Improving the environmental performance of laminated wood products

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Abstract. Modification of the formaldehyde resins with an extracts of softwood bark makes it possible to reduce a free formaldehyde emission from laminated wood products, in particular plywood, to increase the strength in chipping and static bending of plywood, to reduce the cost price of adhesive composition.

The laminated wood panels based on formaldehyde resin have many advantages with significant weakness of the high toxicity, which was caused by content of phenol and formaldehyde in the resins used. Production of laminated panels, in particular plywood, based on phenol-formaldehyde resins is environmentally hazardous for both environment and human health. One way of the toxicity reducing of the laminated products is modification of the phenol-formaldehyde resins with an aqueous extracts of softwood bark [1, 2].

Phenol-formaldehyde resin and extracts of softwood bark used for the modification of phenol-formaldehyde resin. Extracts obtained from bark of larch and fir with the use of inorganic and organic solvent, such as water, sodium hydroxide in water and isopropyl alcohol, were used as modifiers. The physico-chemical properties of extracts and their modified adhesives were initially defined [3]. The organoleptic properties, viscosity, pH ranges, refractive index and content of polyphenol substances are the basic properties of extractives influencing the properties of their modified adhesive compositions and bonded materials. The tables 1 and 2 show the basic physico-chemical properties of extracts investigated.

Table 1. The physico-chemical properties of extracts from a fir bark

| Names of the indicators | Extraction of fir bark |    |    |
|------------------------|-----------------------|----|----|
|                        | coldwater             | hotwater | isopropanol |
| Appearance             | muddy liquid          | liquid  |    |
| Relative viscosity on VZ-4, c | 11,01               | 10,96     | 9,91 |
| Color                  | light-yellow          | dark-yellow | red-brown  |
| Smell                  | wood                  | solvent  |    |
| pH ranges              | 6,50                  | 5,80     | 3,00 |
Table 2. The physico-chemical properties of extracts from a larch bark

| Names of the indicators | Extraction of larch bark |
|-------------------------|-------------------------|
|                         | coldwater | hotwater | isopropanol |
| Appearance              | muddy liquid | liquid |             |
| Relative viscosity on ВЗ-4, с | 9,81     | 12,60   | 10,01       |
| Color                   | light-yellow | dark-yellow | red-brown |
| Smell                   | wood       | solvent |             |
| pH ranges               | 6,38      | 5,750   | 2,90        |

One of the most important properties of extracts, on which properties of modified adhesive depends, is quantity of polyphenol substances in an extract [4]. Figure 1 presents extractives emissions according to wood and concentration of solvent (sodium hydroxide in water). With increasing of solvent concentration, there has been an increase in quantitative emission of polyphenol extractives. Larch has quantitative emission of polyphenol extractives more than a fir.

Changing the concentration of extractives changes the viscosity of the extracts. High molecular weight phenolic components and intermolecular interactions, increasing with increasing concentration, increase the viscosity. The increase in concentration by 50% leads to an increase in the viscosity of the aqueous extract by 34%, isopropanol extract by 25%.

The obtained extracts were introduced into the adhesive composition based on SFZ-3013. Analysis of the physicochemical properties of the compositions obtained shows that with an increase in the concentration of polyphenolic substances in the extract in the modified composition, the mass fraction of alkali increases and the amount of brominated substances decreases, the time of gelatinization decreases. The remaining properties are unchanged [5].

To determine the physicomechanical properties of glued wood materials based on the modified glue composition in laboratory conditions, samples of FSF plywood were made. Testing of the mechanical properties of the obtained plywood samples was carried out in accordance with the requirements of the current.

Figure 1. The dependence of the yield of extractives the concentration of the solvent (Wood species: 1 - fir, 2 – larch)
As a result of mathematical processing of the experimental results, regression equations were obtained, expressing the dependence of the mechanical properties of plywood on the modified binder from the pressing mode. As an example, we present the equation of dependence of the shear strength:

\[
\sigma_{sh} = 1.48 + 0.106\nu + 0.098p + 0.032T - 0.09\nu^2 - 0.035p + 0.07T^2 + 0.025pT - 0.08T^2
\]

The influence of the studied factors on the shear strength of the adhesive layer was evaluated using a graphical interpretation of the regression equation and graphs of the effects of the factors and their interactions.

Analysis of the nature of the joint influence of factors on the strength of cleavage showed that the amount of extractives has a greater effect on the strength of the lower level of variation of the pressing pressure (strength change is 0.14 MPa). The change in strength at the upper level of pressure variation is only 0.08 MPa, and the dependence is extreme with an inflection point at 25 % of extractives. The change in strength when changing the amount of extractive substances at the minimum and maximum pressing temperature is the same, the difference between the indicators is from 0.02 to 0.03 MPa, which indicates a slight influence of temperature on the strength of the adhesive compounds on the modified adhesives. A similar character is observed when the pressure and the pressing temperature change. When the pressing pressure is at the lower level (1.2 MPa), the pressing temperature does not affect the strength of the adhesive joint. When the pressing pressure is increased to 1.8 MPa, the difference in strength between the samples compressed at 120 and 200 °C is 0.05 MPa.

In accordance with the accepted regimes, birch plywood samples were made to determine the effect of the amount of added extract on the tensile strength of the cleavage layer and the tensile strength of the static bending.

As a result, the greatest strength among the samples, using modified adhesives, have samples made with glue containing 25 % of extract. Samples of plywood made with glue containing 15 % of extract, the maximum tensile shear fracture do not meet the requirements of the standard (when using birch veneer ultimate strength in shearing adhesive layer after boiling for 1 h is for PSF 1,5 MPa), the tensile strength at a static bend is located at the lower boundary. This is due to the insufficient amount of the introduced polyphenolic substances in the adhesive composition for the polycondensation reaction, while reducing the viscosity, pH and increasing the gelatinization time of the resin. The depth of the polycondensation reaction depends on the amount of free reactive phenol, which, when modified by extracts, will depend on the content of polyphenolic substances. The amount of isolated formaldehyde (gas-analytical method) from the tested samples ranged from 1.5 to 3.6 mg/m³ · h, which corresponds to the E1 emission class [6].

As a result of researches possibility of use for modification of phenol-formaldehyde resin of extracts of coniferous breeds of the trees received with use of inorganic and organic solvents (water, water solutions of sodium hydroxide and isopropyl alcohol is established. Introduction to the adhesive composition of the above extracts can reduce the toxicity of plywood based on phenol-formaldehyde resins by reducing the concentration of phenol and formaldehyde in the adhesive composition, improve the physical and mechanical properties of plywood. The cost of modified adhesive composition is 35 % of the cost of phenol-formaldehyde resin.

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