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On Determination of Surface Emission Factors in Wood Drying

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Summary

The diffusion problem with internal and external resistances to moisture transport is theoretically analysed with special attention paid to wood drying problems. The coefficients involved are all assumed to be constant. The results both clarify why peculiar results have been obtained earlier by others and give facilities to analyse sorption experiments that are designed to simulate a wood drying process in a practical kiln.

Introduction

The main reason for degrade of wood in the Nordic countries is surface checking. Therefore, it is important to study the stress development during drying. A successful study of that requires a good control of the moisture transport and, especially, the moisture content of the surface.

The wood drying problem can be treated as a diffusion problem. The internal moisture transport is in the first approximation well characterized by a constant diffusion coefficient. However, there is also a resistance for the moisture to leave the wood surface and to be transferred to the ambient drying air. This effect is characterized by the so-called surface emission factor. One of the components of this factor is the resistance for the moisture to penetrate the boundary layer. The theory for that is well-known from the science of heat and mass transfer. There are indications from experiments that the surface emission factor has an additional component emanating from the porous and hygroscopic nature of wood. The aim of this work is to find a method to measure this latter component and to analyse the diffusion problem theoretically applied to the wood drying problem.

The diffusion problem is of course not a new problem. Newman gave a solution already 1931 (Newman 1931 a,b) and his results were applied for the first time to the wood drying problem 1954 (Skaar 1954). Extensive measurements were made later (Comstock 1963). A new method was developed for separating the internal and external resistance to the moisture removal from wood (Choong and Skaar 1969, 1972). Other similiar methods were used by others (Rosen 1978; Avramidis and Siau 1987). A literature survey has been presented (Rosen 1987). A completely different approach has recently been used (Liu 1989). There seems to be a renewed interest for modelling the sorption process in wood, because during the last years several articles in the field have been published (Droin *et al.* 1988; Droin-Josserand *et al.* 1988, 1989 a,b; Simpson and Liu 1991; Lee *et al.* 1991; El Kouali and Vergnaud 1991; El Kouali *et al.* 1992 a,b; Mounji *et al.* 1991 a,b,c). Published data of surface emission factors are presented in Table 1. These data are obtained from experiments on various wood species.

Theory

The one-dimensional diffusion problem is expressed in the differential equation:

$$\frac{\partial u}{\partial t} = D\frac{\partial^2 u}{\partial x^2} \tag{1}$$

where u is the moisture content of wood as mass of water/mass of dry wood, t the time, x the space coordinate and D the diffusion coefficient, which here is assumed to be constant. It is also assumed that the wood piece is homogeneous, isotropic and symmetric. This is used in the initial condition given by:

$$u = u_0 \quad \text{for } x \in (0, a),\ t = 0 \tag{2}$$

where a is half the thickness of the board.

Due to the symmetry it is sufficient to consider the halfspace so that the boundary condition can be written:

$$-D\left(\frac{\partial u}{\partial x}\right)_a = S(u_a - u_{eq}) \quad \text{for } \forall t,\ x = a \tag{3}$$

where S is the surface emission factor. Subindex a refers to the value at the surface and eq to the value that is in equilibrium with the ambient air climate. At the surface there is a flux of moisture driven by the difference of the surface moisture content and the equilibrium moisture content of wood in the ambient air. If there is a low external resistance for the moisture removal, S is very large and the surface moisture content is in equilibrium with the ambient air ($u_a = u_{eq}$).