrm{MC})}{\partial \mathrm{x}^2}$$

When the diffusivity D is constant

Moisture absorption is controlled by the phenomenon of diffusion, in this case the material studied at a uniform concentration C_i, and surfaces are maintained at constant moisture content MC1 throughout the process.
The initial and boundary condition are:
t = 0   0 < x < LM C = MCi (1)
t≥ 0   x = 0   MC =M C1 (2)
In this sample case, an analytical solution exists for the concentration solution is the concentration Cx, t, at time t and x positions

$$\frac{MC_1 - MC_{x,t}}{MC_1 - MC_i} = \frac{4}{\pi}.\sum_{n=0}^{\infty}\frac{1}{2n+1}.\sin\left(\frac{(2n+1)\pi x}{L}\right).\exp\left(\frac{-(2n+1)^2\pi^2}{L^2}D_t\right) \quad (3)$$

The total amount of diffusion material which is between the flat sheet at the time t, Mt, is obtained depending on the amount of substance diffusing infinitive carried after time [1], [2], [3], [4], [5].

$$\frac{M_\infty - M_t}{M_\infty} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\cdot \exp\left(\frac{-(2n+1)^2\pi^2}{L^2}D_t\right) \quad (4)$$

For small time, when M_t/M_∞ is small enough, the equation reduces to the well known equation:

$$\frac{M_t}{M_\infty} = \frac{4}{L}\left(\frac{D_t}{\pi}\right)^{0.5} \quad (5)$$

For longer periods, when M_t/M_∞ is sufficiently large, the equation (4) is reduced to the first term with $n = 0$

$$\frac{M_\infty - M_t}{M_\infty} = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_t}{L^2}\right) \quad (6)$$

A-experimental procedure:

Materials

Three samples of Moroccan origin Epicia are used in the study.

Wood samples

Various samples of wood are used in this study. They are cut such a way that their three axes are the same are the three principal axes of diffusion.

Sample 1 size: (L = 1.964cm3, R = 1.957cm3, T = 6.126cm3)
Sample 2: (L = 2.056cm3, R = 2.056cm3, T = 6.029cm3)
Sample 3: (L = 2.043cm3, R = 2.043cm3, T = 6.112cm3)

-A balance (sensitivity 10^{-3}g) to follow the evolution of the mass of the sample over time with weight gain in successive intervals of time, the balance is equipped with a frame with all its faces closed to avoid disturbance measures caused air movement in the laboratory.
-An oven for drying the sample at 102 ° C and having the measurement of the sample in the anhydrous state.
-Dryer
-Crystallizer glass placed in the dryer
-Thermometer

B-Experiments:

Sample preparation does not require deep pockets. Indeed, the samples were cut in the longitudinal and radial directions tangential timber.
Distribute the solution with excess salt (NaCl, 76% RH) in the crystallizer that is arranged in the desiccators.
The solution may be put directly into the bottom of the dryer to a height of a few centimeters in order to have a maximum evaporation surface.
The weight change of the sample is measured at well determined intervals.

III. Results and Discussion

Three types of results are interest in this paper:
-The determination of parameters such as the main and the diffusivities moisture content equilibrium.
- The validity of the numerical analysis and the model is tested by comparing the absorption kinetics obtained from experiments and calculations.
- Determination of concentration profiles.

Measurement parameters:

Transfer to a dimension along a main direction of diffusion and the four sides are protected by a waterproof film. Each main diffusivity is calculated from the straight line obtained by plotting the quantity (Mt) of the moisture carried by the corresponding axis in function of the square root of time, diffusivity is readily calculated when the moisture content in the balance (M∞).

With:

$$\frac{M_t}{M_\infty} = \frac{4}{L}\left(\frac{D.t}{\Pi}\right)^{0.5}$$

Where L is the thickness of the sheet.

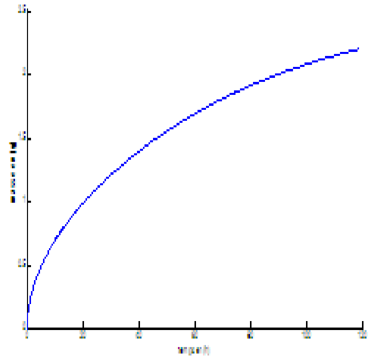

Figure 1 : Kinetics of diffusion of moisture in the tangential direction at T = 25 ° C

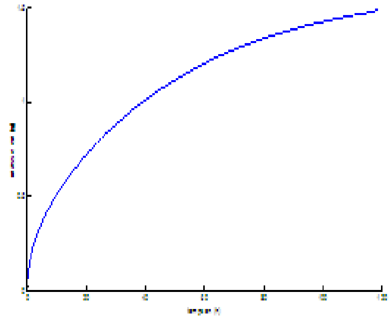

Figure 2 : Kinetics of diffusion of moisture in the longitudinal direction at T = 25 ° C

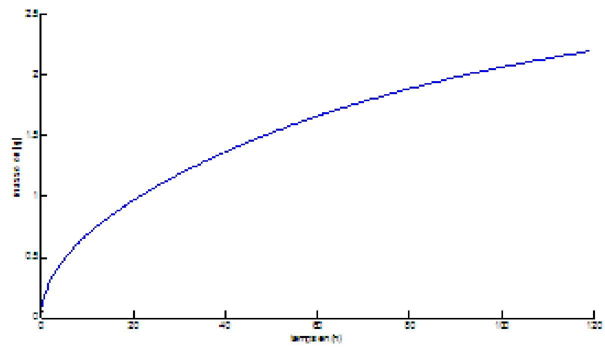

Figure 3 : Kinetics of diffusion of moisture in the radial direction at T = 25 ° C

Table 1: Parameter Values

main axis	diffusivity (cm^2/s)
Longitudinal	$1,97.10^{-5}$
Radial	$1,49\ .10^{-6}$
Tangentiel	$1\ ,53.10^{-6}$

The following results are obtained by calculations on scientific software:

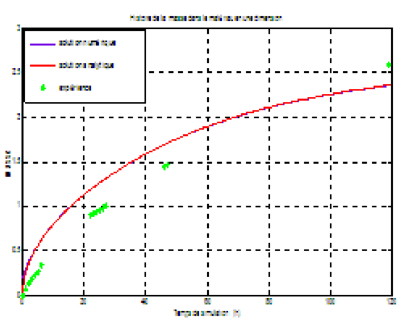

Figure 3-10: The amount of moisture transferred into the sample 1 as a function of simulation time

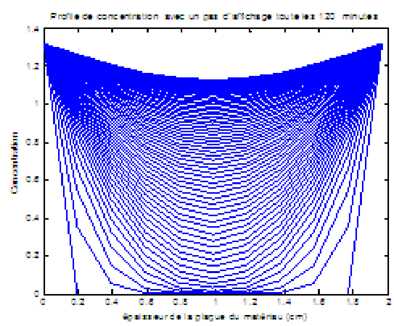

Figure 3-11 : The concentration profile in the longitudinal direction

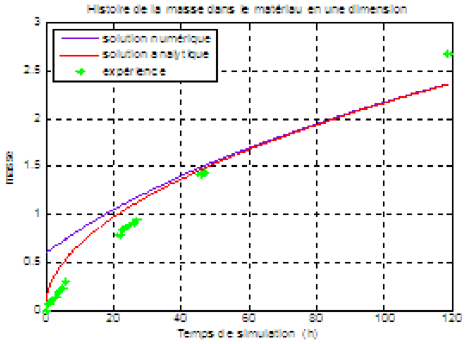	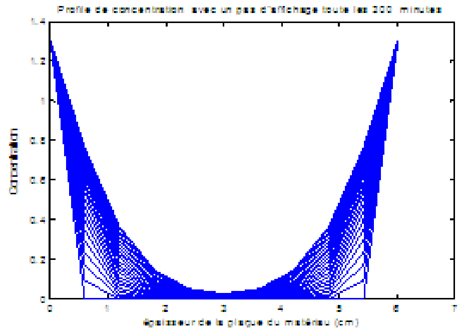
Figure 3-14 : The amount of transferred moisture in the sample 3 as a function of time of simulation	Figure 3-15 : The concentration profile in the radial direction

- The validity of the numerical model is assessed by comparing the absorption obtained either by tests or by calculation using the above parameters kinetics.
- Under these conditions, the analytical solution and the numerical model gives almost the same curves.
- A fairly good agreement is found between the theoretical and experimental kinetic, proving the validity of the model.

IV. Conclusion

The problem of absorption the moisture content below the fiber saturation point has been study. The following results are obtained;

-Validation of analytical and numerical model was made by comparing the experimental results and the theoretical results.
-The profile obtained gives better information on the levels of moisture in the wood.
-This model simulates a few hours of mass transfer in reality lasting several months or more.

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