

## ENGINEERING OF SELECTED PROPERTIES OF LIGHT MEDIUM DENSITY FIBREBOARDS PRODUCED FROM HARDWOOD TREE SPECIES

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### ABSTRACT

In this paper are presented results from study for the influence of hot-pressing temperature and press factor on some properties of light Medium Density Fibreboards (MDF) from hardwood tree species. MDF were produced from under laboratory conditions with phenol-formaldehyde resin as binder. The press factor varied from 45 to 90 s.mm<sup>-1</sup> and the hot-pressing temperature was from 150° to 190 °C.

For the engineering of selected properties of the boards were applied the methods of regression analyze. Experimentally-statistical models that describe the studied relations and the optimal values of the factors were deduced. It has been established that by adjustment of the studied factors the properties of MDF from hardwood tree species can be significantly improved. It was also found that in the studied range, the temperature of hot pressing has a significantly greater influence on properties of MDF than the press factor.

**Key words:** light MDF, hardwood tree species, phenol formaldehyde resin, temperature of hot-pressing, press factor.

### INTRODUCTION

Light Medium Density Fibreboards (MDF) is found to be of major use as a cladding and partition element, with no significant strength requirements (Mihailova, J et al. 2007; Thoemen, H. et al. 2010). As low-density building materials, they are often used as superstructures and enclosures over large areas (Mihailova, J 2008). They are also used as noise-canceling barriers of machines, for interior lining of noisy production premises, packaging of equipment, sensitive to temperature changes. Other application of light MDF is as filler materials in a composite wood based panels. That is, they find applications similar to those of wet processed soft boards. In view of the global trend of replacing the wet processed fibreboards with dry processed ones the tendency to increase the consumption of light MDF is substantiated.

Data on the forestry fund in Bulgaria show the presence of significant quantities of

low-stemmed and lower quality wood resources from hardwood tree species (Tritchkov, N et al. 2005; Neykov, N et al. 2018). This wood is unsuitable for the production of solid wood materials and currently much of it is used for thermal purposes (firewood) (Savov, V. 2007). This type of wood raw material is suitable for the production of fibreboards, mainly for hardboards and High Density Fibreboards (HDF) (Mihajlova J. et al. 2018 a; Mihajlova J. et al. 2018 b), and represents a significant raw material potential for this production. However, there are a number of technological difficulties (Doosthoseini, K et al. 2010), due to the low compression ratio and low slenderness of hardwood fibers, in the production of MDF (Mihajlova, J et al 2016; Thoemen, H. et al. 2010).

Whit main significant for the engineering of fibreboards properties is the hot pressing regime (Carvalho, L. et al. 2003; Gupta,

A 2007). As in the MDF production, the influence of the maximum value of the specific pressure is limited insofar as it plays the role of desensitization, up to the set value, of the wood mat and fiber elements (Khayal, Os. 2019; Gul, W et al. 2017). Therefore, the temperature of hot-pressing and press factor were selected as determinants in this study.

### MATERIALS AND METHODS

In view of the presented above, the hot pressing process was the object of study and the subject of the study were the effect of temperature of hot pressing and press factor on some properties of light MDF produced from hardwood tree species with the use of phenol formaldehyde resin as a binder.

To determine the influence of the factors, an optimal type  $B_2$  composite plan was applied, table 1. As raw material was used hardwood – Beech (*Fagus Silvatica*, L) and Turkish Oak (*Quercus Cerris*, L) in a 2: 1 ratio. The mass is produced in “Welde Bulgaria” AD, using the “Asplund” thermo-mechanical method. The fibreboards were produced in the laboratory for press materials at the University of Forestry – Sofia. Phenol formaldehyde resin was used as a binder at 8% content to absolutely dry fibers. The boards have a set density of  $620 \text{ kg.m}^{-3}$  and thickness of 8 mm. The experimental plan is given in Tabl.1.

**Table 1: Experimental plan for engineering of selected properties of light MDF from hardwood by variation of temperature of hot pressing and press factor**

№	Temperature of hot-pressing, $T$ °C	Press factor $\tau$ , s.mm <sup>-1</sup>	Temperature of hot-pressing in coded value $X_1$	Press factor in coded value $X_2$
1	150	45	-1	-1
2	150	90	-1	+1
3	190	45	+1	-1
4	190	90	+1	+1
5	150	72.5	-1	0
6	190	45	+1	0
7	170	72.5	0	-1
8	170	90	0	+1
9	170	72.5	0	0

As main properties of light MDF, according to the application of this type of panels, were selected bending strength, water absorption and swelling in thickness. The properties were determined by the requirements of the relevant EN standards (EN 310, EN 317, EN 323). For every property 8 test samples were tested and the results were processed by the methods of variation statistics.

The final results were processed by the methods of regression analyze through specialized software – *QStatLab* version 6.0.

The general type of regression model composed according to an optimal composite plan of type  $B_2$  is (Vuchkov, I. and Stoianov, St. 1980):

$$\hat{Y} = B_0 + B_1 \cdot X_1 + B_2 \cdot X_2 + B_{12} \cdot X_1 \cdot X_2 + B_{11} \cdot X_1^2 + B_{22} \cdot X_2^2, \quad (1)$$

where  $\hat{Y}$  it is predicted by the equation output value;

$B_0, B_1, B_2, B_{12}, B_{11}, B_{22}$  – regression coefficients;

$X_1, X_2$  – encoded values of press factor and temperature of hot-press.

The decoding of equation (1) is carried out according to the formula:

$$\tilde{X}_i = \Delta_i X_i + \tilde{X}_{i0}, \quad (2)$$

where  $\tilde{X}_i$  is the natural meaning of the  $i^{\text{th}}$  factor;

$\tilde{X}_{i0} = \tilde{X}_{i \min} + 0,5(\tilde{X}_{i \max} - \tilde{X}_{i \min})$  – medium of the range of variation of the  $i^{\text{th}}$  factor;

$$\Delta_i = \frac{\tilde{X}_{i \max} - \tilde{X}_{i \min}}{2} \text{ – interval of variation of the } i^{\text{th}} \text{ factor.}$$

**RESULTS AND DISCUSSION**

The results for the studied properties of light MDF made from hardwood in the individual test points of the experimental plan are presented in Table 2.

**Table 2: Properties of light MDF, from hardwood tree species, at different values of temperature of hot pressing and press factor**

Board №	Temperature of hot-pressing, $T, ^\circ\text{C}$	Press factor, $\tau, \text{s.mm}^{-1}$	Density $\rho, \text{kg.m}^{-3}$	Bending strength, $fm, \text{N.mm}^{-2}$	Water absorption $A, \%$	Swelling in thickness, $Gt, \%$
1.	150	45	$635 \pm 4$	$11.50 \pm 0.26$	$120.11 \pm 1.57$	$35.55 \pm 1.34$
2.	150	90	$630 \pm 6$	$12.99 \pm 0.43$	$109.82 \pm 2.48$	$34.14 \pm 0.75$
3.	190	45	$631 \pm 5$	$19.01 \pm 0.61$	$104.46 \pm 7.13$	$30.27 \pm 0.42$
4.	190	90	$621 \pm 18$	$18.10 \pm 0.69$	$105.45 \pm 5.35$	$25.84 \pm 0.54$
5.	150	72.5	$633 \pm 5$	$10.53 \pm 0.09$	$119.19 \pm 2.55$	$36.43 \pm 1.42$
6.	190	45	$620 \pm 8$	$19.24 \pm 0.33$	$110.47 \pm 3.51$	$27.20 \pm 0.43$
7.	170	72.5	$639 \pm 5$	$13.76 \pm 0.45$	$110.43 \pm 1.91$	$32.92 \pm 1.31$
8.	170	90	$631 \pm 10$	$19.33 \pm 0.23$	$103.07 \pm 2.13$	$28.15 \pm 0.15$
9.	170	72.5	$613 \pm 5$	$17.96 \pm 0.43$	$111.41 \pm 1.72$	$32.70 \pm 0.76$

The variation in density of the panels is below the acceptable 5%, which is why this basic characteristic should not affect significantly the other physical and mechanical properties of MDF. None of the MDF properties meet the requirements of EN 622-5. However, it should be emphasized that the panels are with relatively low density and their application does not meet the significant

requirements for their strength characteristics.

A stepwise regression was applied in processing the results in order to be derived models with maximum accuracy of approximation. The determination coefficient was used as a measure of model accuracy.

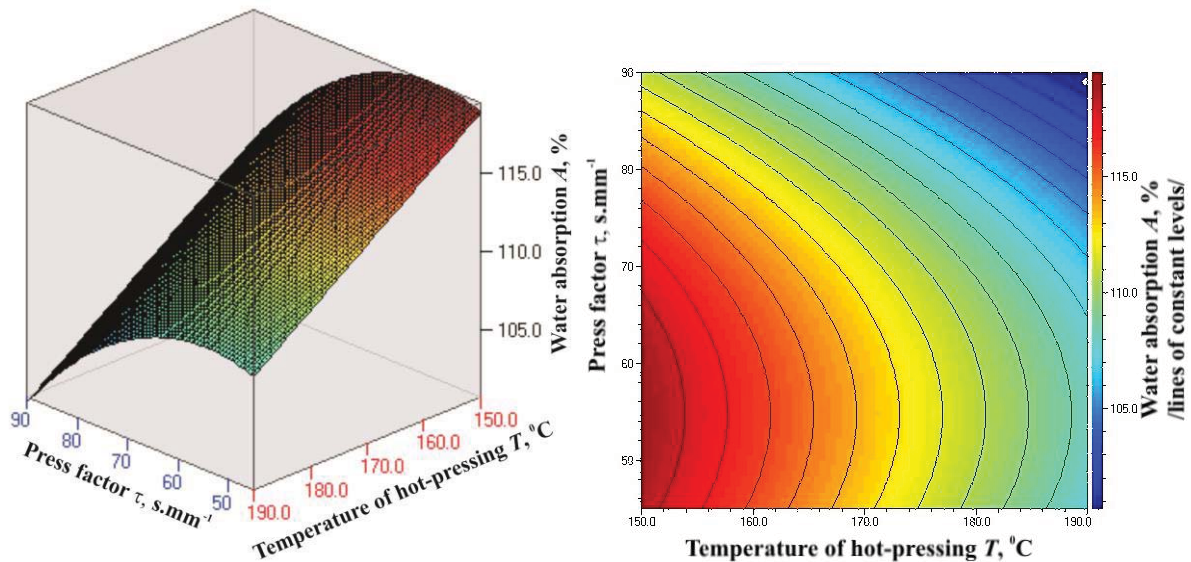
The values obtained after processing the results are presented in Table 3.

**Table 3: Data from regression analysis for the effect of temperature hot-pressing and press factor on selected properties of light MDF**

Indicator of the regression model	MDF property		
	Water Absorption	Swelling in thickness	Bending strength
Free member $B_0$	113.70	32.11	17.02
Coefficient of linear member $B_1$	-5.19	-3.80	3.56
Coefficient of linear member $B_2$	-2.87	-1.77	1.02
Coefficient of interaction $B_{12}$	-	-0.76	-
Coefficient of square member $B_{11}$	-	-	-1.78
Coefficient of square member $B_{22}$	-4.71	-0.97	-
Coefficient of determination $R^2$	0.89	0.92	0.86

The dependence of the water absorption of light MDF from the temperature of hot-

pressing and press factor is presented in Figure 1.



**Figure 1: Dependence of the water absorption of light MDF from the temperature of hot-pressing and press factor**

The optimum (minimal) value of the water absorption from 101% is obtained at the limit values of the factors – press factor of 90  $\text{s.mm}^{-1}$  and temperature of hot pressing of 190<sup>0</sup> C.

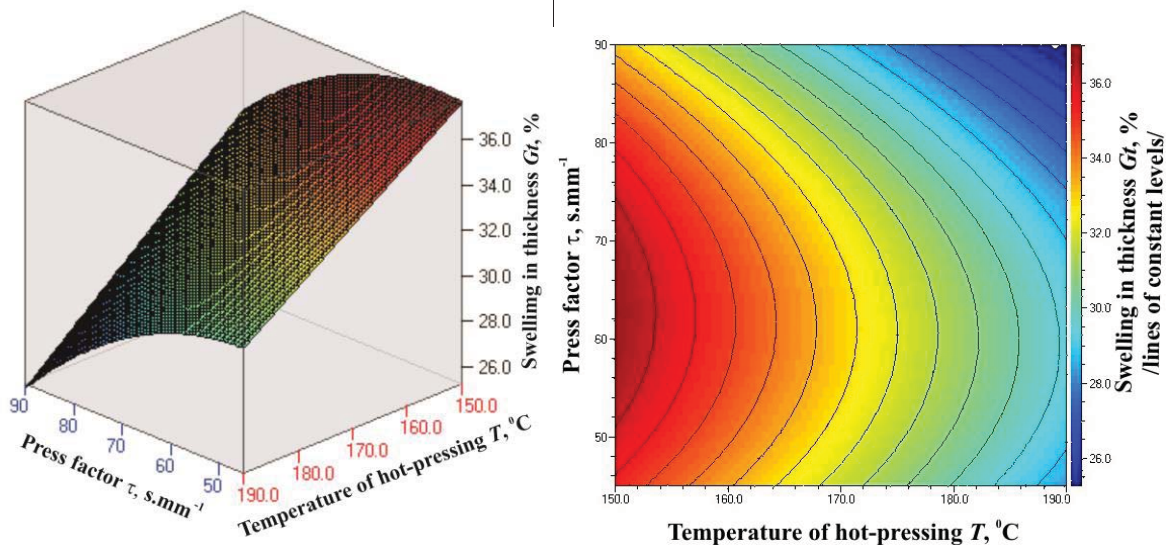
With the increase of hot-pressing temperature from 150 to 190 °C, water absorption of panels shows a significant decrease, i.e. there is an improvement in this property of light MDF. The property shows a constant rate of improvement as the temperature of hot-pressing increases.

When the press factor was increased from 45 to 65  $\text{s.mm}^{-1}$ , no significant change

in the water absorption of light MDF was observed, the fluctuation being within the accuracy of the model. After passing the press factor of 75  $\text{s.mm}^{-1}$ , a significantly improvement in the values of the studied property is observed.

The recommended values for the studied factors to improve the quality of the light MDF made from hardwood are 190 °C and a press factor of 90  $\text{s.mm}^{-1}$ .

In graphical form, the dependence of the swelling in thickness of light MDF from hardwood on the press factor and the temperature of hot-pressing is shown on Figure 2.



**Figure 2: Dependence of the swelling in thickness of light MDF from the temperature of hot-pressing and press factor**

The swelling in thickness improves, respectively, decreasing its values as the press factor and hot-pressing temperature increase. The gradient of decrease with increasing the temperature from 150 to 190 °C is constant. Very significant is the improvement of the property at 190 °C and a press factor of over 55 s.mm<sup>-1</sup>. At a temperature of 150 °C, the reduction of swelling in thickness with increasing of press factor is much smaller. Therefore, from the point of view of improving the quality of the panels, their production should be recommended at the upper limits of this factor (temperature of hot-pressing).

The relationship between the increase of the press factor and the swelling in the thickness of the panels is of a square character. As

the press factor increased from 45 to 65 s.mm<sup>-1</sup>, no significant change in the property was observed, after which the swelling in thickness improved with the increase of the press factor. The significance of the factor at crossing the limit of 75 s.mm<sup>-1</sup> is much stronger.

The optimum (minimal) value of the swelling in thickness from 25.5 % again is obtained at the limit values of the factors – press factor of 90 s.mm<sup>-1</sup> and temperature of hot pressing of 190 °C.

The graphical expression of the dependence of the bending strength on the temperature of hot-pressing and the press factor is presented in Figure 3.

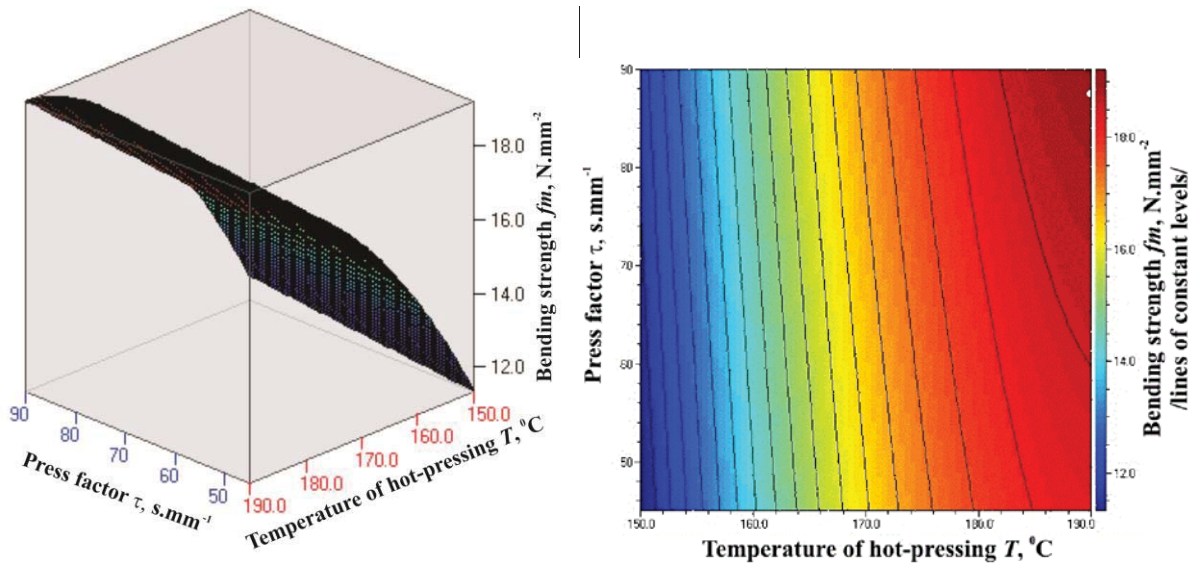


Figure 3: Dependence of the bending strength of light MDF from the temperature of hot-pressing and press factor

The bending strength of the panels improves, increases, with increasing the temperature of hot-pressing from 150 to 190 °C. The gradient of increase in the values of the studied property is greater to a temperature of hot-pressing of 170 °C, after which the tendency remains, but the relative improvement of the bending strength due to the increase of the temperature is smaller. An increase in the press factor of 45 to 90  $\text{s.mm}^{-1}$  shows an improvement in the bending strength of light MDF from hardwood. The gradient of increasing of values of the property is steady.

The optimum (maximal) value for the bending strength from 19.2  $\text{N.mm}^{-2}$  is obtained at press factor of 88  $\text{s.mm}^{-1}$  ( $\approx 90 \text{ s.mm}^{-1}$ ) and temperature of hot pressing of 190 °C. That is, again, the most appropriate hot-pressing regime is at the upper limits of the factors.

## CONCLUSIONS

As a result of the conducted study, the following main conclusions can be drawn:

1. Significantly better values of properties of light MDF are observed at 190 °C and a press factor of 90  $\text{s.mm}^{-1}$  compared to other hot-pressing regimes;
2. Water absorption decreased with increasing of press factor; this dependence is particularly pronounced at a press factor exceeding 75  $\text{s.mm}^{-1}$ ; with increasing temperature of hot-pressing, a significant decrease in water absorption is observed;
3. The swelling in the thickness of the light MDF from hardwood is more influenced by the temperature of hot-pressing, in the studied range of variations of the factors;
4. By increasing the press factor and hot-pressing temperature, the bending strength of the MDF is improved; this increase is more significant up to a temperature of 170 °C, after which its rate decreases.
5. In all the studied properties, the hot-pressing temperature is significantly more influenced, which leads to the conclusion that with the increase of temperature in the range from 150 to 190 °C, the properties of light MDF from hardwood produced with phenol-formaldehyde resin can be significantly improved.

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