# THREE-DIMENSIONAL SIMULATION OF ISOTHERMAL WOOD DRYING OF RADIATA PINE USING EFFECTIVE DIFFUSION COEFFICIENTS

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***Abstract*— The objective of the present work was to simulate three-dimensional drying of wood, based on the concept of the effective diffusion coefficient. For this, we used a conventional drying process of radiata pine in a controlled environment (dry and wet bulb temperatures of 44 and 36 ºC, respectively). This experiment allowed us to gather data on: a) the spatial distribution of moisture content at different drying times, b) the drying curve, and c) the surface emission coefficient. A differential, partial, non-linear, second-order mathematical model was used, and the exponential functions of the effective diffusion coefficient characterized the three-dimensional orthotropic (radial, tangential, and longitudinal) transport of moisture content in the wood. This mathematical model was integrated numerically through the control volume finite element method, which contemplates: a) tetrahedral elements for discretization, b) implicit Euler method for the time differential, and c) Gauss-Seidel with successive over-relaxation method to resolve the linear equation system. We compared these results for the three-dimensional spatial distributions of moisture content after 22, 44, 66, and 88 (h) of drying, and the resulting drying curves were in good agreement with the experiments.**

***Keywords*—mathematical model, wood drying, radiata pine, effective diffusion, CVFEM**

## I INTRODUCTION

A detailed understanding of the wood drying process and the optimization of its technological aspects require to know the transitory distribution of moisture content (*M*) inside the wood (Keey *et al.,* 2000). In this context, the present work shown an experimental and numerical methodology that allows postulating a tridimensional model based on effective diffusion coefficient for wide range of *M* like suggested by Hukka (1999) and analyzed by Chen (2007).

Transport models of *M* can be grouped according to the phenomenology (Ananías *et al.,* 2009; Salinas *et al.,* 2008) or physical aspects of the transport phenomena (Keey *et al.,* 2000). The latter approach includes classic diffusive models such as those presented by Pang (1997), models based on the thermodynamic of irreversible processes as established by Luikov (1966), and models developed using Whittaker's multiphase approach (Whittaker, 1977).

In particular, the diffusive models stand out for their simplicity and ease of implementation. These models are widely accepted for *M* below the fiber saturation point (FSP), given the diffusive nature of the transport when *M*<FSP. Research in this line has been done by Smith and Langrish (2008), Hukka (1999), Pang (1997), and others (Zhan *et al.,* 2007; and Pereira *et al.,* 2011). Above the FSP, diffusive models lose validity due to the predominance of capillarity and permeability in detriment to the diffusive phenomenon (Keey *et al.*, 2000). Thus, researchers have proposed models differentiated by drying stage, such as that proposed by Davis *et al.,* (2002). Nonetheless, diffusive models can be used for *M*>FSP by incorporating what is known as the effective diffusion coefficient (EDC), as analyzed by Chen (2007) and applied to the simulation of the drying kinetic for *M*<50% by Defo *et al.,* (2004) and for the entire range of *M* by Rozas *et al.,* (2009).

The problem of determining the values of the diffusive coefficient (or functions of the type given by Comstock, 1963) can be approached inversely: that is, given a known distribution of *M*, the diffusion coefficients can be determined (Simpson and Liu 1997; Liu *et al.,* 2001; Olek and Weres, 2007; Kang *et al.,* 2009). This has resulted in several proposals of inverse strategies for obtaining the EDC. The present study is framed within this context; specifically, we propose a three-dimensional simulation of conventional drying of radiata pine for the entire range of *M* based on the EDC differentiated by orthotropic (radial, tangential, longitudinal) direction. In Gatica *et al.,* (2011), the EDC of the radial and tangential directions are reported. Herein, these will be complemented by the EDC of the longitudinal direction. For purposes of validation, experimental data are generated in the form of three-dimensional distributions of *M* and drying curves. Based on these experimental data, we determine surface emission coefficients ($S_E$), which are required by the mathematical model as a boundary condition.

The resulting mathematical model is characterized by a partial, differential, second-order diffusive transport equation with variable, non-linear coefficients (exponential variation with *M*) exposed to Neumann boundary conditions. This mathematical model is inte-