MODELING CONVENTIONAL TWO-DIMENSIONAL DRYING OF RADIATA PINE BASED ON TRANSVERSAL EFFECTIVE DIFFUSION COEFFICIENT

Y.A. GATICA†, C. H. SALINAS‡ and R.A. ANANIAS§

† *Doctoral student, Department of Wood Engineering, U. del Bío-Bío, Collao 1202, Concepción, CHILE. ygatica@ubiobio.cl*
‡ *Department of Mechanical Engineering, U. del Bío-Bío, Collao 1202, Concepción CHILE. casali@ubiobio.cl*
§ *Department of Wood Engineering, U. del Bío-Bío, Collao 1202, Concepción, CHILE. ananias@ubiobio.cl*

Abstract*— We modeled conventional two-dimensional drying of radiata pine (*Pinus radiata*) wood using the concept of effective diffusion extended to overall drying process. Effective diffusion coefficients were determined experimentally on the transversal plane and depended exponentially on the moisture content. These coefficients were characterized by two parameters determined through optimization within the context of an inverse problem. Spatially variable convection coefficients were determined in the same manner. Experiments using constant drying 44/36 (ºC/ºC) were carried out in order to determine transitory spatial distributions of moisture and drying curves, which were then used to determine and validate the model parameters. The mathematical model consisted of a partial, non-lineal, differential equation of the second order, was characterized by coefficients that varied exponentially with moisture content, integrated numerically through the finite volume method. Results of two-dimensional simulations for isothermal drying of radiata pine timber, correlated with experimental data, are shown: a) Transitory distribution of moisture gradients, b) drying curves and c) parameter of mathematical model (effective diffusion and mass convection coefficients).

***Keywords*—drying, wood, radiata pine, diffusion**

I. INTRODUCTION

Wood is a particularly non-homogeneous biomaterial with a porous anisotropic structure. For purposes of flow transport, wood is often described in terms of its properties (diffusiveness, permeability, porosity, etc.). It is taken to be a continuous, homogeneous material. However, the properties of wood differ markedly according to the spatial direction (radial, tangential, longitudinal) in which it is observed: known orthotropic behavior of wood (Siau, 1984). Moreover, there is a preferential drying direction for moisture transport, normally towards the surface exposed to the drying environment and, therefore, relied on one-dimensional modeling. Nevertheless, depending on how the wood is placed in the dryer, could result in one or more preferential directions, like discussed in Pang (1996) for relevant two-dimensional transversal transport in drying processes.

Modeling the moisture transport within wood can be done with classic diffusive models such as those suggested by Stamm (1964) or Siau (1984); those based on the thermodynamics of irreversible processes, as established by Luikov (1966); and those developed from Whitaker's multiphase approach (Whitaker, 1977).

In one dimensional models: Plumb *et al*. (1985) and Nasrallah and Perré (1988) have used the Whitaker focus. Furthermore, Jen and Chen (1991) applied a more analytical methodology following the Luikov formulation. In two-dimensional drying modeling: Cloutier and Fortin (1991, 1993) and Perré *et al*. (1993) used the moisture potential concept of Luikov's approach, whereas Turner (1996) used a model in accordance with Whitaker's proposition and incorporated aspects associated with deformation during drying. Works of three-dimensional drying simulations of wood had been performed according to Withaker`s jobs by Perré and Turner (1999) and using the approximation of Luikov by Younsi *et al.* (2006).

The properties characterizing the transport of moisture have been determined (Siau, 1995; Tremblay *et al*., 2000; Nabhani *et al*., 2003).

This study deals with diffusive models, traditionally used for simulating the drying of conifer and broadleaf wood below the fiber saturation point (FSP). Diffusive transport is the dominant mechanism in this drying range (Smith and Langrish, 2008; Hukka, 1999; Pang, 1997), but above the FSP, diffusive models are hindered by other dominant transport phenomena such as capillarity and permeability (Keey *et al*., 2000). By the way, the researchers have formulated models that made difference above and below FSP like the one proposed by Davis *et al*. (2002). Nonetheless, diffusive models can be used beyond the hygroscopic range by obtaining an effective diffusion coefficient (EDC) for water as generally done for porous materials (Simpson and Liu, 1997; Hukka, 1999; Chen, 2007), and applying it to the simulation of drying kinetics over the entire moisture range of conifer woods (Rozas *et al*., 2009). Other studies have explored the determination of diffusive coefficients using two experimental methods solved through the finite difference method (Droin *et al*., 1988) or applied to the case of one-dimensional transport in radiata pine (Gatica *et al*., 2011), the approach taken by the present authors.