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INVESTIGATION OF SOME PROPERTIES OF WOOD-POLYMER MATERIAL BASED ON MODIFIED UREA-FORMALDEHYDE RESIN

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ABSTRACT

Wood processing is related to the release of large amounts of waste, such as wood dust, sawdust and others. In order to their utilization perspective direction is the wood-polymer materials production, which can be applied in many industries.

In the present study some physical and mechanical properties of wood-polymer material based on modified urea-formaldehyde resin with chlorine-containing polymers were investigated. The obtained results showed that the increase of chlorinated paraffin content leads to an improvement in all investigated physical and mechanical properties.

Key words: wood-polymer material, urea-formaldehyde resin, chlorine-containing polymers.

INTRODUCTION

In the last years, there is a great interest in the development of new technologies related to the utilization of wood waste (sawdust, shavings, etc.), (Antonović et al. 2010, Mamza et al. 2014, Kord et al. 2015, Teuber et al. 2016). Promising direction in this area is the production of wood-polymer materials which are used in various industries (Ellis 2000, Li 2011). These materials could replace the currently used particleboards and fiberboards. By pressing under suitable conditions can be produced variety of details with good operating properties (Wolcott and Englund 1999, Rafighi et al. 2014, Azeez 2017).

Along with a number of positive qualities: easy workability, low cost, low density, good physical and mechanical properties, acoustic properties, etc., wood has some drawbacks. One of these is its flammability. The elimination of this disadvantage would lead to significantly expansion of the application of wood products.

There are several studies about fire resistance of wood using water-soluble and water-insoluble inorganic, organic, mineral and synthetic substances (Seefeldt 2012). The fire resistance action is explained by the different theories of fire retardancy (Nikolaeva and Karki 2011).

The introduction of synthetic polymers as supplement to the adhesive allows increasing the fire resistance of wood materials. Such action has polymers which at high temperature do not release non-combustible gases.

The purpose of this work is to examinate some physical and mechanical properties of wood-polymer materials obtained by a modified ureaformaldehyde resin, and determine their fire resistance.

MATERIALS AND METHODS

For the production of plates from wood-polymer materials are used sawdust from beech fraction 1–5 mm with humidity 6.5%. For their sticking is used ureaformaldehyde resin-KFS 1 ("Neochim" PLC Dimitrovgrad), which is modified with chlorinated compounds.

In order to achieve optimal fire resistance of wood-polymer composites, as well as good physical and mechanical properties are manufactured plates with different variations of the supplement components. The composition of the plates is the following: sawdust, UFR- 80% and supplement 20%. Five versions of the supplement were developed:

Sample № 1

PVC containing 56% chlorine and antimony trioxide (Sb_2O_3). During combustion polyvinyl chloride decomposes to release hydrogen chloride which inhibits the combustion process. Sb_2O_3 is an activator and stimulates the release of hydrogen chloride during the combustion.

The quantity of antimony trioxide in all samples was 2%.

Sample № 2

In this case, besides polyvinyl chloride, and Sb_2O_3 – 70%, the supplement contains chlorparaffin – 30%. Chlorparaffin is a plasticizer and it is assumed that at high temperatures It will also release hydrogen chloride and thus will increases the fire resistance of the supplement.

Sample № 3

This sample was developed based on UFR, modified with chlorinated rubber containing 12 –15% chlorine. The content of chlorinated paraffin in the supplement is increased, chlorinated rubber, Sb_2O_3 – 55% and chlorparaffin – 45%. High content of soot helps to increase the fire resistance of the resulting materials.

Sample № 4

The obtained wood-polymer material is similar to the sample № 3, but with a changed percentage composition of the supplement components: a chlorinated rubber, Sb_2O_3- 40% and chlorparaffin 60%.

Sample № 5

This sample was developed using chlorinated polyvinyl chloride with a chlorine content of about 70%. The percentage of the components of the supplement is: chlorinated polyvinyl chloride, Sb_2O_3- 70% and chlorinated paraffin- 30%. The amount of the released hydrogen chloride will be higher, in comparison to ordinary polyvinyl chloride, which will lead to increasing of fire resistance.

After mixing of raw materials, test pieces of wood composites were produced by pressing at 140 ^{o}C, pressure 10 MPa and duration time- 1 min / mm thickness. The samples were conditioning at 20 ºC temperature and 65% humidity and following physical-mechanical characteristics were defined: thickness swelling and water absorption after treatment in water at 20 ± 2 ºC, bending strength. The fire resistance of the resulting wood-polymer composites was also studied.

Thickness swelling is determined in accordance with БДС EN 317:1998, using the following formula:

$$G_t = \frac{t_2 - t_1}{t_1}.100\ ,\% \qquad (1)$$

where:

t_1 – thickness of test sample before immersion in water, mm

t_2 – thickness of test sample after immersion in water, mm

Water absorption of the samples was determined in accordance with СТ СИВ 1768:1979 using the following formula:

$$\Delta_W = \frac{m_2 - m_1}{m_1}.100\ ,\% \qquad (2)$$

where:

m_1 – mass of test sample before immersion in water, g

m_2 – mass of test sample after immersion in water, g

Bending strength is determined in accordance with БДС EN 310:1999. The calculations were made by:

$$f_m = \frac{3F_{max}.l_1}{2bt^2}\ ,\ \text{N/mm}^2 \qquad (3)$$

F_{max} – failure load, N

l_1 – distance between the centers of the supports, mm

b – width of the test sample, mm

t – thickness of the test sample, mm

Fire resistance of wood-polymer materials used flame retardant additives is established according to БДС 16359:1986. The method determined the loss of mass of the samples with dimensions 30x60x150 mm. Combustion is made for at least 10 samples. The loss of mass is determined with an accuracy of 0.1% by the formula:

$$\Delta m = \frac{m_1 - m_2}{m_1}.100\,,\% \quad \textbf{(4)}$$

where:

m_1 – mass of test sample before the test, g

m_2 – mass of test sample after the test, g

The results were calculated based on statistical methods and the following parameters were determined: average arithmetical values ($\bar{x}$), average quadratic diversion (S_x),variation coefficient(V_x), average error (m_x), index of accuracy (P_x) and a maximum range of diversion (i_x).

RESULTS AND DISCUSSION

In order to investigate the effect of different additives on the physical and mechanical properties and fire resistance of the plates, the obtained results of wood-polymer materials were compared with those of the reference plate.

The results of testing the bending strength of wood-polymer materials are shown in Table 1.

Table 1: Bending strength of samples depending on the additive type in wood-polymer materials

№	Additive	Samples	$\bar{x}$ [MPa]	Sx [MPa]	Vx [%]	mx [MPa]	Px [%]	ix [MPa]
0	UFR	10	20.56	0.02	0.08	0.01	0.04	14.52
1	PVC	10	17.32	0.29	1.60	0.10	0.50	13.14
2	PVC+ chlorinated paraffin	10	20.70	0.20	0.10	0.005	0.02	104.9
3	chlorinated rubber + chlorinated paraffin	10	18.14	0.02	0.10	0.005	0.03	66.10
4	chlorinated rubber + chlorinated paraffin	10	15.35	0.01	0.06	0.006	0.04	98.10
5	chlorinated PVC + chlorinated paraffin	10	22.20	0.026	0.12	0.01	0.04	58.70

The bending strength was 3 MPa lower when UFR is modified with PVC. The addition of chlorinated paraffin in sample № 2 led to bending strength similar to that of the reference plate. Sample № 3 and № 4 with additive of chlorinated rubber and chlorinated paraffin showed relatively low parameters. Best results were obtained in sample № 5 (22.20 MPa).

Investigation of water absorption of the samples showed that all the additives reduce this indicator. Relatively lowest water absorption was observed at sample № 3 with additive of chlorinated rubber. The results are shown in Table 2:

Table 2: Water absorption of samples depending on the composition of wood-polymer materials

№	Additive	Samples	$\bar{x}$ [%]	Sx [%]	Vx [%]	mx [%]	Px [%]	ix [%]
0	UFR	10	6.10	0.02	0.30	0.01	0.02	3.70
1	PVC	10	2.90	0.15	5.10	0.04	1.40	7.60
2	PVC+ chlorinated paraffin	10	2.07	0.02	1.10	0.04	0.20	3.42
3	chlorinated rubber + chlorinated paraffin	10	1.67	0.02	0.40	0.005	0.30	2.66
4	chlorinated rubber + chlorinated paraffin	10	1.93	0.01	0.70	0.004	0.30	0.82
5	chlorinated PVC + chlorinated paraffin	10	2.07	0.003	0.14	0.001	0.04	2.03

The obtained results from the analysis of the swelling of test samples are shown in Table 3:

Table 3: Swelling of samples depending on the composition of used additives

№	Additive	Samples	$\bar{x}$ [%]	Sx [%]	Vx [%]	mx [%]	Px [%]	ix [%]
0	UFR	10	4.79	0.01	0.15	0.002	0.04	2.30
1	PVC	10	2.70	0.08	2.90	0.02	0.74	6.02
2	PVC+ chlorinated paraffin	10	2.28	0.02	0.80	0.004	0.20	2.61
3	chlorinated rubber + chlorinated paraffin	10	2.11	0.01	0.50	0.002	0.10	7.83
4	chlorinated rubber + chlorinated paraffin	10	1.74	0.004	0.20	0.002	0.10	1.79
5	chlorinated PVC + chlorinated paraffin	10	2.50	0.09	3.60	0.025	1.00	2.51

The obtained results showed that the modification of urea formaldehyde resin with the used chlorine-containing polymers decreases the swelling in all options almost twice compared to that of the reference plate. Relatively lowest value was found for sample № 4 (1.74%).

The presented data in Tables 2 and 3 clearly showed that the chlorinated rubbers, in combination with chlorinated paraffin impart good water resistance of the wood-polymer materials.

The main purpose of the used additives is to enhance the fire resistance of received materials. The analysis data of the fire resistance of the samples are present in Table 4:

Table 4: Loss of mass in burning depending on the composition of used additives

№	Additive	Samples	$\bar{x}$ [%]	Sx [%]	Vx [%]	mx [%]	Px [%]	ix [%]	Smoking [S]
0	UFR	10	16.75	0.05	0.29	0.04	0.21	12.31	84

1	PVC	10	8.50	0.08	0.94	0.03	0.41	2.24	65
2	PVC+ chlorinated paraffin	10	7.25	0.38	5.24	0.13	1.79	1.70	48
3	chlorinated rubber + chlorinated paraffin	10	7.60	0.03	0.40	0.01	0.20	1.69	56
4	chlorinated rubber + chlorinated paraffin	10	8.10	0.10	0.40	0.04	0.6	2.60	62
5	chlorinated PVC + chlorinated paraffin	10	6.30	0.30	4.50	0.13	1.90	3.90	30

The obtained results illustrate that all the additives improve the fire resistance. The smallest mass loss displays wood-polymer material with the addition of chlorinated PVC. The last contains the highest percentage of chlorine than other used polymers and therefore show a greater fire resistance. In none of the samples was not observed self-burning or smoldering.

CONCLUSION

Based on the analysis and the obtained results it was found that all investigated wood-polymer materials refer to hard burning. They do not burn on their own. Smoking has also been minimal.

By modifying the UFR with chlorinated PVC was observed very good physical and mechanical properties and the greatest fire resistance compared to other samples. In the use of chlorinated rubber were prepared wood-polymer materials with the lowest water absorption and swelling, thereby increasing the percentage of the chlorinated paraffin show a tendency to increase the water resistance.

The obtained wood – polymer materials by these methods can be used in the furniture industry, construction, shipbuilding, and other wagon industries.

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