WOOD DRYING IN MICROWAVE FIELD

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Abstract

The main objective of this research is to determine the effects of the thermal treatment with microwaves on the wood material for different processing parameters. During our studies we followed the relation between the thermal properties of the wood and the required heat and energy to achieve the drying temperature. The water from wood must be removed to some degree to make the wood usable (Reeb, 1997).

Key words: microwave drying, humidity, woody material, dielectric properties, parameter variation.

INTRODUCTION

Microwaves occupy the portion of the electromagnetic spectrum between 300MHz and 30 GHz (Metaxas and Meredith, 1998). Microwaves are a more efficient method of drying than the traditional thermal treatment, because it delivers the energy required for heating due to its volumetric, direct coupling with the material (Mujumdar, 2006), (Metaxas and Meredith, 1983).

Articles (Metaxas and Meredith, 1983) and (Metaxas and Driscoll, 1974) present a series of theoretical aspects concerning the industrial heating in a microwave field and compares the properties of dielectric materials and their evolution when exposed to radio-frequency and microwave, and (Metaxas, 2001) describes the recent steps forward made in relation to the numerical techniques that are used when simulating applications in the domain of microwave field heating.

MATERIAL AND METHODS

Microwave drying represents a volumetric process, which is different from other drying conventional methods (Simpson, TenWolde, 1999). The heat is being generated in the interior of the material through a selective absorption of the electromagnetic energy by the water molecules, creating a transfer of humidity outside the material, unlike the other methods that implicate a slower heat transfer through conduction inside and outside the nucleus for generating humidity transfer (Maghiar and Soproni, 2003), (Datta, 2001). The dielectric properties describe the behavior of material when subjected to electromagnetic fields for dielectric heating applications (Nelson, 1995). These properties are important in predicting power absorption rate by the material in a microwave field. Dielectric properties determine the penetration depth of microwave power and local power absorption rates. The choices of measurement technique, equipment and sample holder design depend upon the dielectric and frequency (Bandici and Molnar, 2007). With the development of suitable equipment for time domain measurements, techniques were developed for measurement of dielectric properties of materials over a wide range of frequency (Molnar et.al., 2008). Since modern microwave network analyzers have become available, the methods for obtaining dielectric properties over a wide range of frequency have become even more efficient. The change of microwave energy absorption value by the wood appears because of the material properties variation with temperature and humidity (Silva, 2001), (Denis, 1998). These parameters are dielectric constant (ε'), the dielectric loss factor (ε''), that lead to the calculation relation for permittivity:

$$\underline{\underline{\varepsilon}} = \varepsilon' - j\varepsilon'' \qquad (1)$$

The relation between the dielectric loss factor and the dielectric constant is the tangent of the loss angle:

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \qquad (2)$$

During our research we used the stand within the laboratory of microwave Technologies, EMUEE department, faculty of Electrical Engineering and Information Technology, University of Oradea. This installation is composed of the following: Microwave generator with maximum power of 850 W, waveguide, monomode applicator, absorbent charge, hot air source with regulation of the temperature, electrical inter-blockage, impedance adapter with 3 divers, directional coupler. The stand is supplied at the tension of 220V±5%, 50 Hz frequency. The microwave generator has adjustable power and an included potentiometer for adjusting the power of the microwaves. The monomode applicator has parallelepiped form with interior sizes of 109.22*54.6*150mm.The monomode applicator is designed so that the air stream may enter from downwards upwards in the dielectric's material bed in order to eliminate the water on the surface of the wood, to avoid the hot spots from the bed and so to insure the homogeneity of the temperature in the entire mass of the dielectric (Hathazi and Maghiar, 2003).

The absorbent adapted charge situated at the end of the installation eliminates the energy of the residual high frequency electromagnetic field. In case the dielectric material does not absorb efficiently the energy of the microwaves, a sizable quantity of energy may be reflected towards the microwave generator (Metaxas and Meredith, 1983). The excessive quantities of reflected energy may deteriorate the microwave generator.

The circulator protects the equipments of the system with microwaves by determining the movement of the microwaves in a single direction. There are three ports in the circulator: one is connected to the microwave generator, the other is connected to the applicator and the last to the artificial charge.

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 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 doesn't exceed 55^0C±5%, the temperature from the microwave bed and in the close proximity of the system.

The temperature of the wood was taken with a special device - Material Moisture Wood Building Materials- Type Testo 616.

RESULTS AND DISCUSSIONS

For determining the percentage of humidity of the dried wood sample we use the mass of the wood before drying, m_i, and after drying m_u (Maghiar and Soproni, 2003):

$$U\ [\text{Humidity}] = \frac{m_i - m_u}{m_u} \times 100[\%] \qquad (3)$$

In our research we chose two drying cases using for each one three samples of wood, beech wood with different weights and moisture content. We applied in both cases variable power with cold air stream; for the first case we chose a higher power but following so that the reflected power remains at normal values and not reach more than 20% of the direct power.

1. In the first case we had the next three samples: Sample 1, Sample 2 and Sample 3.

Table 1 presents the initial and final values of the samples concerning weight, moisture, temperature.

We measured the final humidity of the wood with a special device - Material Moisture Wood Building Materials- Type Testo 616 after 15 minutes from the end of the experiment so that the dielectric is cooled and ready for measurement.

Table1

Drying Parameters	*Sample 1*	*Sample 2*	*Sample 3*
Variable Power	200W-120W-60W/10 minutes		
Initial Weight	49.18g	50.76g	31.64g
Final Weight	38.63g	45.79g	28.35g
Initial Humidity	28.5%	46%	21.6%
Final Humidity	20.8%	31.7%	16.4%
Humidity calculated with formula (3)	27.31%	10.85%	11.6%
Initial Output Air Temperature	23.87^0C		
Final Output Air Temperature	27.8^0C		
Initial Output Air Humidity	55.76%		
Final Output Air Humidity	36.5%		

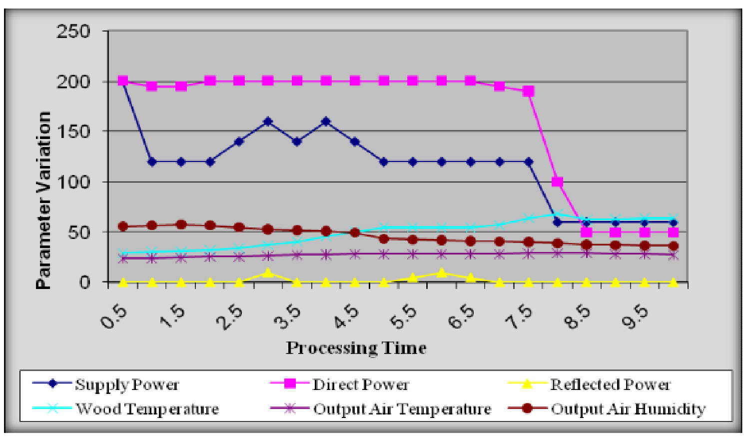

Fig.1 Parameter Variation in Variable Heating using cold air stream

2. In the second case we had the next three samples: Sample 1, Sample 2 and Sample 3.We positioned sample 1 on the down part of the applicator, for a better airing. In this case we used a lower variable power during the 10 minutes of drying (See fig.2).

Table 2 presents the initial and final values of the samples concerning weight, moisture, temperature.

Table2

Drying Parameters	***Sample 1***	***Sample 2***	***Sample 3***
Variable Power	200W-50W/10 minutes		
Initial Weight	20.31g	25.51g	27.49g
Final Weight	18.36g	24.09g	25.84g
Initial Humidity	33.6%	31.4%	22.6%
Final Humidity	10%	27%	28%
Humidity calculated with formula (3)	10.62%	5.89%	6.38%
Initial Output Air Temperature		22.6^{0}C	
Final Output Air Temperature		28.1^{0}C	
Initial Output Air Humidity		51.8%	
Final Output Air Humidity		36.2%	

From the data presented in the table we may see that sample 1 which was positioned in the direction of the cold air stream shows a better evaporation of the water with a significant difference between the initial and final humidity.

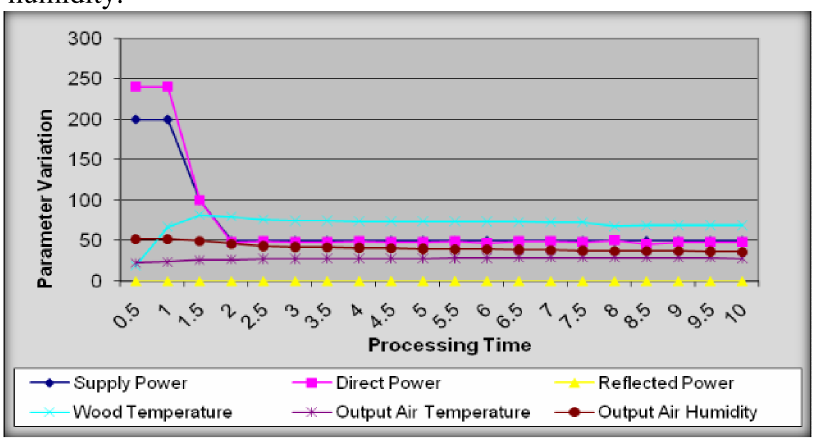

Fig.2 Parameter Variation in Variable Heating using cold air stream

CONCLUSIONS

The influence of the dielectric properties on wood heating by absorption of energy through radio frequency or microwave frequencies has been known for some time, and many potential applications have been explored (Simpson, 2001), (Seyfarth, Leiker, Mollekopf, 2003). As a result of this experiment we may say that the continuous monitoring of the generated power is required, in order not to reach an excessive temperature. It is important to use microwave with cold air stream to eliminate the high humidity and to have homogeneity of the temperature in the entire mass of the dielectric.

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