ASPECTS CONCERNING DRYING PARAMETER VARIATION IN MICROWAVE FIELD OF WOODY MATERIAL

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Abstract

The purpose of the present study is to monitor the variation of the drying parameters of wood in the microwave field. It is very important to know the appropriate temperature and power when drying wood so that problems like shrinkage and swelling would not appear. Drying methods used for industrial processing are based on high-frequency electromagnetic field, microwaves, sometimes in combination with vacuum or radio frequency and vacuum.

Key words: wood, microwave, dielectric properties, drying parameters, moisture content.

INTRODUCTION

The energy use of the high frequency electromagnetic field in the heating of the dielectrics offers multiple advantages, such as the reduction of the energetic consumption, the reduction of the processing times, the quality of the heating as well as economic advantages regarding the production costs (Eric St. Denis, 1998).

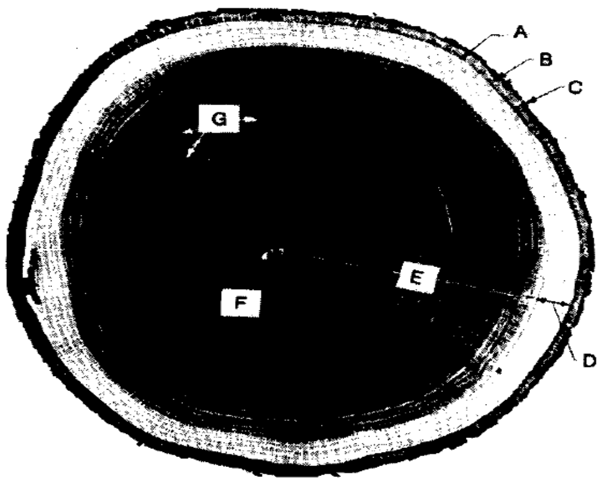
Microwaves are high frequency electromagnetic waves composed of a magnetic field and an electric one. The components of the electric field, noted (E) and of the magnetic field (H) are perpendicular on each other. The microwaves frequency ranges from 300MHz to 300GHz, equivalent to wavelengths of 1mm to 1m (Metaxas and Driscoll, 1974), (Metaxas and Meredith, 1983).

MATERIAL AND METHOD

The research was carried out in the period 01.10.2009-01.07.2010 in the Center for Research and Technological Engineering in Electromagnetic Energy Conversion. The electromagnetic field, coupled with the thermal field and together with the mass problems, involves the knowledge of the temperature and humidity dielectric material properties dependence. The usual techniques at high frequency have the advantage that, at the same time with the water vaporization, the support of transforming electromagnetic power in heat disappears and the wood cools down.

The drying characteristics are being influenced by the structure of the wood and water content. The wood is composed of bark, sapwood, heartwood, and pith (fig.1). Each wood cell has a cavity (lumen) and walls composed of several layers arranged in different ways (Simpson and TenWolde, 1999), (James W., 1975). The installation used for this experiment is a microwave system that has three basic components: a microwave generator with a maximum power of 850W, a waveguide and an applicator. The microwave system also has an absorbent charge, a directional coupler and an impedance adapter with 3 divers (Soproni et. al, 2001).

The stand is supplied at the tension of 220V±5%, 50 Hz frequency. The monomode applicator of the microwave system is designed so that the hot/cold air stream may enter from downwards upwards in the applicator in order to eliminate the water on the surface of the wood, to avoid the hot spots and, thus, to insure a homogenous temperature distribution (Maghiar and Soproni, 2003).With the help of the measurement devices we monitored the parameters of the process: the power of the microwaves, the direct power, the humidity of the hot/cold air stream at exit, the position of the divers at the adaptation of the charge impedance, the temperature of the air stream which is set so that it does not exceed 55^0C±5%, the temperature in the microwave and in the close proximity of the system. The temperature of the wood was measured with a special device - Material Moisture Wood Building Materials- Type Testo 616.



A- Cambium layer (microscopic) is inside inner bark and forms wood and bark cells;
B- Inner bark is moist and soft, and contains living tissue; the inner bark carries prepared food from leaves to all growing parts of tree;
C- Outer bark containing corky layers is composed of dry dead tissue

Fig.1. Cross Section of Oak Wood (William T.Simpson,2011)

The simulation of the drying process using special programs like Ansoft HFSS (High Frequency Structure Simulator) or Comsol Multiphysics is very important in understanding the physical processes in the interaction between wood and microwaves, which could be the basis for controlling and scheduling the heating (Hansson, 2007).

Electric field equations in microwave regime and thermal field equations are those well known (Metaxas and Meredith, 1983), (Datta, 2001).

The power dissipated in the heating systems with microwaves is proportional with the frequency, the dielectric permittivity and the distribution of the electric field (Olmi et. al., 2000), (Zhang and Datta, 1999):

$$P = \omega \cdot \varepsilon_0 \cdot \varepsilon^{'} \cdot \tan\delta \cdot E^2 \cdot V \quad (1)$$

Where *E* is the intensity of the electric field [V/m], f is the frequency [Hz]; V is the volume of material [m^3].

RESULTS AND DISSCUSIONS

The characteristics of microwave drying of wood with different initial moisture contents and geometries were investigated using a microwave installation under different power inputs (Tabassum, 2003), (Reeb, 1997) .

Temperature and moisture changes along with the drying efficiency were examined at different drying scenarios (Seyfarth, Leiker and Mollekopf, 2003). Temperature and moisture distributions during drying are highly correlated with the internal drying stresses. Harris and Taras compared moisture content distribution, stress distribution, and shrinkage of oak wood dried in a microwave frequency process with these in the conventional process (Guanben et. al., 2005). The dielectric properties of wood have both theoretical and practical importance. Theoretically, they give a better understanding of the molecular structure of wood and wood-water interactions. The practical applications of the dielectric properties are that the density and moisture content of wood can be determined nondestructively (Mohammed Firoz Kabir, 2001).

During our experiments we used oak wood, preliminarily moisturized and with natural moisture content. We measured the initial and final temperature of the wood and in the proximity of the applicator, the supply and reflected power.

Our study began be using an initial mass of 35 g oak wood preliminarily moisturized with an initial humidity of U=25.6%; for this case we used a variable power of the microwaves (300 W) without air stream to eliminate the water formed in the applicator. After two minutes the experiment was stopped because the water from the absorbent charge reached its boiling point due to the high value of the reflected power.

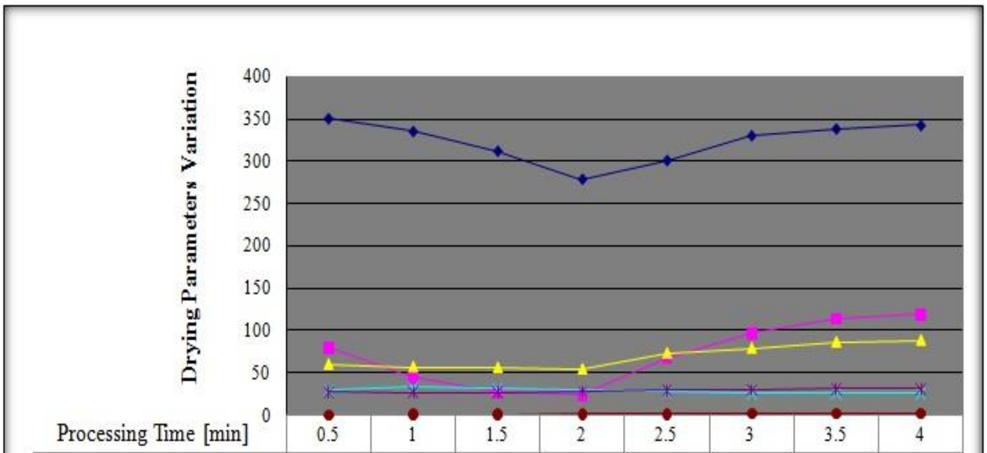
The reflected power could not be adapted to respect the condition of not exceeding by more than 20% the supply power that led to the overheating of water's absorbent charge.

The absorbent adapted charge situated at the end of the installation eliminated the energy of the residual high frequency electromagnetic field. In case the dielectric material did not absorb efficiently the energy of the microwaves, a sizable quantity of energy may have been reflected towards the microwave generator.

The excessive quantities of reflected energy may have deteriorated the microwave generator (Bandici and Molnar, 2007), (E.Da Silva, 2001). On the back side of the sample we noticed black areas caused by the thermal instability and maladjustment of the inside. The mass obtained after the drying was 27.8 g. After the failure of this experiment we decided that we would use air stream for the next case.

For the second case we had an initial mass of wood of 18.43g and moisture content of U=27%. The wood was dried using a variable power of the microwave 350W-300W for 4 minutes with cold air stream. The final mass achieved after the drying process ended was 15.27 g with a moisture content of U=19.6%. Because the wood was preliminarily moisturized, the process of evaporating water from the dielectric material was quicker, the ratio between the supply and reflected power was hard to maintain at its normal values.

The reflected power showed high values, even of 120 W, a problem that made us stop the microwave installation. The values obtained during this study and the variation of the drying parameters are shown in figure 2.



Processing Time [min]	0.5	1	1.5	2	2.5	3	3.5	4
Supply Power[W]	350	335	312	279	301	330	338	342
Reflected Power[W]	80	45	28	24	68	97	115	120
Wood Temperature[°C]	61	57.8	56.9	55	74	79.8	87	89
Output Air Temperature[°C]	29.8	33.6	32	28.9	27.1	26.8	26.3	26
Output Air Humidity[%]	28	27.5	27.2	28.9	29.8	30.2	31.4	31.8
Power Consumption[W]	1	1.31	1.42	1.65	1.82	1.98	2.11	2.28

Fig. 2. Parameter Variation in Microwave Drying Process with Cold Air Stream

Figure 3 describes the variation of the three divers while trying to keep the value of the reflected power at normal values.

For the last experiment we decided to use natural moisturized oak wood. We had an initial mass of 45.6 g with a moisture of U=45.6%. After drying the sample in the microwave field (350W-263W)/8 minutes using hot air stream, we obtained a quantity of 23.4g of dried wood with a moisture content of 22.1%. It is remarkable the difference of weight and moisture of initial and final value, due to the supply power used during the experiment with hot air stream that favored the elimination of water from the applicator and from the dielectric material. It was also noticeable the value of the output air humidity that increased to the high value of 107.8 due to the big amount of water that evaporated from the applicator.

For this experiment we successfully managed to keep the reflected power at normal values. Because we used hot air stream, the wood temperature increased even to 125^{0}C.

Figure 4 presents the experimental data obtained and the variation of the drying parameters.

Figure 5 presents the variation of the reflected power and the consumption power depending on the supply power.

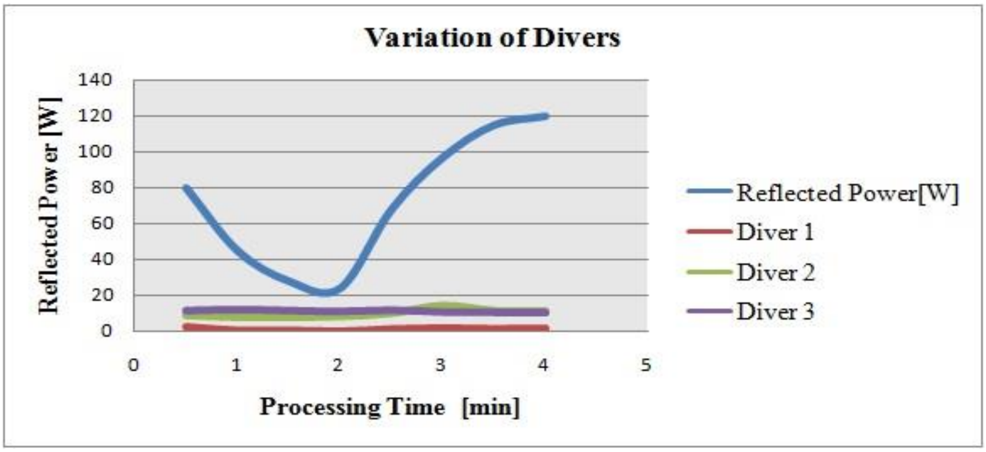
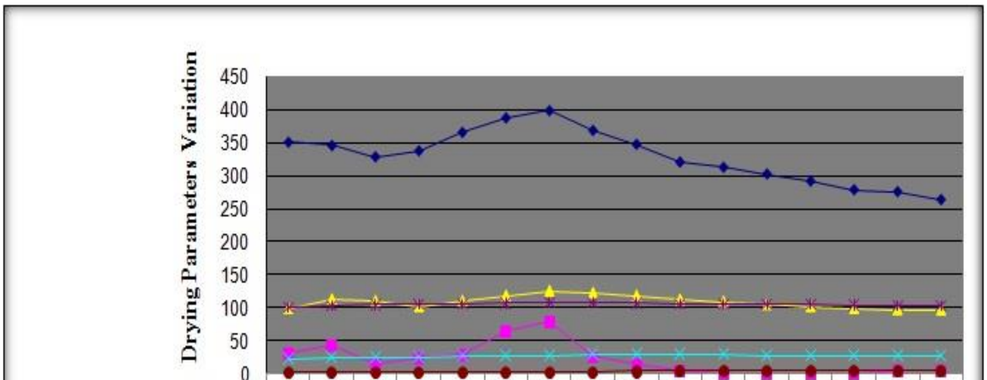


Fig. 3. The Variation of the Divers



Processing Time[min]	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Supply Power[W]	350	345	328	337	365	387	398	368	347	320	312	302	291	278	275	263
Reflected Power[W]	30	43	15	23	28	64	78	25	15	5	0	0	0	0	5	5
Wood Temperature[°C]	98.6	112.4	110	102	110	118	125	122	118	112	109	105	102	99	97	96.2
Output Air Temperature[°C]	23	24.8	25.6	26.2	27	27.8	28.1	29	30.1	29.3	29.1	28.7	28.5	28.3	27.9	27.6
Output Air Humidity[%]	101	103	104.5	106	106.5	107	107.4	107.8	106.9	106.5	106	105.7	105	104.2	104	103.6
Power Consumption[W]	2	2.2	2.45	2.36	2.54	2.6	2.81	2.9	3.1	3.23	3.45	3.52	3.7	3.81	3.93	4.1

Fig. 4. Parameter Variation in Microwave Drying Process with Hot Air Stream

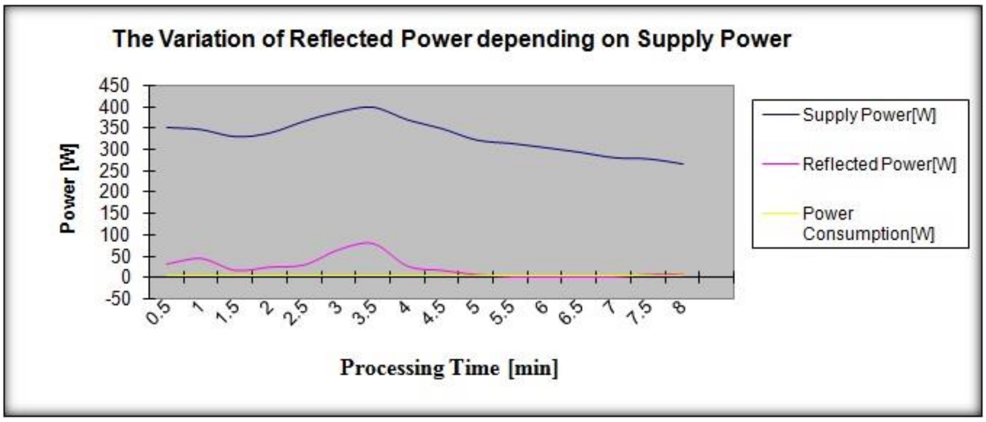


Fig. 5. The Variation of the Reflected Power depending on the Supply Power

CONCLUSIONS

When heating materials we can choose many methods. If we are using the method of convective heating the heat is transferred to the material surface by a circulating fluid; when using the radiation method, heat is transferred to the material surface by radiation. In the case of conductive heating the heat is transferred to the material surface through the connection to another material surface with higher temperature. When talking about internal heating, only the material will be heated, compared to conventional heating where the surrounding area takes part in the transfer of energy or heat. The material heats instantly in the interior regions, making heating faster than with conventional heating.

As a result of the experimental data one may notice the necessity of the variation of the power generated by the magnetron for the adaptation of the charge impedance by modifying the position of the divers 1, 2 and 3 so that the reflected power would be zero or would converge to 0. The maximum reflected power for an adapted enclosure must not exceed 20% of the direct power.

It is important to use air stream to create homogeneity of the temperature in the whole mass of the seeds, to avoid hot spots and to eliminate the water from the seedbed.

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