Modeling the Absorption of Water by the Wood

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Abstract: ***This article describes the transfer of the water inside the wood in the field of the free water, which is controlled by the diffusion in transitory regime, especially when the wood is immersed in some liquid water. The method used is to couple the experimental study with a theoretical approach. Also we developed mathematical models of the transfers of water capable of identifying this phenomenon.***

Keywords: Transfer, diffusion, modelisation, Finite difference method

1. Introduction

The wood is a material anisotropy, towards mechanical properties and properties of transfer of liquids. The pressure gradient of the water within the pores of the wood may be responsible for the migration of water into the wood.

The wood absorbs some water when we immerse him inside it, and obviously the concentration of the water in the latter is superior to that associated the point of fiber saturation.

The main objective of this study is to describe the water absorption process, when we are over saturation point of fibers and especially when the wood is in touch with the liquid water [1] [2]. The second objective of this study is to build a mathematical model capable of describing the process of absorption of the water over the saturation point of fibers.

2. Theoretical and Experimental approach

Transfer of the water in the timber is governed by the Fickian diffusion in one dimension.

$$\frac{\partial MC}{\partial t} = \partial\left(D.\frac{\partial MC}{\partial x}\right)(eq1)$$

We obtain:

$$\frac{\partial MC}{\partial t} = D.\frac{\partial^2 MC}{\partial x^2}(eq2)$$

- **Analytical Treatment**

When the diffusivity is constant, the equation of the transport inside the wood has an analytical solution with the following particular conditions:

$$t = 0 \quad 0 \prec x \prec L \quad C = C(x,t) = 0(eq3)$$

$$t \succ 0 \quad x = 0 \quad x = L \quad C = C(x,t) = C_{éq}(eq4)$$

Or 0 and L indicate the abscissas of both faces of the sheet, C (x, t) is the concentration of the liquid in the sheet in the abscissa x and in time t. Ceq is the concentration reached at the equilibrium.

The solution of diffusion equation becomes:

$$\frac{C(x,t)}{Céq} = 1-(4\pi).\sum_{x=1}^{\infty}\left[\frac{1}{2n+1}\right]^2 \sin\left[\frac{(2n+1)\pi x}{L}\right]\exp\left(-\frac{(2n+1)\pi^2}{L^2}Dt\right)(eq5)$$

The total mass transferred at time t is given by:

$$M_t = -\int_0^t D\left(\frac{\partial C}{\partial x}\right)_{x=L}.dt(eq6)$$

$$\frac{M_t}{M_\infty} = 1-(8\pi).\sum_{x=1}^{\infty}\left[\frac{1}{2n+1}\right]^2.\exp\left(-\frac{(2n+1)\pi^2}{L^2}Dt\right)(eq7)$$

For short times, when the equation (5) is very useful for short durations, as it can be reduced to:

$$\frac{M_t}{M_\infty} = \frac{4}{L}\left(\frac{Dt}{\pi}\right)^{0.5}(eq8)$$ [3], [4] and [5].

$$\frac{M_t}{M_\infty} \prec 0,5$$

- **Numerical Treatment**

When the analytical treatment is not valid anymore, the problem of the diffusion can be solved by using a numerical process of finished differences explicit along the section perpendicular to the faces of the sample. The principle of this method is to divide the space and the time slice Δx and Δt successively, knowing that $x = n\Delta x$ and $t = i\Delta t$.

This method leads to:

$$CN_{(x)} = \frac{1}{M}\left[C_{n-1} + (M-2)C_n + C_{n+1}\right] (eq9)$$

With:

$$M = \frac{(\Delta x)^2}{D.\Delta t} (eq10)$$

3. Materials and Methods

3.1 Materials

Three samples are cut so that their three sides are the same.
Sample 1 : (e T = 1.3 cm, l=1.6 cm, L=1.9 cm)
Sample 2: (e L = 1.3 cm, l=1.9 cm, L=3 cm)
Sample 3: (e R = 1.3 cm, l=1.9 cm, L=2.1 cm)
A balance (of sensibility 10^{-4}g) to follow the evolution of the mass in the sample.
An oven to dry the sample in 102°C for measuring the sample in the anhydrous state.

3.2 Experimental Procedure

The samples were cut in the radial, tangential and longitudinal directions of the wood. The contact is made in one direction and the other two directions are protected by an impermeable film (glue). The Samples were soaked in liquid water contained in a beaker of 250 ml capacity. The weight gain is followed by successive weighings taken at selected intervals of time until equilibrium.

4. Results and Discussion

The results obtained are:

- The kinetics of transfer of water absorbed by the wood.
- The concentration profiles.
- The models validated by comparing the experimental and theoretical results

Figure1 illustrate the kinetics of transfer for every direction of anisotropy and shows the one-dimensional evolution of the weight as function of time. From this curve, we found that the longitudinal diffusion is always faster than the other two directions

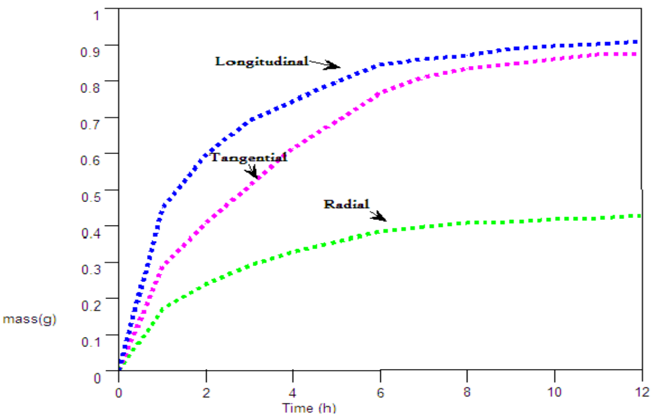

Figure 1: The dimensional variation of the water content as a function of time

Table 1: Parameter values

Main axes	*diffusivity (cm2/s)*
Radial	DR= 1.0038×10-5
tangential	DT= 1.1854×10-5
Longitudinal	DL= 1.5118×10-5

The following results are obtained by calculations on the scientific software:

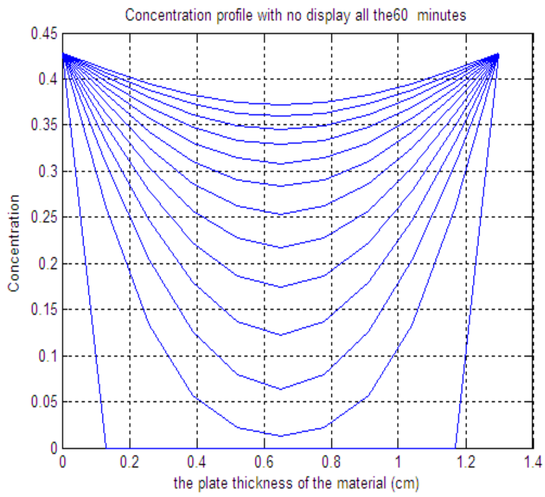

Figure 2 : Concentration profile in the tangential direction

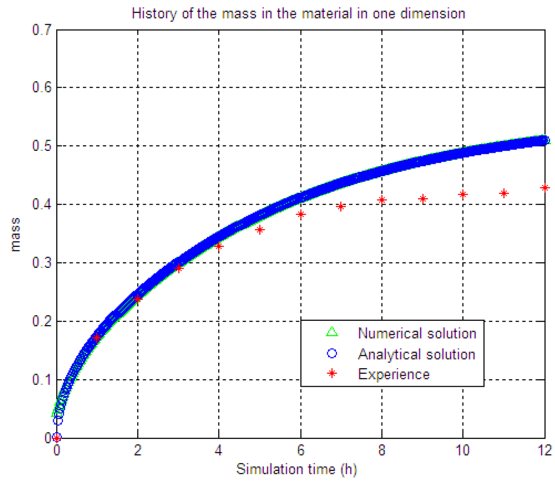

Figure 3 : the quantity of water transferred into the sample 1 as a function of the simulation time

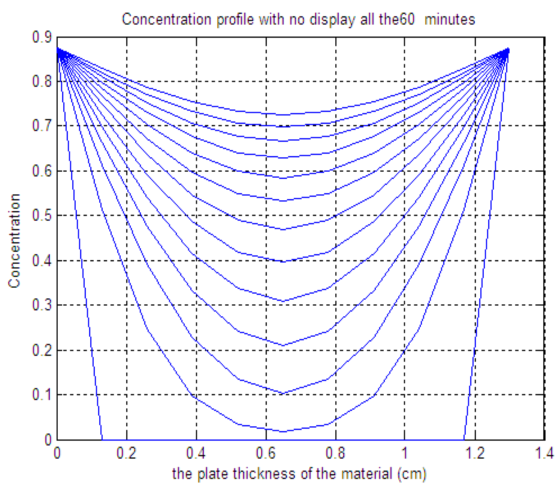

Figure 4 : Concentration profile in the longitudinal direction

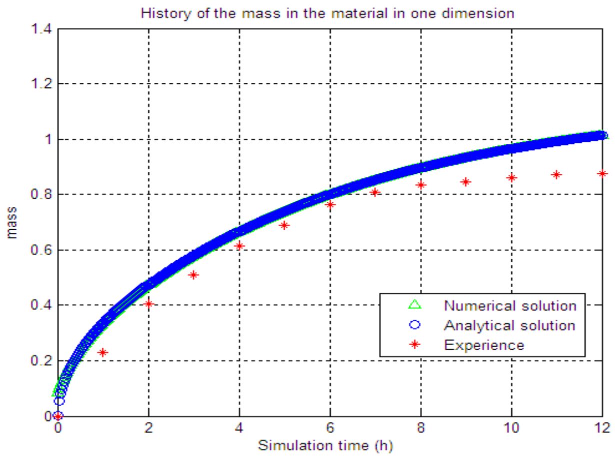

Figure 5: the quantity of water transferred into the sample 2 as a function of the simulation time

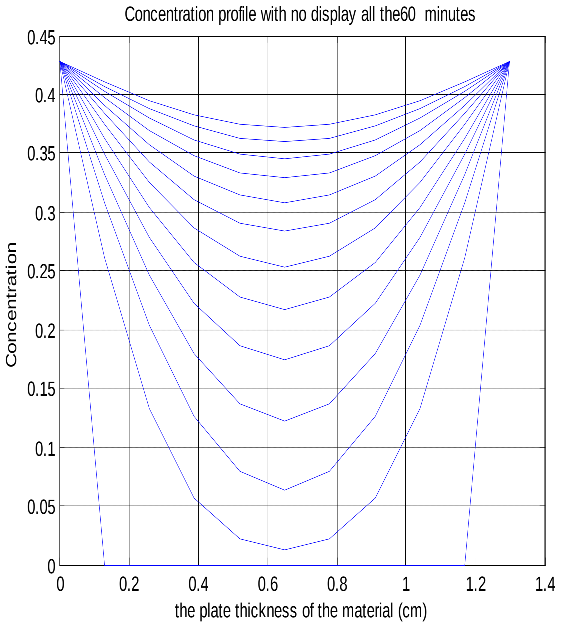

Figure 6: Concentration profile in the radial direction

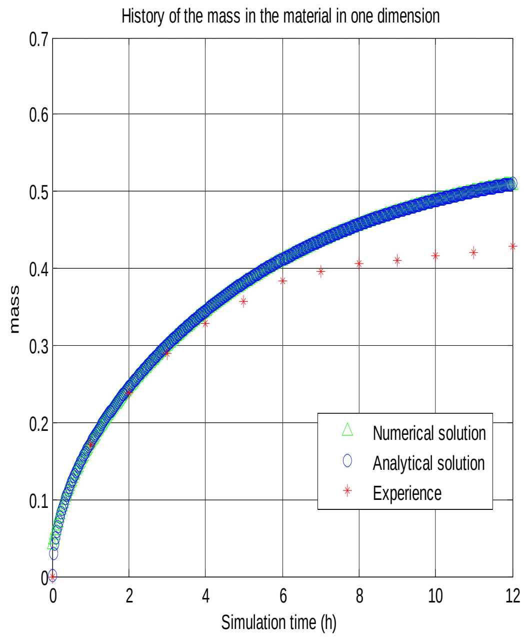

Figure 7 : the quantity of water transferred into the sample 3 as a function of the simulation time

The validity of the model is evaluated by comparing the experimental absorption with the theoretical results of the kinetic parameters above.

- In these conditions, the analytical solution and the digital model gives the same curves.
- A good concordance is found between the theoretical and experimental kinetics that's proves the validity of the model.
- Figures 2, 4 and 6 show the profiles of the concentration in water after every 60 time.
- These profiles of concentration are intended to provide good information on the water inside wood, for each point of our sample; we can easily determine its concentration.

5. Conclusion

The water absorption process above the saturation point of the fibers was studied. We were able to show some results.

- Model validation was done by comparing the theoretical results with the experimental results.
- The profiles obtained gave us good information on concentrations of water inside the wood locally.
- These models allow us to simulate in a few hours, with a very good approximation of the mass transfer can last in reality several months.

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