SIMULATION OF WOOD DRYING STRESSES USING CVFEM

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***ABSTRACT*— The drying of solid wood and associated stresses were simulated by applying the Control Volume Finite Element Method (CVFEM) to a transversal section of solid wood on the radial/tangential plane. The transport of moisture content and stresses produced by its gradients associated with the phenomena of shrinkage and mechanical sorption were modeled simultaneously. In particular, we used a CVFEM program (Fortran 90) that allows integrating a differential equation of non-linear transient diffusion, defining triangular finite elements with linear interpolation of the independent variable within itself. The model was validated by comparing the experimental and analytical results available in the specialized literature. Finally, we showed the original results of the simulation applied to the drying of *aspen* wood (*Populus tremuloides*) at three drying temperatures.**

***Keywords:* Simulation, drying, wood, stress, CVFEM**

I. INTRODUCTION

The present study focuses on heat and mass transfer coupled with strain/stress problem during drying process in terms of modeling and simulating the drying of solid wood. A collection of related works can be found in Turner and Mujumdar (1997) and an updated review of these methods is given in Hernandez and Quinto (2005).

In particular, Cloutier and Fortin (1994) develops a numerical model that predicts the drying curve using the water potential model. In the present works, this model is adopted to simulate the transport of moisture content within the wood as described in Salinas *et al.* (2004).

The effects of heat and mass transport cause strain/ stress within the wood. Modeling this phenomenon is a complex process due to the effects that the drying process produces on the wood. These lead to stresses that cause permanent and transitory deformations due to variations of moisture contents.

The models proposed for wood focus mainly on deformations caused by the transport of energy (temperature) and mass (moisture content). Some works (Perre *et al.*, 1993; Chen *et al.*, 1997; Pang, 2000; Pang, 2007) propose one-dimensional models for determining the deformations resulting from heat and mass transport; notably, deformation by shrinkage and mechanical sorption. Likewise, in two-dimensional (Turner and Ferguson, 1995; Lin and Cloutier, 1996; Ferguson, 1998; Kang and Lee, 2004) and three-dimensional (Ormarsson *et al.*, 2003) models have been proposed for deformation.

Numerically, we use the Control Volume Finite Element Method (CVFEM) to solve the transport and deformation equations induced during the drying process. In general terms, the method CVFEM consists of a Finite Volume that is made up with Finite Elements. This model offers advantages related mainly to its intrinsic quality of conservatively given by Finite Volume Method and the topological versatility bestowed by Finite Elements Method (Baliga and Patankar, 1983).

Thus, we consider linear orthotropic variations of the properties and independent variables within the Finite Element, considering the discrete variable centered on the Control Volume. The numerical approach leads to the formulation of linear algebraic equations systems that are solved through iterative and direct methods (Gauss Saidel with SOR and Gauss Elimination, Lapidus and Pinder, 1982).

The aim of the present work is concerning with simulation of the drying/stress problem, following systematic variations of geometric and physical parameters for the analysis of stability and consistency of the algorithms developed. Moreover, we validate the results obtained by comparing them with the experimental, numerical and analytical data available in the literature.

II PHYSICAL MODEL

We study a physical model of the wood strain/stress problem during drying process. We consider the non-uniform transitory effects induced by the variation in the moisture content (M); that is: stress (s_{ij}), strain (e_{ij}), and displacements ($u_i = (u,v)$).

As shown in Fig. 1, we consider a transversal two-dimensional section of wood on the radial-tangential plane. The properties are given in Table 1 (Cloutier *et al.*, 1992). The dimensions of this piece of wood are: wide L=0.045 (m) and thickness H=0.045 (m).

The initial and contour conditions are: a) for the problem of moisture content transport, initial moisture