

INFLUENCES OF SOME FACTORS ON ADHESION STRENGTH BETWEEN PVC FOIL AND PARTICLE BOARD

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Abstract:

The article discusses the influence of some technological factors on the through feed wrapping of wood-board materials with foils. For the aim of the study particle board details with dimensions 350/50/18 mm have been used. The specimen details were wrapped through feed at an automatic panel wrapping machine "FUX Austria" with polyvinyl chloride (PVC) foil. The used materials in the experimental operation were as follow: particle board from „Kronospan" company and PVC foil made by „Hornshuch". The wrapping of the specimen details was made with reactive hot melt polyurethane glue Purmelt QR 5300 from „Henkel"-Germany. The main characteristic of the adhesive connection between the materials is its adhesion strength. In this relation, the tensile strengths of the compound has been determined, perpendicular to the plane of adhesion. The influence of the following technological factors on the adhesion strength was also investigated: temperature of glue, quantity of glue, feeding speed. Three-factor experiment has been accomplished at three levels of the factors values. The adhesion strength has been determined following the RAL RG 716/1 standard, Part 7, according to DIN 16 860. The experimental data were processed using the regression analyses method and a mathematic equation has been done to determine the relationship interrelation between the factors and the output data value. The dependencies are presented by graphics and the results are analyzed.

Key words: particle board; PVC foil; adhesion strength; technology factors of laminating.

INTRODUCTION

In furniture made of wood and wood-based materials, the technology of bonding of multiple thin layers of veneers is most commonly used. The adhesive material aims to ensure a rigid, irreversible and sufficiently strong fixation of the laminating material to the elaborated surface. The surface of the furniture elements to be laminated should be smooth, homogenous and clean out of dust and other contaminants. The medium-density fiberboards (MDF) as well as some multilayer high quality particleboards easily met these requirements. Lamination in the furniture production is performed either stationary or through feed. In the recent years, the through feed laminating technologies draw a lot of attention and are widely used in the modern furniture plants with large-volume production.

Polyvinylchloride (PVC) is one of the most flexible and durable laminating material. Thus, the PVC foil is preferred for the through feed wrapping of furniture elements. 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). Knowing this, the panels need to be flat with a maximal deviation in the thickness of $\pm 0,2\text{mm}$ and to lack imperfections which could be "marked" through the foil. 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. 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).

For through feed wrapping with PVC foil, polyurethane (PUR) hotmelt glues are preferred. Their benefits include immediate bonding, no solvents are used, water resistance and low application temperature that prevents distortion of heat-sensitive substances. Depending on air humidity and material conditions the polyurethane hotmelt adhesives can achieve 50-80% of the ultimate bond strength in approximately 6 hours

with a full cure achieved in 24 hours. The main parameter for the quality of the wrapping process of the furniture panels is the adhesive strength of the bonding material. Adhesion is a complex physico-chemical phenomenon for which, however, there is not a rigorous theoretical definition (Kaelblea 1964, Silva et al. 2011). One of the most common and accepted techniques for measuring polymer adhesion is the peel test (Zosel 1991). The method is simple and represents one of the main problems of the laminated furniture elements - delamination. This is grounds for the wide use of this method in the assessment of the final product. Basic technological parameter of the through feed wrapping process is the feeding speed of the details. For the laminating process using PVC foil the feeding speed is recommended to be between 6 to 15m/min (Albin et al. 1991). It is well-known that the adhesion is influenced by the temperature and the quantity of the applied adhesive. The values of these parameters depend on the glue type. The smooth panel surface, accompanied by its lower permeability requires smaller amount of the adhesive. When high quality adhesive material and furniture panels meeting all the above mentioned requirements are used, the adhesive strength should depend mainly on the parameters of the laminating process. The influence of some fundamental technical parameters on the laminating quality could be evaluated through derivation of a regressive equation.

OBJECTIVE

The aim of the current study was to evaluate and compare the influence of the fundamental technical parameters: speed feed (U), quantity of the adhesive material (Q), temperature of the adhesive material (t_g) on the through feed wrapping of particle boards with PVC foil. This study is a follow up of our previous work where we determined the influence of the above-mentioned parameters on the adhesive strength over a through feeding wrapping process of MDF with PVC foil (Angelski and Vitchev 2014). For the assessment, a standardized peeling test was performed. An additional objective of this study was to evaluate the influence of the basic material (board for lamination) on the strength of the adhesive material.

MATERIAL, METHOD, EQUIPMENT

Materials

For the objectives of the study, particle boards with density of 680kg/m^3 have been used. A total of 75 samples (50/300/18mm) have been made. Semi-rigid PVC foil, UV-protected by transparent acrylic film with a thickness of $0,18\pm 0,22\text{mm}$ was used as laminating material.

Reactive hotmelt polyurethane adhesive system "Purmelt QR 5300" (Henkel) was chosen as a bonding material. Purmelt QR 5300 had viscosity of $26000\text{ mPa s}/130^\circ\text{C}$ and melting point about 65°C . The operating temperature, recommended by the manufacturer is between 110°C to 150°C and the quantity of the applied glue (Q) should be between 40 to 100g/m^2 .

Experimental Method

To determine the influence of the selected technical parameters on the adhesive strength of the adhesive substance, a method of regression analysis was used. As it is known, the changes of the output value depending on the variation of the values of the technical factors could be expressed by a parabolic regression equation of second order. On this basis, a matrix composition plan of G.Box (Box et al. 1951) strongly influencing the adhesion technical factors has been designed and performed.

The factors with lower influence on the adhesion have constant values, considered beneficial for the adhesive process. The variable factors vary at three levels: maximum, medium and minimum. For convenience of the mathematical analysis of the data, the factors in the experimental matrix are given with the following codes: maximum (+1); medium (0); minimum (-1). In the carried out experiment the values of the variable factors in non-coded form are as follows:

- quantity of the applied adhesive material $Q (x_1) - 60, 80, 100\text{g/m}^2$;
- temperature of the applied adhesive material $t (x_2) - 110, 135, 160^\circ\text{C}$;
- feeding speed $U (x_3) - 6, 13, 20\text{m/min}$.

The through feeding lamination of the tested samples has been performed on a specialized automated profile laminating machine „FUX Austria“. The working temperature of the applied adhesive material and the feeding speed are set automatically by the used software. The quantity of the adhesive to be applied is calculated on the basis of the foil width using a mathematical algorithm. The polyurethane hotmelt adhesive is applied on the PVC foil seconds before laminating of the elements. Passing through the laminating zone, silicone-pressing rollers are shaping the foil onto the element. The results are expressed as averaged values of five experiments. Statistical software "Qstatlab 5" was used for the analysis of the data and calculation of the regression coefficients.

Test method

The adhesion has been determined by peel test based on the standard RAL RG 716/1 according DIN 16 860, Part 7. The samples were tested 24 hours after laminating. The preparation includes stationary positioning of the samples and cutting the foil. The metal former was positioned over the foiled side of the test sample and two cuts with knife have been made upon it so that lines with 36 mm width to be cut. Afterwards, the edge of the cut foiled line was unstuck and gripped by a mechanical pulling device and subsequently peeled away from the particle board at a constant speed and angle of peeling (Fig. 1). An electronic digital weight scale was attached to the mechanical pulling device. During the test, the peeling speed and peeling force were recorded. The recorded destructive forces were re-calculated and expressed in N/mm. On the basis of these data the influence of the assessed factors on the adhesive strength of the adhesive compounds has been evaluated.



Fig. 1.
Peeling test.

RESULTS AND DISCUSSION

Matrix compositional plan and average values (F_p) obtained from the peeling test are shown in Table 1. The second order equation from which the regression coefficients have been derived is as follow:

$$y = 1,53 + 0,34 x_1 + 0,34x_2 - 0,37x_3 + 0,05x_1x_2 - 0,03x_1x_3 + 0,14x_2x_3 - 0,01x_1^2 - 0,1x_2^2 + 0,07x_3^2 \quad (1)$$

The influence of the technological factors on the strength of the adhesive compound is presented in Figs. 2, 3 and 4. From the results, it is visible that the adhesion strength of the adhesive material does not exceed 2N/mm.

Table 1

Matrix compositional plan and average values from the peel test

No	$Q \equiv x_1$ g/m ²	$t \equiv x_2$ °C	$U \equiv x_3$ m/min	Fp_1 N/mm	Fp_2 N/mm	Fp_3 N/mm	Fp_4 N/mm	Fp_5 N/mm	Fp N/mm
1	60(-)	110(-)	6(-)	1.455	1.305	1.175	1.490	1.320	1.349
2	60(-)	110(-)	20(+)	0.615	0.430	0.460	0.480	0.535	0.504
3	60(-)	160(+)	6(-)	1.655	1.580	1.655	1.840	1.710	1.688
4	60(-)	160(+)	20(+)	1.235	1.310	1.215	1.430	1.290	1.296
5	100(+)	110(-)	6(-)	1.900	1.965	1.985	1.890	1.940	1.936
6	100(+)	110(-)	20(+)	0.895	0.895	0.840	0.795	0.830	0.851
7	100(+)	160(+)	6(-)	2.165	2.350	2.200	2.630	2.360	2.341
8	100(+)	160(+)	20(+)	1.980	1.795	1.990	2.155	1.905	1.965
9	100(+)	130(0)	13(0)	1.840	1.995	2.240	2.135	2.240	2.09
10	60(-)	130(0)	13(0)	0.835	0.900	0.990	0.970	1.145	0.968
11	80(0)	160(+)	13(0)	1.880	2.040	2.120	1.900	1.840	1.956
12	80(0)	110(-)	13(0)	0.845	0.840	0.765	0.960	1.090	0.900
13	80(0)	130(0)	20(+)	0.980	1.105	1.110	1.080	1.065	1.068
14	80(0)	130(0)	6(-)	2.280	2.180	1.845	2.090	2.230	2.125
15	80(0)	130(0)	13(0)	1.340	1.360	1.235	1.330	1.275	1.308

According to the DIN 16 860 standard the adhesion strength is recommended to be over 2,5N/mm. The tested samples do not meet this requirement. On the other hand their adhesion strength is by 0,7N/mm lower compared to the strength of the adhesives used for bonding the PVC foil to the MDF, using the same polyurethane adhesive (Angelski and Vitchev 2014).

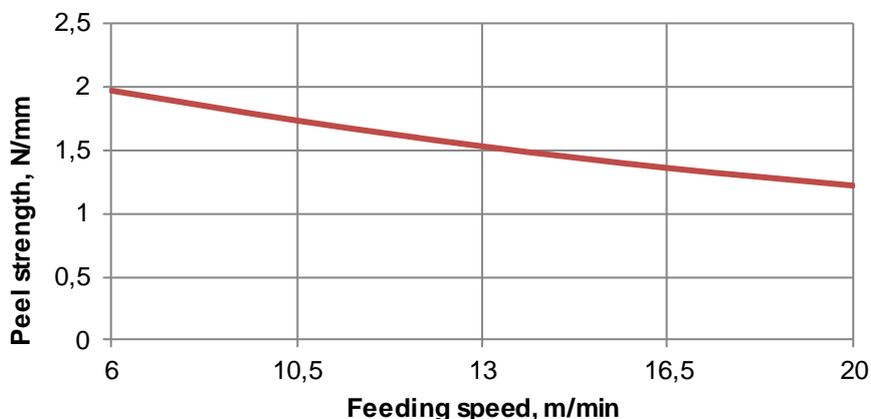


Fig. 2.

Relationship between peel strength of glue joint and feeding speed during through feed lamination of particle board with PVC foils.

In principle, the bonding strength of the adhesive compounds could be increased by improving the quality of the surface subjected to lamination. Improving the smoothness of the surface of particleboards can be effectively achieved by performing the following technological operations: laminating a special plaster, drying of plaster and sanding. These processes, on the other hand would increase the duration of the technical cycle and the production price. Based on these data we could draw the conclusion that the subjected to laminating with PVC foil furniture elements are preferable to be made out of MDF instead of particleboards.

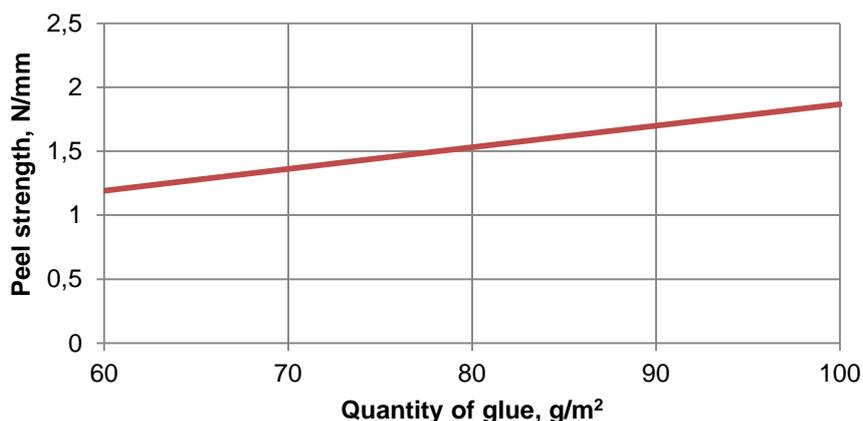


Fig. 3.

Relationship between peel strength of glue joint and quantity of glue during through feed lamination of particle board with PVC foil.

The regression coefficients in front of the variable factors x_1 , x_2 and x_3 in the derived equation have approximately equal values. This means that the variable technological factors exert commensurable influence on the adhesion strength of the adhesive compound. Their variations in the test range could result in either an increase or a decrease by 30% of the adhesion strength of the adhesive. The low values of the regression coefficients determine the weak parabolic relationship presented in Fig. 1, 3 and 4. There is a dual interaction between the feeding speed and the temperature of the glue on the adhesion strength. This means that the combination of high temperature of the adhesive with high feeding speed should be avoided. The inversely proportional relationship between the feeding speed (U) and the adhesion strength of the

adhesive compound is clearly depicted in Fig. 2. In order to produce objects with high strength the recommended feeding speed in laminating is between 6 to 10m/min.

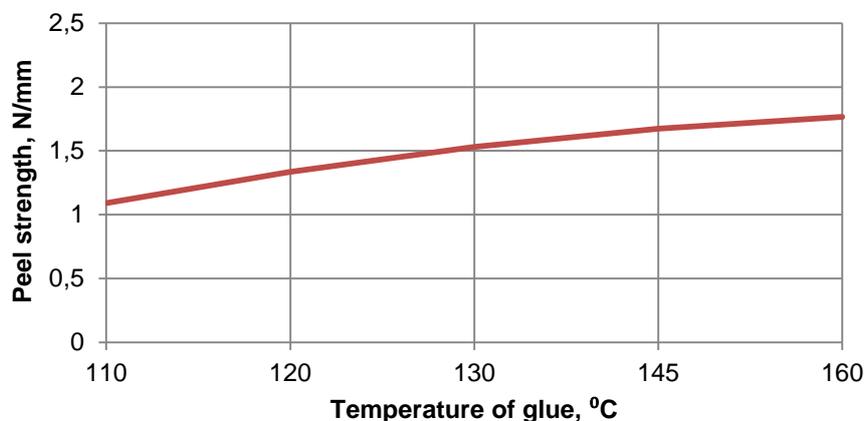


Fig. 4.
Relationship between peel strength of glue joint and temperature of glue during through feed lamination of particle board with PVC foil.

After the optimization performed by the scanning method the highest adhesive strength value of the adhesive compound was achieved at $Q = 100 \text{ (g/m}^2\text{)}$, $t = 160 \text{ (}^\circ\text{C)}$, $U = 6 \text{ (m/min)}$. Higher adhesive strength could be achieved and by increasing the adhesive quantity (Fig. 3). This, however is regarded as unfavorable to the technological process, since a larger amount of adhesive material would lead to smearing the surface as well as the polyurethane hotmelt adhesives are relatively expensive

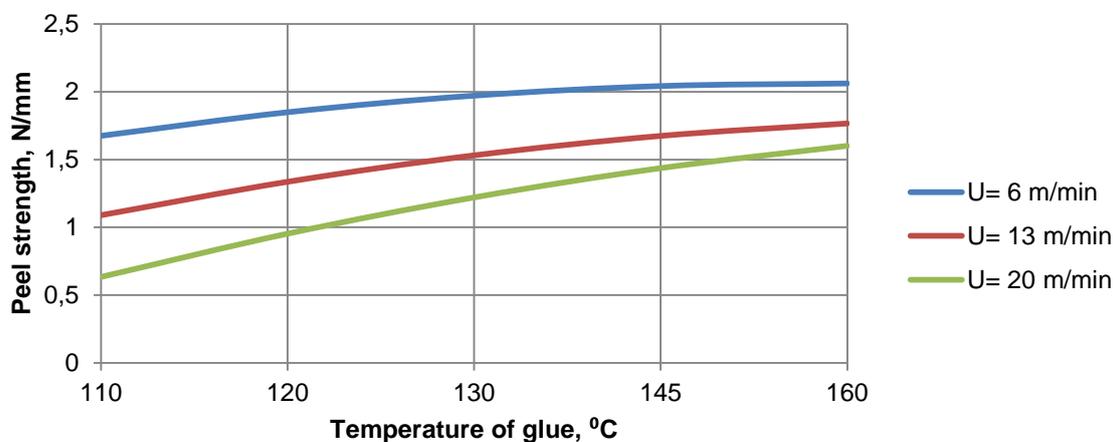


Fig. 5.
Relationship between peel strength of glue joint, feeding speed and temperature of glue during through feed lamination of particle board with PVC foil.

The range of the temperature variations of the melt is restricted as by the working viscosity of the adhesive compound, as well as by the temperature at which the adhesive is destroyed. Generally, the bonds formed at higher temperatures of the adhesive compound possess also higher adhesion strength (Fig. 4). This means that in the lack of restricted conditions higher temperatures are preferred. Even though, as it is already mentioned above, the technological relationship between the temperature of the glue and the feeding speed. At high feeding speed the cooling time of the hot melt adhesive may not be sufficient and may hamper the following process of removing the protruded parts of the PVC foil. Thus, the thermal conductivity of the material has to be taken into account when the through feed wrapping process is set up. In relation to this, the combined influence of these two factors - temperature and feeding speed on the adhesion strength of the adhesive compound is shown in Fig. 5. The most favorable conditions for through feeding wrapping of particles boards are achieved at feeding speed over 10m/min and temperature of the

glue below 130°C. This is due to the fact, that at higher feeding speed the compression is insufficient for obtaining of high quality adhesive compounds.

CONCLUSIONS

On the basis of our study and the results obtained, the following conclusions regarding the feed through lamination of particle boards with PVC foil and polyurethane hotmelt adhesive could be drawn:

- The adhesive compounds possess lower adhesion strength compared to those, recommended by the DIN 16 860 standard (adhesion strength over 2,5N/mm). In order to obtain adhesives with the recommended adhesion strength, the smoothness of the subjected to lamination article should be increased. Technologically, this can be achieved by plastering the particleboard surface with subsequent drying and sanding. In our previous study, we found that the standard requirements are met when the coated articles are MDF. Considering this, we conclude that the subjected to laminating with PVC foil furniture elements are preferable to be made out of MDF instead of particleboards.
- The three evaluated technological factors: feeding speed (U), quantity (Q) and temperature (t) of the applied adhesive material exert commensurable influence on the adhesion strength of the adhesive compound. Their variations in the tested range could result in either an increase or a decrease by 30% of the adhesion strength of the adhesive.
- For the tested range of the factors variation, the highest adhesive strength value of the adhesive compound was achieved at $Q = 100$ (g/m²), $t = 160$ (°C), $U = 6$ (m/min).
- In order to achieve the optimal adhesion strength over the through feeding wrapping process of furniture elements, the most favorable conditions are achieved at combination of low feeding speed and high temperature of the adhesive.

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