The Influence of Microwaves on Wood Drying and Moisture Migration Inside

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Abstract: ***This paper presents a study on the behavior of wood materials which contain different amounts of water in the presence of microwaves.***

Keywords: ***samples; dispersed medium; electromagnetic waves; polar molecules; microwave drying.***

I. INTRODUCTION

Drying is the physical process of removing wet substances, which result only solid substances, based on the thermal effect of high frequency waves. This process can be achieved by removing water in vapor form the material's surface, where pressure, temperature and air humidity are external conditions that may influence the process, and the second process is the moisture movement within the solid. In the second case the key external variables are temperature, humidity, the air's speed and circulation direction, the solid's physical form, mixing request and methods of fixing the solid along the cycle, being controlled by vapor diffusion on the solid's surface.

A porous medium can be considered as a dispersing medium, in which the volume that is unoccupied by the solid can be taken by the the liquid or gas part, depending on its porosity as well as on the ratio of pore area and total volume. [1,2,5]

In this paper we have tried to conduct a study on the behavior of wood materials subjected to microwave drying, experiment in which we could measure the temperatures and the pressures in the product for different exterior conditions for several wood essences (beech, oak and softer essence – fir tree).

A. MOISTURE TRANSFER IN POROUS MEDIA

For a better understanding of this pnenomenon we should first notice the properties of porous media to retain moisture, which actually represents their absorption power and their water retention capacity.

If these environments can react with water, causing a chemical reaction, the power absorption as well as the capillarity changes substantially, increasing the absorption power because besides the two properties there is also a chemical bond that leads to increasing the water storage capacity.

The absorption isotherms obtained were classified into five main types Brunauer in 1944, because the amount of water absorbed per solid substance unit depends on temperature, vapor pressure and absorbent nature.

If we increase the value of the temperature so will increase the water vapor amount, in a different way depending on monomolecular absorption capacity, plurimolecular absorption capacity and water fixing capacity.

If the porous medium has a much higher water retaining capacity than absorbing capacity and we analyze the condition of equilibrum we see the emergence of some differences between wet air pressure and water pressure being known as capillary, which directly influences drying. [6.7]

Another way to remove water from samples is vaporizing, which has been very well described by Dalton, who noted that at the liquid-gas layer limit there is a thermodynamic equilibrum between the wet surface and the gas particles found in the vicinity of this layer, because its molecules are in constant movement all throughout the drying process.

This process of getting rid of the moisture contained by our sample is a much slower one, because the phenomenon occures under the influence of environmental temperature and is considered as being an adibatic process because by having a single heat source which is air, the circulation direction of the water particles will be towards the gas state, and the temperature will decrease to the liquid state.

Starting form Dalton's law, Sprenger has established an empirical relation that has been experimentally verified by Häussler, relation that is based on air velocity and from these studies results that in the drying process, in addition to temperature and pressure variation what also matters is the total pressure to which the system is subjected, where in the installation we use vacuum pumps that have an influence on the evaporation rate.

Another important element that affects the microwave drying process is the penetration depth, which increases with increasing wavelenght. In the process of microwave drying, this penetration depth is in the tens of milimeters and is influenced both by temperature and by that dielectric's properties.

Of the 6 bands allocated to microwaves in the electromagnetic spectrum of 433,92 MHz, 2,45 GHz, 5,8 GHz, 17,85 GHz, 22,125 GHz the most used are those of 915 MHz in the U.S.A and 2,45 GHz in Europe, because only at these frequencies microwaves generators can be used as reliable oscillations sources and powers from 0,2 to 30 KW.

Drying a wet material consists of a transfer of moisture from the material to the environment, and if we consider the amount of water removed, elimination done through evaporation, transmitting a quantity of heat with a convenient temperature per unit area in unit time we see that the process of drying goes through different phases, as shown in the figure below where in the first phase the material subjected to drying is brought to a certain temperature, then water comes out in different ways leading to a contraction of the inner capillaries and its volume becomes equal to the volume of water eliminated, and in the third phase the water from the surface capillaries is removed at a very low drying speed until the contraction line is reached, and in the end remains a small amount of water that cannot be eliminated [2,3,4].

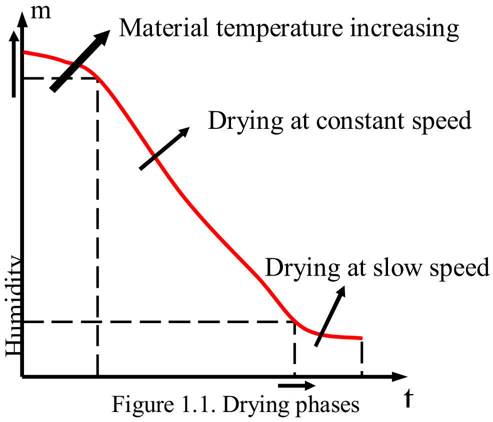

Figure 1.1. Drying phases

Electromagnetic wave induces two processes at microscopical scale, namely an oscillation of electrons and other free charges, that are characterized by conduction losses and a rotation of polar molecules at the frequency of the wave characterized by dielectric losses. [7,9].

With the use of energy an acceleration of moisture migration within the material is obtained, but also a reversal of the temperature value inside the material, being higher inside the product and therefore dielectric losses are higher in that area, so we can say that internal evaporation is accelerated with the help of waves.

As shown in the studies made by Parési regarding the improvement of the efficiency of drying techniques using numerical simulations, it is possible to find a solution to electromagnetic wave drying with having a small consumption of energy and a very short drying time [8,9]

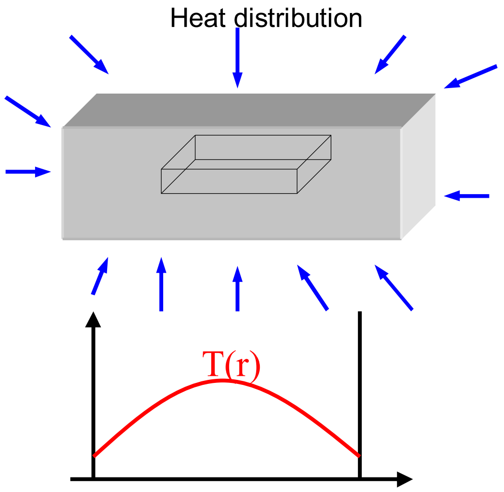

Figure 1.2. Microwave drying: heat and humidity distribution

In the next experiment we used, samples of oak and lime which are at specific humidity, using the system with the features:

- anode current - 300mA
- Anode voltage -3600
- Filament voltage - 3.3 V
- Filament current - 10.5 A
- Resistance - 0.03 Ω

- Dimensions of guide: 86.4 x 43.2 x 122.4 mm

Electronic Balance allows measuring down to 3100 g with an accuracy of 0.1 g.

(Table 1) Dry wood (lime and oak dried at room temperature).

Nr	Dimensions [mm]	Initial mass[g]	Dry weight [g]	Working temp. [^{0}C]	Initial moisture	Partial moisture	Working time [s]
1	100x40x35	110,3	107,5	24	60	50,28	50
2	100x40x35	107,5	104,7	47	50,28	41,3536	100
3	100x40x35	104,7	102	66	41,3536	34,085	150
4	100x40x35	102	99,8	88	34,085	27,1445	200
5	100x40x35	99,8	97	117	27,1445	17,8989	250
6.	100x40x35	97	95,4	131	17,8989	12,6109	300
7.	90x40x35	74	71	24	60	46,1467	50
8.	90x40x35	71	68	57	46,1467	32,1934	100
9.	90x40x35	68	63,2	78	32,1934	9,8681	150
10.	90x40x35	63,2	62,4	98,8	9,86	6,14	200
11.	90x40x35	62,4	-	-	-	-	-
12.	90x40x35	-	-	-	-	-	-
13.	210x100x35	565,2	565	24	60	58,5186	25
14.	210x100x35	565	565	43	58,5186	58,5186	50
15.	210x100x35	565	564,7	57	58,5186	56,2966	75
16.	210x100x35	564,7	563,1	77	56,2966	44,4456	100
17.	210x100x35	563,1	561,8	98	44,4456	34,814	125
18.	210x100x35	561,8	559,6	101	34,814	18,52	150
19.	90x60x35	279,9	279,7	24	60	59,5152	25
20.	90x60x35	279,7	278,1	46	59,5152	55,6365	50
21.	90x60x35	278,1	273,4	75	55,6365	44,2428	75
22.	90x60x35	273,4	268,6	86	44,2428	29,6067	100
23.	90x60x35	268,6	263,4	96	29,6067	17,0009	125
24.	90x60x35	263,4	260,8	98	17,0009	10,698	150

Oak Samples [s] have dimensios table: 210x100x35 100x40x35 and in [mm], and lime samples [T] have dimensios table: 90x40x35 and 90x60x35

(Table 2) Green wood (freshly cut lime and oak)

Nr	Dimensions [mm]	Initial mass [g]	Dry weight [g]	Working temp. [^{0}C]	Initial moisture	Partial moisture	Working time [s]
1.	100x40x35	110,3	109,5	26	70	67.924	50
2.	100x40x35	109,5	106,1	45	67.924	61,5107	100
3.	100x40x35	106,1	100	58	61,5107	50,0019	150
4.	100x40x35	100	94	71	50,0019	38,6817	200
5.	100x40x35	94	88	82	38,6817	27,3608	250
6.	100x40x35	88	83	98	27,3608	17,9273	300
7.	90x40x35	74	73,2	29	70	67,058	50
8.	90x40x35	73,2	69	53	67,058	51,6181	100
9.	90x40x35	69	65,2	76	51,6181	37,6449	150
10.	90x40x35	65,2	63,3	84	37,6449	30,6598	200
11.	90x40x35	63,3	61,4	106	30,6598	23,6742	250
12.	90x40x35	61,4	59,6	156	23,6742	17,0566	300

(Table 3). Wood saturated (lime and oak waterlogged)

Nr	Dimensions [mm]	Initial mass [g]	Dry weight [g]	Working temp. [^{0}C]	Initial moisture	Partial moisture	Working time [s]
1.	100x40x35	122,7	121,8	19	87	84,4009	50
2.	100x40x35	121,8	117,1	48	84,4009	70,8278	100
3.	100x40x35	117,1	111,1	76	70,8278	53,5004	150
4.	100x40x35	111,1	104,1	89	53,5004	33,2851	200
5.	100x40x35	104,1	101,5	112	33,2851	22,8887	250
6.	100x40x35	101,5	99,6	124	22,8887	17,4017	300
7.	90x40x35	84,6	81,4	14	89	78,825	50
8.	90x40x35	81,4	79,3	20	78,825	72,1477	100
9.	90x40x35	79,3	75	73	72,1477	58,475	150
10.	90x40x35	75	66,6	83	58,475	31,7656	200
11.	90x40x35	66,6	61,5	76	31,7656	15,5492	250
12.	90x40x35	61,5	59,7	114	15,5492	9,8258	300

Fig.1.3. Installation view

Fig.1.4.Dry wood burned lime

Fig 1.5. Wood of green oak

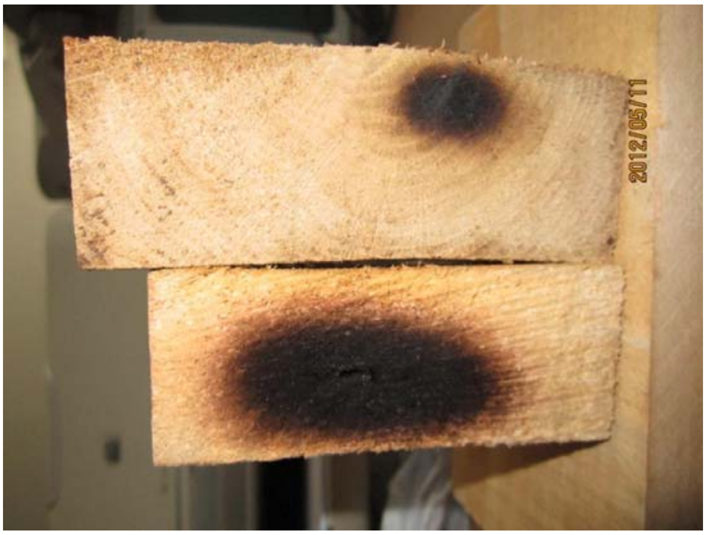

Fig.1.6. Essence of oak and lime burned

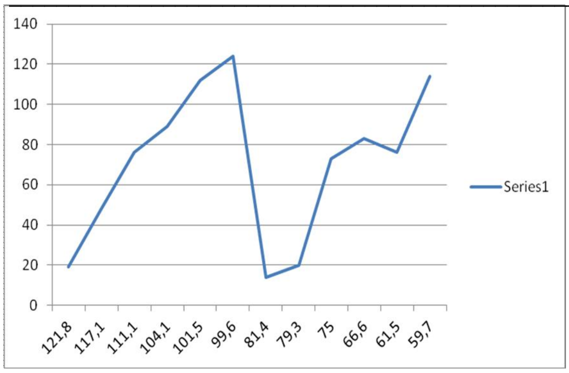

Fig 1.7. Drying graph of oak and lime

III. CONCLUSIONS

It can be noticed that oak samples does not support high temperatures, causing deformations in it and becoming unusable.

Pressure inside the wood is small connected to the high loss during drying.

At the beginning of the drying process the losses are higher caused by the air they contain.

When the pressure is higher than saturated pressure, water boils.

In the absence of free water the total pressure is considered to be in equilibrum to local temperature and moisture content, and the pressure is smaller than saturated pressure.

Drying speed depends on the wood's temperature, exhausting pressure and its properties and especially permeability.

There are small losses of heat and moisture along the side planks due to the small permeability in transversal direction.

Loss of moisture in harder woods is more linear.

From experiments we observed that drying is influenced by the length, moisture moves along the longitudinal direction, and if its pore size prevents lime purge vapor generation because it has higher permeability, it is slower drying which results in ultimately its destruction by burning wood.

So basically how much wood is softer the more sensitive it is.

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