

INFLUENCE OF THE PRESS CLOSING TIME UPON THE PROPERTIES OF HDF PANELS

Nicolae BĂDIN

PhD student - Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
E-mail: nicolae.badin@kastamonu.ro

Mihai ISPAS

Prof.dr. - Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
E-mail: ispas.m@unitbv.ro

Bogdan BEDELEAN

Lecturer dr. - Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
E-mail: bedelea@unitbv.ro

Mihaela CÂMPEAN

Prof.dr. - Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
E-mail: campean@unitbv.ro

Abstract:

The closing time of the press is an important technological parameter which influences the density profile of the panels. It also has a decisive influence within the gluing process. When the closing time is too high, the adhesive hardening begins premature due to the heat radiation of the press platens. The resulting panels are fragile and have a very low internal bond. However, the reduction of the press closing time is limited by technical considerations. The present research envisaged an in depth study of this aspect, with a view to establish if it is possible to obtain optimized characteristics of the HDF panels (3mm thick door-skins) by reducing the press closing time from 3s to 2s.

Key words: high-density fiberboards; press closing time; product optimization.

INTRODUCTION

The most important property of HDF panels is their density, due to its decisive influence upon all physical and mechanical properties of these panels, e.g. (Ayrilmis 2007; Wong *et al.* 2000), so the general trend is to attain a density as high as possible.

According to EN 622-5 (2009), the minimum value is 800kg/m³, but optimum values are 1000kg/m³ or higher, as long as they do not increase unnecessarily the cost of the product.

Optimization is possible by varying the composition of panels (percentage of softwood fibers, hardwood fibers, and bark), considering that fibers from resinous wood are longer and have higher slenderness degree than those from hardwood species (Niemz and Wagenfuhr 2008) and that wood bark fibers are denser (Miles and Smith 2009) and have different chemical composition than wood fibers especially in terms of lignin and amount of extractive substances (Harkin and Rowe 1971).

The closing time of the press is an important technological parameter which influences the density profile of the panels (Wang *et al.* 2001). It also has a decisive influence within the gluing process and the formation of the chemical bonds between the wood fibers and the adhesive. When the closing time is too high, the adhesive hardening begins premature due to the heat radiation of the press platens. The resulting panels are fragile and have a very low internal bond.

OBJECTIVE

The mechanical strengths of thin HDF panels (door-skins) are modest, so the main aim of the present research was to establish if it is possible to increase them (as compared to the minimum standard requirements given in Table 1) by reducing the press closing time. Different raw material recipes and different surface treatments of the fiber mat before pressing were applied.

Table 1

Minimum values for the mechanical properties of HDF panels (EN 622-5:2009)

Bending Strength (N/mm ²)	Modulus of Elasticity (N/mm ²)	Internal Bond (N/mm ²)
23	2700	0.65

METHOD, MATERIAL AND EQUIPMENT

The tests were performed with 3mm thick HDF panels (door-skins), manufactured on an industrial-scale line at KASTAMONU Romania.

The panels were manufactured by using three combinations of the percentage participation of the raw materials (hardwood fibers / resinous wood fibers): 20%/80%, 30%/70% and 40%/60, and a bark content below 5%. Approximately 7000 pieces of HDF panels were produced from each recipe.

The surface treatment of the fiber mat before being introduced into the press was also varied: one third of the panels remained untreated, one third were sprayed with water and one third were sprayed with a MOULEX WE07BSP release agent by Additek (France). MOULEX WE07BSP is a release agent based on two different surface-active compounds:

- EMPHOS PS 236 (CAS 68908-64-5) - (C10-C12) alkylethoxylate-mono- phosphate and
- ISOTRIDEKANOL (CAS 27458-92-0)-11-methyldodecan-1-ol, in a mixture of 2-amino-ethanol and 2 propanol, with an addition of 1% biocidal products (5-chloro-2-methyl-3(2H)-isothiazolone with 2-methyl-3(2H)-isothiazolone).

Before being sprayed over the mat surface, the release agent was diluted in water to a 4% concentration.

The pressing parameters were the same for all applied recipes: temperature (T) of 150°C, pressing time (t) of 30s, pressure (p) of 180bar. Two press closing times were applied: 2s and 3s. A press closing time of 4s was also tested, but the resulted panels were extremely fragile and inconsistent (crumbly edges).

After pressing, the boards were conditioned for 30' at ambient temperature, and specific test pieces were cut out of eight randomly selected panels from each recipe, according to EN 326-1:1994. Density, bending strength & modulus of elasticity in bending and the internal bond were determined according to the standards in force (EN 323:1993, EN 310:1993, EN 319:1993).

In order to determine the density of the panels, sixteen test pieces from each of the eight test-panels from each recipe, sized at 100mmx100mmx 3mm, were first weighed at an accuracy of 0.01g. The thickness (t) was measured in the central point by a micrometer at an accuracy of 0.01mm, and the dimensions b_1 and b_2 were measured at mid width and length, by a sliding gauge at an accuracy of 0.1mm.

The density of each test piece was then calculated according to Eq (1):

$$\rho = \frac{m}{b_1 \cdot b_2 \cdot t} \cdot 10^6 [\text{kg} / \text{m}^3] \quad (1)$$

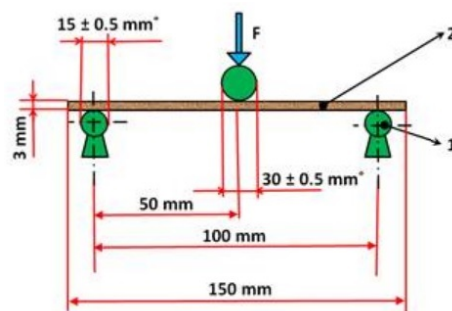
where: m is the sample mass (g);

b_1, b_2 are the sample dimensions (mm);

t is the sample thickness (mm).

For the determination of the bending strength and modulus of elasticity, six samples from each of the eight test-panels from each recipe, sized at 150mmx50mmx3mm were cut and tested on a Z010 equipment, manufactured by ZWICK GmbH & Co. (Germany) (Fig. 1).

The distance between the centers of the supports was adjusted at 100mm. The test piece was placed flat on the supports, with its longitudinal axis at right angles to those of the supports with the center point under the load. The load was applied at a constant rate of the cross-head movement throughout the test. The rate of loading was adjusted so that the maximum load was reached within (60 ± 30)s. The deflection in the middle of the test piece (below the loading head) was measured to an accuracy of 0.1mm. These values were plotted against the corresponding loads measured to an accuracy of 1% of the measured value. The maximum load was recorded to an accuracy of 1% of the measured value.



1 – support; 2 – test piece

Fig. 1.

Determination of the bending strength and modulus of elasticity.

The bending strength of each test piece (f_m) was calculated according to Eq. 2:

$$f_m = \frac{3 \cdot F_{\max} \cdot l_1}{2 \cdot b \cdot t^2} [N/mm^2] \quad (2)$$

where: $F_{\max}$ is the maximum load (N);

l_1 is the distance between the centers of the supports (mm);

b is the test piece width (mm), and t is the test piece thickness (mm).

The modulus of elasticity in bending (E_m) was calculated according to Eq. 3:

$$E_m = \frac{l_1^3 \cdot (F_2 - F_1)}{4 \cdot b \cdot t^3 \cdot (a_2 - a_1)} \left[\frac{N}{mm^2} \right] \quad (3)$$

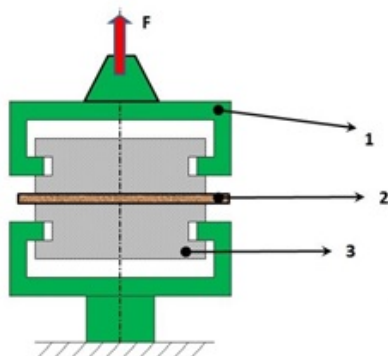
where: $(F_2 - F_1)$ is the increment of load on the straight line portion of the load-deflection curve,

$(a_2 - a_1)$ is the deflection increment at the mid length of the test piece corresponding to $(F_2 - F_1)$.

In order to determine the internal bond, four samples from each of the eight test-panels from each recipe, sized at 50mm×50mm×3mm, were used. Each sample was first glued to the metallic jig with a melting adhesive (Fig. 2) and then subjected to a tensile force on the same ZWICK Z010 equipment, endowed with the adequate special device (Fig. 3), until rupture occurred. The maximum force that produced failure was recorded, and the internal bond was calculated according to Eq. 4:

$$f_{t1} = \frac{F_{\max}}{a \cdot b} [N/mm^2] \quad (4)$$

where: $F_{\max}$ is the maximum load (N) and a , b are length and width of the test piece (mm).



1 - clamping device; 2 - test piece; 3 - metallic jig;
F-tensile force

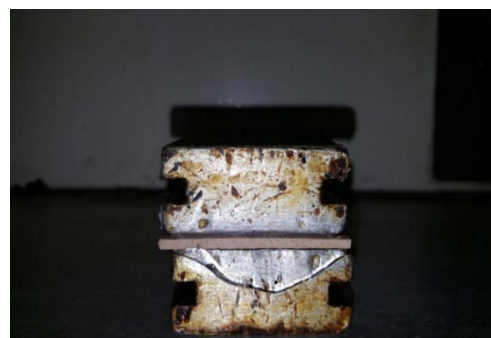


Fig. 2.

Test piece for internal bond test.

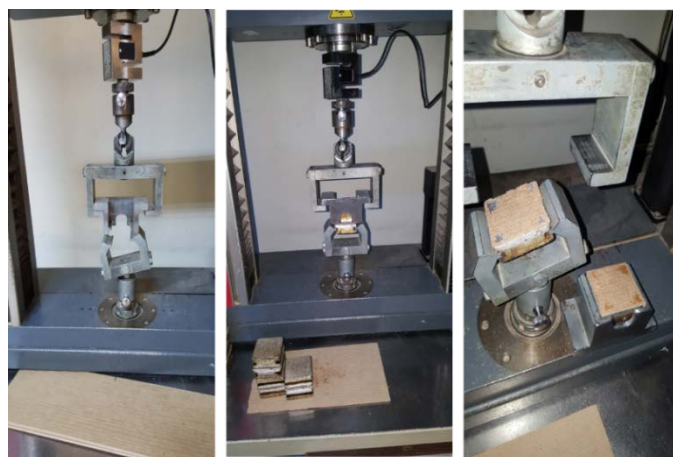


Fig. 3.

Determination of the internal bond of HDF panels by means of a Zwick010 equipment endowed with special traction device.

Three-way between-groups analysis of variance (ANOVA) was conducted to explore the influence of the raw material recipe, the surface treatment of the fiber mat before pressing and of the press closing time upon the selected mechanical properties of 3mm thick HDF panels.

EXPERIMENTAL RESULTS

The experimental results obtained with 3mm thick HDF door-skin panels regarding the influence of the raw material recipe, the surface treatment of the fiber mat before pressing and the press closing time upon their density and mechanical properties is presented in Table 2.

Table 2

Influence of the raw material recipe (%hardwood/%softwood fibers), surface treatment of the fiber mat before pressing and the press closing time upon the density and mechanical properties of 3mm thick HDF panels

N ^o	Raw material recipe (%/%)	Surface treatment	Density (kg/m ³)	Bending strength (N/mm ²)	Modulus of elasticity (N/mm ²)	Internal bond (N/mm ²)
Press closing time: 2s						
1	20/80	None	1078 (26.50)	79.6 (3.28)	6807 (196.84)	2.52 (0.17)
2		Water	1076 (22.39)	65.2 (2.26)	4493 (356.24)	1.90 (0.03)
3		Release agent	1005 (25.37)	71.36 (3.24)	5380 (369.76)	1.80 (0.09)
4	30/70	None	1063 (20.39)	77.74 (3.39)	6224 (377.95)	2.04 (0.16)
5		Water	993 (29.19)	63.76 (4.45)	4800 (249.00)	1.95 (0.42)
6		Release agent	1022 (13.05)	67.05 (3.36)	4892 (163.27)	1.77 (0.29)
7	40/60	None	1058 (17.36)	76.27 (3.73)	5558 (259.18)	2.95 (0.40)
8		Water	1032 (30.85)	68.76 (3.73)	5052 (215.07)	2.23 (0.36)
9		Release agent	1016 (13.28)	63.61 (5.27)	4342 (142.18)	1.13 (0.24)

Press closing time: 3s						
10	20/80	None	990 (25.38)	71.39 (8.12)	6100 (317.17)	2.11 (0.15)
11		Water	970 (28.87)	61.83 (5.63)	4427 (214.54)	1.85 (0.45)
12		Release agent	996 (25.20)	62.03 (2.16)	4480 (77.97)	1.67 (0.07)
13	30/70	None	952 (26.11)	68.95 (0.60)	5697 (146.10)	1.47 (0.04)
14		Water	973 (28.70)	59.41 (4.51)	4683 (122.26)	1.25 (0.11)
15		Release agent	1025 (29.52)	66.86 (6.68)	5022 (332.77)	1.16 (0.06)
16	40/60	None	950 (22.40)	68.96 (4.67)	4897 (355.85)	2.08 (0.08)
17		Water	1022 (18.73)	68.60 (3.46)	5020 (318.68)	1.67 (0.37)
18		Release agent	984 (24.80)	57.80 (3.19)	4097 (130.18)	1.09 (0.14)

Note: Mean values are shown, with standard deviations in parentheses.

Influence of the Raw Material Recipe

As far as the influence of the percentage participation of the raw materials (ratio between hardwood and softwood fibers) in the HDF recipe is concerned, the values in Table 2 and the graphic illustration in Fig. 4 show that the density of HDF decreases with the increase of the hardwood fibers amount, in case of no surface treatment.

Although this result might seem unexpected, it can be explained by the fact that softwood fibers have a higher degree of compressibility and therefore, panels with higher amount of softwood fibers have higher density and better bending properties. No coherent tendency could be established with regard to the internal bond.

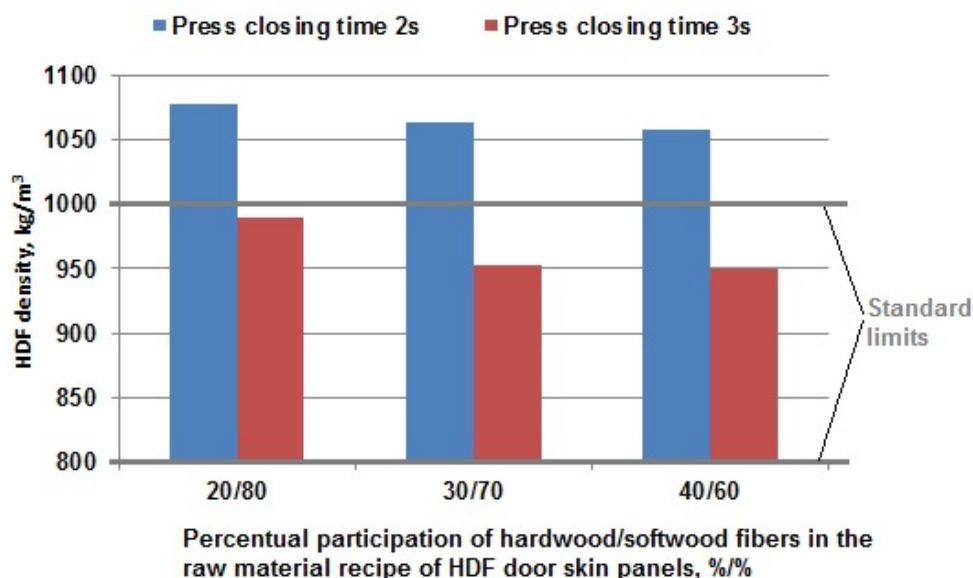


Fig. 4.

Influence of the raw material recipe upon the density of HDF door-skins, with no surface treatment.

The three-way ANOVA analysis revealed that the raw materials recipe has a significant effect ($p < 0.05$) on the density, modulus of elasticity and internal bond. The raw materials recipe has not a significant effect ($p > 0.05$) on the bending strength.

Based on the resulting eta squared (η^2) and Cohen's classification, with 0.01 as a small effect, 0.06 as

a medium effect and 0.14 as a large effect (Pallant 2007) it could be established that the raw materials recipe has medium effect on the density ($\eta^2=0.06$), large effect on the modulus of elasticity ($\eta^2=0.41$) and, also, a large effect on the internal bond ($\eta^2=0.33$).

Influence of the Surface Treatment

The influence of the surface treatment applied to the fiber mat before pressing is illustrated in Fig. 5, for panels with 20% hardwood fibers and 80% softwood fibers.

It was found that spraying (wetting) the fiber mat before pressing has negative influence upon the mechanical performances of HDF panels, as all mechanical properties were lowered by the use of a spraying agent. The lowest (worst) values were obtained when spraying with water, which resulted in significant reduction by 13.4-18.1% of the bending strength, by 27.4-34.0% of the elasticity modulus, and by 12.3-24.6% reduction of internal bond compared to the panels which were not surface treated. However, even these values are considerably higher than the standard requirements.

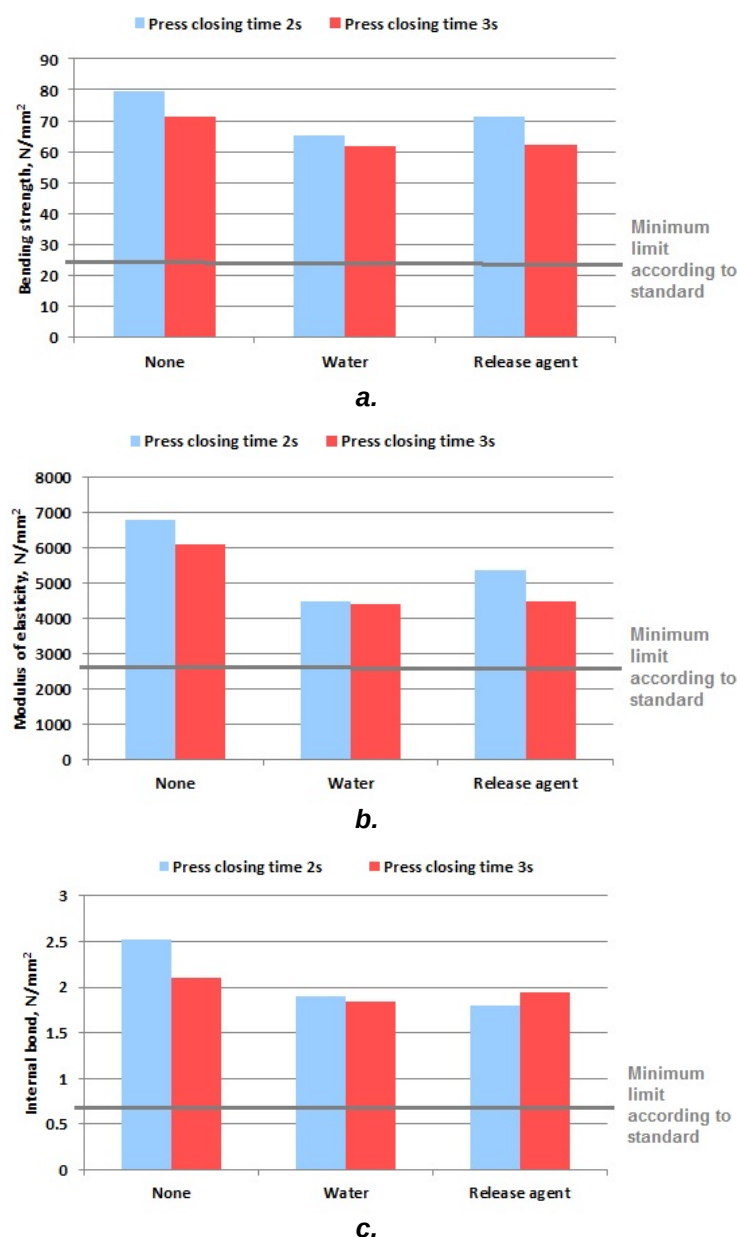


Fig. 5.

Influence of the surface treatment applied to the fiber mat before pressing upon the bending strength (a), modulus of elasticity (b) and internal bond (c) of HDF door-skins (raw material recipe 20% hardwood fibers / 80% softwood fibers).

The three-way ANOVA analysis showed that the surface treatment has a significant effect ($p < 0.05$) on the bending strength (F-value = 53.12), modulus of elasticity (F-value = 238.53) and internal bond (F-value = 56.27). Based on the resulting eta squared (η^2), it could be established that the surface treatment has large effect on the bending strength ($\eta^2 = 0.54$), modulus of elasticity ($\eta^2 = 0.84$) and internal bond ($\eta^2 = 0.67$).

Influence of the Press Closing Time

The influence of the press closing time upon the mechanical properties of HDF panels is illustrated in Fig. 6 for panels with no treatment applied on their surface. For these panels, when decreasing the press closing time from 3s (usual value) to 2s:

- the density increases by 8.89-11.66%;
- the bending strength increases by 11.18-12.75%;
- the modulus of elasticity increases by 9.25-13.50%;
- the internal bond increases by 19.43-41.83%.

When spraying with water, the increase intervals are slightly lower:

- the density increases by up to 10.93% (maximum increase for 20%/80% raw material recipe);
- the bending strength increases by up to 7.32% (maximum increase for 30%/70% raw material recipe);
- the modulus of elasticity increases by insignificant 2.50%;
- an exception was registered with the increase of the internal bond, which reached up to 56% for the recipe with 30% hardwood fibers / 70% softwood fibers.

When using the MOULEX WE07BSP release agent, although the density of the panels is hardly affected, the mechanical properties register important increases, higher than in the case of panels with non-treated surfaces:

- by up to 15.04% in case of the bending strength (maximum increase for 20%/80% raw material recipe);
- by up to 20.09% in case of the modulus of elasticity (maximum increase for 20%/80% raw material recipe);
- by up to 52.6% in case of the internal bond (maximum increase for 30%/70% raw material recipe).

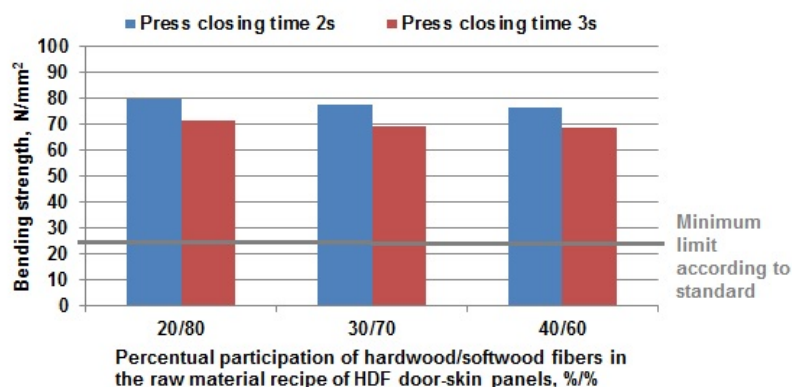
According to the three-way ANOVA analysis of the experimental data, the press closing time has a significant effect ($p < 0.05$) on all analyzed properties: density (F-value = 349), bending strength (F-value = 40.36), modulus of elasticity (F-value = 48.34) and internal bond (F – value = 57.34).

Based on the resulting eta squared (η^2), it could be established that the press closing time has a large effect on the density ($\eta^2 = 0.56$), bending strength ($\eta^2 = 0.31$), modulus of elasticity ($\eta^2 = 0.34$) and internal bond ($\eta^2 = 0.51$).

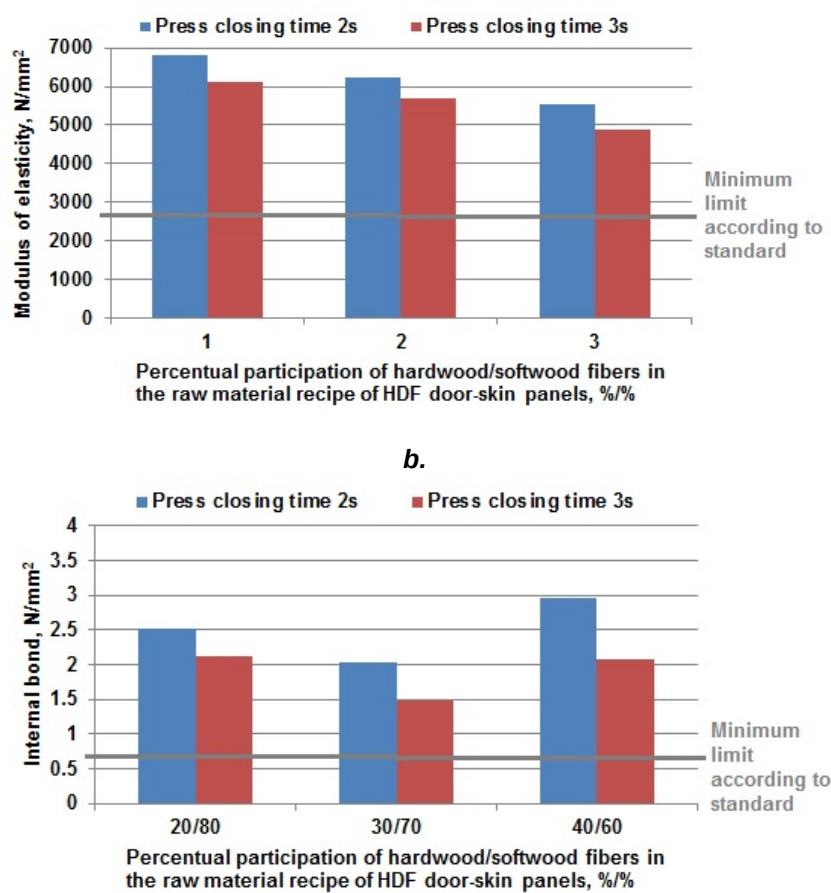
CONCLUSIONS

The results obtained within the present research allow formulating the following conclusions:

- The raw materials recipe has a significant effect upon the density, modulus of elasticity and internal bond of 3mm thin HDF panels. By varying the percentage of hardwood/ softwood fibers from 20/80 to 40/60 (with no surface treatment of the fiber mat before pressing), the density decreases by 1.85%, the bending strength decreases by 4.18%, the modulus of elasticity decreases by 18.35%, with a press closing time of 2s. The percentage modifications are similar for a press closing time of 3s. No coherent tendency of the raw material recipe upon the internal bond could be established.



a.



c.
Fig. 6.

Influence of press closing time upon the bending strength (a), modulus of elasticity in bending (b) and internal bond of HDF door-skins manufactured according to three different raw material recipes, with no surface treatment.

- The surface treatment has a significant (negative) effect upon all analyzed mechanical properties. It was found that spraying (wetting) the fiber mat before pressing leads to lower mechanical strengths. When spraying with water, the bending strength is reduced by 13.4-18.1%, the elasticity modulus by 27.4-34.0% and the internal bond by 12.3-24.6% compared to the panels which were not surface-treated.
- The press closing time has a significant effect upon all analyzed properties. For panels with no surface treatment, when decreasing the press closing time from 3s (usual value) to 2s: the density increases by 8.89-11.66%, the bending strength increases by 11.18-12.75%, the modulus of elasticity increases by 9.25-13.50%, the internal bond increases by 19.43-41.83%.

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