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# WETTABILITY CHARACTERIZATION OF *MDF* COMPOSITE MATERIALS USED FOR INDUSTRIAL PRODUCTS

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***Abstract:*** *The growing concern for the environment, in relation to the need for more versatile polymer-based materials, has led to a high interest in research into polymer composites filled with natural-organic fillers, which come from renewable sources. MDF is a high grade, composite material and it is made from recycled wood fibers and resin, and it is less expensive This composite material is dried and pressed to produce dense, stable sheets and because of this process, MDF does not warp or crack like wood. And since MDF is made from small particles, it doesn't have noticeable grain patterns, showed by electronic microscopy. This will result in a smoother finish for the industrial product. In general, wood contracts or expands when it is exposed to changing heat and humidity and can appear some cracks on the industrial products. In this paper were realized water absorption tests on the MDF samples, in function of different temperature and humidity levels. The water absorption content for each piece of MDF composite material is represented as a percentage of the weight of the water and oven-dry weight. The humidity absorption depends on the composite material type, their structure, and it depends on the environment in which the product is used. The quality and moisture resistance of a composite material is extremely important for the durability and degradation degree of an industrial product.*

***Key words:*** *MDF composite material, moisture, thermostat enclosure, microscopic structure, industrial products.*

## 1. Introduction

In general, moisture absorption is known to alter many of the mechanical properties of polymer-based composites. For ultrasonic characterization of moisture content can based on the transmission of acoustic waves through composite plates.

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The composite materials are used in many fields, such as automotive, aeronautic, transport, construction, armament, furniture, etc., grace of their attractive mechanical properties, high rigidity, low relative weight, and much higher moisture resistance than wood [5].

The effect of water absorption/desorption on their mechanical properties was remarked and can induce severe changes in the material behavior.

In literature, was observed that a lowering of the glass transition temperature with water content and the appearance of microcracks due to induced residual stresses. At the same time, the moisture content generates swelling and density variations. The most common methods for characterization are: weight measurements or nuclear magnetic resonance spectroscopy, unfortunately but they are generally destructive. Moisture content can be estimated using acoustic waves, determining the change of the material mechanical properties. The method is nondestructive and allows in situ measurements [1].

Wood is a hygroscopic material. The moisture content of a wood sample is expressed by the percentage of the mass of water present in the sample to the relative anhydrous mass. The wood must be dried before being used in the various industries; therefore, it is necessary to carry out a control of its humidity. Wood drying can be done either in the atmosphere or in furnaces or both at the same time.

Most drying processes use a system with a temperature and humidity-controlled thermostat enclosure. Most of the mechanical and physical properties of wood or composite material depend on the final humidity [2]. Generally, the composite material can be degraded by a drying process due to the severe conditions to which it is subjected. In this study are presented the effects of drying and the types of defects that result. The humidity contained in fresh or dry wood can be evaluated at 35% for fir and can increase up to 300% for red wood [3].

To measure the moisture of the composite materials there are several methods, but the most common used are:
-by oven-drying;
-distillation;
-the electrical method.

The oven-drying method is not very precise, because the wood is dried at high temperatures above 103±2$^o$C. The method considers that the lost weight corresponds to the evaporated water, but it does not consider that volatile extractions are also lost by evaporation.

The distillation method presents a modification compared to the oven-drying method because the wet wood is dried in immiscible water where there is a solvent for the volatile extractions.

The electrical method is often used to measure moisture content in composite materials because it gives immediate and accurate results.

MDF is a highly stable material compared with solid wood. The effect of water content change on tensile strength of MDF board is basically similar as the static flexural strength, but the change rate is not as large as in the static flexural strength. The tensile strength decreases by 2%-3% in rapport with the increase by 1% of the water content.

The static flexural strength and tensile strength for the MDF board are the highest, if the moisture content is between 3%-5%. The water in the MDF board plays, in this case, a similar role to the binding force between the fibers. The moisture content exceeding this value will weaken the binding force between fibers [4].

## 2. Method

The whole of the thermostatically controlled enclosure regulated in temperature and humidity includes: a test enclosure with its conditioning, the installation support, in which the machinery and the control panel are placed.

For the calculus for the level of moisture it is used the next formula:

$$H_{wood} = \frac{(M - M_a)}{M_a}$$

where:

M - initial mass;

Ma – final mass.

The function principle for the heating and cooling thermostat enclosure is the next:

1- The cooling is realized grace of the fluid evaporation condenser
2- The heating is realized by releasing the caloric resitances in stainless steel
3- For the temperature adjusting:
   - The cooling is realized through closing/opening tuning electro valves.
   - The heating is made by putting under voltage the resistances heating by static relays.
4- For humidity adjustment, the drying process is realized by opening and closing a solenoid feed a cold drying system. The humidity is performed by opening or closing the electro valves and put under tension of thermo plunger of humidifier.

The measuring device used is of the H.M.P.230 type and is a microprocessor transmitter for measuring the relative humidity and air temperature. Based on these data, the absolute humidity can be calculated, dew point temperature, temperature humidity relationship and wet bulb temperature. The samples of MDF.12 are introduced in a enclosure thermostat controlled in temperature and humidity, as in Figure 1.

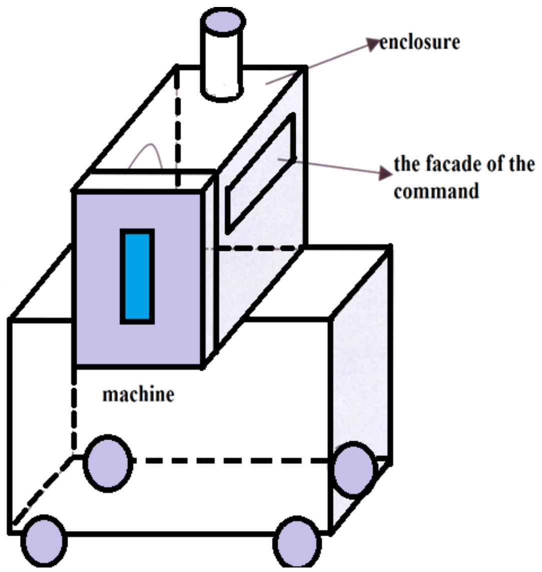


Fig.1. *Enclosure thermostat controlled in temperature*

The thermostat enclosure is constituted of the next elements: the inner tube of welded stainless steel sealed and exhaust bung; mineral wool insulation; 2 joints in silicon; door opener with wedge-thermal bridges. Cold production is carried out by evaporation of a refrigerant fluid in a finned copper tube exchanger, located behind the screen plate. The cooling capacity can be increased by injecting liquid nitrogen into the enceinte volume.

Hot production is carried out by heat release from armored resistors with stainless steel fins, arranged behind the screen plate. Air circulation is carried out by a fan motor with an external motor. Conditioned air is sucked in and discharged into the workspace.

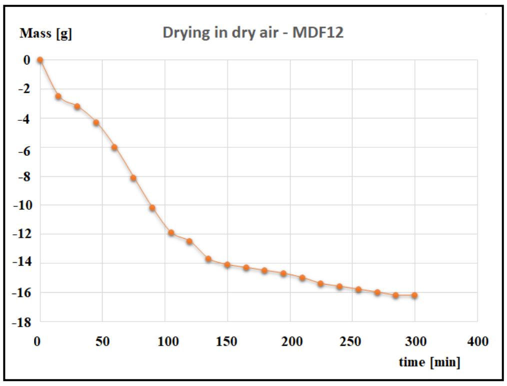


Fig.2.*Drying in dry air for MDF.12 composite material*

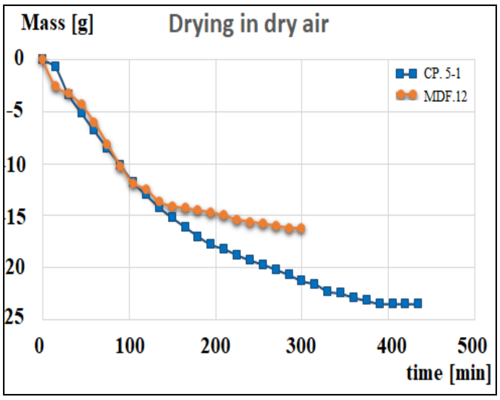


Fig.3. *Comparison of drying behaviour of the two composite materials CP5-1 and MDF.12*

This technique allows a very good homogeneity, the streams of cold and hot air being very strongly brushed.

The control of the humidity is realized by a solenoid feed, a cold drying system and electro valves for injecting compressed and dried air. In figure 2, it is represented the graph concerning the drying in dry air for MDF.12 composite material, and in figure 3 can remark MDF.12 lose less mass after drying than CP.5-1 composite material.

## 3. Results and Discussion

The water absorption behavior for traction tests for the MDF.12 composite material was established and the moisture coefficients of MDF.12 composite material, for the temperature of 100°C and humidity level of 1%H are presented in table 1.

Table 1

*Moisture coefficients for MDF.12 composite material at 1%H and the temperature of 100°C*

| **Temperature [°C]** | **Time [min]** | **Humidity [H]** | **Mass [g]** |
|---|---|---|---|
| 103 | 0 | 1 | 0 |
| 102.9 | 15 | 1 | 2.5 |
| 102.7 | 30 | 1 | -3.2 |
| 102.6 | 45 | 1 | -4.3 |
| 102.5 | 60 | 1 | -6 |
| 102.5 | 75 | 1 | -8.1 |
| 102.5 | 90 | 1 | -10.2 |
| 102.6 | 105 | 1 | -11.9 |
| 102.6 | 120 | 1 | -12.5 |
| 102.5 | 135 | 1 | -13.7 |
| 102.5 | 150 | 1 | -14.1 |
| 102.4 | 165 | 1 | -14.3 |
| 102.6 | 180 | 1 | -14.5 |
| 102.4 | 195 | 1 | -14.7 |
| 102.6 | 210 | 1 | -15 |
| 102.4 | 225 | 1 | -15.4 |
| 102.5 | 240 | 1 | -15.6 |
| 102.6 | 255 | 1 | -15.8 |
| 102.5 | 270 | 1 | -16 |
| 102.5 | 285 | 1 | -16.2 |
| 102.6 | 300 | 1 | -16.2 |

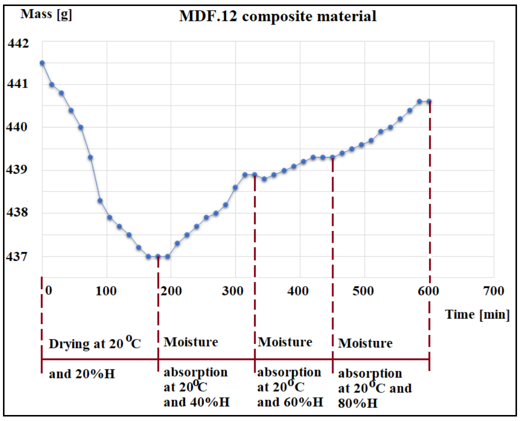


Fig. 4. *Graph of variation between the mass values and time for the temperature of20°C and different moisture coefficients (20%H, 40%H, 60%H, 80%H)*

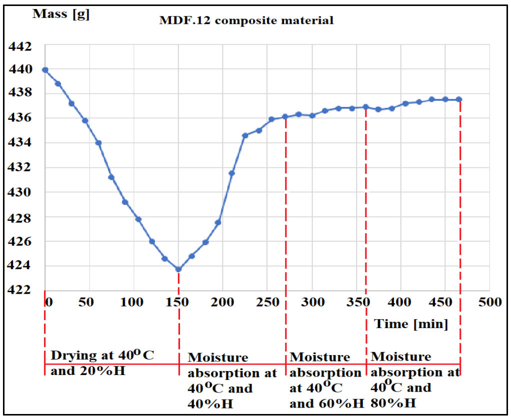


Fig.5. *Graph of variation between the mass values and time for the temperature of 40°C and different moisture coefficients (20%H, 40%H, 60%H, 80%H)*

The variation of the experimental mass values in rapport of time for the MDF.12 composite material for temperature of 20°C and different moisture values is shown in the table 2 and in the table 3 are presented the modification of the mass value during the time at the temperature of 40°C and different moisture values (20%H, 40%H, 60%H, 80%H). In the figure 4 is determinate the graph of MDF.12 composite material concerning the variation between the mass values and time for the temperature of 20°C and different wettability coefficients (20%H, 40%H, 60%H, 80% H), respectively, in the figure 5 is represented the variation graph for the similar conditions at the temperature of 40°C.

The variation of the mass values in function of the time for the MDF.12 composite material for temperature of 60°C and different moisture values is determined in the table 4 and in the table 5 is presented the mass value variation during the time at the temperature of 80°C for different moisture values (20%H, 40%H, 60%H, 80%H). The graph of variation of MDF.12 composite material between the mass values and time for the temperature of 60°C and different wettability coefficients (20%H, 40%H, 60%H, 80% H) is represented in figure 6 and in the figure 7 it is presented the variation graph for the similar conditions, for the temperature of 80°C.

Table 2

*Mass variation in time for MDF.12 composite material at different moisture coefficients (20%H,40%H, 60%H, 80%H) and the temperature of 20°C*

| **Temperature[°C]** | **Time [min]** | **Humidity [H]** | **Mass [g]** |
|---|---|---|---|
| 19.9 | 0 | 20 | 441.5 |
| 19.9 | 15 | 20 | 441 |
| 19.9 | 30 | 20 | 440.8 |
| 19.8 | 45 | 20 | 440.4 |
| 19.8 | 60 | 20 | 440 |
| 19.9 | 75 | 20 | 439.3 |
| 20.1 | 90 | 20 | 438.3 |
| 19.8 | 105 | 20 | 437.9 |
| 19.9 | 120 | 20 | 437.7 |
| 20 | 135 | 20 | 437.5 |
| 20 | 150 | 20 | 437.2 |
| 20 | 165 | 20 | 437 |
| 20 | 180 | 20 | 437 |
| 20 | 195 | 40 | 437 |
| 20 | 210 | 40 | 437.3 |
| 20 | 225 | 40 | 437.5 |
| 20 | 240 | 40 | 437.7 |
| 19.9 | 255 | 40 | 437.9 |
| 19.9 | 270 | 40 | 438 |
| 19.9 | 285 | 40 | 438.2 |
| 20 | 300 | 40 | 438.6 |
| 20 | 315 | 40 | 438.9 |
| 20 | 330 | 40 | 438.9 |
| 20 | 345 | 60 | 438.8 |
| 20.1 | 360 | 60 | 438.9 |
| 20.1 | 375 | 60 | 439 |
| 20.1 | 390 | 60 | 439.1 |
| 20 | 405 | 60 | 439.2 |
| 20 | 420 | 60 | 439.3 |
| 20 | 435 | 60 | 439.3 |
| 20.1 | 450 | 60 | 439.3 |
| 20 | 465 | 80 | 439.4 |
| 20 | 480 | 80 | 439.5 |
| 20 | 495 | 80 | 439.6 |
| 20.1 | 510 | 80 | 439.9 |
| 19.9 | 525 | 80 | 439.7 |
| 19.9 | 540 | 80 | 440 |
| 19.9 | 555 | 80 | 440.2 |
| 19.9 | 570 | 80 | 440.4 |
| 19.8 | 585 | 80 | 440.6 |
| 19.9 | 600 | 80 | 440.6 |

Table 3

*Mass variation in time for MDF.12 composite material at different moisture coefficients (20%H,40%H, 60%H, 80%H) and the temperature of 40°C*

| **Temperature [°C]** | **Time [min]** | **Humidity [H]** | **Mass [g]** |
|---|---|---|---|
| 39.7 | 0 | 20 | 441.9 |
| 39.7 | 15 | 20 | 440.8 |
| 39.8 | 30 | 20 | 439.2 |
| 39.8 | 45 | 20 | 437.8 |
| 39.9 | 60 | 20 | 436 |
| 40.1 | 75 | 20 | 433.2 |
| 39.8 | 90 | 20 | 431.2 |
| 39.9 | 105 | 20 | 429.8 |
| 40 | 120 | 20 | 428 |
| 40 | 135 | 20 | 426.6 |
| 40 | 150 | 20 | 425.7 |
| 40 | 165 | 40 | 426.8 |
| 40 | 180 | 40 | 427.9 |
| 40 | 195 | 40 | 429.5 |
| 40 | 210 | 40 | 433.5 |
| 40 | 225 | 40 | 436.6 |
| 39.9 | 240 | 40 | 437 |
| 39.9 | 255 | 40 | 437.9 |
| 39.9 | 270 | 40 | 438.1 |
| 40 | 285 | 60 | 438.3 |
| 40 | 300 | 60 | 438.2 |
| 40 | 315 | 60 | 438.6 |
| 40 | 330 | 60 | 438.8 |
| 40.1 | 345 | 60 | 438.8 |
| 40.1 | 360 | 60 | 438.9 |
| 40.1 | 375 | 80 | 438.7 |
| 40 | 390 | 80 | 438.8 |
| 40 | 405 | 80 | 439.2 |
| 40 | 420 | 80 | 439.3 |
| 40.1 | 435 | 80 | 439.5 |
| 40 | 450 | 80 | 439.5 |
| 40 | 465 | 80 | 439.5 |

Table 4

*Mass variation in time for MDF.12 composite material at different moisture coefficients (20%H,40%H, 60%H, 80%H) and the temperature of 60°C*

| Temperature [°C] | Time [min] | Humidity [H] | Mass [g] |
|---|---|---|---|
| 59.8 | 0 | 20 | 441 |
| 60 | 15 | 20 | 440.8 |
| 59.9 | 30 | 20 | 440.5 |
| 59.9 | 45 | 20 | 439.8 |
| 59.9 | 60 | 20 | 439.5 |
| 59.8 | 75 | 20 | 438.2 |
| 60 | 90 | 20 | 437.5 |
| 60.1 | 105 | 20 | 436.9 |
| 60 | 120 | 20 | 436 |
| 60 | 135 | 20 | 435.5 |
| 60 | 150 | 20 | 434.4 |
| 60.2 | 165 | 20 | 434 |
| 59.9 | 180 | 20 | 433.5 |
| 59.9 | 195 | 20 | 433 |
| 59.9 | 210 | 20 | 433 |
| 59.8 | 225 | 40 | 433.6 |
| 59.7 | 240 | 40 | 433.8 |
| 60.1 | 255 | 40 | 433.8 |
| 59.8 | 270 | 40 | 433.9 |
| 59.9 | 285 | 40 | 434 |
| 59.9 | 300 | 40 | 434.2 |
| 60 | 315 | 40 | 434.2 |
| 60 | 330 | 40 | 434.2 |
| 60 | 345 | 60 | 434.5 |
| 60.1 | 360 | 60 | 434.5 |
| 59.9 | 375 | 60 | 434.8 |
| 59.9 | 390 | 60 | 435 |
| 60 | 405 | 60 | 435.2 |
| 60 | 420 | 60 | 435.4 |
| 60 | 435 | 60 | 435.5 |
| 60.1 | 450 | 60 | 435.5 |
| 60 | 465 | 80 | 435.7 |
| 60 | 480 | 80 | 436.2 |
| 60.1 | 495 | 80 | 436.5 |
| 59.9 | 510 | 80 | 436.7 |
| 59.9 | 525 | 80 | 437 |
| 59.9 | 540 | 80 | 437.2 |
| 60 | 555 | 80 | 437.5 |
| 60.1 | 570 | 80 | 437.8 |

Table 5

*Mass variation in time for MDF.12 composite material at different moisture coefficients (20%H,40%H, 60%H, 80%H) and the temperature of 80°C*

| Temperature [°C] | Time [min] | Humidity [H] | Mass [g] |
|---|---|---|---|
| 79.6 | 0 | 20 | 438.5 |
| 79.6 | 15 | 20 | 437.2 |
| 79.7 | 30 | 20 | 435.8 |
| 79.6 | 45 | 20 | 434.7 |
| 79.6 | 60 | 20 | 433.5 |
| 79.8 | 75 | 20 | 432.2 |
| 79.8 | 90 | 20 | 431.6 |
| 79.8 | 105 | 20 | 430.9 |
| 79.6 | 120 | 20 | 430 |
| 79.7 | 135 | 20 | 429.5 |
| 79.8 | 150 | 20 | 428.9 |
| 79.6 | 165 | 20 | 428.5 |
| 79.7 | 180 | 20 | 428.2 |
| 79.6 | 195 | 20 | 428 |
| 79.6 | 210 | 20 | 427.8 |
| 79.7 | 225 | 20 | 427.8 |
| 79.8 | 240 | 40 | 428.6 |
| 79.8 | 255 | 40 | 429.3 |
| 79.7 | 270 | 40 | 430.2 |
| 79.6 | 285 | 40 | 430.6 |
| 79.6 | 300 | 40 | 431.4 |
| 79.8 | 315 | 40 | 431.8 |
| 79.8 | 330 | 40 | 431.8 |
| 79.9 | 345 | 60 | 432 |
| 79.9 | 360 | 60 | 432 |
| 79.8 | 375 | 60 | 432.1 |
| 79.9 | 390 | 60 | 432.4 |
| 79.8 | 405 | 60 | 432.6 |
| 79.8 | 420 | 60 | 432.5 |
| 79.8 | 435 | 60 | 432.7 |
| 79.8 | 450 | 60 | 432.9 |
| 79.7 | 465 | 60 | 432.9 |
| 79.8 | 480 | 80 | 433 |
| 79.8 | 495 | 80 | 433.4 |
| 79.7 | 510 | 80 | 434.2 |
| 79.8 | 525 | 80 | 434.5 |
| 79.7 | 540 | 80 | 435.5 |
| 79.7 | 555 | 80 | 435.7 |
| 79.8 | 570 | 80 | 436 |

| Temperature [°C] | Time [min] | Humidity [H] | Mass [g] |
|---|---|---|---|
| 60 | 585 | 80 | 438 |
| 60 | 600 | 80 | 438.2 |
| 60 | 615 | 80 | 438.4 |

| Temperature [°C] | Time [min] | Humidity [H] | Mass [g] |
|---|---|---|---|
| 79.8 | 585 | 80 | 436.1 |
| 79.8 | 600 | 80 | 436.3 |
| 79.8 | 615 | 80 | 436.3 |
| 79.8 | 630 | 80 | 436.3 |

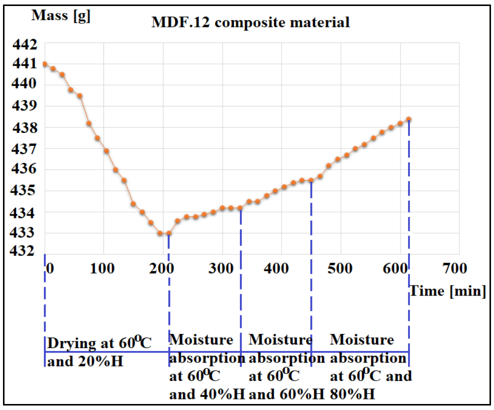


Fig.6. *Graph of variation between the mass values and time for the temperature of 60°C and different wettability coefficients (20%H, 40%H, 60%H, 80% H)*

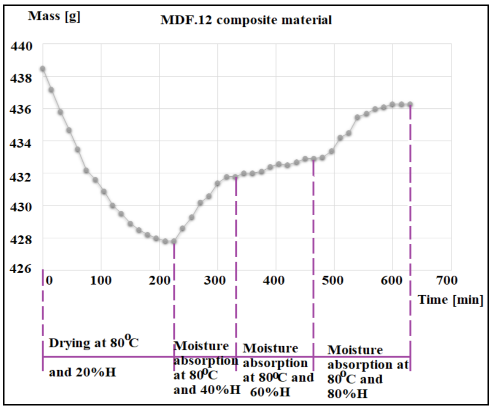


Fig.7. *Graph of variation between the mass values and time for the temperature of 80°C and different wettability coefficients (20%H, 40%H, 60%H, 80%H)*

In the figure 8 are shown the curves that present the variation of the mass during the time for the MDF.12 composite material and can remark when the temperature and humidity increase, the mass of the material increases, to a critical point of humidity, when a water saturation of the fiber occurs. In figure 9 is presented the microscopic structure of MDF.12 composite material.

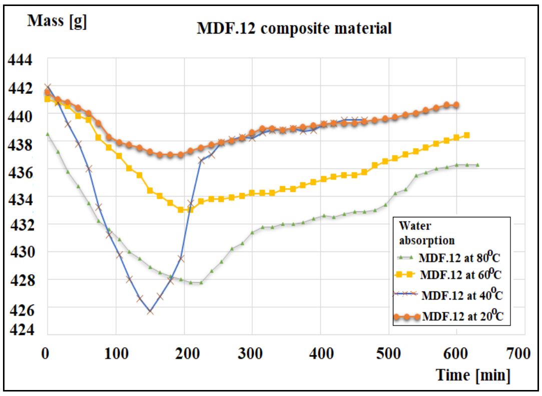


Fig.8. *Curves of the variation of the mass during the time in function of different temperatures for MDF.12*

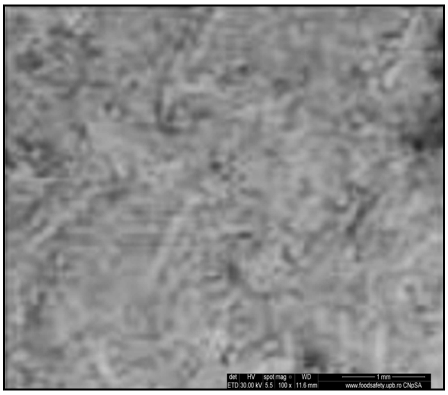

Fig. 9. SEM *analyses MDF.12 composite material (x100)*

## 4. Conclusion

MDF.12 composite material presents high strength and high efficiency, elastic modulus is better than steel, with excellent creep resistance, corrosion resistance, light weight, good flexibility and for this it is used in a variety of industries.

The degree of novelty consists in establishing that MDF.12 composite materials has a higher moisture resistance in comparison with different other composites and absorbs less water than CP.05 composite material.

At the temperature of 20°C, all composites have a drying process for the composite materials, if it increases the temperatures and it varies the humidity values, can remark an increase of mass values proportional with the humidity percents, because of the water absorption in the composite materials, although the temperature rises.

Due to the superior mechanical properties, these composite materials of MDF.12 type will be able to successfully replace the natural wood kinki pine, walnut, W. Spruce wood and the non-degradable plastics, in the furniture and in the building construction, MDF.12 type being degradable materials.

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