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INFLUENCE OF THE CONTENT OF LIGNOSULFONATE ON MECHANICAL PROPERTIES OF MEDIUM DENSITY FIBERBOARD

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Abstract:

One of the essential shortcomings in the production of MDF is the existence of formaldehyde emissions from boards. This could be overcome by replacement of the currently used synthetic binders. Lignin is a natural binder in wood. MDF find mainly used in the production of furniture and furnishings. For that their application essential in view of the suitability of the boards are their mechanical properties.

In this article is presented a study on the influence of the content of lignosulfonate in the composition of MDF made from hardwood tree species on their mechanical properties. The boards were produced with only 5% content of urea-formaldehyde resin and alteration in the content of calcium lignosulfonate from 0 to 20%.

The approximating functions for the influence of the content of lignosulfonate on mechanical properties of MDF were derived. On that base is made analysis with proper conclusions and recommendation for optimal content of calcium lignosulfonate in the composition of fiberboard.

Key words: *MDF; urea-formaldehyde resin; formaldehyde emission; calcium lignosulfonate.*

INTRODUCTION

Medium Density Fiberboard (MDF) is wood based engineered material which is characterized by a homogeneous distribution of physical and mechanical properties and stringent requirements to the raw materials used in production. The latest is essential in view of growing raw material deficit and shortage of large-sized wood raw material used for materials of solid wood. Its good physical and mechanical properties are due to the homogeneity of the material and the fact that MDF are composed of a plurality of lingo-cellulose components with high slenderness. This allows large active surface of the fibers and from there multiple contact areas within the boards which increasing quantities of both cohesion and adhesion bonds. Therefore this material finds numerous interior and exterior applications.

A major disadvantage of dry processed boards in comparisment of wet-processed ones is the existence of formaldehyde emissions.

There are successful attempts for production of eco-friendly MDF with the addition of enzyme lignin as a binder (Zouh et al. 2011; Mancera et al. 2011; Nasir et al. 2014). It should be emphasized that the use of enzyme lignin on an industrial scale is associated with a number of technological difficulties and lead to increased costs of the boards.

Calcium lignosulfonate is a residual product from the production of cellulose by the sulphate method. Lignosulfonates have a very low degree of harmfulness and find use, as a binder for the animal feed additives and in the production of pellets. They have relatively low glass point. A major advantage of lignosulfonates, compared with the enzyme lignin, is that they can be introduced into MDF in the form of solutions, to facilitate their even distribution and activation of the connections with the wood fibers.

Mechanical properties of MDF are essential in order to assess the suitability of the material for use in the furniture industry.

This defines the relevance of a study on the influence of the content of calcium lignosulfonate on the mechanical properties of MDF.

MATERIALS AND METHODS

The main goal of this study is to be determined the influence of the content of calcium lignosulfonate in the composition of MDF to their mechanical properties. To be fulfilled this goal in laboratory conditions they were produced MDF containing urea-formaldehyde resin of 5% and with variation in the content of calcium lignosulfonate from 0 to 20% with increment of 5%. The boards were produced with a density 850kg.m-3. For the production of MDF in laboratory conditions was used thermo-mechanical pulp of distributions in Bulgaria tree species – total content of beech (*Fagus silvatica* L) and cerris oak (*Quercuss*

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cerris L) of 80% and 20% content of poplar (*Populus alba* L). Wood fiber mass was with moisture content of 11%.

It was used calcium lignosulfonate with characteristic as follow: calcium – up to 6%; reduced sugars – up to 7%; dry content – 93%; acid factor in a 10% solution - pH = 4,3 ± 0,8; bulk density – 550kg.m^{-3}.

In order to more uniform distribution and easier activation of the calcium lignosulfonate it is inserted into the pulp in the form of a solution having a concentration of 30%, Fig.1.

Fig. 1.
Calcium lignosulfonate.

The mechanical properties of MDF were determined by standard methods (EN 310; EN 316; EN 323; EN 622-5). For each property were used in eight test specimens per board. And main statistical parameters (average, standard deviation, probability) were calculated.

The data were processed by the methods of regression analyze and it was displayed approximating function to the influence of the content of calcium lignosulfonate on the MDF properties.

As a measure of accuracy of the regression models was used the coefficient of determination – R^2 (Trichkov 2015)

RESULTS AND DISCUSSION

The summarized results for the properties of MDF, with different participation of lignosulfonate are presented in Table. 1.

Table 1

Experimental results for physical and mechanical properties of MDF

Board №	**Content of calcium lignosulfonate *Px*, %**	**Density ρ, kg.m^{-3}**			**Bending strength (MOR), *fm*, N.mm^{-2}**			**Modulus of elasticity (MOE), *Em*, N.mm^{-2}**		
		Average	STDV	*P*-value	Average	STDV	*P*-value	Average	STDV	*P*-value
1	0	843.96	89.05	0.037	25.18	4.06	0.040	2867.50	412.41	0.036
2	5	845.98	44.97	0.019	30.63	3.56	0.029	3645.00	308.73	0.021
3	10	836.18	31.17	0.013	34.73	2.38	0.017	4253.75	427.18	0.025
4	15	839.19	68.46	0.029	27.16	2.91	0.027	4151.25	303.10	0.018
5	20	844.45	66.28	0.028	24.05	1.47	0.015	3445.00	182.13	0.013

Analysis of experimental results for bending strength of MDF

The dependence of bending strength of MDF from the content of lignosulfonate, at range of variation from 0 to 20%, is described by the equation of the regression of the form:

$$\hat{f}_m = 25.38 + 1{,}53.P_x - 0.08P_x^2 \text{, N.mm}^{-2}, \quad (1)$$

where: $\hat{f}_m$ is predicted value for bending strength, N.mm^{-2};
Px – content of calcium lignosulfonate in MDF, %.

The equation is characterized by the coefficient of determination R^2 = 0.82.
Dependence is represented graphically in Fig.2.

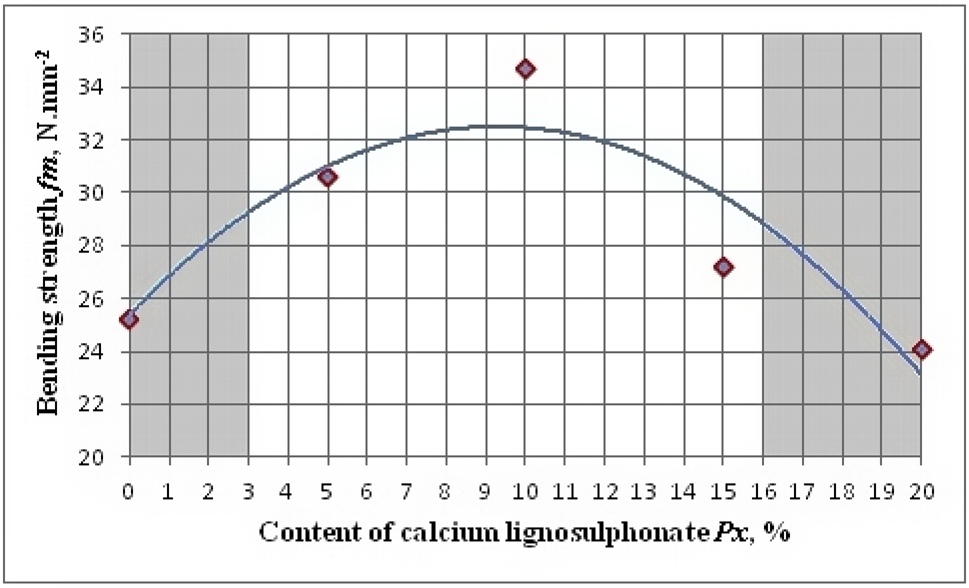

Fig. 2.
Variation of bending strength of MDF in dependence from the content of calcium lignosulfonate.

Under the conditions of the experiment bending strength varied from 24 to 34.7N.mm^{-2}. The highest bending strength was observed in MDF with 10% lignosulfonate. Bending strength increases with the increase in the content of lignosulfonate from 0% to 10%, and after passing 10%, which appears to be the inflection point, there is a decrease in value of that property. The lowest value of bending strength was accounted at MDF without lignosulfonate (0%) and with 20% of lignosulfonate, as the values of bought MDF are commensurate with differences within the statistical error. Whit the addition of up to 10% lignosulfonate the bending strength of MDF increases from 25N.mm^{-2} at boards without lignosulfonate to 35N.mm^{-2}, or it is observed an improvement of the property by 1.4 times.

All boards meet the requirements in terms of bending strength for general purpose and for use in dry conditions.

In a study by the approximated function is established that MDF with a content of lignosulfonate from 3 to 16% meets the requirements of such intended for load-bearing boards (EN 622-5). The gray area in the figure is marked MDF with a content of lignosulfonate in which the boards do not meet those requirements.

Analysis of the experimental results for the modulus of elasticity of MDF

The dependence of the modulus of elasticity in bending of MDF from the content of lignosulfonate over a range of variation of 0 to 20%, is described by the equation of the regression (approximating function) of the type:

$$\hat{E}_m = 2814.70 + 243.44.P_x - 10.51.P_x^2 \text{, N.mm}^{-2}, \quad (2)$$

where: $\hat{E}_m$ is predicted value of modulus of elasticity, N.mm^{-2};
Px – content of calcium lignosulfonate in MDF, %.

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The equation is characterized by the coefficient of determination R^2 = 0.98.

Fig. 3 illustrates the variation of the modulus of elasticity of MDF in dependence of the content of lignosulfonate.

Under the conditions of the experiment, content of urea-formaldehyde resin of 6% and lignosulfonate content between 0 and 20%, the modulus of elasticity of MDF is changed in the interval from 2868 to 4254N.mm^{-2}. The lowest value of modulus of elasticity is accounted in MDF without lignosulfonate and the best values of the property in boards with 10% content of lignosulfonate. After raising the content of lignosulfonate of more than 10% the modulus of elasticity declined.

The deterioration in the boards by increasing the content of the lignosulfonate from 10% to 15% is not significant. While the transition from 15% to 20% content of lignosulfonate lead to significant decrease in the values of the modulus of elasticity.

The improvement in the values of the modulus of elasticity of MDF with the addition of 10% lignosulfonate as compared to those without lignosulfonate is 1.5 times.

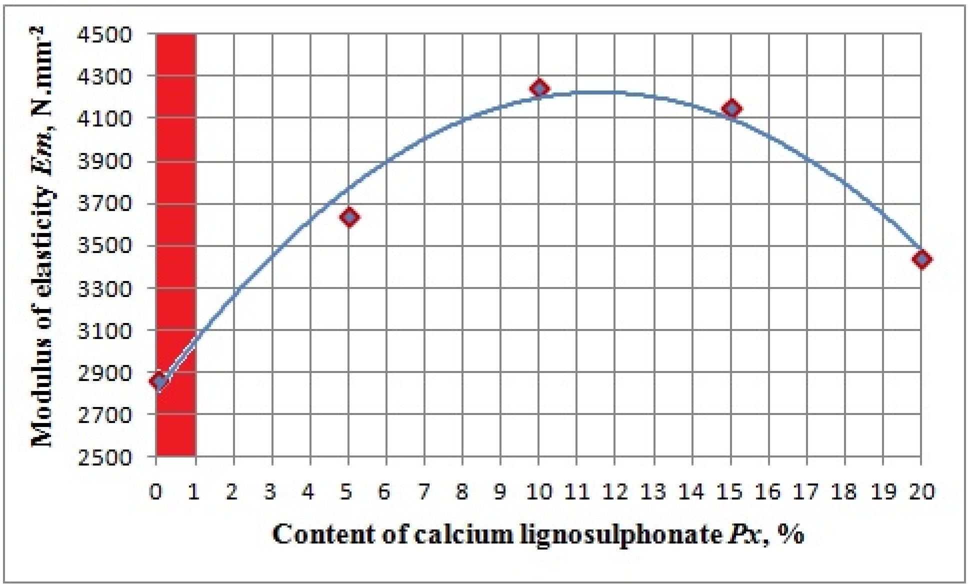

Fig. 3.

Variation of modulus of elasticity of MDF in dependence from the content of calcium lignosulfonate.

With respect to the property modulus of elasticity in bending, all boards meet the requirements for general purpose and use in humid conditions. The MDF containing lignosulfonate of one percent or more comply with the requirements for load-bearing boards and use in humid conditions (EN 622-5). With the red zone in Fig. 3 are marked MDF with content of lignosulfonate in which the requirements for the modulus of elasticity for use as load-bearing boards are not achieved.

In tested mechanical properties of MDF, bending strength and modulus of elasticity in bending, there is a decrease after passing the lignosulfonate content of 10%. An explanation of these results can be given with the greater fragility of the boards when increasing the content of lignosulfonate and a high content of the steam-gas mixture in the process of pressing, associated with the increase in moisture content with an increased content of lignosulfonate solution. To be given more specific answer to this question it should be studied and other factors affecting the process as the influence of the dry content of lignosulfonate solution, influence of the hot pressing regimes, etc.

CONCLUSIONS

As a result of the conducted study on the influence of the participation of lignosulfonate in composition of MDF on its properties, can be made the following conclusions:

1) The addition of lignosulfonate up to ten percent in the composition of MDF significantly improves bending strength and modulus of elasticity in bending of boards;
2) MDF with ten percent lignosulfonate meet the highest classes of requirements for bending strength and modulus of elasticity in bending;
3) The relationship between the content of lignosulfonate and mechanical properties of the MDF is of the second degree, as it is observed inflection point in content of lignosulfonate by ten percent;

4) Upon addition of amounts more than ten percent lignosulfonate, under conditions of the experiment, is observed degradation, respectively decreasing, of bending strength and modulus of elasticity in bending of MDF.

In conclusion with the addition of lignosulfonate, which is a waste product in the production of cellulose, are achieved the most stringent requirements for mechanical properties of MDF. As the content of the urea-formaldehyde resin is only 5%, i.e. the boards are with a very low content of free formaldehyde.

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