NUMERICAL SIMULATION OF WOOD DRYING

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Abstract

This paper presents research of the electromagnetic field distribution when drying wood in microwave field. There are being studied two situations of heating the wood in a high frequency field. The dielectric behavior of wood is strongly dependent on moisture content, density and structural anisotropy of the wood sample (Anagnostopoulou-Konst, Pissis, 1988). Through microwave drying it is being reduced the moisture of the wood, the liquid being evaporated into a vapor phase by the application of heat (Berberovic, 2007).

Keywords: heat treatment, dielectric properties, microwave drying, numerical modeling

INTRODUCTION

In 1988, Rice affirmed that the quality of drying depends on the understanding and controlling of moisture movements in wood during drying. Different techniques are available for determining moisture movement in wood during drying. Many researchers have been carried out on the difference of diffusion coefficient, water conductivity and shrinkage between the radial and tangential directions (Clouties and Fortin, 1993; Li and Plumb, 1994; Wu and Milota, 1995, and Shupe et al., 1995). In 1992 Williams studied moisture content of 13 eastern red cedar heartwood samples using both the distillation and oven-drying methods and concluded that the distillation method gave more accurate results (Hamiyet Sahin Kol, 2009).

When drying wood in the microwave field a decisional factor is the structure of the wood that limits the way of removing the water (Seyfarth, Leiker and Mollekopf, 2003). The properties of the wood structure decides the drying rates and limits of heating, so problems like internal and surface checks, splits or collapse are being avoided (Simpson, Anton TenWolde, 1999). The properties of wood are variable in many directions and a successful process of drying depends on them. Each species has different properties, and even within the same species, the variability in drying rate and properties imposes limitations on the development of standard drying procedures (Berberovic, 2007).

During drying process of great importance are:

- physical properties of drying agent;
- evaporation of water from both timber and free surface;

• hygroscopic properties of wood (depending on the species);
• hygroscopic equilibrium of wood;
• changes inside wood during evaporation (Barański, Wierzbowski and Stasiek, 2010).

MATERIAL AND METHODS

The moisture content of wood depends on the relative humidity and temperature of the surrounding air. If wood remains long enough in air where the relative humidity and temperature remain constant, the moisture content will also become constant at a value known as the equilibrium moisture content (EMC) (Baronas, 2001) .

Drying is an essential operation in the wood processing industries and is needed for the following reasons:

a) Preservation and storage
b) Reduction in cost of transportation by a weight reduction
c) Increased mechanical properties
d) Dimensional stability
e) Increased specific heat of combustion
f) Achieving an appropriate color of the wood product
g) Ability to be painted or finished (Adin Berberovic, 2007).

Important issues when drying wood in the microwave field are the dielectric properties that help us understand the molecular structure of the wood and the interaction between wood and water (Norimoto, 1970). Because of the advantage of using microwave energy in front of the conventional methods of drying, many researchers are exploring the utilization of high frequency and microwave techniques.

The study of dielectric properties was developed in time by the research of many science people - Skarr in 1948; James and Hamil in 1965; Jain and Dubey in 1988; Peyskens et al in 1984; Tinga in 1969; Jarvis et al in 1990; Dubey and Deorani in 1995 (Tabassum, 2003).The dielectric properties of wood have both
theoretical and practical importance.

The practical applications of the dielectric properties are that the density and moisture content of wood can be determined nondestructively (Olmi, 2000). It has also been reported that knots, spiral grain, and other defects can be detected by measuring dielectric properties (Martin et al. 1987).

When wood is placed in an electric field, the current-carrying properties of the wood are governed by certain properties, such as moisture content, density, grain direction, temperature; and by certain components such as cellulose, hemicellulose, and the lignin of wood. The overall effects of these parameters interact with each other and add to the complexities of the dielectric properties. (Mohammed, 2001).

The permittivity represents a complex quantity that describes the dielectric properties that influence reflection of the electromagnetic waves at interfaces and the attenuation of the wave energy within materials (William, 1975). The relative complex permittivity, ε_r, describes permittivity related to free space and it is represented as:

$$\varepsilon_r = \varepsilon'_r - j\varepsilon''_r \quad (1)$$

where ε'_r and ε''_r are the dielectric constant and loss factor

$j = \sqrt{-1}$

ε'_r describes the ability of the dielectric material to store energy

ε''_r is the ability to dissipate energy

The increase in temperature of a material due to dielectric heating can be calculated as:

$$\rho C_p \frac{dT}{dt} = 55.63 \times 10^{-12} fE^2 \varepsilon'' \quad (2)$$

Where Cp represents the specific heat of the material

ρ is the density of the material

E- electric field

f- frequency

The penetration depth (dp) is the depth into the sample where the microwave and RF power has dropped to 1/e (e=2.718) or 36.8% of its transmitted value.

The penetration depth is represented by ε'_r and ε''_r:

$$d_p = \frac{\lambda_0 \sqrt{\varepsilon'}}{2\pi\varepsilon''} \quad (3)$$

Where

λ_0 is the free space microwave wavelength (for 2.45GHz λ_0=12.2cm) (Sosa- Morales et.al, 2010)

Sandoval Torres and his colleagues presented the moisture content profile of the wood using the software Comsol Multiphysics, when drying in the microwave field (see Fig.1).

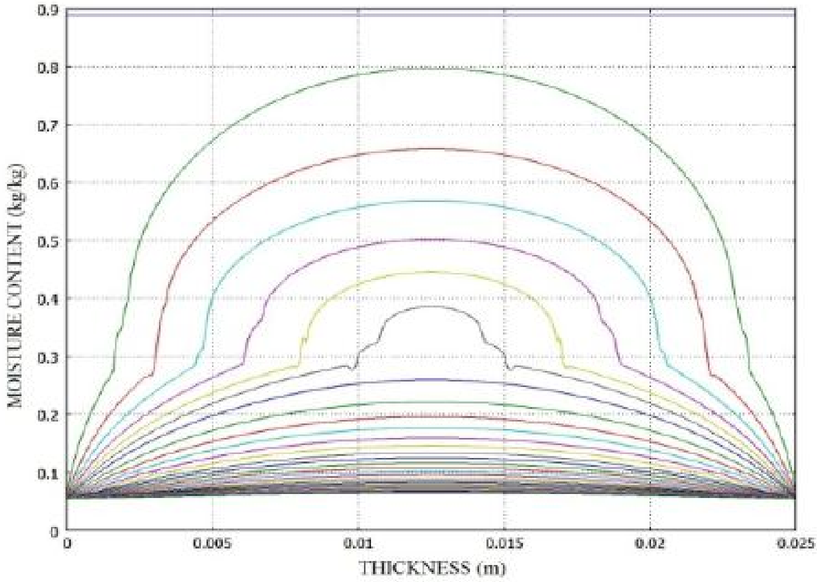

Fig.1 Moisture Content Profile (Sandoval-Torres, 2011)

RESULTS AND DISCUSSIONS

The present work presents studies regarding the numerical modelling of drying wood in the microwave field at a frequency of 2.45GHz. The numerical modelling was made using the software Ansoft HFSS (High Frequency Structure Simulator). ANSYS HFSS™ simulation results give you the confidence you need: The technology delivers the most accurate answer possible with the least amount of user involvement. As the reference-standard simulation tool for 3-D full-wave electromagnetic-field simulation, HFSS is essential for designing high-frequency and/or high-speed components used in modern electronics devices.

During research we followed electromagnetic field's distribution through the dielectric material which was considered to be pine spruce with a humidity of U=25%.

In figure 2 and 3 there is being presented the distribution of the electric field through the waveguide and wood at the frequency of 2.45GHz. Figure 3 presents the distribution of the electric field through the wood that is placed in the waveguide perpendicular. Three pieces of pine wood, of the same size are placed in the waveguide perpendicular with equal distance between them and having the same properties.

We decided to place the wood perpendicular and with distance between the pieces of pine for a better airing and better quality of the drying parameters. If the dielectric material would have been superimposed the first piece of wood would have been dried, but the other would had the same humidity or even bigger because of the lack of airing (see Fig.7).

Figures 4,5 and 6 present the distribution of magnetic field through the waveguide and material dielectric.

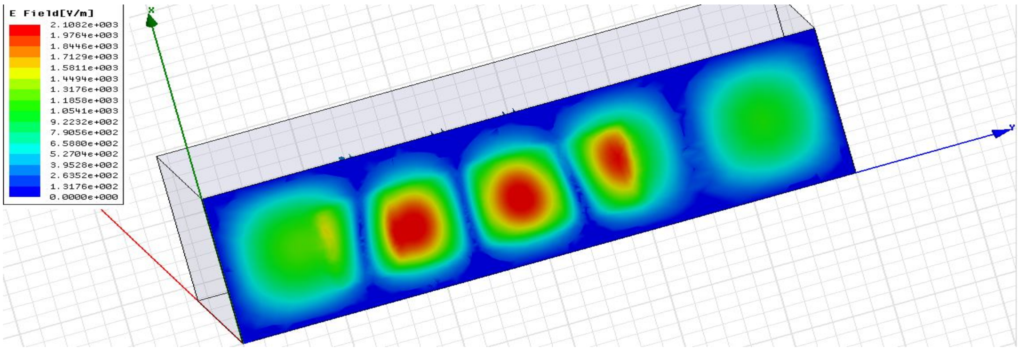

Fig.2 Electric Field Distribution Through Waveguide

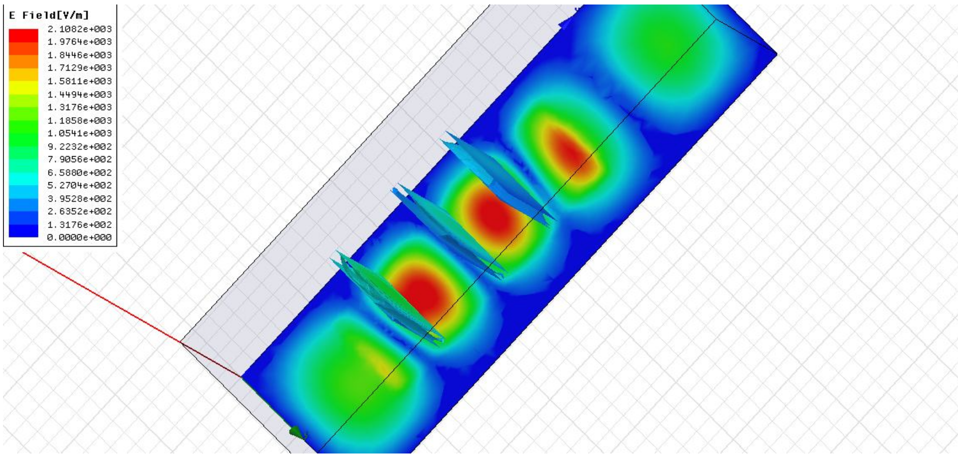

Fig.3 Electric Field Distribution Through Waveguide and Wood

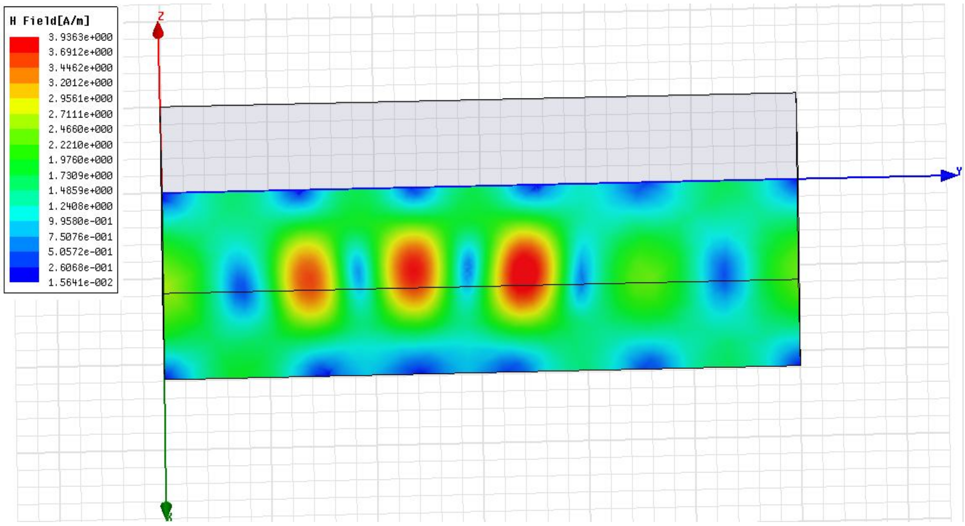

Fig.4 Magnetic Field Distribution Through Waveguide

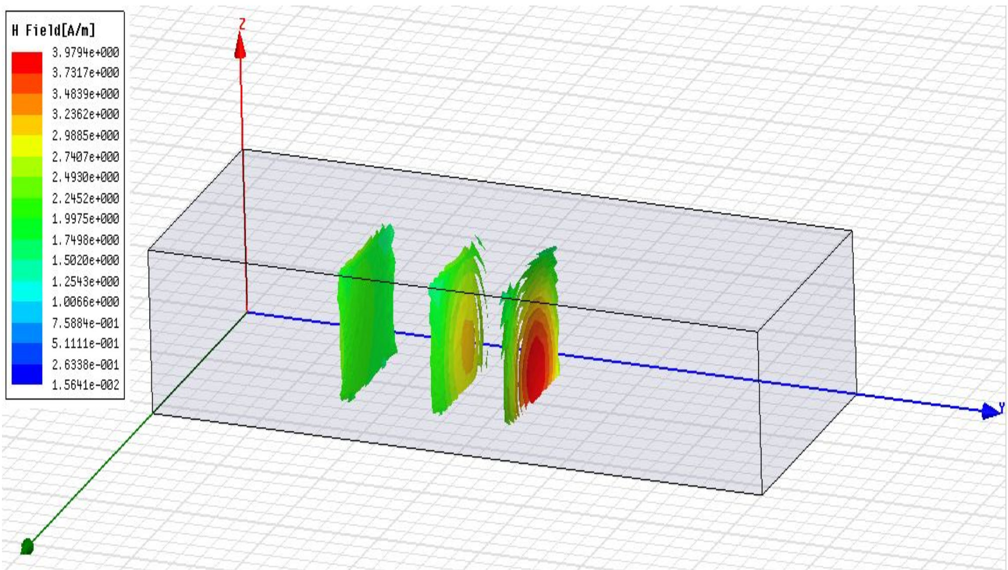

Fig.5 Magnetic Field Distribution Through Wood

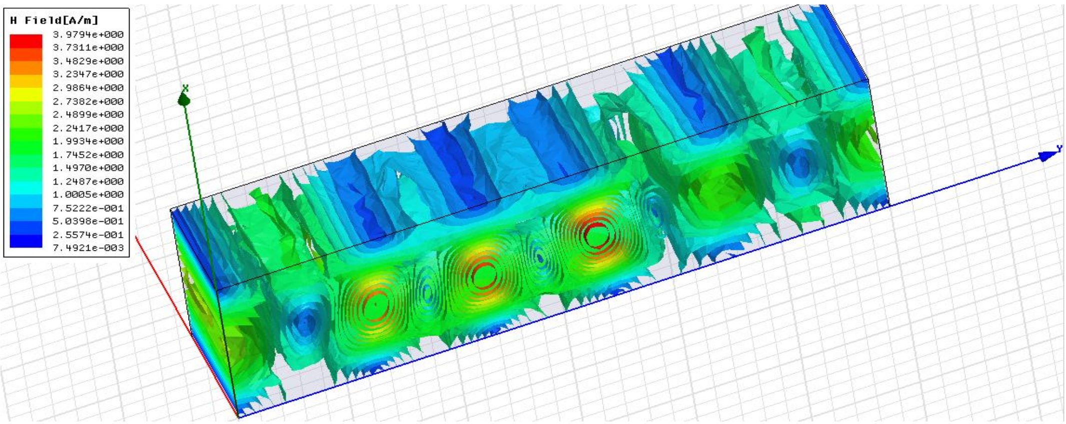

Fig.6 Magnetic Field Distribution Through Waveguide

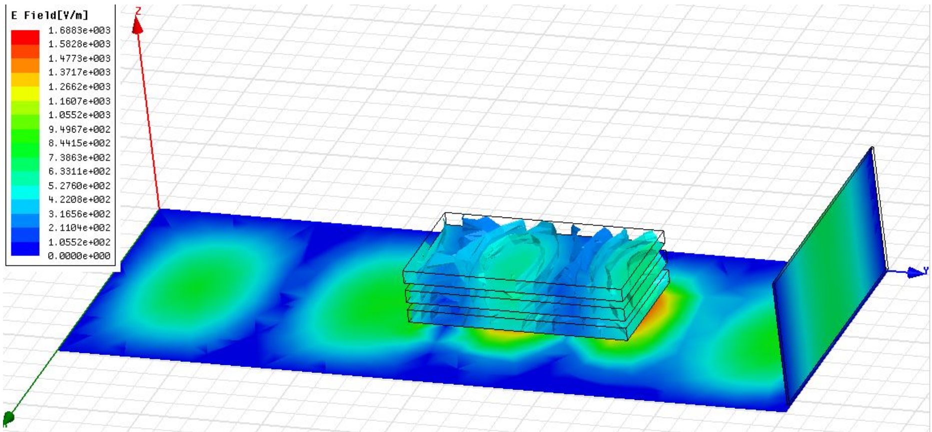

Fig.7 Electric Field Distribution Through Waveguide and Wood Placed Superimposed

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CONCLUSIONS

The numerical simulation help the user to make conclusions based on its results without needing to conduct time-consuming and expensive experiments.

Reduction of energy consumption and drying processing time are currently two important objectives of timber industry, as drying is one of the most costly consuming steps in terms of energy and time. Extensive researches have been done and are still in progress to determine the optimal drying strategy to achieve the required timber quality at minimum cost (Barański, Wierzbowski and Stasiek, 2010).

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