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Foaming of polyvinylacetate adhesives – improved technologic parameters for a solid wood gluing process

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Abstract: *Foaming of polyvinylacetate adhesives – improved technologic parameters for a solid wood gluing process*. Adhesives are in the woodworking and furniture industry important auxiliary materials, which greatly contributes not only to improving the quality of products, but are also the basis for the development of new products. Foaming adhesives is a technology that allows achieving the desired bonding strength at significantly reduced spread rate of adhesive. The results of our research confirmed that the proposed technology can reduce the spread rate from conventional 180 g/m^2 down to 125 g/m^2.

Keywords: polyvinylacetate adhesives, gluing, solid wood panels, shear strength

INTRODUCTION

Dispersion adhesives based on polyvinyl acetate (PVAC) are often used for gluing of wood. Due to easy preparation and application of these adhesives, health safety and also the corresponding quality of the bond, their use is growing. PVAC adhesives provide very strong bonds, having a good affinity to wood and flexibility. Curing of PVAC dispersions is essentially a physical process in which wood gradually takes water from the glue, while the glue line creates a continuous polymer film. Adhesive penetration into the wood structure was evaluated by (Hass et al. 2012). PVAC are resistant to microorganisms and fungi, non-flammable, with partial resistance to increased temperature, humidity and water (Proszyk and Krystofiak 1997). Due to their favourable non-toxic properties, they replace formaldehyde adhesives at the production of plywood, veneering of furniture parts or surface finishing e.g. laminating. These adhesives are most often used for assembly bonding joints of furniture parts, finger jointing, production of solid wood panels (SWP), or for the production of glued laminated timber (Glulam) for non-bearing construction purposes (Sedliačik 2005).

In recent years, there has been a significant increase of productivity by improving technology through the shortening of the curing time as described in (Avramidis et al. 2009) This also includes new requirements for dispersion adhesives. Reducing the amount of water in dispersion adhesive causes deterioration of the coating quality. Too small amount of adhesive spread rate leads to insufficient and reduced bonding strength of the joint. A frequent problem is the uniformity of coating on the surfaces to be glued and exceeding the recommended open time.

FOAMING OF PVAC ADHESIVES

Foaming of PVAC adhesives can obtain technological and economic importance in the process of gluing in woodworking and furniture industry. Available types of dispersion adhesives can be foamed through the addition of substances causing foaming – surfactants. Surfactants reduce the surface tension and enable the formation of foam. Foam bubbles could have different size, strength and durability of the walls according to the desired viscosity of the adhesive, the concentration of surfactants and other parameters. The device with a mixing head is necessary for air foaming of adhesive that creates soft foam structure consisting of very small air bubbles, as can be seen on Figure 1.

Figure 1. Foamed PVAC dispersion

The advantages of using a coating of foamed dispersion PVAC adhesives are several technological and also economic aspects. Diffusion of water from the foamed adhesive into the surface layers of wood due to the reduced contact area is significantly slower, thereby reducing the size of the swelling of wood fibres near the surface of the coated dispersion and the surface has a finer microstructure. At the same time, the slower diffusion of water into wood and its slower evaporation prolongs the open time after adhesive coating, which is one of the most important technical parameters of PVAC adhesives. At the same spread rate of the adhesive coating 120 g/m^2, Fig. 2 presents that the coating thickness of the foamed adhesive is about 30 % higher than the thickness of regular one. This insures a more uniform coating of adhesive, uniform wetting of the bonding surface, and possibly better cover of cracks and defects arising during the surface machining before bonding. Optimizing the thickness of the adhesive coating can reduce flat consumption of adhesive and save. Foamed dispersion adhesives do not change their classification into classes of durability and water resistance D3 resp. D4.

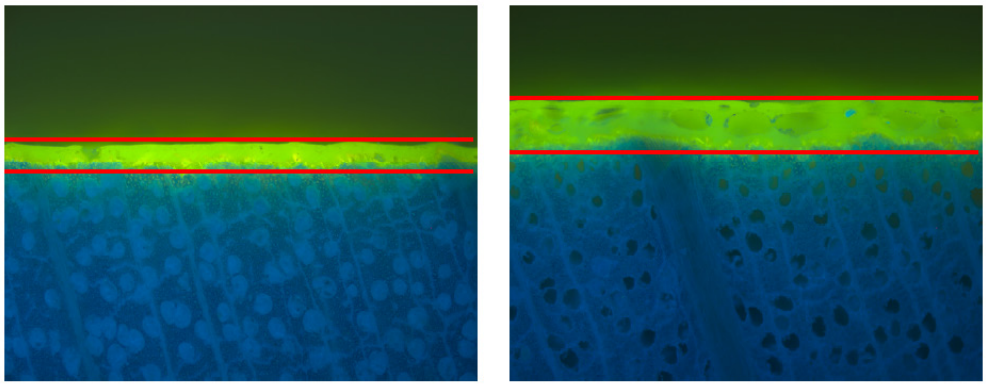

Figure 2. Difference in the thickness of regular (left) and foamed adhesive at the spread rate of 120 g/m^2

MATERIAL AND METHODS

In laboratory conditions, industrially produced samples of glued wood timber with regular and foamed PVAC dispersion were tested according to standards „EN 13353: 2011 Solid wood panels (SWP). Requirements “ and „EN 13354: 2009 Solid wood panels (SWP). Bonding quality. Test method“. These standards define testing method for determination the bonding quality of solid wood panels and give requirements for the bonding quality intended for use in dry, humid and exterior conditions. Solid wood panel samples were prepared from beech wood (*Fagus sylvatica* L.), samples of glued laminated timber were prepared from spruce wood (*Picea abies (L) Karst.)* and all test pieces were cut according to Fig. 3. Pieces were conditioned according to the standard EN 13354 during 7 days in normal conditions (20 ± 2 °C, 65 ± 5 % relative air humidity). Test pieces were pre-treated according to conditioning for dry use (SWP/1): 24 h in water (20 ± 3 °C). The shearing force was applied parallel to the glue line under testing. Constant rate of loading motion was applied, so the failure occurred

within approximately 60 ± 30 s. The testing machine recorded the maximum load, and the shear strength of each test piece was calculated.

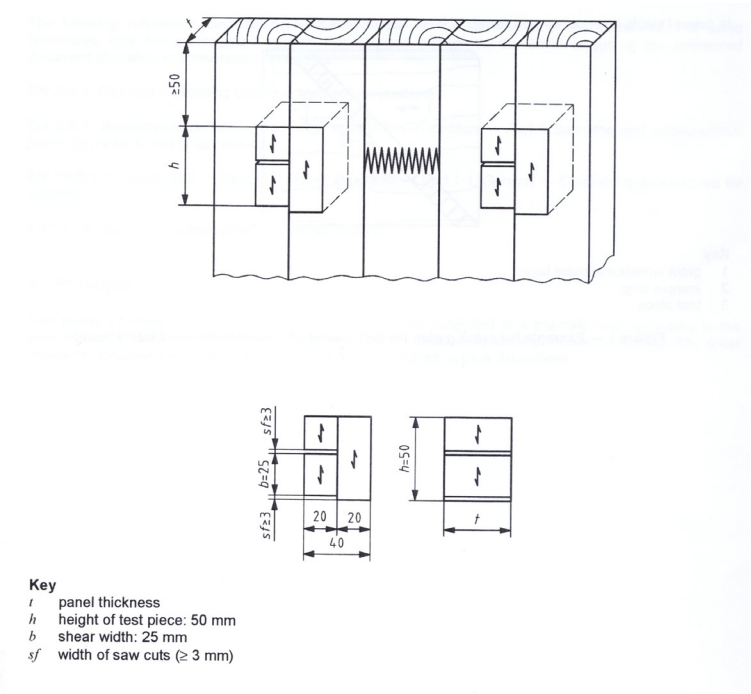

Figure 3. Testing samples

RESEARCH RESULTS

The comparison of obtained values of the shear strength of glued joints of solid beech wood panels and basic statistical evaluation proved, that both adhesives have the same strength properties after dry conditioning and moisture conditioning in water 24 h in water 20 °C, results are presented in Table 1.

Table 1. Results of shear strength properties of solid beech wood panels

Shear strength after conditioning:	Basic statistic evaluation			
	Foamed adhesive		Regular adhesive	
	x [MPa]	s_n [MPa]	**x [MPa]**	s_n [MPa]
Dry state	**14,55**	1,930	**14,08**	2,046
Soaking in water 24 h	**0,41**	0,253	**0,41**	0,302

Note: x – arithmetic mean
s_n – standard deviation

Spruce Glulam samples were prepared and tested at different amount of spread rate of foamed PVAC adhesive. Results of shear strength properties are presented in Table 2.

Table 2. Results of shear strength properties of spruce Glulam

Shear strength after conditioning:	Basic statistic evaluation							
	100 g/m^2		110 g/m^2		115 g/m^2		125 g/m^2	
	x [MPa]	s_n [MPa]	**x [MPa]**	s_n [MPa]	**x [MPa]**	s_n [MPa]	**x [MPa]**	s_n [MPa]
Dry state	**5,67**	0,775	**5,63**	0,486	**6,15**	0,793	**7,76**	0,658
Soaking in water 24 h	**1,35**	0,446	**2,22**	0,845	**2,28**	1,209	**2,73**	0,508

Note: x – arithmetic mean
s_n – standard deviation

The obtained data of shear strength properties after soaking in cold water 24 h were analysed by methods of one-way ANOVA and Two Sample t-Test, using STATISTICA 10 software package. Test results did not reveal statistically significant difference (α = 0,001) between the strength at the spread rate of 115 g/m^2 and 125 g/m^2. The shear strength properties at spread rate of 100 g/m^2 and 110 g/m^2 are statistically significantly lower than spread rate of 115 and 125 g/m^2. Statistical evaluation is presented in Figure 4.

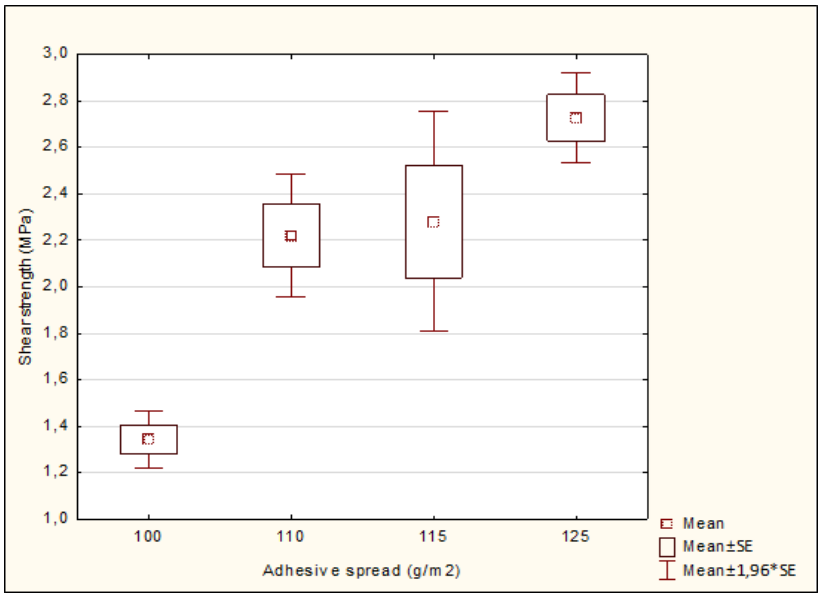

Figure 4. Box and whisker plot generated in Two Sample t-Tests

CONCLUSION

The aim of this contribution was to introduce the technology of foaming of PVAC adhesives. Although, there is not new, but very current method of increasing the volume of the adhesive, thus reducing costs for bonding. Testing of the shear strength properties and statistical evaluation of obtained results confirmed that foaming technology of PVAC adhesive keeps the same quality of glued joints. Foaming of adhesives is used in woodworking practise more often, as this technology is more appropriate not only from technologic, but also from economic view. This proposed technology can reduce the spread rate from conventional 180 g/m^2 down to 125 g/m^2.

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Streszczenie: *Spienianie klejów polioctanowinylowych – poprawa parametrów technologicznych do klejenia drewna litego*. Kleje w stolarstwie i przemyśle drzewnym należą do najistotniejszych materiałów pobocznych, mających nie tylko wkład w jakość wyrobu gotowego, lecz również stanowiących podstawę rozwoju nowych produktów. Spienianie klejów jest technologią pozwalającą na osiąganie pożądanej wytrzymałości spoin klejowych, przy jednocześnie obniżonym naniesieniu. Badania wykazały że prezentowana technologia pozwala obniżyć naniesienie kleju z 180 g/m2 do 125 g/m2.

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