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REGIMES FOR LAMINATING CURVED FURNITURE ELEMENTS WITH POLYVINYL CHLORIDE FOILS

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Abstract

The article discusses the influence of some technological factors on the laminating of curved furniture elements with polyvinyl chloride foils. High-density fiberboards (HDF) with 3 mm thickness and 850 kg/m³ density have been used in the study. The specimen details were laminated at a vacuum press with polyvinyl chloride (PVC) foil. The laminating of the specimen details was made with polyvinyl acetate (PVAc) and polyurethane (PU) adhesives. The influence of the quantity of adhesive on the adhesion strength was investigated. The adhesion strength has been determined by pull-off testing method. The influence of the following technological factors was also investigated: vacuum pressure in the vacuum system, temperature of pre-heating of the foil, heating temperature, duration of pressing.

Key words: *laminating, adhesion strength, polyvinyl chloride foil, polyurethane (PU) adhesive, polyvinyl acetate (PVAc) glue*

INTRODUCTION

As it's known, the basic method of laminating (lining) curved furniture elements is by gluing. It is performed on specialized membranes and other 3D presses. The advantages of the membrane technologies are above all the complete versatility of the cladding in relation of type, dimensions and configuration of the details, the type of cladding materials and the adhesives used for this purpose. In addition, the face and the edges of the furniture elements can be lined simultaneously (by one technological cycle). A major advantage is the lack of molds and resetting when changing objects for processing.

The most preferred laminating (lining) materials are the thermoplastic foils (polyvinyl chloride - PVC, ABS - acrylonitrile butadiene styrene, polypropylene – PP), with good elasticity and plasticity, with sufficient strength and resistance to elevated temperature and considerable mechanical stresses. Polyvinylchloride (PVC) is one of the most flexible and durable laminating material. One of the main technological disadvantages in lamination with foils is that usually overlays are very thin and they do not have the strength to hide the surface irregularities of the laminated article. This defect known as "marking" negatively affects the adhesion strength of the bonding compound (Kılıç et al. 2009). In case of laminating of structural elements with foils, furniture boards with powder or fibrous surface layers are preferred. The surfaces must be of a homogeneous structure, strictly planar, dust-free, with a high grade of roughness. Specifically, the maximum deviations by thickness must be within ± 0,2 mm, local deviations from flatness - up to 0,1 ÷ 0,15 mm, and the

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roughness is Rm ≤ 30 μm. Since the foils do not absorb water and steam, another important requirement for the panels is to possess even minimal water and steam penetration to render uptake of the glue solvents. Because most wood adhesives are aqueous, loss of water to wood is an important part of the cure. However, most adhesives generally polymerize and cross-link, and the rate of chemical reactions and of strength development are used to look at curing (Charles R. Frihart 2015).

For laminating curved furniture elements the PVC foils are mostly used with polyvinyl acetate dispersions (PVAc) and low viscous reactive polyurethane dispersions (PUs) with low polymerization temperature (50 °C) and increased open time are used.A main advantage of these adhesives has been that they can be formulated to have a wide range of properties, depending on the types and ratio of monomers (Charles R. Frihart 2015). The bonding principle of PVAc adhesives is based on the removal of the water by penetration into the wood substrate or by evaporation to the surrounding air. The forming of the bondline also requires the application of proper pressure. The final bond strength is reached after migration of the residual water away from the bondline (Dunky, M. 2003). In order to achieve minimal shrinkage of the adhesive layer during its hardening, it is recommended the adhesives to have the highest possible dry residue content (Albin et al. 1991).

Adhesion is a complex physic-chemical phenomenon for which, however, there is not a rigorous theoretical definition. Adhesion is difficult to define, and an entirely satisfactory definition has not been found (Kaelblea 1964, Landrock A. 2008, Silva et al. 2011).

In principle, laminating with membrane technologies do not differ much from those applied to the positioning of flat furniture boards on ordinary hydraulic presses. However, the pressing regimes are difficult to control and control. The problems are mainly related to the large number of factors influencing the process of cling and the restrictive conditions for its implementation. As a result of improper combination of materials and cladding modes, adhesive compounds with low adhesion strength are obtained. Adhesion strength is an important feature to measure the durability of the peel cover from the substrate. Various methods are used to determine adhesion strength. The most objective and widespread method is the pull off test. It is essentially determined the force with which the coating is removed from the pad at a tensile load perpendicular to its orientation. The bonding process is influenced both by the properties of the materials (foil, glue and furniture plate) and by the values of the main operating parameters - quantity, viscosity and temperature of the adhesive, pressure and duration of pressing, pre-stretching, etc. Only if all of these parameters are correct and well balanced in the PVC bonding process, can proper bonding results be achieved. In this regard, the aim of the present study is to determine rational ranges for the variation of basic operating parameters when facing PVC film curvilinear details.

MATERIAL AND METHODS

To determine the rational range for varying the quantity of adhesive in the laminating of curved furniture elements, a one-factor experiment was performed. The chosen range for the technology factor test is from 100 to 220 g/m^2. High-density fiberboards (HDF) with 3 mm thickness and 850 kg/m² density have been used in the study. The curvature details are made by folding and gluing of three layers by HDF by initial thickness and bent radius of 100 mm. From them were made test pieces to provide a 10-fold repeat of each experimental series for determining the strength of an adhesive bond between the laminate and substrate. The PVC foil (by "Hornshuch") 3D formable with thickness of 0,4 mm. The surfaces of the foil are protected by a highly light-resistant lacquer on PUR/acrylate basis. The reverse side

of the foils is coated with primer to ensure a safe and temperature-resistant bond. For bonding, is used adhesive system produced by Jowacol - D3 polyvinyl acetate (PVAc) glue (№103.05) and polyurethane (PU) adhesive dispersion (№150.50).
The test samples were laminated in a membrane press. The press mode for the test samples glued with PVA adhesive system is: vacuum pressure - 0,4 N/mm^2 and time for pressing 30 min. For the test samples wit PU adhesive dispersion was used temperature 75 °C, pressure 0,4 N/mm^2 and time for pressing 30 min. After the laminating with the PVC foil to determine the adhesion strength of the compounds is defined by a standardized pull-off method (ISO 4624:2016) with a glued stamp, was applied to the PVC film perpendicularly to the laminated board.

RESULTS AND DISCUSSION

Laminating mode. General requirements. For qualitative laminating of curved furniture elements, the parts need to be perfectly clean and smooth. Even dust and hairs are printed on the film due to high pressure. Before finishing the details, it is advisable to tempered, which leads to the improvement of the adhesion quality. The laminating case is desirably isolated from external sources of dust and air currents. It should be borne in mind that even the smallest changes in the composition and the thickness of the foil have a great effect on the regime. Changing the thickness of the foil leads to its tearing in the process. The type and composition of glue is also essential for adhesion. In order to achieve minimal compressibility of the adhesive layer when it is hardened to prevent marking of the HDF micro relief structure, it is recommended that the adhesive be as dry as possible. When PVC-free foil is coated without a membrane, at least 30% of the foil waste is realized. Therefore, if it is intended for rational use of the film, it is advisable to work with a membrane.
Determination of quantity of the adhesive for laminating curved furniture elements. The results of the one-factor experiments to determine a rational rate for the quantity of adhesive in laminating curved furniture elements are presented in Figures 1 and 2.
The adhesion strength of the tested adhesive compounds between HDF and PVC foil is relatively low. The adhesion strength of PU adhesive compounds meets the required minimum tensile strength at a glue expense over 150 g / m^2. On the basis of the results obtained, it can be assumed that the adhesive strength of the compounds increases in the range of 100 to 200 g / m^2 as the quantity of adhesive increases.

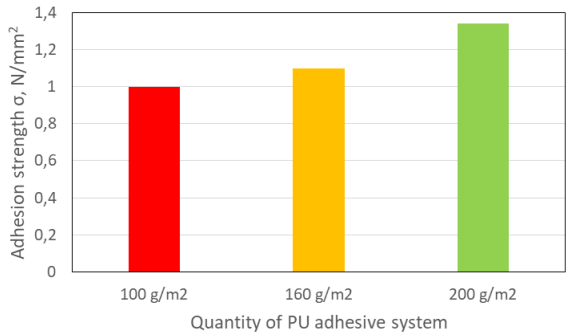

Fig. 1. Relationship between adhesion strength and the quantity of glue on laminating of curvilinear furniture parts (made of HDF) with PU adhesive

The adhesion strength of PVA adhesive compounds between HDF and PVC foil does not meet the minimum technological strength requirements. A major problem with bonding is the inability of the film to pass and adsorb water. In fact, water is adsorbed entirely into HDF. It can be argued that in the studied range the greater the quantity of glue and the presence of more water, respectively, leads to a decrease in adhesion. This problem can be limited by pre-drying of the applied glue and subsequent thermal-activation in the press equipment. However, it can be argued that the PVA dispersion used is unsuitable for laminating HDF curved structural elements with PVC foil.

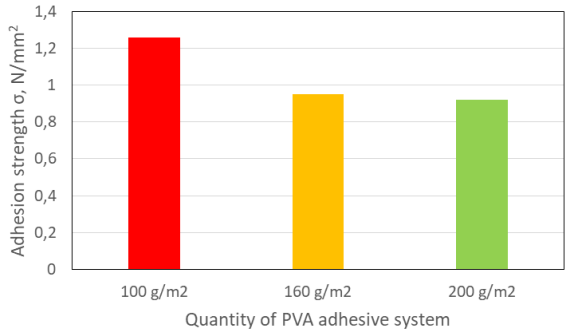

Fig. 2. Relationship between adhesion strength and the quantity of glue on laminating of curvilinear furniture parts (made of HDF) with PVA adhesive

Determination of pressure for laminating of curved furniture panels with PU adhesive. The pressure for laminating of curved furniture elements with PVC foil depends on many factors. Even the composition of the foil and the atmospheric pressure have a significant impact. Typically, the thickness of PVC cladding film is 0.35-0.5 mm. Due to the specificity of the vacuum presses, the pressure of the PVC film liner is relatively small. For laminating lining curved structural elements with a large radius of curvature at a thickness of 0,4 mm the minimum pressure is - 0,4 N / mm^2. If the thickness of the foil is greater and the radii smaller, then the working pressure is 0.5÷0.6 N/mm^2.

Temperature of heating by working with PU adhesive. The industrial use of PU adhesives for bonding PVC film to furniture components requires heating. The typical working temperature is between 65 and 125 ° C. The quality of the foil is very important, the higher the temperature the foil holds without changing its structure, the better the adhesion.

Preheating of the foil when working with PU adhesive. It mainly depends by the thickness of the foil. When working with 100 °C and with a foil thickness of 0.4 mm, it takes 55÷65 seconds to preheat the foil. It is desirable to reduce it by 4÷5 seconds. at an increase in temperature of 5 ° C. When reducing the thickness of the film, the time is reduced by 3÷4 s. For foils with a thickness of 0.4 mm and a heating temperature of 120 ° C, the preheating time of the foil is 45 seconds.

Time for pressing. The pressing time depends mainly on the type of glue used. The duration of adhesion depends on the type of adhesive, the thickness and temperature of the membrane, the chosen way to further feed the heat to the membrane. PU adhesive is pre-applied to the parts and allowed to dry for about 20-60 seconds (depending on room temperature). Once the adhesive has dried, it forms a film on the parts that are reacted in the press at 70 °C. The use of polyurethane thermosetting adhesives with a minimum cure time of 45 s is recommended for laminating of curved furniture elements.

CONCLUSION

Based on the research, the following conclusions could be made:
- The adhesion strength of the tested adhesive compounds between HDF and PVC foil is relatively low.
- The adhesion strength of PU adhesive compounds meets the required minimum tensile strength at a glue quantity over 150 g/m^2. On the basis of the results obtained, it can be assumed that the adhesive strength of the compounds increases in the range of 100 to 200 g/m^2 as the quantity of adhesive increases.
- The PVA dispersion used is unsuitable for laminating HDF curved structural elements with PVC foil. When using PVA adhesives, it is recommended to dry the applied adhesive layers in advance and to use adhesives with high concentration and viscosity.

Table 1 presents a technological regime for laminating bent HDF structural elements with PVC foil and PU adhesive.

Table 1. Cladding mode for bent HDF structural elements with PVC foil and PU adhesive

Parameters of the regime	**Values of the parameters**
Quantity of the adhesive	150÷200 g/m^2
Prepress technology stay	minimum 55-65 s
Temperature of heating	65÷125°C
Pressure	0,4÷0,6 N/mm^2
Pressure time	minimum 45÷60 s
Post pressure technology stay	minimum 4 h.

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