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SELECTED PHYSICAL AND MECHANICAL PROPERTIES OF COMBINED WOOD BASED PANELS FROM WOOD FIBERS AND SAWDUST

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ABSTRACT

The production of wood fiber mass is a very energy-intensive process This is also one of the reasons for the higher cost of this material in comparison of that at particleboards. One possibility to partially solving this problem is the inclusion of industrial wastes, which has not undergone a refining process, in MDF composition.

There is a significant amount of industrial wastes resulting from logging – these are mainly the sawdust resulting from the processing of solid wood with a band saw. It should be pointed out that this method of obtaining solid wood materials is widespread, both globally and in Bulgaria.

This report presents a study on the influence of the content of coniferous sawdust on the properties of combined panels from wood fiber and sawdust. Produced panels were with variation of sawdust content from 0 to 50% and respectively the fiber content was from 100 to 50%. The increase in sawdust content was with a step of 10%. The main physical and mechanical properties of panels were determined and experimentally-statistical equations for the influence of coniferous sawdust content on the properties of the panels were derived. It was determined at what percentage of sawdust the panels have properties that meet the requirements of the relevant standards for MDF.

Key words: MDF, refining, combined wood based panels, coniferous sawdust.

INTRODUCTION

Fiberboards are a composite wood based engineered material with a dispersed phase from wood fibers and a compound matrix phase formed by adhesion and cohesion bonds (Ayrilmis et al., 2017; Benthien, J. et al., 2014; Heiko Thoemen et al 2010).

In a manufacturing plant for Medium Density Fiberboard (MDF) about 35% of thermal energy and 44% of electricity are consumed in steaming and refining processes as the specific energy consumption at this technological stage is from 80 to 140 $kWh^{-1}.t^{-1}$ (Li, J et al. 2006). Because of which the refining process plays a significant role in the formation of the final cost of production (Jun Hua et al., 2017, Martínez et al., Hellström, L.M et al 2012). The engineering of MDF properties can be effectively accomplished by adjusting the parameters of wood pulp (Shi, J. et al 2006; Htun, M., and Salmén, L. 1996).

In determining the characteristics of the raw material, account should be taken of both their impact on the MDF properties and the cost of production (Li, J et al 2007). Reducing the cost of the panels can be achieved by incorporating in their composition wastes from the woodworking industry which do not undergo to a refining process. An example of such raw material is sawdust obtained by sawing of logs with band saw (Bello R. S. 2017). At present, this waste from the wood industry is mainly used in the production of pellets (Bergström D. et al., 2008) and briquettes (Pushpa J. et al 2012) and also in the production of bioethanol (Irawati D., 2006). It should be said that the possibility of using such type of sawdust as a raw material for one of the fastest growing industries, namely that of MDF production, has not been sufficiently studied.

The presented shows the relevance of a study on the possibility for inclusion of coniferous sawdust in the composition of MDF and the effect of this inclusion on the properties of the panels.

MATERIALS AND METHODS

For the purpose of the study was used industrial wood pulp, produced by *Asplund* thermo-mechanical refining process. The pulp is produced in "Wellde – Bulgaria" from hardwood tree species – beech (*Fagus silvatica* L.) and Turkish oak (*Quercus cerris* L.) in a 2:1 ratio.

The sawdust was from coniferous wood species – a mixture of spruce (*Picea abies* L.) and white pine (*Pinus silvestris* L.), respectively in a ratio of 3:1 and was obtained from cutting of logs by band saw. Coniferous sawdust was chosen as it is the most common waste from cutting logs for construction beams. The moisture content was 11% for the wood pulp and 12% for the sawdust. The pulp freeness was determined by the Shopper-Rigler method and was 11 ShR°, which corresponds to the pulp freeness of 22 DS. The bulk density of the pulp was 32 kg.m^{-3}, and of sawdust – 145 kg.m^{-3}. The fractional composition of sawdust was as follows: 2.0 mm/2.0 mm – 1.24%; 2.0 mm/1.0 mm – 25.71%; 1.0 mm / 0.8 mm – 6.67%; 0.8 mm / 0.5 mm – 34.2%; 0.5 mm / 0.315 mm-19.0%; 0.315 mm/ 0.2 mm – 9.25%, 0.2 mm/ 0 mm – 3.94%.

The target density of the panels was 820 kg.m^{-3} and the target thickness was 8 mm.

The combined wood based panels, composed of wood fiber mass and coniferous sawdust, were produced according to plan of the experiment presented in Table 1.

Table 1: Experimental plan

№	Content of wood fiber mass, kg	Content of coniferous sawdust, kg	Content of coniferous sawdust P_x,%
1.	1.964	0	0
2.	1.768	0.196	10
3.	1.571	0.393	20
4.	1.375	0.589	30
5.	1.178	0.786	40
6.	0.982	0.982	50

The hot-pressing regime was as follow: 1st stage – duration 3 min at specific pressure of 2.5 MPa; 2nd stage – duration of 3 min at specific pressure of 1.5 MPa; 3rd stage – duration of 6 min at specific pressure of 0.8 MPa. The temperature of hot-pressing was 185±5° C. The content of urea-formaldehyde resin was 10%.

The properties of the panels were determined by standardized methods in accordance with EN 310, EN 316, EN 317, EN 319 and EN 323. Based on experimental data were derived approximating functions for the influence of the content of conifers sawdust on properties of panels. As a measure for accuracy of the approximation was used a coefficient of determination – R^2.

RESULTS AND DISCUSSION

The results for the properties of the panels at different content of sawdust are presented in Table 2.

Table 2: Physical and mechanical properties of combined wood based panels

Panel №	Content of coniferous sawdust *Px*,%	Density, ρ, kg.m^{-3}	Water absorption, *A*,%	Swelling in thickness, G_t,%	Bending strength, *fm*, N.mm^{-2}	Internal Bond strength, *ft*, N.mm^{-2}
1.	0	827±11	13.52±0.64	13.21±0.64	35.39±0.95	0.54±0.06
2.	10	815±9	23.51±0.79	15.26±0.73	32.24±0.51	0.51±0.08
3.	20	832±21	45.74±0.84	24.11±0.90	28.99±0.79	0.48±0.06
4.	30	844±11	49.13±1.20	27.09±1.30	26.40±0.61	0.35±0.05
5.	40	847±14	55.76±1.21	28.04±1.22	18.81±0.53	0.33±0.06
6.	50	836±15	64.70±1.07	29.85±1.48	18.64±0.19	0.28±0.08

The approximation function for the influence of sawdust content on water absorption of the panels is:

$$\hat{A} = 12.602 + 1.621.P_x - 0,012.P_x^2 ,\%, \quad \mathbf{(1)}$$

where $\hat{A}$ is the predicted value for water absorption and P_x is the content of sawdust,%.

The coefficient of determination for the equation is $R^2 = 0.97$.

The graphical interpretation of the studied dependence is presented in Figure 1.

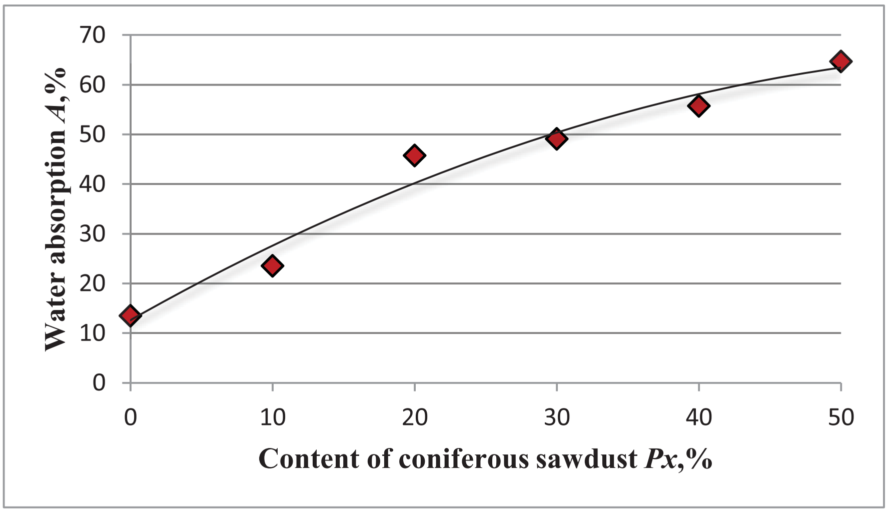

Figure 1: Dependence of water absorption of the panels from the content of coniferous sawdust

The water absorption of the produced panel varied from 13.52 to 64.70%. As the sawdust content increases, the water absorption of the panels increase significantly, i.e. this property is deteriorating when sawdust is added to the MDF composition. In comparison of water absorption at 0% sawdust content and 50% sawdust content, is accounted an increase of 4.8. A significant increase of the property is also observed with the addition of only 10% sawdust. The deterioration in that case is from 1.74 times. Another significant increase in values of the property is observed when sawdust content increase from 10% to 20%, the deterioration here is 1.95 times. After 20% content of sawdust is passed the deterioration of the property is significantly less and ranges from 5% to 7% relative difference between the individual panels.

The results obtained for this property of the panels can be explained by a reduction in the active contact area between the fibers, resulting in a reduced number of both the cohesion and adhesive bonds in the combined wood based panels.

The dependence of swelling in thickness of the panels from content of coniferous sawdust can be described by the equation:

$$\hat{G}t = 12.08 + 0.649.P_x + 0.006.P_x^2, \%, \quad \textbf{(2)}$$

where $\hat{G}t$ is the predicted value for swelling in thickness and P_x is the content of sawdust,%.

The equation is characterized by coefficient of determination $R^2 = 0.95$.

The graphical interpretation of the studied dependence is presented in Figure 2.

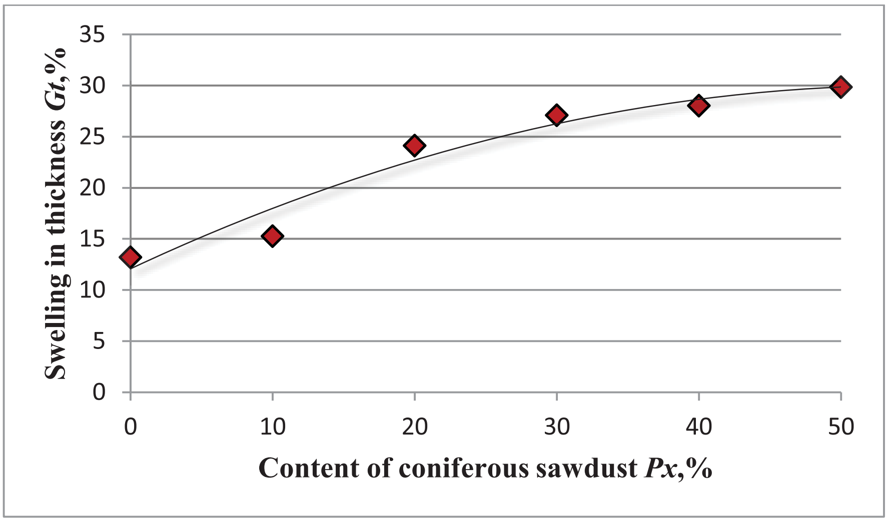

Figure 2: Dependence of swelling in thickness of the panels from the content of coniferous sawdust

The dependence of swelling in thickness is similar to that observed at water absorption of the panels, with an increase in sawdust content the swelling in thickness increases from 13.2% to 29.9%. So the panels with 0% content of sawdust have 2.26 times better, respectively lower, swelling in thickness compared to the panels obtained with 50% coniferous sawdust. For this property, the deterioration with increasing content of conifer sawdust from 0% to 10% is relatively less than the deterioration observed at water absorption. Increasing of the swelling in thickness in this case is 1.16 times. The most significant is the deterioration of the property when the content of coniferous sawdust is increased from 10% to 20% – 1.56 times. After this limit for saw dust content, is observed evenly, small in value, deterioration of the property, as the difference between 20% and 50% coniferous sawdust content is in the order of 1.24 times.

Panels containing 10% coniferous sawdust meet the requirements for the swelling in thickness of MDF for general purpose and use in humid conditions (type MDF) and for use as bearing structures in dry conditions (type MDF.HL). The requirements for the swelling in thickness for other types of MDF were not covered. Panels with a coniferous sawdust content of more than 10% do not meet the requirements of the standard in terms of swelling in thicknesses (EN 622-5).

The regression equation reflecting the influence of coniferous sawdust content on the bending strength of the panels is as follows:

$$\hat{f}_m = 35{,}78 - 0{,}362.P_x, \text{ N.mm}^{-2}, \quad \textbf{(3)}$$

where $\hat{f}_m$ is the predicted value for bending strength and P_x is the content of sawdust,%.

The coefficient of determination R^2 is 0.96 and the graphical interpretation of the studied dependence is presented in Figure 3.

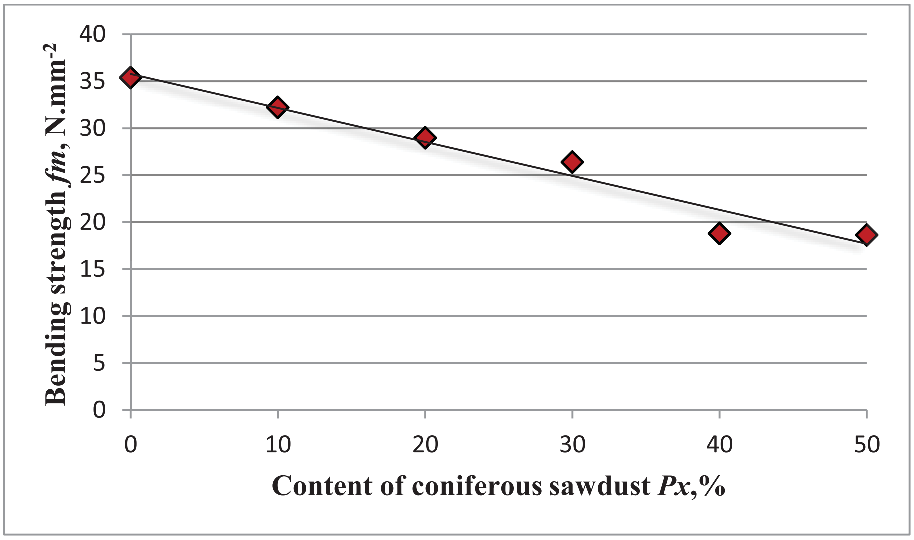

Figure 3: Dependence of bending strength of the panels from the content of coniferous sawdust

As can be seen from the figure, the studied dependence is linear, with an increase in the percentage of sawdust is observed significant decrease in bending strength from 35.4 to 18.6 N.mm^{-2}. Therefore, the decrease in the property values is 1.9 times. Although in this property there is no significant change with increase content of coniferous sawdust up to 30%, when content of sawdust increase from 30% to 40% there is a decrease in the bending strength of 1.4 times. The difference in bending strength between the panels with 40% and with 50% sawdust content is within the statistical error (below 5%).

Panels with up to 10% coniferous sawdust content meet the requirements for MDF for bearing structures and use in dry conditions. Panels with up to 20% sawdust content meet the requirements for bending strength for general purpose and use in wet conditions, and MDF with up to 30% sawdust content meet the requirements for general purpose and use in dry conditions.

The dependence of the Internal Bond (IB) strength on the sawdust content is described by an equation of the type:

$$\hat{f}_t = 0{,}56 - 0{,}006.P_x\text{, N.mm}^{-2}, \qquad \textbf{(4)}$$

where $\hat{f}_t$ is the predicted value for IB strength and P_x is the content of sawdust,%.

The coefficient of determination is R^2 = 0.97.

The dependence between coniferous sawdust content and IB strength is negative. As with the other properties, there is also a significant deterioration in the values of the property with an increase in the content of sawdust, Figure 4.

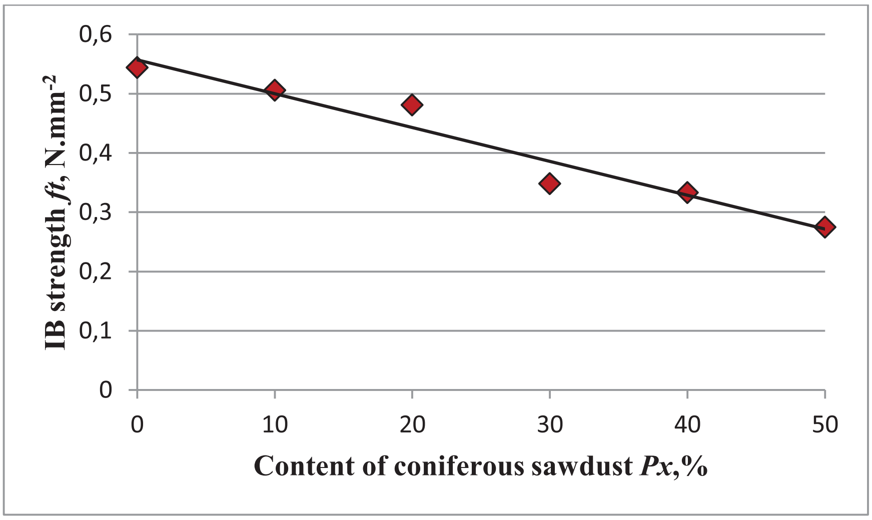

Figure 4: Dependence of IB strength of the panels from the content of coniferous sawdust

With the addition of sawdust up to 10%, there is a relatively small, 1.07 times, deterioration of the property. When the sawdust content increases from 10% to 20% this decrease is 1.05 times. In the studied range of variation, the biggest drop in the values of IB strength, respectively the most significant deterioration is observed when the content of coniferous sawdust increased from 20% to 30%. The difference in the value of this property at 30% and 40% sawdust content in the panels is within the statistical error and the drop when content of sawdust increase from 40% to 50% is 1.21 times. Therefore, to be obtained satisfactory values for this property, the content of coniferous sawdust should not exceed 20%.

CONCLUSIONS

As a result of the study can be made the following conclusions:

1. Coniferous sawdust obtained from cutting of solid wood with band saw can be included as a raw material in the production of MDF;
2. Increasing the sawdust content increases significantly the water absorption of the panels. This can be explained by a reduction in the active zone of contact between the fibers and hence the reduced number of both the cohesive and adhesive bonds in the panels;
3. The swelling in thickness of the panels also increases with the enlargement of coniferous sawdust content; Significant increase of the values of the property is observed with the addition of only 10% sawdust and even more with the increase of sawdust content from 10% to 20%; However, panels with 10% content of coniferous sawdust meets the requirements for the general purpose MDF and use in dry conditions;
4. The bending strength of the panels is not as sensitive as other properties until the coniferous sawdust content is below 30%, but with an increase in coniferous sawdust content from 30% to 40% there is a decrease in bending strength of 1.4 times; Panels containing up to 30% sawdust meet the requirements for bending strength of MDF for general purpose and use in dry conditions;
5. There is significant deterioration in IB strength when coniferous sawdust is included in composition of

the panels; The most significant decrease in the values of that property is observed when the sawdust content is more then 20%;

6. Coniferous sawdust content of up to 10% in the MDF composition provides relatively good physical and mechanical properties of the panels, that covers the requirements for general purpose application and use in dry conditions.

REFERENCES

Ayrilmys N., Yurttas E. 2017. Effect of core layer fiber size and face to core layer ratio on properties of three layered fiberboard. BioResources 12(4), pp. 7964–7974.

Benthien, J. T., C. Bahnisch, S. Heldner, M. Ohlmeyer, Effect of fiber size distribution on medium-density fiberboard properties caused by varied steaming time and temperature of defibration process. Wood and Fiber Science 46(2) (2014) 175–185.

Bello R. S. 2017. Characterization of Sawdust Produced from Circular, Chain and Band Sawing Machines. Bioprocess Engineering. Vol. 1, No. 1, 2017, pp. 21–29. doi: 10.11648/j.be.20170101.14.

Bergström D., S. Israelson, M. Öhman, S. A Dahlquist, R. Gref, C. Boman and Wästerlund. 2008. Effects of raw material particle size distribution on the characteristics of Scots pine sawdust fuel pellets. Fuel Processing Technology 6.

Heiko Thoemen, Mark Irle, Milan Sernek. 2010. Wood-Based Panels An Introduction for Specialists. Brunel University Press, p.284. ISBN: 978-1-902316-82-6.

Hellström, L. M., Carlberg, T., Engstrand, P., Gradin, P. A. and Gregersen, Ø. W. 2012. Evaluation of collimated chipping technology for reducing energy consumption in mechanical pulping, Journal of Science & Technology for Forest Products and Processes 2(3).

Htun, M., and Salmén, L. 1996. "The importance of understanding the physical and chemical properties of wood to achieve energy efficiency in mechanical pulping," Wochenbl. Papierfabrik 124, pp. 232–235.

Irawati D. 2006. The utilization of sawdust for ethanol production. URI http://repository.ipb.ac.id/handle/123456789/9013.

Jun Hua, Guangwei Chen, Dapeng Xu , Sheldon Q. Shi. 2012. Impact of termomechanical refining conditions on fiber quality and energy consummation by mill trial. BioResources 7(2), pp 1919–1930. DOI: 10.15376/biores.7.2.1919-1930.

Kupolati W. K., Grassi, St., Frattari, A. 2012. Environmental Greening through Utilization of Sawdust for Production of Bricks. OIDA International Journal of Sustainable Development, Vol. 4, No. 12, pp. 63–78, 2012.

Li, J., Pang, S., and Scharpf, E. W. 2007. Modeling of thermal energy demand in MDF production. Forest Prod. J. 57(9), pp 97–104.

Martínez, A. Huber, C. D., Pinkl, S., Mahrdt. E, Alfred Teischinger, A., Müller, U. 2017. Dynamic Compression: A Novel Technique to Reduce Energy Consumption during Wood Fiber Production. BioResources 12(4), pp 7376–7394.

Pushpa, J., Pramod, Y. 2012. Briqueting of saw dust. Applied Mechanics and Materials Vols. 110–116 pp. 1758–1761. doi:10.4028.

Shi, J. L., Zhang, S. Y., and Riedl, B. 2006. Multivariate modeling of MDF panel properties in relation to wood fibre characteristics, Holzforschung. 60(3), 285–293.

EN 310: 1993. Wood-based panels – Determination of modulus of elasticity in bending and of bending strength.

EN 316:2009. Wood fibreboards – Definition, classification and symbols.

EN 317:1993. Particleboards and fibreboards – Determination of swelling in thickness after immersion in water.

EN 319:1993. Particleboards and fibreboards – Determination of tensile strength perpendicular to the plane of the board.

EN 322:1993. Wood-based panels – Determination of moisture content.

EN 323:1993. Wood-based panels – Determination of density.

EN 622-5:2009. Fibreboards – Specifications – Part 5: Requirements for dry process boards (MDF)”.

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