Advances in Science and Technology Research Journal
Volume 14, Issue 1, March 2020, pages 58–68
https://doi.org/10.12913/22998624/113612

Received: 2019.10.15
Revised: 2020.01.10
Accepted: 2020.02.01
Available online: 2020.02.14

The Strength of the Adhesive Joints of the Medium-Density Fireboards and Particle Boards with the PVC Film

Anna Rudawska[1*], Dana Stančeková[2], Mirosław Müller[3], Tetiana Vitenko[4], Vlodymyr Iasnii[5]

[1] Lublin University of Technology, Faculty of Mechanical Engineering, ul. Nadbystrzycka 36, 20-618 Lublin, Poland
[2] University of Žilina, Faculty of Mechanical Engineering, Univerzitna 1, 010 26, Žilina, Slovak Republic
[3] Czech University of Life Science Prague, Faculty of Engineering, 165 21, Prague, Czech Republic
[4] Ivan Puluj TNTU, Faculty of Engineering of Machines, Structures and Technologies, Ruska 56 Street, 46001 Teronpil, Ukraine
[5] Ivan Puluj TNTU, Faculty of Engineering of Machines, Structures and Technologies, Ruska 56 Street, 46001 Teronpil, Ukraine
* Corresponding author's e-mail: a.rudawska@pollub.pl

ABSTRACT
The aim of the present article was to analyse the adhesive joints of different types of the furniture boards used for the furniture production. The present article included a comparative analysis of the adhesive joints of the particle board and the medium-density fireboard (MDF) pressed with the following types of film: A 0.3 mm thick PVC film and a 0.8 mm thick acrylic film, made with use of a single-component reactive hot-melt adhesive based on the PUR 706.2 ME polyurethane. It was observed that, among others, the adhesive joints made of the particle board with a pressed 0.3 mm thick PVC film and the adhesive's basis weight of 24 g/m^2 is characterised by better strength properties than the adhesive joints of the particle board with the adhesive's basis weight of 48 g/m^2.

Keywords: adhesive joints, strength, MDF, particle board, PVC film

INTRODUCTION

The bonding technology enables to obtain the high-quality adhesive joints that are characterised by high strength and resistance to the extrinsic factors [1–5]. An adhesive-bonded joint is characterised by a low joint mass, smooth surface at the bond and a lack of heat impact in the bond area [1, 6]. A minimum contraction occurs at the bond during the bonding process. As a result, the adhesive is distributed evenly in the adhesive-bonded joint and does not cause any stresses, which enables to obtain a specified dynamic strength [7, 8].

The bonding technology enables to bond different types of constructional materials (metal with polymer, wood with a PVC film) that may be used for various applications, including the furniture industry [9–14]. Bonding is used for bond the wooden elements, as well as to create various layer structures that are subject to further processing and that may be bonded with use of the bonding method later on. Such structures include various types of the furniture boards [15–18], e.g. particle board and MDF, which are used for production of either whole furniture constructions or their pieces. These materials are heavy-duty. What differs them from other constructional materials is the fact their structure is inhomogeneous. They are made of various particles that are arranged in a disordered manner [19].

MDF (Medium Density Fibreboard) represents 90% of the wood-based materials in Europe. It comes as a medium density (from 650 to 750 kg/m^3) wood fibre board. A wood-based product analysed herein is made by pressing wood fibres with an addition of organic binding and setting compounds under high pressure and at elevated temperature. MDF has a homogeneous density and raw material composition along its total cross-section [18]. Thus, it shows a perfect mechanical process ability during cutting. MDF is a basic material used for the production of furniture and interior fittings, such as mouldings, wall panels and caissons, as well as for the production of wood-work elements, e.g. doors. Due to their surface properties, they are suitable for treatments such as covering with thin melamine resin films, varnishing and covering with natural and artificial veneers [19].

The particle board is a three-layer wood-based material with a sand-papered surface, made by pressing wood particles at a high temperature and under pressure, using urea-formaldehyde resin as a bonding agent. The particle boards are formed from the wood particles, including: woodchips, continuous chips, wood residue chips, wafer chips and sawdust [19]. The inner layer consists of coarse fraction particles, while the external layers are formed from very fine and thin particles (micro-particles). The layers are of different density, whereas the difference may be up to even 500 kg/m^3. An external layer of the particle board has a maximum density. Thanks to that the surface is characterised by a low surface roughness and a high resistance to tearing off. The higher is the particle board's density, the lower is the internal density. The particle board is a basic material in furniture production [18]. It is also widely used as: lining and insulating material in interiors, partition walls, as well as a base material for the production of worktops, windowsills, wall panels and floors.

The present article includes the analysis of the adhesive joints made of the particle board and the medium-density fireboard (MDF) pressed with the following types of film: a 0.3 mm thick PVC film and a 0.8 mm thick acrylic film, pressed with use of PUR 706.2 ME – a single-component reactive hot-melt adhesive based on polyurethane. The aim was to assess the impact of the multilayer structures' material on the strength of their adhesive joints.

METHODS

Adherends characteristics

The experimental tests included using two materials in the form of samples, which were made of the furniture boards (a particle board and a MDF board), whose surface was covered with two types of the furniture film: a PVC film (variant 1) and the acrylic film (variant 2). The samples are described in Table 1.

The specified adhesive's basis weights were used during the preparation of the samples made of the furniture boards with the furniture films, depending on the film type and thickness. It was in accordance with a technological process adopted by a wood board production plant.

Table 2 presents the values of the physiochemical parameters of a 18 mm thick MDF board, whereas Table 3 – those of the 18 mm thick particle board.

The covers on the furniture boards were made with use of two film types (PVC and acrylic), which are often used as an additional cover in order to protect the furniture board or make it more aesthetic.

A white (backpressure and waterproof) 0.3 mm thick PVC furniture film (Fig. 1a), aimed at laminating the furniture boards, was used in the experimental tests. The backpressure film is

Table 1. Variants of samples made of the furniture boards

Board type	Board thickness, mm	Film type	Film thickness, mm	Adhesive basis weight, g/m^2	Variant designation
MDF board	18	PVC	0.30	0.24	MDF/PVC/0.24
		PVC		0.48	MDF/PVC/0.48
		acrylic	0.80	0.24	MDF/AK/0.24
		acrylic		0.48	MDF/AK/0.48
Particle board	18	PVC	0.30	0.24	W/PVC/0.24
		PVC		0.48	W/PVC/0.48
		acrylic	0.80	0.24	W/AK/0.24
		acrylic		0.48	W/AK/0.48

Table 2. Physiochemical parameters of a 18 mm thick MDF board [20]

Parameter	Value	Tests according to the norm
Density, kg/m^3	750	EN 323
Bending strength, MPa	20	EN 310
Tensile strength, MPa	0.55	EN 319
Longitudinal elasticity modulus, MPa	2200	EN 310
Upset after 24 hrs, %	12	EN 317
Humidity, %	4–11	EN 322

Table 3. Physiochemical parameters of a 18 mm thick particle board [21]

Parameter	Value	Tests according to the norm
Density, kg/m^3	650	EN 323
Bending strength, MPa	11	EN 310
Tensile strength, MPa	>0.35	EN 319
Tear strength, MPa	>0.80	EN 311
Upset after 24 hrs, %	<15	EN 317
Humidity, %	5–13	EN 322

used to stabilise the stresses that occurred covering a particle board or a MDF board with laminates, veneer and finish film. It is used on a reverse or a bottom side of the elements in order to prevent the board from deforming (e.g. a bottom side of the kitchen worktop). The advantage of a backpressure film is that it may be drilled, cut or milled after having been pressed on the board. In addition, this film type is resistant to scratching, stains and high temperature. The chemical composition of the PVC film is the following: PVC polymer (80–92%), diisononyl phthalate plasticizer (0–12%), and other additives (8%).

White acrylic 0.8 mm thick film (Fig. 1b) is a high-gloss film producing a unique mirror effect. It is aimed at covering the furniture fronts. Its characteristics are the following: high gloss, colour durability, high resistance and durability, high stability and wear resistance, high chemical and thermal resistance, as well as easy cleaning.

Adhesives' characteristics

Two adhesive types were used in the experimental tests: a polyurethane adhesive PUR 706.2 ME to bond the film with the board and a two-compound epoxy adhesive Epidian 53/Z1/100:10 to make the adhesive joints. PUR 706.2 ME is a single-compound reactive hot-melt adhesive based on polyurethane. It is made "on the basis of the prepolymers that are moisture crosslinkable" [22] and its density is ca. 1.1 g/cm^3. Epidian 53/Z1/100:10 is a two-component epoxy adhesive, based on the Epidian 53 epoxy resin with addition of the Z-1 curing agent in proportion 100:10. Epidian 53 is a light-yellow viscous liquid and its characteristics are the following: may be cured at ambient temperature; has excellent adherence to most materials, such as: metal, glass, ceramics, wood, etc.; has good mechanical properties and high resistance to numerous factors, such as: oils, lubricants, diluted alkalis and acids. Thanks to addition of styrene, the epoxy resin has low viscosity and is able to infiltrate mats and woven fibre glass.

The physical and chemical properties of the Epidian 53 epoxy resin are as follows [23]:

- epoxide number: mole/100 g – min. 0.410
- density at 20 °C: 1.110–1.150 g/cm^3,
- viscosity at 20 °C: 900–1500 mPas,
- gelation time of 10 g of Epidian + 1.05 g of the curing agent at 20°C- 200 min.

The Z-1 curing agent is used for curing the liquid epoxy resins. It increases the compounds' elasticity and impacts its strength. It is used to make the joints that are prone to deformation, e.g. in boatbuilding for bonding the elements made of wood or polyester–glass laminate, for bonding rubber with metal, thin metal sheets, plywood and for flood filling of elements in electronics. When the curing agent is being added to the resin, the curing process starts. After that there is so called 'open' time left, i.e. the portion of the cure time,

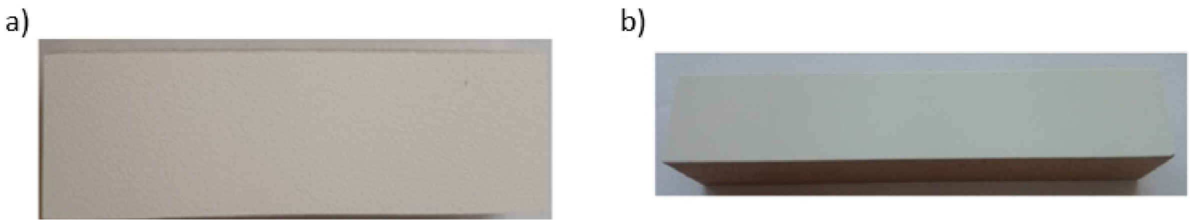

Fig. 1. Films serving as a surface cover of the furniture boards: a) acrylic film, b) PVC film

after mixing the resin and curing agent to incite an epoxy chemistry reaction. The amount of the open time depends on several factors: temperature, mixture amount, etc., and differs depending on the individual conditions. Initial curing is finished after 48 hours – the degree of cure is ca. 80–90%. Final curing takes from 7 to 14 days. The Z-1 curing agent has the following properties [24]:

- viscosity at 25 °C: 20 – 30 MPas
- density at 20 °C: 0.978 – 0.983 g/cm^3
- amino number: min. 1100 mg KOH/g.

Shape and dimensions of the adhesive joints

Single-lap adhesive joints of the MDF boards and the particle boards were used in the experimental tests. Fig. 2 presents a scheme of a single-lap adhesive joint made for the experimental tests.

The single-lap adhesive joints were made of the 18 mm thick furniture boards, which were covered with a 0.3 mm and 0.8 mm thick furniture film with use of the polyurethane adhesive PUR 706.2 ME of 24 g/m^2 and 48 g/m^2 basis weight accordingly. The adhesive joints were made with use of the two-component structural epoxy adhesive – Epidian 53/Z1/100:10. Dimensions of the bonded elements were the following: width – 20 mm, length – 100 mm. The assumed length of the adhesive joints was 20 mm for each single-lap joint. 40 adhesive joints were made for the experimental tests – 5 joints from each sample described in Table 1 hereinabove. The adhesive joints obtained in such a way consisted of 7 materials, including those with 6 adhesive joints of various materials of different thickness and properties.

Figure 3 and Figure 4 present some exemplary variants of adhesive joints made with use of the materials enumerated in Table 1 hereinabove.

Preparation of the furniture board samples and the adhesive joints

Preparation of the furniture board samples, which were used to make the adhesive joints, included two main stages:

1. Covering (pressing) the film on the furniture boards: MDF and particle board.
2. Preparing the samples from the boards.

In the first stage the film was being covered on the MDF boards and particle boards by pressing. The film pressing was conducted on an automated line. Firstly, a board was cleaned with use of brushes connected to a hoist, and then with rollers. The board was transported to a furnace,

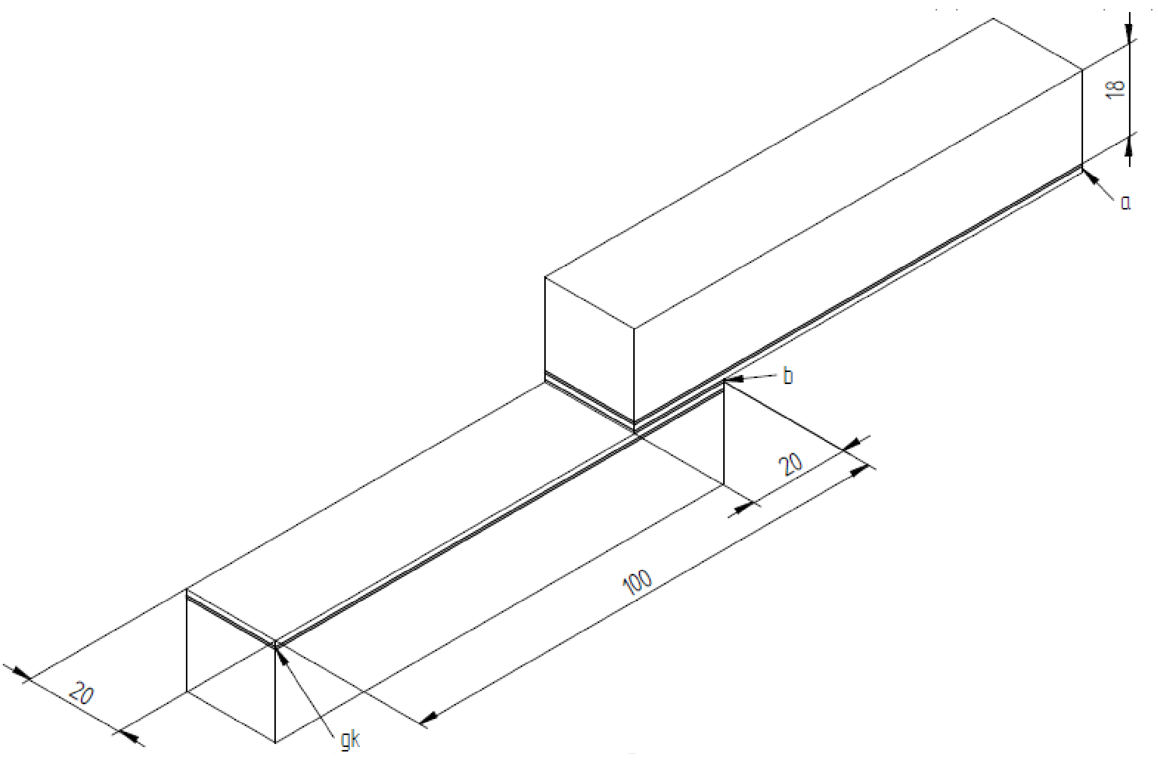

Fig. 2. A single-lap adhesive joint scheme: a – furniture film thickness, b – epoxy adhesive thickness

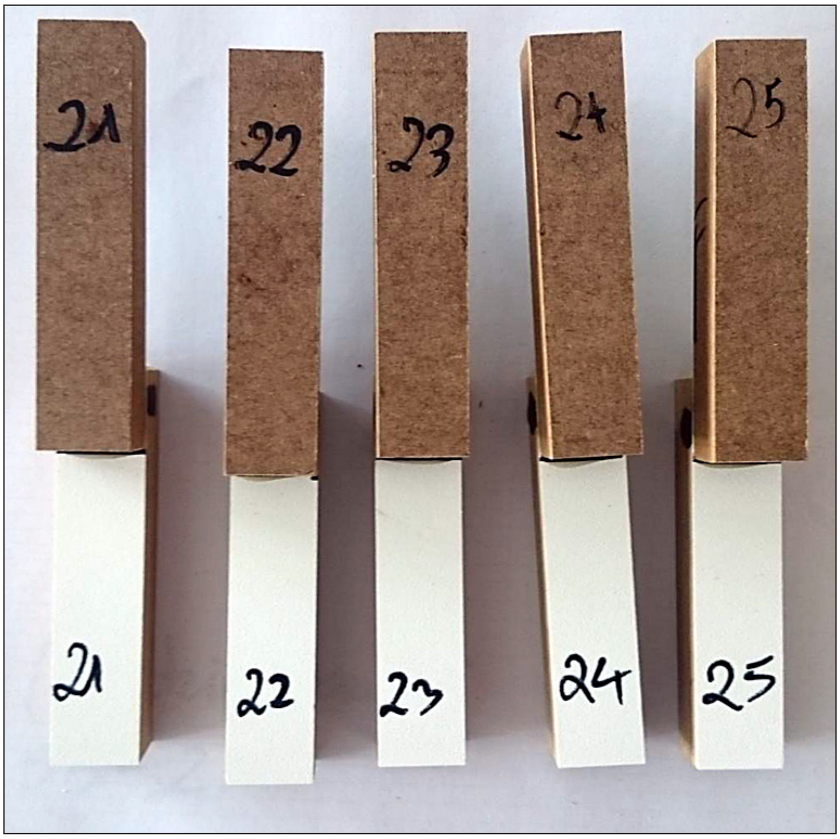

Fig. 3. A single-lap adhesive joint of the MDF board with the 0.3 mm thick PVC film and the adhesive's the basis weight of 24 g/m^2 (MDF/PVC/0.24)

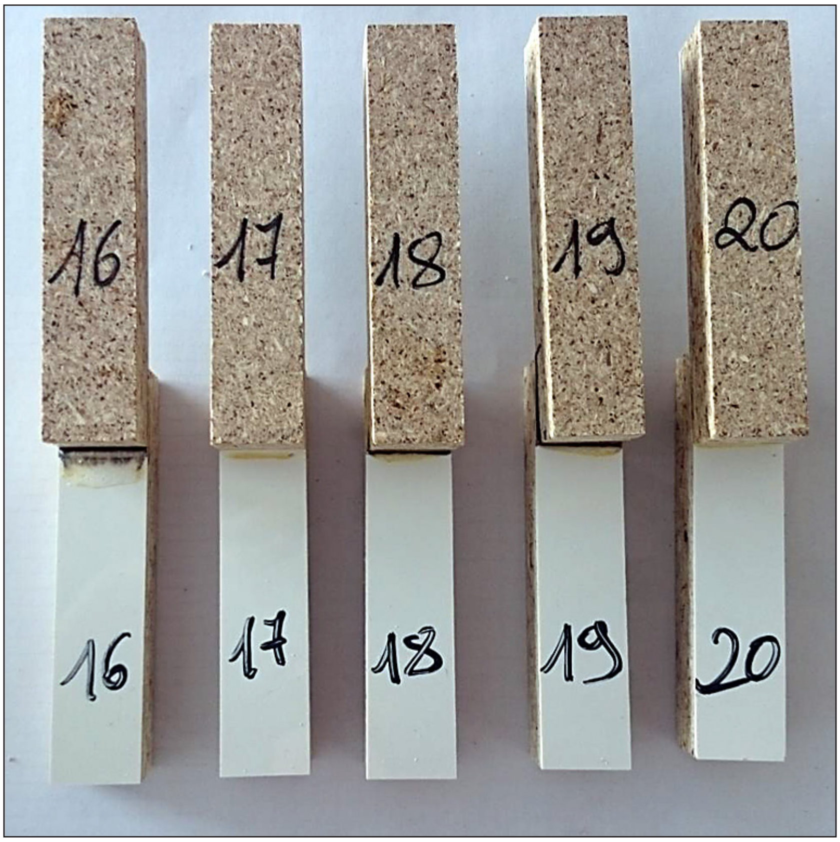

Fig. 4. A single-lap adhesive joint of the particle board with the 0.8 mm thick acrylic film and the adhesive's the basis weight of 48 g/m^2 (P/AC/0.48)

where the bonding rolls were placed. A bonding agent in the form of the polyurethane adhesive was distributed from a premelter with use of hoses. Then it was fed on the rolls with the nozzles. The board was heated with use of lamps all the way before it was finally transported to the film feeder. The adhesive temperature was of 140°C, and the temperature of the adhesive on the board was of 25°C. When the board was transported to a feeder, the film was covered on the board.

The board covered with film was pressed with two types of rolls: a steel roll with a steel roll and a steel roll with a silicone roll. The roll spacing when pressing a MDF board and a particle board with 0.3 mm thick PVC film was: 18.3 mm – for spacing of the top steel roll from the bottom roll; a minimum underdraft was used, and 17.5 mm – for spacing of the top silicone roll from the bottom steel roll. The roll spacing when pressing a MDF board and a particle board with a 0.8 mm thick acrylic (glossy) film was: 18.7 mm for spacing of the top steel roll from the bottom roll. The silicone roll was not used for pressing the 0.8 mm thick film.

The curing time of the adhesive after the process of covering the film was 48 hours at ambient temperature. If the curing time was shorter, the film could get unstuck of the board.

After the curing process was finished, the second stage was initiated – preparation of samples for making the adhesive joints. This stage was conducted with a panel saw Altendorf F 45 (using the HM circular saw, d=300/z=96). 40 elements were cut out of each MDF board (2800 x 1300 mm) and particle board (2800 x 1220 mm). Each element's dimensions were: 100 x 20 mm.

The last stage consisted of making the single-lap adhesive joints. The bonding process was conducted indoors, at the temperature of 22±1°C and the humidity of 22±2 %. The adhesive joint's curing process lasted 7 days at the temperature of 22±1°C.

The bonding process included four stages:

- surface preparation for bonding,
- adhesive's preparation,
- bonding,
- pressure and curing.

Stage 1 – the surface to be bonded was rubbed through. It was cleaned off the impurities with use of paper towels.

Stage 2 – the adhesive was prepared. The epoxy adhesive based on the epoxy resin Epidian 53 was used in the experimental tests. The Z-1 curing agent was used to cure the adhesive. The adhesive with addition of the curing agent was weighed in a container with use of an electronic balance TP-2/1. A correct stoichiometric proportion was kept – 100 g of the epoxy resin Epidian 53 and 10 g of the curing agent Z-1. As a result, the adhesive compound Epidian 53/Z-1/100:10 was obtained. The ingredients were mixed at a mixing stand, with use of a horseshoe mixer, with the mixer's rotational speed of 380 rpm for 2 minutes.

Stage 3 – the adhesive was applied on one of the two elements, which were then bonded properly. The adhesive was applied manually with use of the polymer spatulas. It was necessary to apply the adhesive evenly in order to remove air bubbles.

Stage 4 – the last stage included an important condition of the adhesive joint's curing – a pressure. It was done with use of a weight of 1 kg that was pressing two bonded elements against each other for 7 days. The pressure enabled to distribute the adhesive evenly and to make the bonded elements adhere to each other without moving.

Strength tests

The single-lap adhesive joints were subject to the shear strength tests on the testing machine Zwick/Roell Z150. The tests were conducted in accordance with the norm: DIN EN 1465. The tests were conducted at the initial force of 5 N and the destructive speed of 20 mm/min.

RESULTS

Strength of the adhesive joints of the boards with the adhesive's basis weight of 48 g/m^2

Fig. 5 shows the shear strength test results (mean values) of adhesive joints of the furniture boards with: 0.3 mm thickness PVC film and the 0.8 mm thickness acrylic film with the adhesive of the basis weight of 48 g/m^2. The adhesive joint samples were bonded with the epoxy adhesive Epidian 53/Z-1/100:10.

Based on the results presented in Figure 5, it may be observed that the samples of the adhesive joints made of MDF board showed the highest shear strength. The shear strength obtained by the samples of the adhesive joints made of the particle board was 19% lower. The adhesive

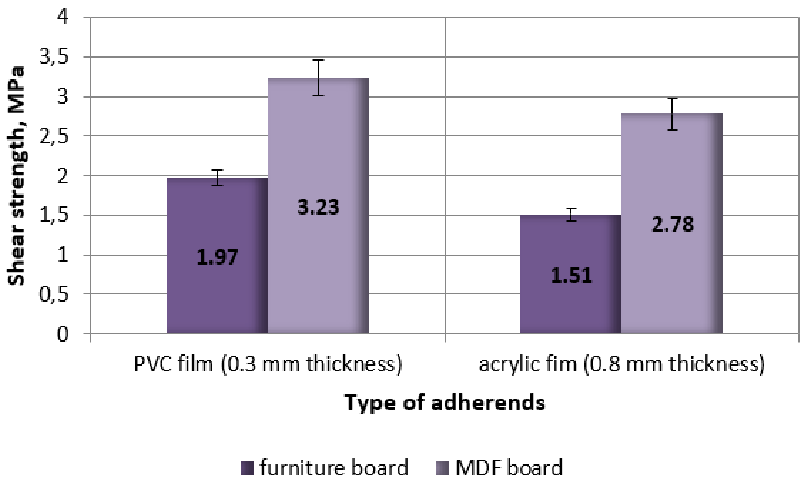

Fig. 5. Shear strength of the adhesive joints with the adhesive's basis weight of 48 g/m^2

joints of the MDF board with the 0.3 mm thick PVC film showed the highest shear strength of 3.28 MPa. Their strength was ca. 15% higher than the strength of the joints with the 0.8 mm acrylic film. Similar results were obtained for the adhesive joints of the furniture boards. The highest shear strength was obtained by the adhesive joints of with the 0.3 mm thick PVC film – it was of 1.97 MPa. This strength value was 23% higher than the one obtained of the samples with the 0.8 mm thick acrylic film, which was of 1.51 MPa.

Standard deviation of the adhesive joints of the furniture boards with the 0.8 mm thick acrylic film was at a similar level. The same situation was observed for the adhesive joints of the furniture boards with the 0.3 mm PVC film.

Strength of the adhesive joints of the boards with the adhesive's basis weight of 24 g/m^2

Figure 6 shows the shear strength test results (mean values) of adhesive joints of the furniture boards with: 0.3 mm thick PVC film and the 0.8 mm thick acrylic film with the adhesive of the basis weight of 24 g/m^2. The adhesive joint samples were bonded with the Epidian 53/Z-1/100:10 epoxy adhesive.

Based on the results presented in Figure 6, it may be observed that the samples of the adhesive joints made of the MDF board showed the highest shear strength. The samples of the MDF board with pressed 0.3 mm thick PVC film were characterised by the highest shear strength, which was of 3.18 MPa. Their strength was ca. 67% higher than

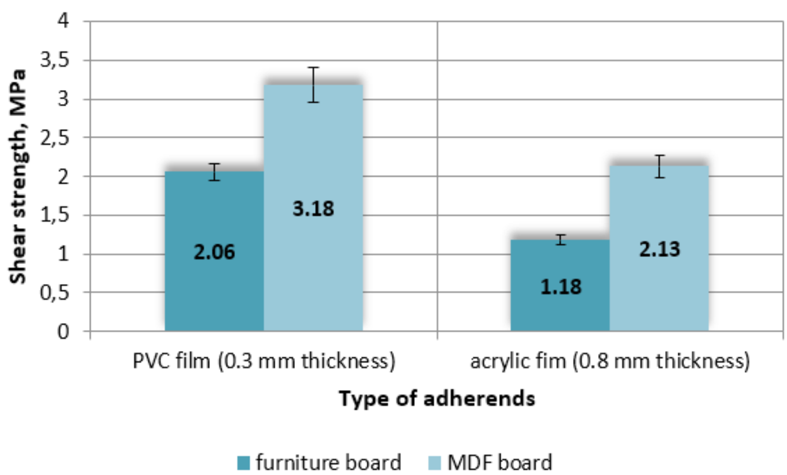

Fig. 6. Strength of the adhesive joints of the boards with the adhesive's basis weight of 24 g/m^2

the strength of the samples of the adhesive joints made of the MDF board with the 0.8 mm thick acrylic board. The shear strength of the adhesive joints of the particle board with the 0.3 mm thick PVC film was of 2.06 MPa and it was 0.88 MPa higher than the strength of the adhesive joints with the 0.8 mm thick acrylic film, which was of 1.18 MPa.

Standard deviation values for the adhesive joints with the 0.3 mm thick PVC film were the following: for the MDF board it was of 0.16 MPa, whereas for the particle board – 0.1 MPa. Standard deviation values for the adhesive joints with the 0.8 mm thick acrylic film, in turn, were the following: for the MDF board it was of 0.52 MPa, whereas for the particle board – 0.15 MPa.

Strength of the adhesive joints of the particle board

Figure 7 presents strength values of the adhesive joints of the particle board with the adhesive's basis weight of 24 g/m^2 and 48 g/m^2, whereas Figure 8 – those of the adhesive joints of the MDF board with the adhesive's basis weight of 24 g/m^2 and 48 g/m^2.

Based on the results presented above, it was observed that the adhesive joints with the 0.3 mm thick PVC film and the adhesive's basis weight of 24 g/m^2 were characterised by better strength properties than the adhesive joints of the with the adhesive's basis weight of 48 g/m^2. As for the adhesive joints of the particle board with the 0.8 mm thick acrylic film, the joints with the adhesive of the basis weight of 48 g/m^2 showed higher shear strength. Figure 8 below shows the adhesive joints of the particle board with the 0.8 mm thick acrylic film and the adhesive of the basis weight of 48 g/m^2 after destructive tests.

When analysing the character of destruction of the adhesive joints, it may be observed that the adhesive joints of the particle board with the 0.3 mm PVC film were completely destroyed at some distance from the joint. A cohesive

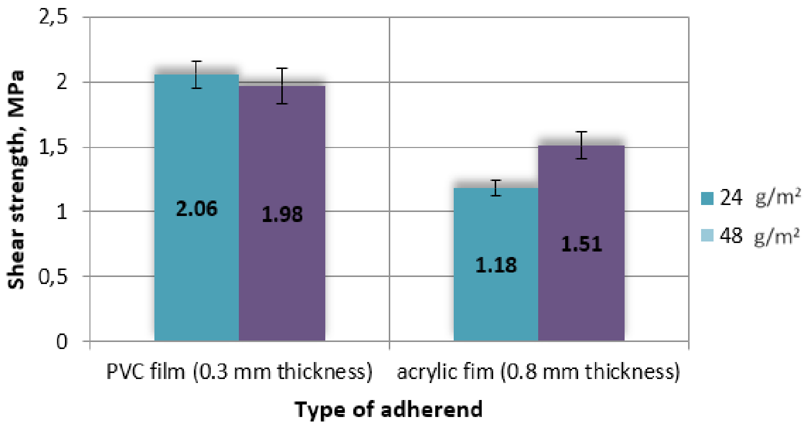

Fig. 7. Strength of the adhesive joints of the furniture board

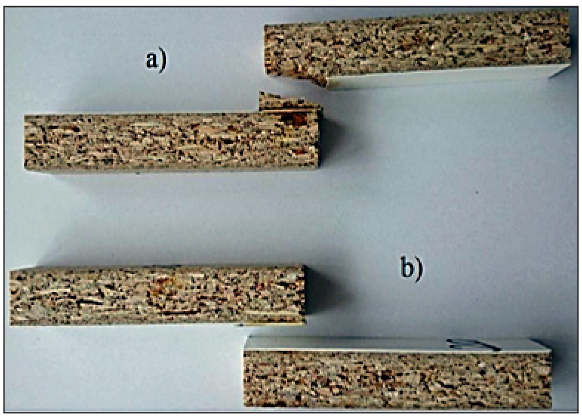

Fig. 8. Adhesive joints of the particle board with: a) the 0.3 mm thick PVC film, b) the 0.8 mm thickness acrylic film and the adhesive of the basis weight of 48 g/m^2, after a destructive test

destruction of the bonded material was observed. As for the adhesive joints of the particle board with the 0.8 mm acrylic film, the adhesive-cohesive destruction was observed in all cases for the adhesive Epidian 53/Z-1/100:10.

Strength of the adhesive joints of the MDF board

Figure 9 presents strength values of the adhesive joints of the MDF board with the adhesive's basis weight of 24 g/m^2 and 48 g/m^2.

When analysing the results presented on the graph, it may be observed that in case of the adhesive joints with the 0.3 mm thick PVC film and the 0.8 mm thick acrylic film, the joints with the adhesive of the basis weight of 48 g/m^2 showed higher shear strength. Figure 10 below shows the adhesive joints of the MDF board with the adhesive of the basis weight of 48 g/m^2 after destructive tests.

When analysing the character of destruction of the adhesive joints, it may be observed that the adhesive with the 0.3 mm PVC film were completely destroyed. The cohesive destruction of the bonded material occurred. When analysing the destroyed adhesive joints of the MDF board with the 0.8 mm thick acrylic film, it should be highlighted that in these cases the adhesive-cohesive destruction occurred for the epoxy adhesive Epidian 53/Z-1/100:10.

CONCLUSIONS

After the tests results, the following conclusions may be drawn:

1. The adhesive joints made of the particle board with pressed 0.3 mm thick PVC film and the adhesive's basis weight of 24 g/m^2 are characterised by better strength properties than the adhesive joints of the particle board with the adhesive's basis weight of 48 g/m^2.

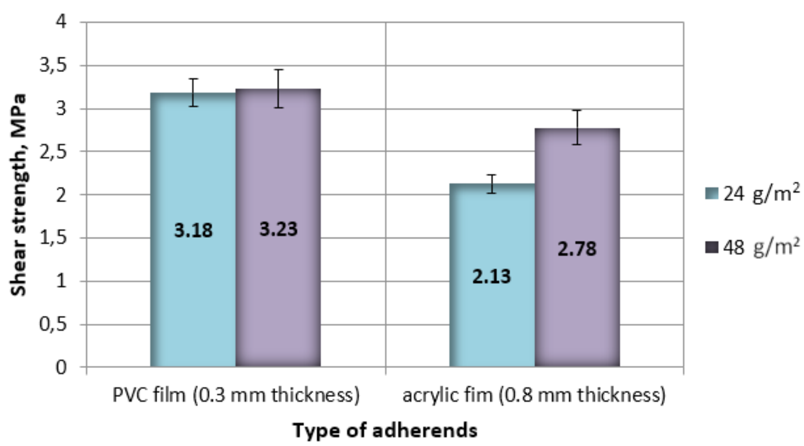

Fig. 9. Strength of the adhesive joints of the MDF board

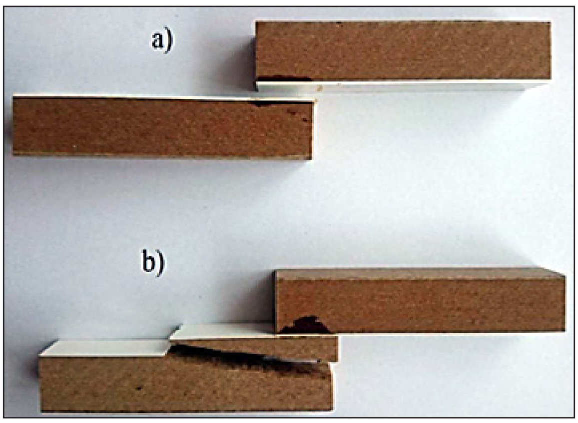

Fig. 10. Adhesive joints of the MDF board with: a) the 0.3 mm thick PVC film, b) the 0.8 mm thick acrylic film and the adhesive of the basis weight of 48 g/m^2, after a destructive test

2. The adhesive joints made of the particle board with pressed 0.8 mm thick acrylic film and the adhesive's basis weight of 48 g/m^2 are characterised by better strength properties than the adhesive joints with the adhesive's basis weight of 24 g/m^2.
3. The adhesive joints made of the MDF with pressed 0.3 mm thick PVC film and 0.8 mm thick acrylic film and the adhesive's basis weight of 48 g/m^2 are characterised by better strength properties than the adhesive joints with the adhesive's basis weight of 24 g/m^2.
4. The adhesive joints made of the particle board and the MDF board with a pressed 0.3 mm thick PVC film and the adhesive's basis weight of 24 g/m^2 and 48 g/m^2 are characterised by higher strength as the cohesive destruction of the bonded material occurred, i.e. both the particle board and the MDF board were destroyed.
5. When comparing the film types used in the tests, it may be observed that in case of the adhesive joint with the 0.3 mm thick PVC film, the destruction occurred in the furniture board, whereas in case of the adhesive joint with the 0.8 mm thick acrylic film, the destruction occurred in the adhesive-cohesive bond. It stems from the fact that the 0.3 mm thick PVC film has irregular structure, as opposed to the 0.8 mm acrylic film.

The experimental tests showed that for the adhesive joints with thicker film and of regular structure, the adhesive with a higher basis weight should be used. When it comes to the joints with film of irregular structure, less adhesive can be used as it will not have a significant impact of the adhesive joint's strength.

REFERENCES

1. Adams, R.D., Comyn, J., Wake ,W.C.: Structural Adhesive Joints in Engineering Book, 2nd edition, Springer, United Kingdom 1997.
2. Pizzi, A.: Advanced Wood Adhesive Technology, Marcel Dekker, New York, 1994.
3. Hass, P., Kläusler, O., Schlegel, S., Niemz, P.: Effects of mechanical and chemical surface preparation on adhesively bonded wooden joints. International Journal of Adhesion and Adhesives, 2014, 51:95–102.
4. Rudawska, A.: Influence of the thickness of joined elements on lap length of aluminium alloy sheet bonded joints. Advances in Science and Technology Research Journal, 2015, Vol 9, no. 27, 35–44.
5. Rudawska, A.: Pressure during curing and the strength of 2024, 2017A and 1050 aluminium alloy sheet adhesive joints. Advances in Science and Technology Research Journal, 2015, Vol 9, no. 26, 96 –103.
6. Conrad, M.P.C., Smith, G.D., Fernlund, G.: Fracture of wood composites and wood-adhesive joints: A comparative review. Wood and Fibre Science, 2004, 1, 26–39.
7. da Silva, L.F.M., Carbas, R.J.C., Critchlow, G.W., Figueiredo, M.A.V., Brown, K.: Effect of material, geometry, surface treatment and environment on the shear strength of single lap joints. International Journal of Adhesion and Adhesives, 2009, 29, 621–632.
8. Bachtiar, E.V., Clerc, G., Brunner, A.J., Kaliske, M., Niemz, P.: Static and dynamic tensile shear test of glued lap wooden joint with four different types of adhesives, International Journal of the Biology, Chemistry, Physics, and Technology of Wood, 2017, 5, DOI: https://doi.org/10.1515/hf-2016–0154.
9. Dunky, M.: Adhesives in the wood industry. In: Handbook of adhesive technology, revised and expanded, ed. A Pizzi, KL Mittal, Marcel Dekker, New York 2003.
10. Selbo, M.L. Adhesive bonding of wood. Tech. Bull. 1512, 1975, Washington, DC: U.S. Department of Agriculture, Forest Service.
11. Sellers, T. Jr.: Plywood and adhesive technology. Marcel Dekker, New York, 1985.
12. Vick, C.B., Rowell, R.M.: Adhesive bonding of acetylated wood. International Journal of Adhesion and Adhesives, 1990, 10, 263–272.
13. Serrano, E.: Adhesive Joints in Timber Engineering. Modelling and Testing of Fracture Properties. Division of Structural Mechanics, Lund University, LUND, Sweden, 2000.
14. River, B.H.: Fracture of adhesive-bonded wood joints. In: Handbook of adhesive technology, revised and expanded, ed. A Pizzi, KL Mittal, Marcel Dekker, New York, 2003.
15. Tankut, A.N., Tankut, N.: Evaluation the effects of edge banding type and thickness on the strength of corner joints in case-type furniture. Materials and Design, 2010, 31, 2956–2963.
16. Frihart, Ch.R., Hunt, G.Ch.: Adhesives with Wood Materials Bond Formation and Performance, Chapter 10, General Technical Report FPL–GTR–190. https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr190/chapter_10.pdf (available at 20.05.2019).
17. Angelski, D., Vitchev, P.: Influences of some factors on adhesion strength between PVC foil and MDF. Processing Technologies for the Forest and Biobased Products Industries Conference, DOI:

10.13140/RG.2.2.26880.12801.

18. Rangava, H., Taghiyari, H.R., Ghofrani, M., Khojaste-Khosr, S.: Improving physical and mechanical properties in particleboard by recycled polyethylene and canola residues. International Journal of Environmental Science and Technology, 2016, 13, 857–864.
19. Kociszewski, M.: Właściwości sprężyste płyty wiórowej i MDF jak materiałów anizotropowych o nierównomiernym rozkładzie gęstości na grubości płyty. Wydawnictwo Uniwersytetu Kazimierza Wielkiego, Bydgoszcz 2014.
20. https://www.swisskrono.pl/mdm/Plyty-MDF/Dane-techniczne (available at 20.05.2019).
21. https://www.swisskrono.pl/mdm/Plyty-wiorowe/Dane-techniczne (available at 20.05.2019).
22. https://www.kleiberit.com/fileadmin/Content/Documents/PL/Info_Sheets/PUR_Uebersicht_Prospekt_PL.pdf (available at 20.05.2019).
23. https://admjacht.pl/public/assets//42-E53_KCh%20PPE%2020.pdf (available at 20.05.2019).
24. http://www.farbyjachtowe.pl/images/karty_techniczne/sarzyna/kt_z1.pdf (available at 20.05.2019).