Original scientific paper
UDK: 674.817-415

PRODUCTION OF MDF FROM HARD HARDWOOD TREE SPECIES WITH UREA-FORMALDEHYDE RESINS

Julia Mihajlova, Victor Savov
University of Forestry, Sofia
jmihajlova@abv.bg; victor_savov@abv.bg

ABSTRACT

There is a number of technological difficulties related mainly to the lower slenderness ratio of the fibrous elements and the relatively small coefficient of compression in the production of MDF from hard hardwood tree species. The negative impact of these factors may be compensated, at least partially, with a change in the technological factors during production.

In this paper, an examination with respect to the effect of some factors in the production of MDF has been presented. The effect of the binder content (when using urea-formaldehyde resin), the effect of the density of the boards and the pressure during pressing have been examined. Regression equations have been worked out for the effect of these factors.

Optimum density of MDF from wood of hard hardwood tree species, as well as values of the pressure during pressing, at which this density shall be obtained, have been determined. Optimum durations of pressing at different temperatures have been determined in order to achieve best values of the physicomechanical indices of MDF.

Key words: MDF, hardwood tree species, technological factors, UFR.

1. INTRODUCTION

Production of wood-based boards is one of the fastest developing productions in woodworking industry. For the period 2009-2014, an increase by 40% of the total volume in this production was recorded, with the production of fibreboards (FBs) being the second in terms of volume, and before it being only the production of veneer and plywood. Due to their considerably better physico-mechanical indicators, the fibreboards replace the particleboards in their traditional spheres of application, related to the production of furniture and equipment. The increase of the production of fibreboards is mainly due to the growth of the production of MDF – this production constitutes 78% of the total production of FBs.

In Bulgaria, there is a considerable raw material potential for utilisation of small-sized wood and wood of lower quality class from hard hardwood tree species. This wood is traditionally used for generation of thermal energy in the form of firewood, which is too inefficient.

In Bulgaria, there exist traditions for utilisation of such type of wood raw material in the production of FBs after the wet process (Donchev, G. 1982.) In the production of MDF from hard hardwood tree species, however, there is a number of technological difficulties related mainly to the lower slenderness ratio of the fibrous elements and the relatively small coefficient of compression. The negative impact of these factors may be compensated, at least partially, with a change in the technological factors during the production (Burmester, A., and H. J. Deppe 1973; Deng, J., D. Q. Yang, and X. Geng 2006; Goroyias G., J., and M. D. Hale 2004; Mihajlova, J., V. Savov, Y. Borshukov. 2013)

In this paper, an examination with respect to the effect of some factors in the production of MDF from hard hardwood tree species has been presented. The phenomena investigated have been the effect of the binder content when using urea-formaldehyde resins, the effect of the density of the boards and the pressure during pressing.. Regression equations have been worked out for the effect of these factors.

Optimum density of MDF from wood of hard hardwood tree species, as well as values of the pressure during pressing, at which this density shall be obtained, have been determined. Optimum duration of pressing at different temperatures has been determined in order to achieve best values of the physico-mechanical indicators of MDF.

2. MATERIALS AND METHOD

For the purpose of the investigation, in the production of the boards under laboratory conditions, industrially manufactured (in Welde Bulgaria AD) wood-fibre was been used. The mass was manufactured as per the Asplund thermo-mechanical method for defibration with use of Defibrator L 46 unit. The mass is composed of wood of beach (*Fagus silvatica* L.) and Turkey oak (*Quercus cerris* L) to the ratio of 2:1 and was dried in a laboratory to water content of 11%, being with bulk density of 29 kg/m^3 and degree of defibration of 22 DS.

The boards were manufactured by means of a laboratory mixer, a moulding box and a laboratory press PMC ST 100 (Fig. 1).

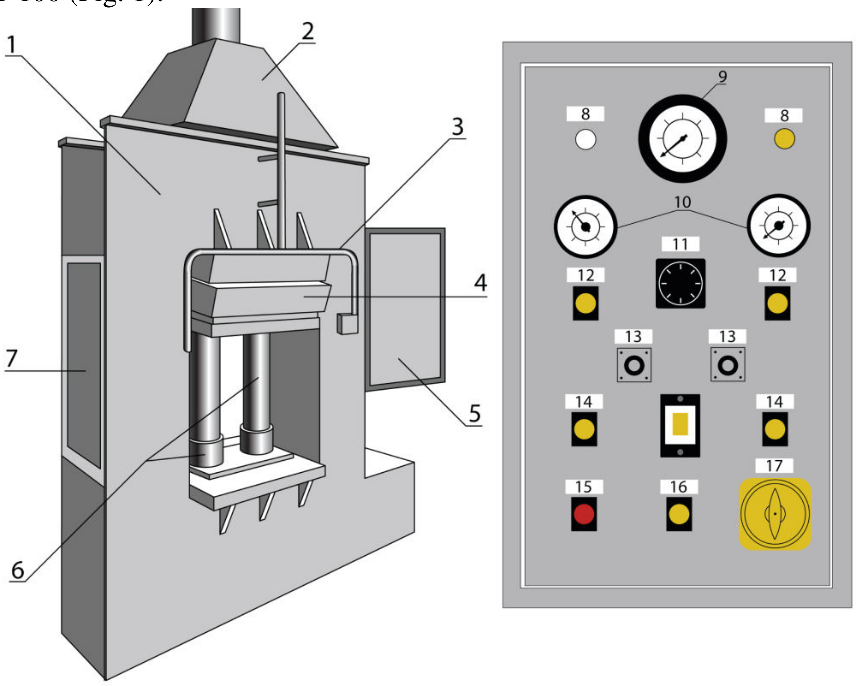


Figure 1. *Laboratory press PMC ST 100*

1 – body; 2 – aspiration; 3 – protection; 4 – press platens; 5 – control board; 6 – hydraulic pistons; 7 – protective grid, 8– control lamps; 9 – setting and control of the temperature of platens; 10 – pressure indicators; 11 – timer; 12 – pressure application; 13 – timer setting buttons; 14 – pressure reduction; 15 – machine emergency stop; 16 – machine start button; 17 – main switch.

The physico-mechanical indicators of the boards were determined in conformity with the requirements of the valid European norms (EN) in the field (BDS EN 310:1999. Wood-based panels: Determination of modulus of elasticity in bending and of bending strength; BDS EN 316:2009. Wood fibre boards. Definition, classification and symbols; BDS EN 317:1998. Particleboards and fibreboards – Determination of swelling in thickness after immersion in water; BDS EN 323:2001. Wood-based panels – Determination of density; BDS EN 326-1:2001. Wood-based Panels – Sampling and cutting of test pieces and inspection; BDS EN 622-5:2010. Fibreboards. Specifications. Requirements for dry process boards (MDF); Mihajlova, J. 2000) .

For analysis of the effect of the factors, single-factor and multifactor regression analyses were used. In the latter case, optimum composition plans of B_k type were used (Trichkov, N. 2015. Course of lectures. Modelling and Optimisation of Process).

The processing of the results was accomplished by means of specialised software – a programme system for quality management and experiment planning QSTATLAB.

Regression equations of the type:

$$\hat{Y} = B_0 + \sum_{i=1}^{k} B_i X_i + \sum_{i=1}^{k} \sum_{q=i+1}^{k} B_{iq} X_i X_q + \sum_{i=1}^{k} B_{ii} X_i^2 \quad (1)$$

where: $\hat{Y}$ is the value of the output quantity, predicted according to the model;
B_0, B_i, B_{iq}, B_{ii} – regression coefficients;
X_i, X_q – values of the controllable factors;
were worked out.

Optimisation of the results was performed after the method of random search with setting factorial and functional limitations by means of QSTATLAB, too.

3. RESULTS AND ANALYSIS

As a result of a number of experimental studies conducted in the Department of Wood Mechanical Technology at University of Forestry - Sofia, it was established that the recommended density in the production of MDF form hardwood tree species is 720 kg/m^3. At higher densities of boards, the limitation for swelling in thickness is not achieved.

On this basis, a factor analysis for the effect of the pressing pressure (*X*) on the density of FBs was performed.

The pressing pressure varies within the range of 0.6 to 3.0 MPa. The derived approximating function is of the type:

$$\widehat{Y} = 829.2 + 153.4X - 40.62X^2 \quad (2)$$

In graphic form, the effect of the pressing pressure within the examined range of variation on the density of MDF is presented in Figure 2.

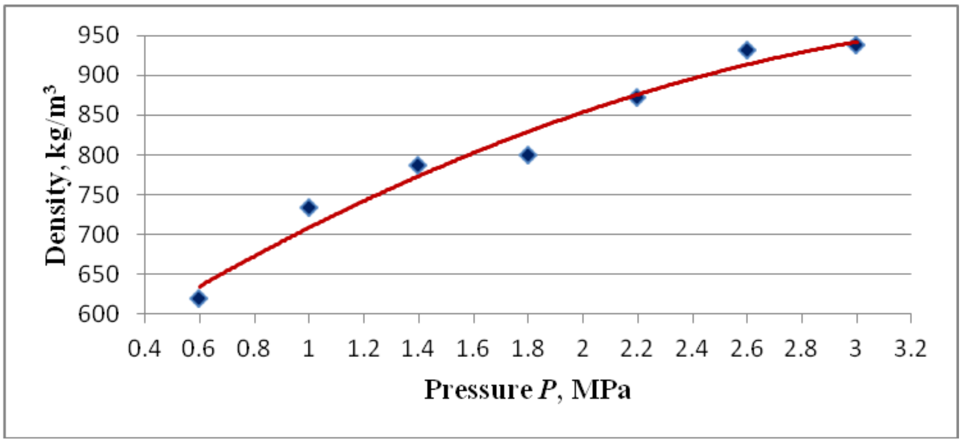


Figure 2. *Effect of pressing pressure on density of MDF at water content of the mass 11%*

The analysis of the regression model shows that in order to achieve density of 720 kg/m^3, the pressing pressure at the first two stages - compaction of the fibre mat and polymerisation of the binder - shall not be under 1.2 MPa. It should be underlined that, with regard to the faster compaction of the wood-fibre mat in case of thicker boards or at lower water content in the mat, it is necessary to apply considerably higher values for the pressing pressure. It is recommended that the pressing pressure during the first stages, until the stage of the real separation of the steam-gas mixtures, is not under 1.2 MPa.

When examining the effect of the temperature of hot pressing (X_1), within a range of variation of 160 to 200 °C, for different thicknesses of MDF (X_2), within a range of variation of 8 to 16 mm, and different urea-formaldehyde resin content (X_3), within a range of variation of 8 to 16 %, the following regression equations were derived:

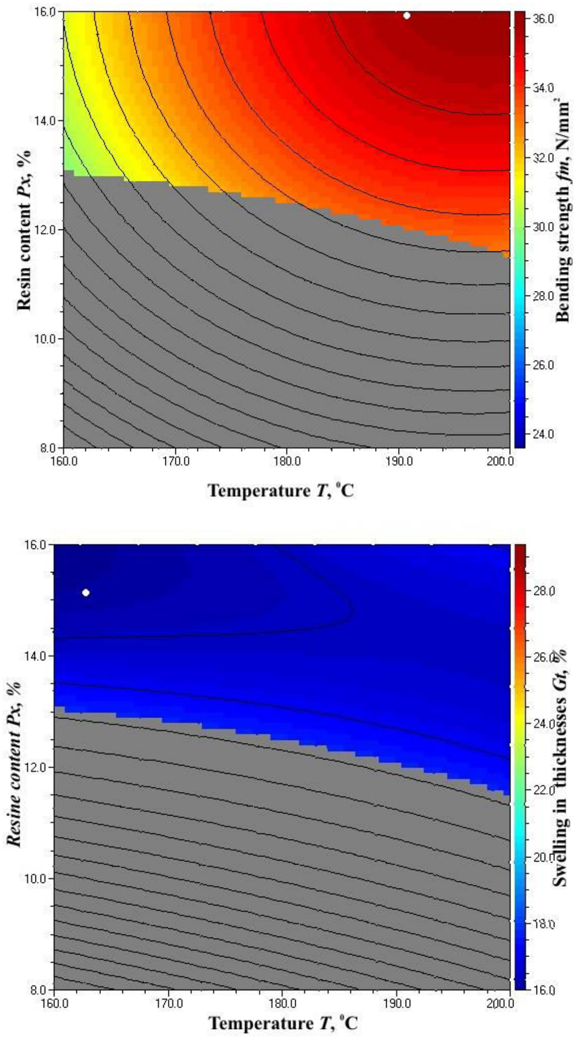
<u>For the effect on the bending strength:</u>

$$\hat{Y} = 32.63 + 1.68\,X_1 - 0.05\,X_2 + 4.56\,X_3 + 0.65\,X_1X_2 - 0.59\,X_2X_3 + 0.11\,X_1X_3 - 1.34\,X_1^2 + 0.25\,X_2^2 - 1.70\,X_3^2 \quad (3)$$

<u>For the effect on the swelling in thickness:</u>

$$\hat{Y} = 17.01 - 1.10\,X_1 + 0.69\,X_2 - 5.45\,X_3 - 0.07\,X_1X_2 + 1.23\,X_2X_3 + 1.33\,X_1X_3 + 3.57\,X_1^2 - 1.52\,X_2^2 + 2.34\,X_3^2 \quad (4)$$

Functional limitations for bending strength of at least 23 N/mm^2 and maximum permissible swelling in thickness of 18% were introduced. For the most often distributed of the examined thicknesses of MDF – 16 mm, the optimum (maximum for the strength and minimum for the swelling in thickness respectively) values of the examined indicators are presented in Fig. 3.



A) B)

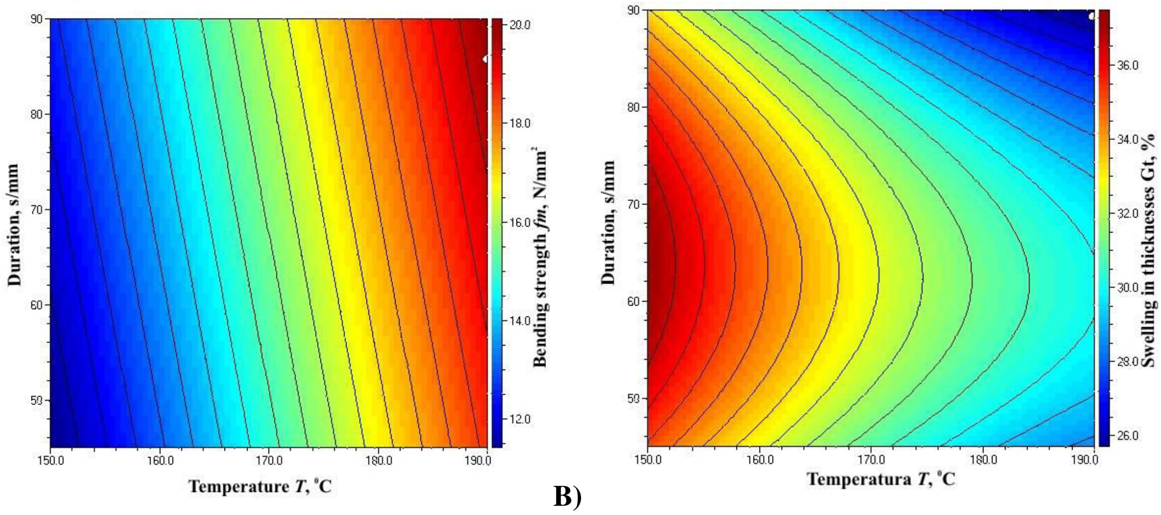
Figure 3. *Optimum value of: A) bending strength and B) swelling in thickness of MDF in case of functional limitations for the two indicators in order to achieve the values required pursuant to the standard, in case of variation of the pressing temperature and the urea-formaldehyde resin content*

The optimum value for the bending strength – 36.4 N/mm^2, was obtained at 190 °C and urea-formaldehyde resin content of 16%. This value is considerable above the value required pursuant to the standard and from economical point of view the increase of the binder content to this value is unjustified.

For the swelling in thickness, the optimum value – 13.4%, was obtained at urea-formaldehyde resin content of 15% and considerably lower temperature of 163 °C, which may be explained with partial destruction of the resin at higher temperatures for the given pressing duration.

Nevertheless, the minimum urea-formaldehyde resin content at which the requirements for bending strength and swelling in thickness of boards may be achieved is 11.5%, with the hot pressing temperature in this case having to be 190 °C. Therefore, from technological, environmental and economical points of view, it is unjustified to use urea-formaldehyde resin content above 11.5%.

When examining the effect of the temperature of hot pressing (at variation of 150 to 190 °C) and the pressing duration (at variation of 45 to 90 s/mm) in the production of MDF on the basis of urea-formaldehyde resins, it was established that both for the bending strength and for the swelling in thickness, the optimum values are obtained at the upper limit values of the factors, viz. 190 °C and 90 s pressing duration, Fig. 4.



A) B)

***Figure 4**. Optimum value of: A) bending strength and B) swelling in thickness of MDF on the basis of urea-formaldehyde resins, in case of variation of temperature and duration of hot pressing*

4. CONCLUSIONS

As a result of the analysis performed with respect to some aspects in the production of MDF from wood of hard hardwood tree species, the following main conclusions may be drawn:

1. MDF may successfully be produced entirely from wood of hard hardwood tree species; This can be achieved in case of application of urea-formaldehyde resin;
2. With a view to achievement of density of 720 kg/m^3 of MDF from wood of hard hardwood tree species, it is not recommendable for the pressing pressure to be under 1.2 MPa during the first stages of hot pressing until the stage of separation of the steam-gas mixtures.
3. In production of MDF from wood of hard hardwood tree species on the basis of urea-formaldehyde resin, the values of the indicators bending strength and swelling in thickness, required pursuant to the standard, may be achieved at minimum binder content of 11.5%, with the hot pressing temperature in this case having to be 190 °C;

REFERENCES

[1] Burmester, A., and H. J. Deppe 1973. Simple methods of improving dimensional stability. (2) Treatment of wood-based materials, technology, economics.

[2] BDS EN 310:1999. Wood-based panels: Determination of modulus of elasticity in bending and of bending strength.

[3] BDS EN 316:2009. Wood fibre boards. Definition, classification and symbols.

[4] BDS EN 317:1998. Particleboards and fibreboards – Determination of swelling in thickness after immersion in water.

[5] BDS EN 323:2001. Wood-based panels – Determination of density.
[6] BDS EN 326-1:2001. Wood-based Panels – Sampling and cutting of test pieces and inspection.
[7] BDS EN 622-5:2010. Fibreboards. Specifications. Requirements for dry process boards (MDF).
[8] Deng, J., D. Q. Yang, and X. Geng 2006. Effect of process parameters on fungal resistance of MDF panels.
[9] Donchev, G. 1982. Fibreboard manufacturing. Technica State Publishing House. S.
[10] Garcia R., A., A. Cloutier, and B. Riedl 2006. Dimensional stability of MDF panels produced from heat treated fibers.
[11] G., J., and M. D. Hale 2004. The mechanical and physical properties of strand boards treated with preservatives at different stages of manufacture.
[12] Mihajlova, J. 2000. Handbook for Exercises in Particleboard Technology. LTU Publishing House. S.
[13] Mihajlova, J., V. Savov, Y. Borshukov. 2013. The Effect of Some Technological Factors on Mechanical Properties of MDFs Made of Wood of Hardwood Tree Species. Sc. J. Wood, Design & Technology, Vol.2, No.1,(2013):86-92.
[14] Programme system for quality management and experiment planning QSTATLAB.
[15] Trichkov, N. 2015. Course of lectures. Modelling and Optimisation of Process.