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EFFECT OF SOME TECHNOLOGICAL FACTORS ON PHYSICAL PROPERTIES OF MEDIUM DENSITY FIBREBOARD MADE OF HARDWOOD SPECIES

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ABSTRACT

On the basis of performed literature overview and analysis of the effect of production modes on physical indices of fibreboards, following variable factors were determined: pressing temperature, board thickness and binder content.

In this paper, the results of the performed analytical and empirical investigations with respect to the effect of pressing temperature, board thickness and binder content on physical properties of MDF-type boards (medium-density fibreboards manufactured after the dry method) made of hard hardwood species are presented. Regression models showing the effect of variable factors on board indices were derived. The changes in the values of those indices in case of combinations of levels of production factors were examined. Analysis of the result was made, with the respective conclusions having been drawn.

Key words: MDF, mechanical indices, hard hardwood raw material, technological factors

INTRODUCTION

In production of FBs, the quantitative yield is very high, and low-stemmed timber and wood of lower quality class of softwood and hardwood tree species may be used as raw material. The medium-density fibreboard (MDF) has considerably higher properties than those of PBs. This is especially characteristic in the case of the water-repellent properties because of the fact that the water movement is impeded by the low flow capacity of the fine fibrous elements connected between each other both with adhesive and cohesive bonds. This predetermines the wider use of MDF in environments with increased humidity – bathrooms, kitchens, wet rooms, cellars, etc.

The water-repellent properties of the boards depend on a number of indices such as mass characteristic, characteristic of the wood-fibre mat, modes during piezothermal treatment, etc. The utilisation of the hardwood raw material in the MDF production is still poorly investigated, and Bulgaria has raw material potential of this type.

The binders perform a main role to improve the MDF performance properties. The investigations in this field show that, with the increase of the binder content, improvement in all indices of the boards is observed, with UFRs finding main application in the capacity of binder. Values from 8 to 12 % are shown as an optimum value for the content of binders in this production, and in case of enhanced requirements to the boards, the share of binder may reach 14–16 %.

The processes of hot pressing in the production of FBs have a key role for the qualitative result of the end product (Donchev, G.). Of main importance for improvement of the water-repellent properties of the boards is the temperature of thermal treatment. Nevertheless, the increase of the temperature above certain limits at the stage of hot pressing may lead to destructive processes both in the binders and in the wood components. This necessitates investigating experimentally the effect of temperature on the characteristics of the wood-fibre mass and wood-fibre mat, including tree species, content and type of the binder. In addition, because of the big range in the MDF dimensions, the effect of the material thickness shall be also taken in account.

The effect of the factors on the physical properties of MDF may not be determined in a purely theoretical way. This is conditioned by the difficulties in deriving exact constants describing the process, which, on its turn, leads to the necessity of application of experimental-statistical modelling.

From the presented, the conclusion shall be drawn that an investigation on the effect of pressing temperature, board thickness and binder content on the physical properties of MDF has the necessary topicality.

MATERIALS AND INVESTIGATION METHODS

For the purposes of this investigation, wood-fibre mass manufactured in Welde Bulgaria AD, Troyan, after the Asplund thermo-mechanical method, with use of defibrator units, was used. The wood raw material used is mixed from wood of common beech and cerris oak.

The boards were manufactured in laboratory conditions with application of a three-stage cycle of hot pressing and total duration of the mode of 1 min/mm. The specific pressure during the individual stages is as follows: 1st stage – 2.5 MPa; 2nd stage – 1.3 MPa; 3rd stage – 0.7 MPa. The set density of the boards is 750 kg/m^3. The experimental-statistical modelling has been realised by means of application of a matrix of *D*-optimum composition plan, Table 1.

The physical properties of MDF were determined in conformity with the standards in force in Bulgaria. The results were processes by means of application of regression analysis, with the coefficient of determination having been used as a measure of accuracy of the model, and the check for adequacy was performed by means of the *F*-criterion (Trichkov, N.).

The random search method was selected for optimisation in view of its advantages in the application of computers. The processing of the results was performed by means of specialised software *QStatLab*.

Table 1: Experiment matrix

Hot-pressing temperature T, °C	Board thickness, t_{bo}, m	Binder content, $p_{bind.}$, %	Board temperature X_1, coded value	Board thickness X_2, coded value	Binder content X_3, coded value
160	0.008	8	-1	-1	-1
160	0.008	16	-1	-1	+1
160	0.016	8	-1	+1	-1
160	0.016	16	-1	+1	+1
200	0.008	8	+1	-1	-1
200	0.008	16	+1	-1	+1
200	0.016	8	+1	+1	-1
200	0.016	16	+1	+1	+1
160	0.012	12	-1	0	0
200	0.012	12	+1	0	0
180	0.008	12	0	-1	0
180	0.016	12	0	+1	0
180	0.012	8	0	0	-1
180	0.012	16	0	0	+1
180	0.012	12	0	0	0

RESULTS AND ANALYSIS

The results for the physical indices of MDFs during the individual experiments from the items in the experiment plan are presented in Table 2.

When deriving the regression models, the attainment of maximum accuracy of approximation was used as a main criterion.

The mean value of density within the range of variation of the factors examined is 741 kg/m^3. The board density varies within ±14.5 kg/m^3 or relative value of the variation of ±2%, with the latter being within the allowable limits.

Table 2: Physical indices of MDFs, at different levels of variation of factors

No.	Density ρ, kg/m^3	Swelling G, %	Water absorption A,%
1	742	30.11	76.66
2	740	12.89	37.83
3	741	29.97	68.56
4	743	17.53	54.86
5	746	23.04	71.33
6	721	15.33	42.02
7	748	24.02	63.65
8	729	16.20	46.11
9	745	14.37	49.59
10	753	19.71	48.83
11	743	15.90	41.87
12	743	17.66	49.35
13	739	25.08	67.08
14	741	15.23	42.48
15	750	22.01	48.87

When investigating the effect of factors on the swelling in thickness of MDFs, regression equation of the following type was derived:

$$\hat{Y} = 17.93 - 0.657X_1 + 0.811X_2 - 5.504X_3 + 3.01X_3^2 + 1.77X_1.X_3 \quad \textbf{(1)}$$

The equation adequately describes the process investigated, being characterised by a coefficient of determination R^2 = 0.87 and $F_{calc.}$ = 11.55 > F_{cr} (α=0.05; ν1=5; ν2=9) = 3.48.

Within the range of investigation of factors, the swelling in thickness varies within 12.9 to 30.1 %, with the variation of the index between the individual experimental series being 150 %.

The effect of pressing temperature and thickness of boards on their swelling in thickness is of linear nature. The action of these two factors is in opposite directions, with deterioration, respectively increase in their water absorption that is presented in Fig. 1, being observed with the increase of the thickness of the boards. Best indices are observed in boards 8 mm thick.

The relationship between the binder content and the swelling in thickness of the boards is of quadratic nature, with improvement in the index investigated being observed with the increase of the factor. Most significant is the improvement up to values of 12 % of binder, whereupon decrease of the water absorption is seen. After going beyond the bound of 15 % (0.7 coded value) binder content, a second drop is registered (Fig. 1).

When designing the swelling in thickness, the oppositely directed effect of board thickness and binder content shall be taken into account.

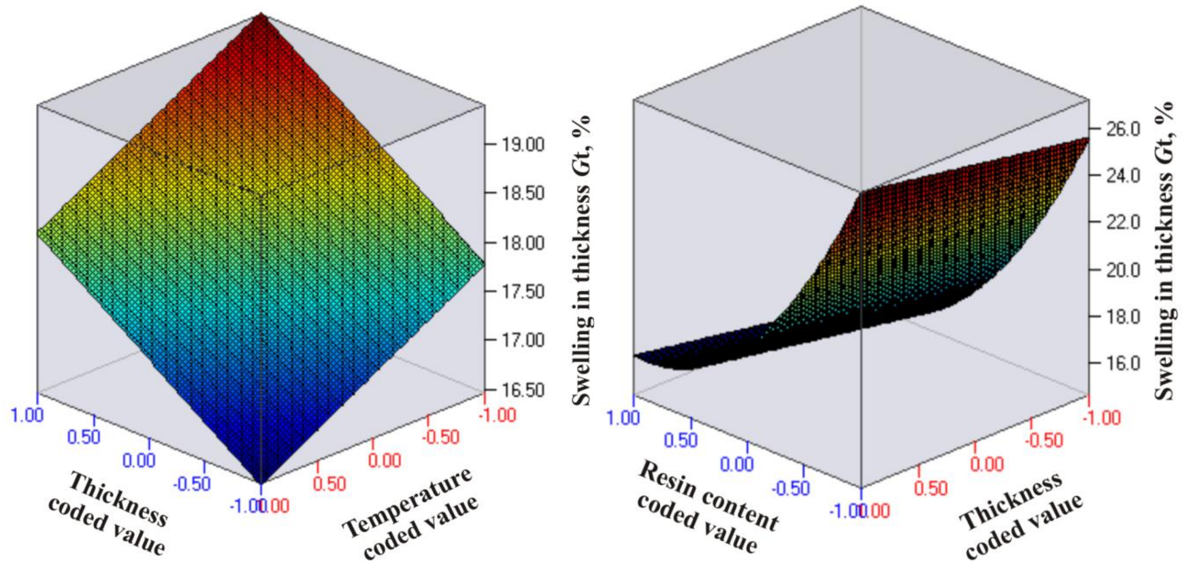

Figure 1: Effect of pressing temperature and board thickness on swelling in thickness of laboratorially manufactured MDF with binder content of 12%; and effect of board thickness and binder content on swelling in thickness of laboratorially manufactured MDF, at pressing temperature of 180 °C

As seen from Figure 2, the only interaction that exercises influence is that between the pressing temperature and binder content. The regression coefficient is positive, which warrants drawing a conclusion about deterioration of the adhesive bonds when increasing the temperature above 190 °C (0.5 coded value).

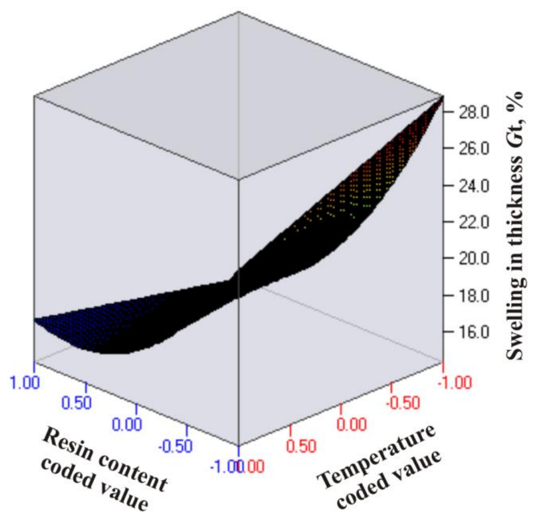

Figure 2: Effect of pressing temperature and board thickness on swelling in thickness of laboratorially manufactured MDF 12 mm thick

This leads to relatively constant values in the index investigated with insignificant increase in the upper limiting range of investigation. In the investigated range of variation of factors, considerably stronger – almost eight times, is the effect of binder content in comparison to that of pressing temperature. The latter shall be taken into consideration when determining the economic efficiency of the production during subsequent investigations of the matter. The question of the interaction of the factors temperature and binder content also requires additional investigation, taking into account the board thickness and the total duration of the pressing cycle.

The optimisation was performed with a view to achieving minimum values of swelling in thickness. As the board thicknesses are standardised, minimum for the three main sizes – 8, 12 and 16 mm, which are subject of this investigation, was sought.

The results are presented graphically in Fig. 3.

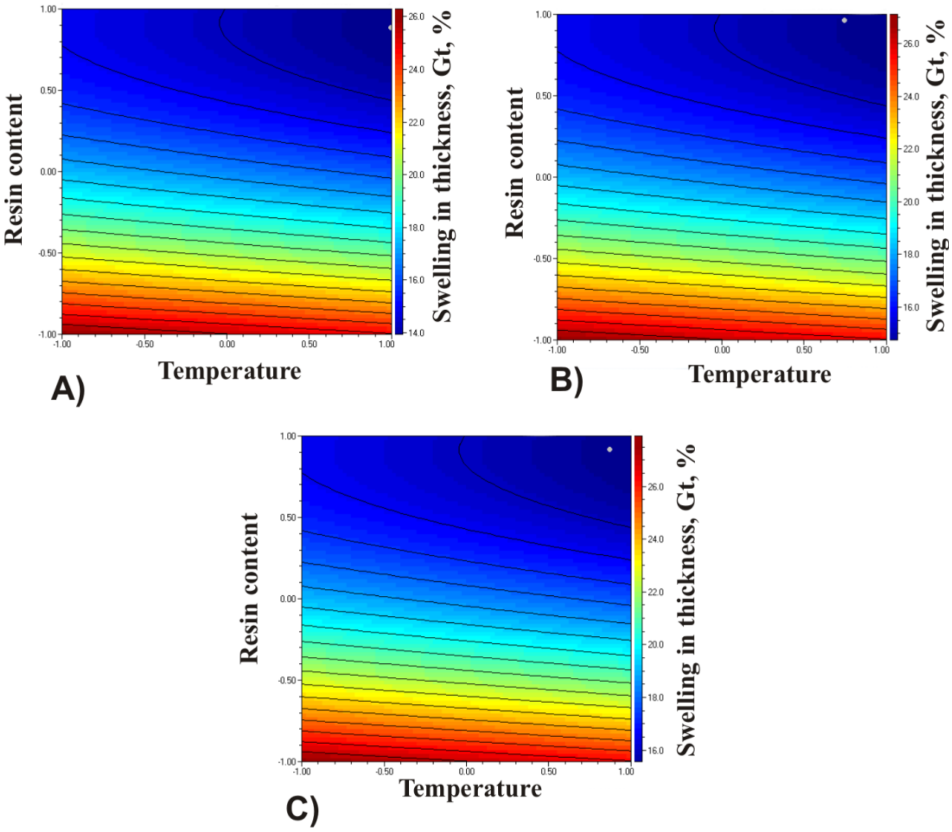

Figure 3: Optimum values of swelling in thickness of MDF
A) in boards 8 mm thick; B) in boards 12 mm thick; C) in boards 16 mm thick

The optimum value for the swelling in thickness in boards 8 mm thick is with distribution centre at 12.74 % and is achieved at pressing temperature of 200 °C and binder content of 15.5 %. The optimum value for the swelling in thickness in boards 12 mm thick is 14.93 %, at pressing temperature of 195 °C and binder content of 15.8 %. In the boards 16 mm thick, the optimum values of the factors are temperature of 197 °C and binder content of 15.7 %.

The analysis of the regression model shows that minimum values for swelling in thickness are observed in the upper limiting range of the factors pressing temperature and binder content. In boards 12 and 16 mm thick, the optimum temperature is below the limit one, which may be explained with the longer time of contact of the face layers of the boards with the platens of the press and the initial processes of destruction of the binder in these layers.

The regression model describing the effect of pressing temperature, MDF thickness and binder content on the water absorption of the boards is of the type:

$$\hat{Y} = 47.70 - 1.556X_1 + 1.282X_2 - 12.398X_3 + 9.36X_3^2 \quad \textbf{(2)}$$

The equation is characterised by a coefficient of determination $R^2 = 0.88$ and $F_{calc.} = 17.81 > F_{cr}$ ($\alpha=0.05$; $\nu_1=5$; $\nu_2=9$) = 3.48 and, therefore, adequately describes the subject investigated.

Within the range of variation of factors, the water absorption of the boards varies from 77 to 38 %, which shows variation of 220 %.

When analysing the effect of the factors on the water absorption of MDFs, the positive effect of temperature and binder content and the negative effect (increase of water absorption) of the board thickness is taken into account.

The effect of the temperature applied and board thickness on the swelling in thickness is described with linear regression, with the two factors having effect in opposite directions, i.e. with the decrease of pressing temperature from 200 °C to 160 °C and respectively increase of the thickness from 8 mm to 16 mm, considerable deterioration in the water absorption of the boards is observed. In terms of absolute value, the effect of the temperature is higher than that of the board thickness in the investigated range of variation of the factors, as seen from Fig. 4.

The intensity of the effect of binder content in the investigated range of variation is considerably higher than that of the pressing temperature. Here, the relationship is quadratic, with main drop of the water absorption being observed in case of increase of binder content to 14 %. After 15.4 %, insignificant deterioration in the water absorption is observed, with this being most strongly expressed in the boards 16 mm thick and at pressing temperature of 200 °C.

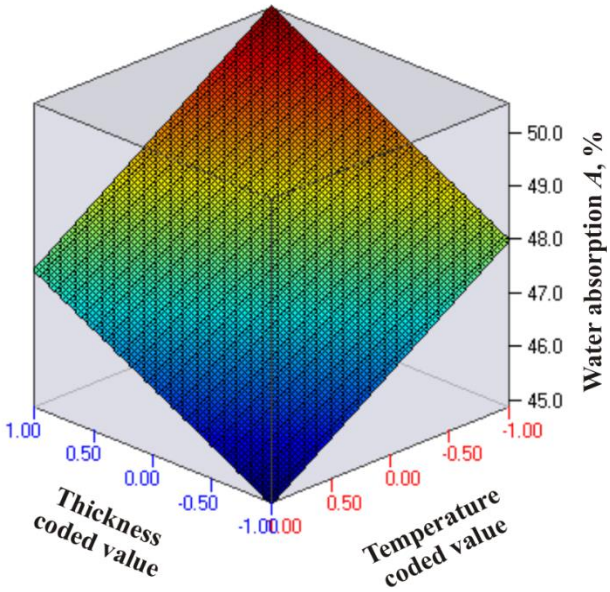

Figure 4: Effect of pressing temperature and board thickness on water absorption of laboratorially manufactured MDF with binder content of 12 %

The latter could be explained with the increased time of contact of the surface layers of the board with the platens of the press and manifestation of initial processes of destruction of the binder (Fig. 5).

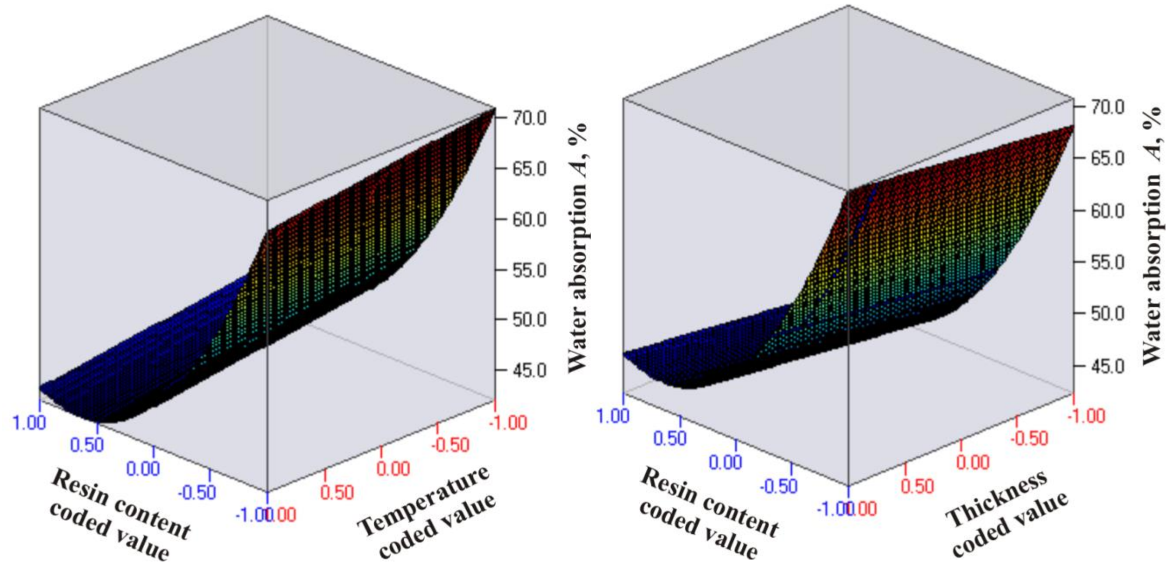

Figure 5: Effect of pressing temperature and binder content on water absorption of laboratorially manufactured MDF, in boards 12 mm thick; and effect of board thickness and binder content on water absorption of laboratorially manufactured FBs, at pressing temperature of 180 °C

Taking into account the effect of board thicknesses and binder content, the factors' effect in opposite directions shall be taken into consideration. Therefore, to attain the same water absorption, in case of increase of board thicknesses and other things being equal, the binder content shall be increased. The intensity of the effect of binder content is more than ten times bigger within the range 8 – 14 %, on account of which, with small increase of this factor, the effect of the increased board thickness may be compensated.

The optimum value of water absorption in boards 8 mm thick is with distribution centre 41.10 %, at values of the factors software: pressing temperature 197 °C, binder content 15.1 %. The optimum value of water absorption in boards 12 mm thick is with distribution centre 42.59 % at pressing temperature of 198 °C and binder content of 15.4 %. In the boards 16 mm thick, the optimum values of the factors are temperature of 200 °C and binder content of 14.52 % (Fig. 6).

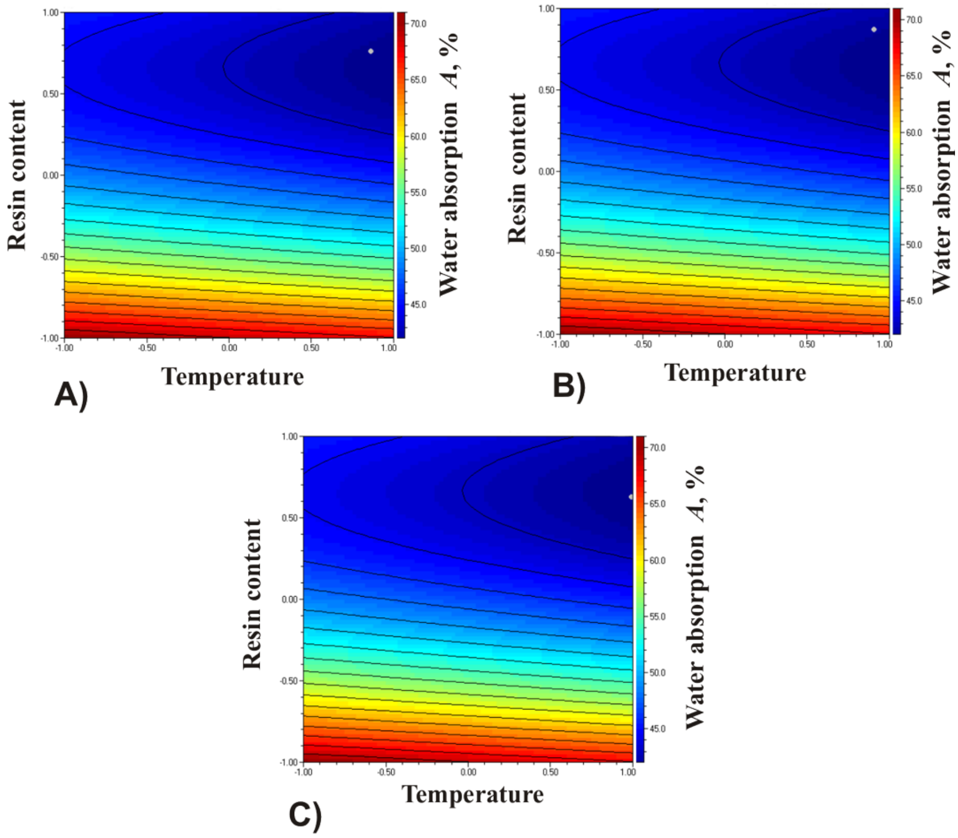

Figure 6: Optimum values of water absorption of MDF
A) in boards 8 mm thick; B) in boards 12 mm thick; C) in boards 16 mm thick

CONCLUSIONS

As a result of the conducted investigation on the effect of pressing temperature and binder content on the main physical properties of MDF with thicknesses of 8 mm and 16 mm, the following main conclusions may be drawn:

1. With the increase of the pressing temperature, considerable improvement in the water absorption and swelling of the boards is observed. The investigated relationship is linear, with decrease of water absorption, respectively swelling in thickness of MDF, being observed with the increase of the temperature from 160 to 200 °C;
2. Out of the factors investigated, of highest intensity of effect on water absorption and swelling of MDF is the binder content, with the relationship being quadratic. Greatest decrease of the factors investigated is

observed in case of increase of binder content to 14 %;

3. The effect of board thickness is negative, with the relationship in the investigated range being linear. I.e., with the increase of board thickness, increase of water absorption and swelling of MDF is observed;
4. In order to achieve equal values water absorption and swelling of MDF in case of increase of their thicknesses, the binder content or the pressing temperature shall be increased. Because of the fact that the effect of binder content is considerably higher, with relatively small increase of this factor, the effect of the increased board thickness may be compensated;
5. The optimum values for water absorption and swelling of the investigated board sizes are obtained at values of temperature and binder content close to the upper limit ones;

In further investigations of the given issue, the effect of the pressing duration at different temperature levels shall be taken into account.

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