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INFLUENCE OF THE TYPE OF ADHESIVE ON THE PHYSICO-MECHANICAL PROPERTIES OF BEND FURNITURE BOARDS

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ABSTRACT

In the manufacture of furniture structural elements from folded glued thin furniture panels, it is important to determine the parameters affecting the performance of the finished wood composite panels. The purpose of the study was to determine the effect of the type of adhesive used on laminated high-density laminated wood fiber boards (HDF) and poplar plywood. The test specimens are made of five layers of 2.8 mm thick HDF slats and 4 mm thick plywood with 260/100 mm glued plate dimensions. For bonding, three types of adhesives were used - polyvinyl acetate (PVA) dispersion adhesive Jowacoll 103.05, polyurethane (PU) dispersion adhesive - Jovapur 150.50 and polyurethane wood adhesive - SOUDAL 66A. Bending and gluing were performed in a laboratory vacuum press with a rubber membrane and a template with a radius of curvature of 150 mm. The time to achieve minimum technological adhesion strength, vacuum velocity and minimum bending radius are determined. Samples were tested by standard bending with shoulder collection. The results obtained are analyzed and presented graphically.

Key words: glued bent furniture panels, HDF, polyvinyl acetate (PVA) dispersion adhesive, polyurethane (PU) dispersion adhesive, bending strength, vacuum presses.

INTRODUCTION

The individual approach in furniture design nowadays leads to great competition of furniture manufacturers; more and more non-standard solutions are sought in the vision and construction of the furniture. Composite materials have potential value for the furniture industry, both aesthetically and economically (Eckelman, 1993). The details are becoming more and more complex and require specialized technologies for making and lining details with a complex shape. Such structural details are: kitchen doors, door frames and wings, wall coverings and a number of other details to whose surfaces there are high requirements. Curved composite parts are a variant of the thin curvilinear details used in furniture constructions. With the mass penetration of wood fiber boards, as the main material for the production of frontal and glued shell structural elements for furniture, the most rational technologies and materials for their production and refinement are sought. There is data about studies on physical and mechanical characteristics of plywood (Shishkov, 1989; Kyuchukov, 1991; Garg AC, 1988; Navi and Sandberg, 2012) but there is no data about strength and deformation characteristics of structural elements made by plywood or HDF. The studies of how the type of adhesive effects on the physical and mechanical characteristics of the composite panels, such as HDF and plywood, are very few. According to Sandberg (2007), the properties of the adhesive, including curing time, adhesion, wettability of surfaces, antifriction, hardness and strength, are important parameters that can affect both the deformation of dimensional stability and the final hardness of the finished product. Temperature-humidity gradients appear in the

process, which complicate the forming of an adhesive bond, with a constantly changing environment to create fixed adhesion properties. The adhesive bond between the adhesive and the veneer sheets was studied by Matuana et al. (1998) and using pulsed thermography by Berglind and Cassens (2003).

Several researchers point out that the properties of the final product depends on certain parameters of the material and the work process, e.g. variations in temperature and moisture content in the materials used (Hvattum et al. 1978), the design of the mold (Stevens and Turner, 1970; Lind 1981), the magnitude of the application pressure (Wu et al. 1999) and the quality and properties of individual materials used (Suchsland and McNatt, 1986; Ohya et al., 1989; Zemiar; Choma, 2002; Suchland, 2004).

MATERIALS AND METHODS

The test specimens are made of HDF boards (first series) with a thickness of 2.8 mm (produced by Kronospan, Bulgaria) and a density of 900 kg/m^3. The plywood (second series) used is manufactured by "WELDE Bulgaria" with a thickness of 4 mm and a density of 500 kg/m^3. Two types of veneer were chosen as cladding materials – beech furniture veneer with a thickness of 0.6 mm and oak veneer with a thickness of 2.2 mm (supplied by J.A.F. Bulgaria). For statistical reliability of the results, 5 identical test specimens were prepared for each test with both types of veneer. A template with a radius of curvature of 100 mm was used for the production of the bent furniture panels. The test body consists of 5 lamellas with dimensions 260/100/2.8 mm glued by PVA dispersion – Jowacoll 103.05, PU dispersion – Jovapur 150.50 and polyurethane wood glue – SOUDAL 66A. The consumption norm of the adhesive used was determined by preliminary tests, so as to be the minimum at which the samples do not stick out – 120 g/m^2 and the initial required adhesive strength of the facing materials is reached. The adhesive was applied unilaterally to the HDF slats, strictly following the consumption rate, by the weight method.

Figure 1: Laboratory vacuum press and the matrix for bending with a radius of curvature of 100 mm

For producing of the test samples was used laboratory vacuum press equipped with rubber membrane with a thickness of 3 mm. The force used for pressing the test samples is equivalent of the used vacuum of -0.08 MPa in the vacuum chamber. The gluing and the lining of the test samples is made at once in a shortened overall technological regime, for studding the impact of the cladding material by the time of hardening of the adhesive on the whole surface of the bend furniture board. By preliminary experiments was determined the borderline radius of bending and gluing the lamellas made from

HDF and plywood. The used matrix is a L-shaped detail with a radius of curvature of 150 mm. The test samples were loaded under compression bending by collecting the shoulders. The testing was carried out by universal testing machine "Heckert – FP 100"– Germany (Figure 2).

Figure 2: The testing machine and the test installation.

A criterion was used to determine the strength of the test samples under compression loading is the maximum bending moment M_{max} (Simeonova, 2014), given by the formula:

$$M_{max} = F .l, [N.m] \quad \textbf{(1)}$$

where:

F is the maximum strength under compression loading, [N];

l is the bending shoulder, [m].

The tests were carried out in temperature of the environment of 22 ± 1°C and humidity 63 ± 5 %. The statistically processed test data are presented in Table 1 with following indicators: average (X), standard deviation (S_x), standard error (m_x), variation coefficient (V_x) and coefficient of accuracy (P).

Table 1: Statistical values of the strength test of the test samples.

Type of glue	Aver. x	Sx	mx	Vx	Px
		beech			
PVA	313.86	65.89	29.47	4341.73	0.065
PU disp. glue	428.81	25.87	11.57	669.20	0.065
PU glue	307.10	94.44	42.24	8919.37	0.065
		Oak			
PVA	419.06	107.16	47.92	11482.82	0.065
PU disp. glue	497.26	32.06	14.34	1027.69	0.065
PU glue	401.76	99.57	44.53	9914.08	0.065

RESULTS AND ANALYSIS

From the carried-out experiments, it was found that for faultless production of bent-glued details, it is essential to determine the time of reaching the given vacuum and the

duration of active vacuuming. In order to determine the time, required to achieve minimal adhesion strength, a preliminary study was carried out. The following values were determined for the three types of adhesives – 30 min at a vacuum of -0.08 MPa, while by PU dispersion and polyurethane wood glue, it was necessary of using additional heat of 75°C. By the use of PU dispersion, that is necessary for activation of the adhesive and to obtain the adhesive forces between the glued lamellas. For polyurethane wood glue the additional heat is needed for shorting the time for hardening of the adhesive of 3 h (required time for cold bonding) to 30 min. After producing the test samples, they are left for fully hardening of the used adhesives for 7 days. After that time the test for determine the bending strength by collecting the shoulders was carried out. On Fig. 3 are shown the average data of the bending strength of the bend furniture boards loaded in compression.

By the test samples glued with PVA dispersion, it can be seen bending strength of 313.86 N.m for the test samples lined with 0.6 mm beech veneer and 419.06 N.m for the test samples lined with 2 mm oak veneer. During the tests was observed that the samples were destroyed at the moment of destruction of the outer lamella and the veneer. The destruction is monitored by major cracks on the veneers and in the outer lamella loaded with critical bending stresses. Also, there can be seen places with delamination between the individual lamellas in the bent furniture board.

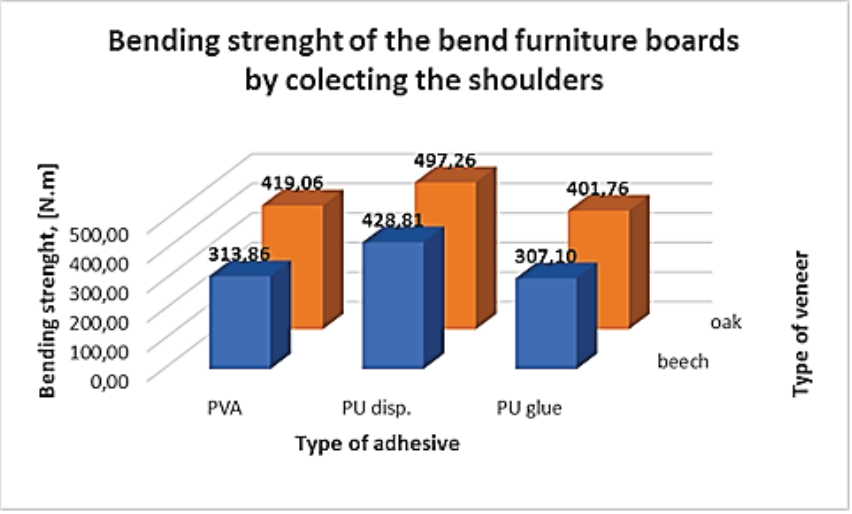

Figure 3: Bending strength of bend furniture boards.

By the test samples glued with PU dispersion, it can be seen bending strength of 428.81 N.m for the test samples lined with 0,6 mm beech veneer and 497.26 N.m for the test samples lined with 2 mm oak veneer. Using this type of adhesive shows the maximum bending moment values. During the tests was observed that the samples were destroyed at the moment of destruction of the outer lamella and still standing until the veneer cracks (Figure. 4). The destruction is monitored by major cracks on the veneers and in the outer lamella loaded with critical bending stresses.

Figure 4: Test samples lined with 0.6 mm beech veneer.

By the test samples glued with PU wood glue, it can be seen bending strength of 307.10 N.m for the test samples lined with 0,6 mm beech veneer and 401.76 N.m for the test samples lined with 2 mm oak veneer. The collected data are similar to the usage of PVA adhesive, but the type of destruction is far different. During the tests was observed that the samples were destroyed by the moment all of the lamellas have delamination one by one, until the last one lined with veneer is broken. The adhesive bonds are more flexible and the test samples are bouncing when the adhesive bond is destroyed. The full destruction of the test samples is when the veneer cracks with the last outer lamella (Figure 5).

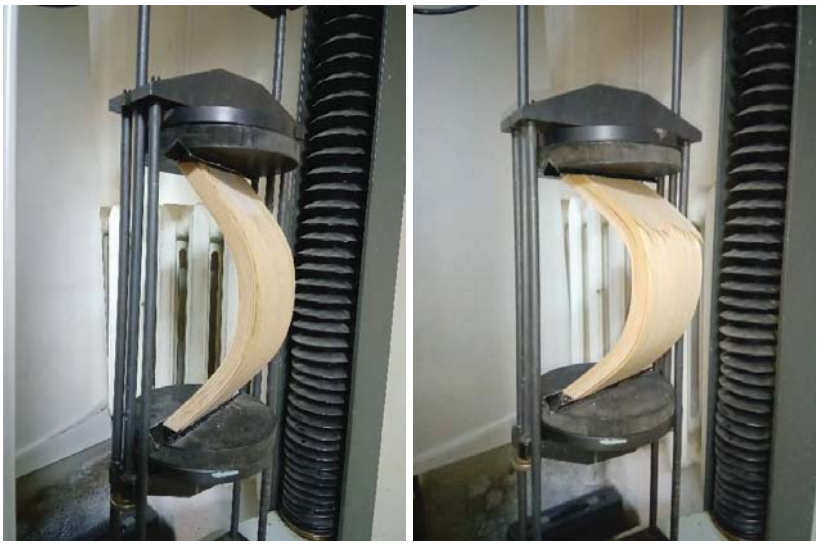

Figure 5: Test samples lined with 2 mm oak veneer.

By the carried-out experiment the best values were observed by the test samples made by using PU dispersion adhesive by bending strength of 428.81 N.m lined with

beech veneer and 497.26 N.m lined with oak veneer. The test samples lined with oak veneer gave higher bending strength, than those lined with beech veneer by all types of the used adhesives.

CONCLUSION

The results of the experimental studies give reason to do the following summarized conclusions:

- The highest bending stress under compression loading of the studied bend furniture boards have the test samples glued with PU dispersion adhesive and lined with 2 mm oak veneer, until the lowest result have the test samples glued with PU wood glue and lined with 0,6 mm beech veneer.
- Higher bending strength have the test samples lined with oak veneer glued with all of the examined types of used adhesives.

The type of glue affects on the end results of the bending strength of the bend furniture boards. For excellent result it is recommended to use PU dispersion adhesive with combination of the cladding material of oak veneer.

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CONTENTS