

HEAT RESISTANCE OF FURNITURE PARTS COVERED BY PLASMA TREATED FOILS

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ABSTRACT

Surface finish of furniture parts with foils is very popular way of decorative 3D–finish of furniture. As the foil is a thermoplastic material, for furniture parts used in interiors of bathroom or kitchen it is important to be water resistant and heat resistant. We tested polyethylene (PET) and polyvinylchloride (PVC) foils with 9 various colourations and gloss, 4 types of polyurethane based dispersions and two press settings. MDF was used as the base board. Surface of selected foil types was modified by electric discharge plasma. Measurement of the contact angle Θ of the surface of foils was done with distilled water as wetting liquid, according to EN 828. Estimation of the adherence of foils to the substrate with the pull-off method was done according to the procedure EN ISO 4624. Heat resistance of glued joint was tested by heating the samples in a chamber at temperatures from 50 °C to heat destruction. The appearance and damage of all tested samples were assessed visually. The results have shown that the type of adhesive, type of foil and vacuum pressing process are significant for joint quality. Heat resistance can be increased up to 20 or 30 °C by proper setting of the pressing process. Appearance was improved on plasma treated samples.

Key words: heat resistance, foil, polyurethane dispersion, vacuum pressing, surface finish

INTRODUCTION

Wood saving and recycling are important topics discussed all over the world. Use of particleboard and MDF boards are increasing. However, the boards need to be protected and visually adjusted by surface finish – there is a wide range of surface materials, such as PVC or PET foils, decorative papers, ABS, and veneer.

Membrane vacuum pressing is an important operation in production of doors and panels for cabinets. Pressing is performed by a membrane; the laminate material is shaped under the influence of pressure and heat – this ensures thorough adhesion of decorative material to all details of the surface of 3D-moulded furniture part (Krystofiak *et al.* 2006).

Before using, the foil surface can be cleaned, treated, or activated by various

ways. The modification of polypropylene foils by corona discharge was performed in a pilot plant Softal (Germany) in 2005, in the presence of oxygen at atmospheric pressure and temperature of 295 K. The used cylindrical electrodes were 98 mm long. The electrode voltage was equal to 9000 V and current density varied in the range between 0,3 and 0,8 mA.

During the foil modification by electric discharge plasma the surface of polymer interacts with the plasma particles. The active particles of plasma can originate either from the electric discharge at the atmospheric pressure (corona discharge) in air, or from high (radio) frequency (RF) discharge at lower pressure in inert (or other) atmospheres. The active particles of discharge plasma transferring the energy during the modification are ionic and neutral particles, electrons and UV radiation. Energy captured

from the particles by the surface initiates chemical reactions leading to changed polarity and adhesion properties of the foil. The effect of plasma on the polymer surface includes the act of photons of UV irradiation having important role during the formation of free radicals. Electrons and ions do not participate in the surface modification directly; but they are crucial for the formation of excited atoms and molecules in the volume of the discharge. These particles, in contact with the surface induce a formation of free radicals and chemical reactions (Novák *et al.* 2012).

Concerning the future usage of produced furniture parts at construction of kitchen furniture, there is very important to ensure a good heat resistance of both decorative foil and glued joint of the foil with board. Thermal characteristics of the materials used are usually known, but heat resistance of glued joint foil-board is highly dependent on the specific technological process of gluing and pressing; on the adhesive

quality and quantity, moisture content of the board, board surface quality, temperature, pressing time, etc. (Hippold 1998, Krystofiak 2006, Proszyk *et al.* 2005).

EXPERIMENTAL METHODS

To measure the contact angle Θ of the surface of solidified adhesive layers, there were 10 drops of redistilled water used, volume of 3,5 μl each, added by chromatographic syringe. Measurement of the contact angle was carried out by a biological microscope with goniometric equipment after the samples conditioning. Measurement of the contact angle Θ of the foil surface was done with distilled water as wetting liquid, according to EN 828 standard.

The adherence of foils to the substrate was measured with the pull-off method, exerting the failure load by the hydraulic method according to the procedure described in EN ISO 4624 standard, using the PostiTest® tester (Fig. 1).



Figure 1: Adherence – hydraulic method pull-off adhesion tester (www.defelsko.de)

Before the investigation, metal stamps (diameter 20 mm) were glued on tested surfaces, using two-component, monosilane-epoxy adhesive JOWAT 690.00. After 72 hours (h) conditioning time incisions were made around the stamp by a circular cutter, and they were placed in the measuring head of the apparatus and subjected to load. De-

laminating images at failure loadings were evaluated visually considering the scale of estimations contracted in the above cited standards.

Onto the MDF boards LUHOPOL milled to the final shape, a few types of decorative foils were glued: PVC foils RENOLIT VACUREN S – Coat, RENOLIT

VACUREN V – Coat, resp. RENOLIT VACUREN – Uni, with various surface finish: glossy, smooth matte, or matte with engraved surface, thickness of 0,3 – 0,4 mm. Four types of polyurethane based adhesives were used: one-component adhesives JOWAPUR 150.50, DUDIPUR D51, KLEIBERIT Supratherm 436 and two-component adhesive KLEIBERIT Supratherm 436 + hardener. Adhesives were hand-applied with spray gun AZ 3 HTE AVb (working pressure 0,2 MPa, nozzle diameter 1,0 mm, flow rate 80 ml/min.). Only one layer was spread on surfaces and two layers on edges. The boards were pressed in membrane vacuum press COATWIZARD (pressing temperature from 55 °C to 60 °C, pressing time 80 s, and subsequent cooling time of 5 minute). Before pressing, the foils were pre-heated for 20 – 40 seconds. For each combination of mate-

rials three separate samples were made. To measure the heat resistance, testing specimens with dimensions of 16 × 16 cm were made, so that the body contained the corner of the board.

Heat resistance of the joint between board and foil was tested in an oven at 50 °C and tempered for 1 hour. Then the quality of joint was assessed visually. The temperature was raised by 10 °C every hour. This process continued till the specimen was damaged. Heat resistance was evaluated as the last temperature at which the specimens was still intact.

RESULTS AND DISCUSSION

Results of the contact angle Θ measurements of foil's surface are shown in Table 1.

Table 1: Contact angle of foils with statistical data

Statistics	Type of foil		
	Control	PVC plasma	PET plasma
x_{avg} [°]	69,92	63,58	59,86
x_{max} [°]	72,53	66,63	63,92
x_{min} [°]	68,25	59,00	52,87
V [%]	2,2	4,1	6,9

Treatment of foil surfaces caused the contact angle Θ decrease about 6 deg and 10 deg and as a consequence improvement of the wettability.

On the basis of the angle Θ values and dependences published in literature

(Kloubek 1974, Liptáková and Paprzycki 1983), surface free energy γ_s together with dispersive (γ_s^d) and polar (γ_s^p) energy were calculated and presented in Table 2.

Table 2: Surface free energy (γ_s) with dispersive (γ_s^d) and polar (γ_s^p) shares of foils

Kind of foils	γ_s	γ_s^d	γ_s^p
	[mJ/m ²]		
control	41,66	32,45	9,21
PVC plasma	45,33	32,79	12,54
PET plasma	47,52	32,78	14,74

The tested finishing materials after treatment showed better interactions in relation substrate – foil. An increasing γ_s^p parameter was observed, while γ_s^d values were on the same level (32 mJ/m²).

For better understanding of the interactions between MDF board and foils critical surface energy (γ_{sc}) was determined after

treatment. For calculations contact angle measurements of various solvents (DMSO, ethylene glycol, formamide, water) was carried out. Dependences for γ_{sc} of foils are shown in Figure 2. Treatment of foils surfaces enhances adhesion properties from the view of adsorption theory of adhesion polymers to wood and wood based materials.

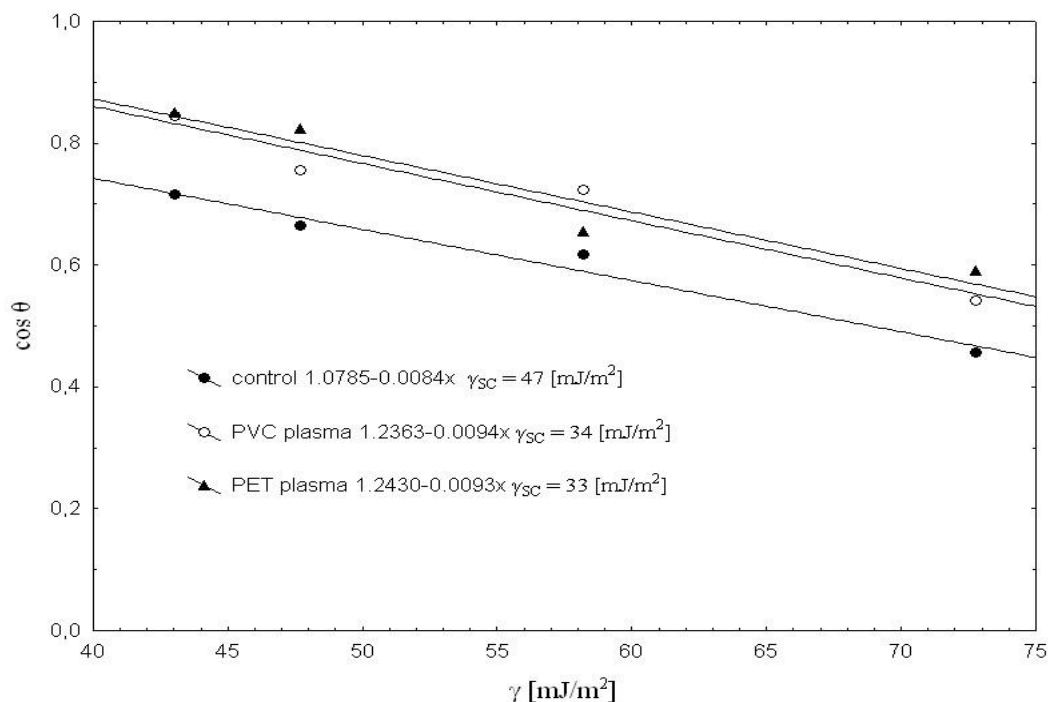


Figure 2: Critical surface energy of foils

Treatment of foil's surfaces enhances the adhesion properties of polymers to wood and wood based materials.

Adherence of foils to the substrate with the pull-off method gave delaminating im-

ages at failure loadings which were evaluated visually considering the scale of estimations presented in Table 3.

Table 3: Different types of delamination and their marking according to EN ISO 4624 standard

Marking	Delamination type – WFP [%]
A	Cohesive in substrate
A/B	Adhesion between substrate and first coating
B	Cohesive in first coating
B/C	Adhesion between first and second coating
-/Y	Adhesion of last coating and adhesive
Y	Cohesive in adhesive
Y/Z	Adhesion between adhesive and measure stamp

The results are summarised in Table 4 and Figure 3. Different types of delamination are clearly described in Table 4.

Table 4: Adherence of foils to the substrate with statistical data

№ of measurements	Foil types					
	control	WFP [%]	PVC plasma	WFP [%]	PET plasma	WFP [%]
1	0,48	100A	0,59	100A	0,65	100A
2	0,61	100A	0,68	100A	0,82	100A
3	0,66	100A	0,76	100A	1,03	100A
4	0,73	100A	0,68	100A	0,73	90A, 10B/C
5	0,70	100A	0,60	100A	0,73	100A
6	0,50	100A	0,66	100A	0,75	80A, 20B/C
7	0,65	100A	0,64	100A	0,79	70A, 30B/C
8	0,82	100A	0,73	100A	0,68	100A
9	0,59	100A	0,75	100A	0,70	100A
$x_{avg.}$	0,64	100A	0,68	100A	0,76	95A, 5B/C
$x_{max.}$	0,82		0,76		1,03	
$x_{min.}$	0,48		0,59		0,65	
V [%]	16,9		9,1		14,7	

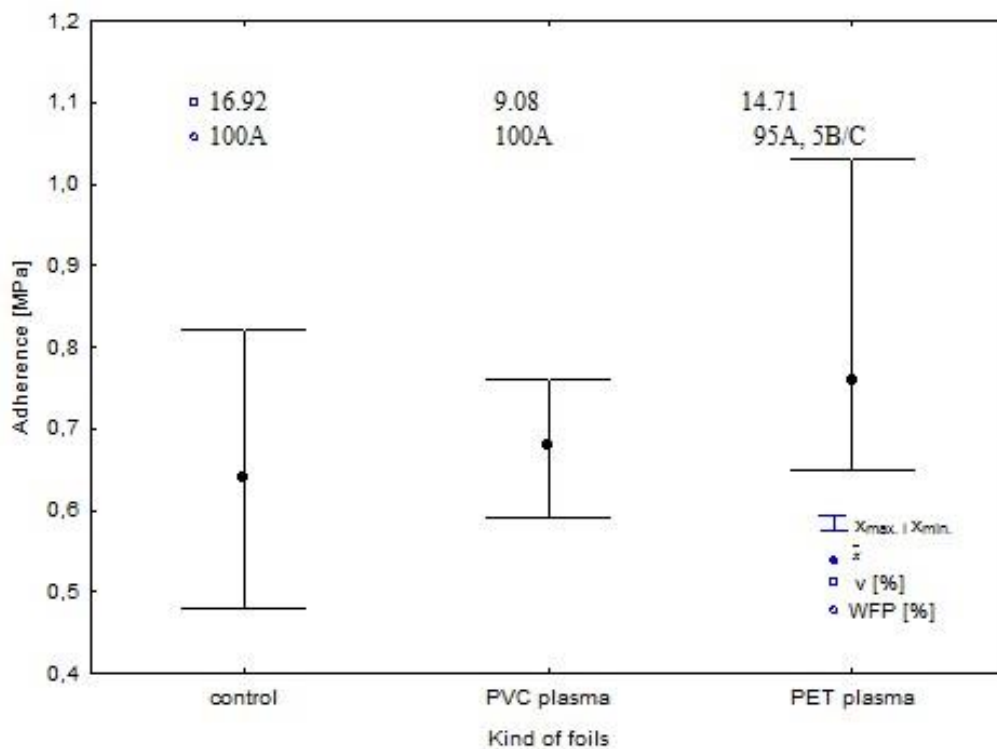


Figure 3: Adherence of foils to substrate with statistical data

In each case, WFP factor in the high level (about 100 %) was observed. It was stated, that treatment of foils surfaces gave very good results of glue-lines.

Obtained values of temperature after testing the heat resistance of the first series of foiled board samples (PVC foils with various textures) are presented in Table 5.

Table 5: Heat resistance of foiled boards for various combinations of materials for the first press setting

Foil	Adhesive	Heat resistance [°C]							
		50	60	70	80	90	100	110	Mean [°C]
Vanilla gloss	Jowapur		*	****	*				70
	Dudipur			**	*				73
Black gloss	Jowapur			*	*	*			80
	Kleiberit			*	**				76
Claret gloss	Jowapur			**	*				73
	Dudipur			****	**				74
	Kleiberit			*****	*				72
	Kleiberit +				***	***			85
Wenge	Kleiberit		**	****					66
	Kleiberit +						***		100
Glass – Q	Kleiberit +						*****	*	102

The quality of glued joint, from the view of heat resistance, is significantly influenced by the type of used adhesive. Joints glued with two-component adhesive KLEIBERIT Supratherm 436 + hardener are characterised by higher heat resistance values (up to 100 °C), in comparison with one-component adhesive at 70 °C to 80 °C, or less than 90 °C. The colour and gloss of

PVC foils do not influence the heat resistance of glued joints.

After the press parameters were changed, the heat resistance was measured again, but only at certain combinations of PVC foils, DUDIPUR D 51 adhesive, and foils with different texture, see Table 6. During the second press setting, the pressing temperature was increased with 5 °C, up to 60 °C.

Table 6: Heat resistance of foiled boards for various combinations of materials for the second press setting

Foil	Adhesive	Heat resistance [°C]							
		50	60	70	80	90	100	110	Mean [°C]
Vanilla gloss	Dudipur				*	*	*		90
Vanilla patina						*	*	*	100
Walnut matt							***		100
Oak matt							**	*	103
White silk						**	*		93

Only the glossy vanilla foil gave us the possibility to compare the quality of pressing of the first setting with the second one.

The influence of increased temperature is clear. The differences between values of heat resistance are shown in Figure 4.

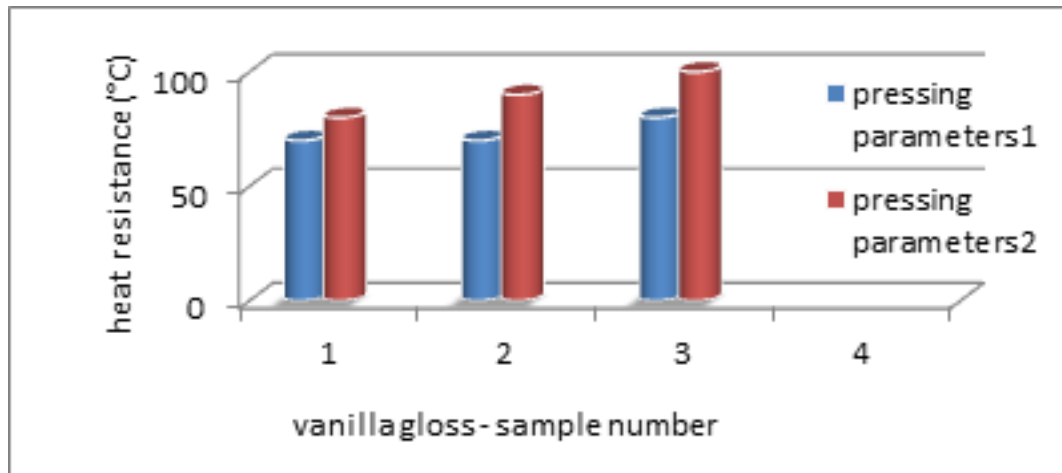


Figure 4: Heat resistance of glued joints board-foil depends on press setting

Results of heat resistance and appearance of plasma treated PVC and PET foils are presented in Table 7. Although, the heat resistance is on the same level, the quality of

appearance is much better for the plasma treated samples i.e. they do not have any orange peel look.

Table 7: Heat resistance and appearance of foiled boards for normal and plasma treated samples

Foil	Adhesive	Heat resistance [°C]								Appearance	
		50	60	70	80	90	100	110	Mean [°C]	orange peel	
PVC	Dudipur				***				80	yes	
PVC plasma					***				80	no	
PET					***				80	yes	
PET plasma					***				80	no	

CONCLUSIONS

It is known that heat resistance depends on many factors; quality of used materials (board, foil and adhesive) and on the parameters of laminating technology, i.e. smoothness, quality of spraying, pre-heating of the foil, pressing parameters: time and temperature. In practice, it is necessary to specify the pressing parameters unambiguously for all types of used foils and adhesives. Testing the heat resistance for each type of foil used, adhesive, way of spraying, and specific setting of press parameters enables to control excellently the quality of the final product. Based on the research results we can state that optimisation of pressing temperature for each used material can move heat resistance from the level “average” (70 – 80 °C) to the

level “very good” (90 – 100 °C) – heat resistance could be raised up with 20 or 30 °C. The plasma treatment do not influenced significantly the heat resistance, but the appearance of the surface finishing was much better and without an orange peel.

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