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RESEARCH OF STRENGTH AND WATER RESISTANCE OF GLUED FIXINGS ON THE BASIS OF PVA DISPERSIONS

This work is devoted to research of strength and water resistance of glued connections. European technique according to DIN EN 204 and DIN EN 205 was used to carry out strength and water resistance tests. The estimation of adhesives used at wood processing enterprises of the Republic of Belarus for production of furniture and joinery products is given. Properties of the modified domestic glues are also taken in consideration.

Introduction. Usage of natural wood is a priority line of production development of furniture and joinery products today. Natural wood became widespread because of a number of advantages: high strength and small weight, simplicity of processing and recycling, high frost resistance, etc. To receive a high-quality product from massive wood it is necessary to glue it together. It is necessary to increase the product stability of shape and rational usage of raw material. Glued furniture baffle is used for furniture production. It is made by gluing together of narrow lamels into a wide baffle. In turn, lamels are made by the method of joining of short workpieces into long ones.

Finally quality of a product is influenced by a considerable quantity of various factors: wood drying quality, lamels orientation in a baffle, glue used, etc. Polyvinylacetate glue (PVA) is most often used today for gluing together of a furniture baffle. The given glue possesses a number of advantages, the main one is ecological compatibility.

At the market of glued materials PVA glue is presented by various firms-manufacturers mainly European. There is also a manufacturing enterprise of the polyvinylacetate glue in our country, however this glued material possesses low physical-mechanical properties and consequently does not find wide application.

D3 brand glues are most often used in furniture production. Glued connections on the basis of this glues brand can be used indoors at frequent short-term exposure to the flowing or condensed water and (or) increase of humidity for short time.

Two standards DIN EN 204 [1] and DIN EN 205 [2] are used in Europe to determine strength and water resistance of glued connections. These standards describe the tests technique and the required values while determining wood strength on shift along fibres.

The purpose of the researches conducted was:

– study of strength and water resistance of the glued connections received on the basis of PVA dispersions of various manufacturers;

– modification possibilities study of domestic PVA glues to receive the glued connections corresponding to European standards.

Main part. For a more complete properties estimation of a glued material it is also necessary to consider its manufacturing technology. Polyvinylacetate is received as a result of emulsion free radical polymerisation. Initial polymer is absolutely fragile but it can be modified by copolymerization with other monomers, in particular with ethylene. When content of ethylene in the copolymer increases the polymer becomes more plastic and its vitrification temperature decreases. However it is impossible to reduce polymer vitrification temperature to a very low level as it can lead to too low strength of the glued layer.

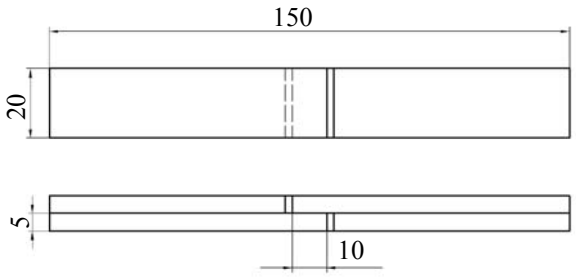
It is also possible to receive polyvinylacetate emulsions using a number of monomers, for example different acrylates and dibutyl maleates. In addition to synthesis of initial polymer, polymers and copolymers of polyvinylacetate type can be received with additional introduction of plasticizers and substances increasing adhesiveness. Joint solvents and coupling agents can also be added. External plasticizers of the dioctyl phthalate type can be introduced into the formula in quantities at which they keep compatibility in the emulsion. It is also true in the case of emulsions using substances increasing adhesiveness. Joint solvents, for example 2-butoksiethanol which is soluble in water and in polyvinylacetate emulsion, make positive impact on gluing of emulsion particles when water starts to evaporate.

An important point in formula development of stable polyvinylacetate emulsions is the usage of surface-active substance and protective colloid. These materials stabilize emulsion. Some polyurethanes can be protective colloids, they are known as «associative" protective colloids or materials on the basis of cellulose, for example oxyethyl cellulose. Besides emulsion stabilisation, protective colloid increases the glue thixotropy. One of the materials, simultaneously used as surface-active substance and as a part of the colloid protective system, is hydrolyzed or partially hydrolyzed polyvinylacetate. This material is either a polyvinyl alcohol, or a copolymer of polyvinylacetate with a polyvinyl alcohol. Such combinations of surface-active substances and cellulose protective colloids permit to optimise glue properties, thereby provide the improved wettability of different surfaces or a possibility of the polymer cross-linking. Cross-linking can be also realised as a result of copolymerization of vinyl acetate with any

carboxyl-containing monomer, for example acrylic acid. Cross-linking leads to the glue resistance increase to creep, however it often increases fragility, that in some cases can have essential importance [3].

To carry out tests according to DIN EN 205 they use beech wood plates with density of 700±100 kg/m^3 and humidity of 12%. Wood fibres should be situated along the gluing plane (in the direction of stretching at test), and annual rings – under the angle of 30–90° to the gluing plane. Samples are received by layers gluing method of two plates with length of 150 mm, width of 20 mm and thickness of 5 mm. After gluing samples are kept for 7 days at the normal climate then cross-section gashes are made at the distance of 10 mm. The sample general view for carrying out of tests is given in figure [1].

To determine the samples strength they used tearing machine RM-0.5 (5,000 N), loading speed was 50 mm/min.



Samples for strength determination of glued connections

To place the glued connection into loading group D3 according to DIN EN 205 it is necessary to meet the requirements given in Table 1.

Table 1

Strength indicators of the glued connection at shift (D3)

Sequence of exposure	Strength of the glued connection, MPa
7 days at normal climate (t = 23–25°C and φ = 50–70%)	≥10
7 days at normal climate 4 days in cold water (t = 20–23°C)	≥2
7 days at normal climate 4 days in cold water 7 days at normal climate	≥6

For making the tests they chose PVA glues of D3 brand which are most often used at our enterprises. It was found out that the glues differences consist not in different additives to the glue aqueous phase but in chemical compositions of PVA macromolecules. Thus radical difference is that the imported glue contains several percent of OH-groups as a part of macromolecules. The role of these groups is in formation of insoluble cross-linked polymers and that increases water and heat resistance of glue lines dramatically.

To study possibilities of strength and water resistance increase of the glued connection some nanomaterials were introducer into the domestic glue: aerosil and bentonite in the form of suspension "liquid-nanomaterial".

At gluing the glue consumption was 200 g/m^2, compacting pressure was 1 MPa; waiting time in the press was 1 hour for PVA and 5 hours for carbamide glue. In each experiment 12 samples were tested.

Tests results are given in Table 2.

Table 2

Strength of wood adhesion by glue

Glue type	Strength at longitudinal chipping, MPa		
	7 days after exposure (after gluing)	7 days + 4 days in water after exposure	7 days + 4 days in water + + 7 days after exposure
German glue № 1	10.95	2.07	8.85
Finnish glue	10.80	2.04	8.75
German glue № 2	9.46	–	–
German glue № 3	8.65	1.01	6.65
DF51/15VP + 0.025% aerosil	10.75	1.34	6.52
DF51/15VP + 0.050% aerosil	10.20	1.24	5.72
DF51/15VP + 0.100% aerosil	10.15	1.24	5.81
DF51/15VP + 0.025% bentonite	10.43	1.35	5.48
DF51/15VP + 0.050% bentonite	10.68	1.43	5.85
DF51/15VP + 0.100% bentonite	10.38	1.34	6.00
DF51/15VP + 15% Finnish glue	10.22	1.04	5.87
DF51/15VP + 30% Finnish glue	10.36	1.24	6.05
DF51/15VP + 50% Finnish glue	10.65	1.48	7.08
DF51/15VP	9.45	0.44	5.20
Carbamide glue	7.0	6.2	8.0

Analysis of the given tests shows that only two glued materials – German glue № 1 and Finnish glue passed a complete cycle of tests. The samples glued together by German glue № 2 after exposure in water became unstuck therefore it is impossible to find out their water resistance.

Glued connections on the basis of German glue № 3 and DF51/15VP did not pass tests to define their conformity to the loading group D3 at any stage.

It is found out that domestic glue has low water resistance. Modification of the given glue by nanomaterials increases strength (1.10–1.13 times) and water resistance (2.8–3.25 times). Increase of strength and water resistance occurs because of the change of limiting wetting angle of wood. It is also necessary to mention that bentonite in limited space for free swelling in the presence of water forms a dense gel which prevents further moisture penetration, and this leads to increase in water resistance of a glued connection.

Addition of the Finnish glue into the domestic glue DF51/15VP allows to increase considerably water resistance of a glued connection (2.37–3.36 times).

It happened to be impossible to determine the real strength of the glued connection formed by the carbamide glue as practically all samples had a wood fracture.

Conclusion. As a result of carrying out of the tests strength and water resistance of the glued connections formed by PVA glues of various firms-manufacturers are determined. It is established that only two glued materials (German glue 1 and Finnish glue) correspond to the requirements of European standard DIN EN 204/205, and German glues 2 and 3, and also DF51/15VP don't meet the requirements of the given standard.

The conducted tests also show that modification of domestic glues by nanomaterials and by the Finnish glue increase strength and water resistance of glued connection and that permits to use them instead of expensive imported glues.

Comparison characteristic of connections water resistance on the basis of carbamide and PVA glues is made. It is found out that water resistance of glued connection on the basis of carbamide glue is several times (3–14 times) higher than of the connection on the basis of PVA glue.

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