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Evaluation of Resistance Properties of Selected Surface Treatments on Medium Density Fibreboards

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Abstract: The protection and decorative value of raw wood-based boards with various coatings can be enhanced during the service life of furniture using surface treatment techniques. In this study, selected transparent, pigmented polyurethane email finish and thin foils, commonly used in furniture, were used for surface treatments of medium-density fibreboards with a thickness of 18 mm. Water-borne finish with polyurethane–acrylate resin, solvent-borne finish with polyacrylate resin, and finish based on native oil and waxes, as well as pigmented polyurethane email finish, were used on veneered medium-density fibreboards. The thin foils (polyvinyl chloride, polyethylene terephthalate, and lacquered acryl film) were used for raw medium-density fibreboards. Several resistance surface properties were investigated. It was found that the hardness and resistance to impact were very much related to the interactions between the coating film or thin foil and the substrate. The type of surface finish had a substantial impact on the coating and foil's resistance qualities, such as resistance to mould and cold liquids.

Keywords: coating; foil; MDF; resistance properties; veneer

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1. Introduction

The methods used to refine the surfaces of raw wood-based composites [1] play a key role in ensuring the usability of furniture products such as interior fittings, office and children's furniture, or kitchen and bathroom cabinets. The following requirement profiles can be described, which are essentially defined by the surface materials used: (1) decorative requirements determined by design, colour, external appearance, and form, as well as possible changes in these properties over the period of use (e.g., colour changes, embrittlement, etc.), (2) protection, functionality, and suitability for use (e.g., durability to chemical and mechanical stresses, but also to heat in accordance to the intended use and service life), (3) processability of the materials in the production process, and (4) product safety (including environmental and health requirements for products) [1,2]. When using wood-based materials as a substrate, it is important to apply a surface treatment to preserve them from various environmental influences (such as ultra-violet radiation, weather effects from hail, etc.) or product-specific requirements (such as scratch resistance, water- and dirt-repellent properties, etc.). Usually, surfaces of particleboards (PB), medium density fibreboards (MDF) and other wood-based boards can be treated (a) by overlaying with wood veneer (the process known as veneering) [3–5], by glueing thin laminated sheets and laminates on them (the process known as laminating) [6–8], and (c) with liquid or powder coatings [5,9–11]. From an esthetical point of view, when using these techniques, the furniture part appears to be made of a solid wood panel. But when made of PB, MDF, and other wood-based boards, it is significantly cheaper.

Sliced veneer is most often 0.2–2.0 mm thick, its moisture content is 8 ± 2%, and the adhesives used are formaldehyde-based (UF, MUF, MF, RF, and RFF) resins [12].

Foils (with numerous colours, decors, and textures) are thin overlaying products in the form of sheets or rolls of metals, plastics, or impregnated cellulose/pigment mixtures (decorative foils). Polyester films, phenolic craft papers, poly (vinyl acetate) and urea-based decor papers, poly vinyl chloride (PVC), resin-impregnated papers, thin papers, and wooden coverings are included in the laminated sheets. Laminates are of two kinds: namely, high-pressure laminates and continuous-pressed laminates [8]. The base and decor papers are based on alpha-cellulose, with the grammage between 50 and 200 g·m^{-2} used to produce the decorative foils for their impregnation or pre-impregnation. These are special papers with an unusual structure to achieve the desired properties. Decorative foils are exposed to high temperatures (up to 200 °C) and pressures (up to 10 MPa) during their application to wood-based boards [1,2]. In recent years, different types of thermoplastic films have been widely used for wood veneer bonding owing to their excellent easy processing, flexibility, water resistance, and secondary melting characteristics [2,8,13,14]. PVC is one of the most flexible and durable laminating materials used for the surface improvement in wood-based panels. PVC foil is a thermostatic foil that is preferred, especially in the production of panel furniture. One of the main technological disadvantages of lamination with PVC foil is that the overlays are usually very thin, and they do not have the ability to hide surface irregularities on the MDF panels. Furthermore, the surface roughness of the MDF could also negatively affect the bonding and coating quality of the PVC [15,16]. Polyethylene terephthalate (PET) film is also widely used in lamination processes due to its low cost and flexibility. The wide use of PET film is attributed to its superior properties, such as low-temperature durability, high mechanical strength, high heat resistance, high electrical insulation, and high transparency [17–19].

MDF is a versatile wood-based panel with good machinability and is proper for joinery, mouldings and furniture manufacture applications. MDF are not meant to be used in exterior applications, but these may be painted for interior use to improve lifespan and ease of cleaning. Currently, it is often used in Slovakia for the production of children's furniture, kitchen furniture, especially cabinet doors and other furniture. MDF is relatively uniform and easy to paint [6]. For PB and oriented strand boards (OSB), a film forming and fully opaque paint is generally considered most suitable. Semi-transparent stains and penetrating systems should generally be avoided for exterior panel products [9]. Coating materials can be categorised as air-drying coatings and reaction-curing coatings. According to the solvent used, they are divided into water-soluble, solvent-based, and oil- and wax-based solvent-free [20]. The most important attribute from the customer's point of view is the visual appearance. The quality of the surface finish is determined by the surface properties of the substrate in interaction with the properties of the coating film. In the case of veneered wood-based composites, the quality of surface finish is influenced by the surface morphology of the veneer and the quality of pigment or transparent coating materials. The pigmented surface finish covers the basic material and gives the product a colourful decorative aspect.

All types of surface treatment of wood-based composites must fulfil the required quality. The quality is assessed according to the properties defined in the standards for the given product and its use. The surface finishes created by lamination or coating materials are evaluated according to appearance and physical, mechanical, and chemical-resistance properties [11,21–28]. It is important to understand the interface of the surface of wood-based composites, the laminated sheet or coating film, and the various interaction forces and interaction constraints. Innovative technological approaches in this field, such as plasma treatment of the surface of wood-based composites, can increase the polar component of surface energy and in total, the surface energy and thus the surface hydrophilicity of wood-based materials [29,30] or the utilisation of various biodegradable, renewable raw materials in wood composite surface finishing [31,32].

The objective of this study was to determine the effect of selected surface treatments on raw and veneer-faced MDF on the quality properties of furniture. These characteristics were (a) mechanical properties (film hardness), (b) mechanical resistance (abrasion and resistance to impact), (c) chemical resistance (contact with cold chemical products), and (d) biological resistance to interior moulds. Via a broader research of resistance properties, we can reevaluate the suitability of the designated surface treatment of individual furniture parts from the point of view of the user's needs.

2. Materials and Methods

2.1. Wooden Composites

Commercial MDF panels with a thickness of 18 ± 0.2 mm and density of 770 ± 5 kg·m^{-3} (bought in Kronospan s.r.o., Zvolen, Slovakia) were used in this experiment:

I. Raw MDF;
II. Veneer-faced MDF—an MDF panel that consists of beech veneer with a thickness of 0.5 mm, which is joined to the MDF using urea–melamine–formaldehyde glue (LEP-PONAL FU 400 (Henkel CR, spol. s.r.o., Praha, Czech Republic). The spread rate was 150 g·m^{-2}.

2.2. Coatings and Process of Coating of Wooden Composites

Coated MDF boards were prepared with different coatings or coating systems as follows:

- Transparent waterborne polyurethane–acrylate (Aqua-Step Professional 30153 from ADLER-Werk Lackfabrik Johann Berghofer GmbH & Co. KG, Schwarz, Austria)—coating with a UV filter. A solution of aliphatic polyisocyanate is employed as a hardener. Three levels of application were used. The spread rate was 100 mL·m^{-2} per layer by spraying;
- Transparent solvent-borne polyurethane (PUR-Strong 26303 from ADLER-Werk Lackfabrik Johann Berghofer GmbH & Co. KG, Schwarz, Austria)—a two-component polyurethane coating that combines unique UV filters. Three levels of application were used. The spread rate was 150 mL·m^{-2} per layer by spraying;
- Transparent natural wax with oil (Naturnah Hartwachs 96050 from ADLER-Werk Lackfabrik Johann Berghofer GmbH & Co. KG, Schwarz, Austria)—hard wax made from natural oils and wax and free of solvents. Linseed oil, beeswax, carnauba wax, and cobalt–zircon siccative are all included in it. Three levels of application were used. The spread rate was 60 mL·m^{-2} per layer by hot spraying;
- Pigmented (white) coating systems with polyester (Polybian COV from SIRCA S.p.A., Sandono di Massanzago Padova, Italy) as a base coat and polyurethane (glossy LPP2530NC/RAL—NCS or matte OPP530NI/GTA RAL—NCS from SIRCA S.p.A., Sandono di Massanzago Padova, Italy) as a top coat. On the surface of the boards, the coating was applied by spraying at a spread rate of 100 mL·m^{-2} per layer of base coat and at a spread rate of 150 mL·m^{-2} per layer of top coat. The coating was created as a three-layer system (two base coats and one top coat) or as a four-layer system (two base coats and two top coats).

Prior to the process of coating, the MDF panel was sanded with sandpaper with grain size number P120 in a wide belt sander.

2.3. Furniture Foils and the Process of Lamination of Wooden Composites

Laminated MDF boards were prepared with different furniture foils as follows:

(a) Gloss/matte PVC foil with thickness of 0.4 mm (Konrad Hornschuch AG, Weißbach, Germany)—both gloss and matte PVC films were glued to the sanded MDF board (with the sandpaper with grain size number P150) using heat-activated one-component adhesives series based on polyurethane—Jowapur® (Jowat Swiss AG, Buchrainon, Switzerland) and vacuum pressed (Wemhöner Surface Technologies GmbH & Co. KG, Herford, Deutschland) at a temperature of about 120 °C and high pressure in company Niva Expo s.r.o. division Svet dvierok (Dobrá Niva, Slovakia).
(b) High gloss PVC foil with a thickness of 0.5 mm (Renolit SE, Worms, Germany). To glue the foils to the MDF, the PUR adhesive Dorus Fd 150 Ls Plus and the hardener Dorus R 397 (3%–10%) (Henkel AG &Co. KGaA, Düsseldor, Germany) were used. It

is a two-component dispersion adhesive for 3D lamination of foiled parts. The MDF panel was sanded with sandpaper with grain size number P150 prior to laminated finishing. The pressing process lasted 80 s at a temperature of 130 °C and a pressure of 0.38 MPa. The surface finish of MDF was performed in the company Sanas a.s. (Sabinov, Slovakia);

(c) High gloss PET foil with a thickness of 0.5 mm (Renolit SE, Worms, Germany)—lamination process was the same as for the previous PVC foil (point b);

(d) High gloss lacquered (acryl) film Senosan® AM1800TopX with a thickness of 0.7 mm (Senoplast Klepsch & Co. GmbH, Piesendorf, Österreich). A commercially prepared acryl (Senosan®) foil-faced MDF board was used in the experiment (from the trading company, Démos Trade, s.r.o., Žilina, Slovakia);

(e) GFE (Ground foil) and subsequent applied pigment polyurethane-based coating system (specified in Section 2.2). A commercially prepared ground-faced MDF board was used in the experiment (from the trading company, Démos Trade, s.r.o., Žilina, Slovakia).

2.4. Determination of Thickness of Coating Film

The thickness of the coating film was measured using a non-destructive method with a thickness gauge (type PosiTector® 200 from DeFelsko Corporation, Ogdensburg, NY, USA) working on the ultrasonic principle. The thickness of the coating film was measured ten times.

2.5. Determination of Mechanical and Resistance Properties

2.5.1. Film Hardness by Pencil Test

The pencil test belongs to the group of tests that determine the scratch hardness. In this test, pencils of different degrees of hardness were passed over the painted surface to determine which pencil left a trace. The film hardness was determined by the pencil test according to the standard STN EN ISO 15184 [33]. The test started with the softest pencil (number 1 = 3B, Figure 1, Table 1).

Figure 1. The pencils of different degrees of hardness and the preparation with a weight of 300 g.

Table 1. Degrees of film hardness by the pencil test.

Pencil number	1	2	3	4	5	6	7	8	9	10	11	12	13
Pencil hardness	3B	2B	B	HB	F	H	3H	4H	5H	6H	7H	8H	9H

We gradually fixed the individual pencils (Koh-i-noor 1500, manufactured by Hardtmuth AG, České Budějovice, Czech Republic) according to order of preparation where they are pressed vertically with a weight of 300 g. We drew a wavy line of approximately

50 mm length on the surface of the sample. The film hardness was measured on 3 samples per surface finish, and 3 measurements were performed on each sample. The results of the test were evaluated visually using a stereomicroscope LEICA MZ 9.5 (Leica, Wetzlar, Germany) with a magnification of 17 according to the pencil number that scratched the surface. The results of the hardness of the foil and coating film were compared with the technical requirements for the quality of surface treatment of wooden furniture given by the standard STN 91 0102 [34]: worktops—grade 8, furniture doors—grade 6, external surfaces of cabinet bodies—grade 6, and inner surfaces of cabinet bodies—grade 5.

2.5.2. Falling-Weight Impact Resistance

The impact resistance was measured with an impact tester (Elcometer 1615, Manchester, UK) by dropping a 0.5 kg weight on the ball (diameter 12.7 mm) according to the standard STN EN ISO 6272-2 [35]. On four test specimens, the intrusion (a pinhole diameter) was measured five times (Figure 2), and the surface finish was assessed subjectively in accordance with Table 2. The impact resistance was assessed visually following each test using a stereomicroscope LEICA MZ 9.5 (Leica, Wetzlar, Germany) with a magnification of 17.

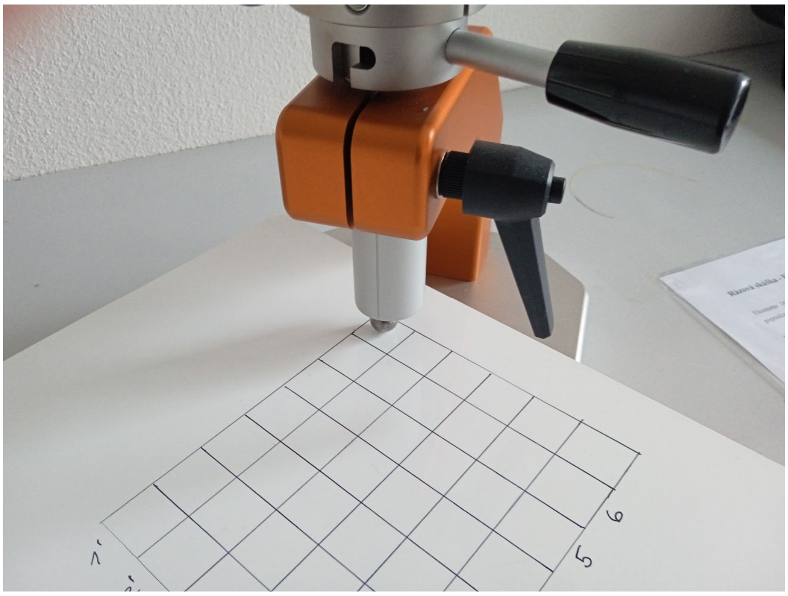

Figure 2. The impact resistance measured by falling weight impact tester.

Table 2. Degree impact resistance according to the standard STN EN ISO 6272-2 [35].

Degree	Visual Evaluation
1	No visible changes
2	No cracks on the surface, and the intrusion was only slightly visible
3	Visible light cracks on the surface, typically one to two circular cracks around the intrusion
4	Visible large cracks at the intrusion
5	Visible cracks were also off site of intrusion; peeling of the coating

2.5.3. Abrasion Resistance

The abrasion resistance was tested on a Taber Abraser model 503 (Taber Industries, North Tonawanda, New York, NY, USA). Three test samples were used to evaluate the surface finish's resistance to abrasion (Figure 3) in accordance with STN EN ISO 7784-1 [36].

The abrasion resistance is expressed as weight loss caused by the passage of the abrasive surfaces after 100 cycles of rotations using the following formula:

$$\Delta m = m_1 - m_2 \quad (1)$$

where m_1 is the initial weight of the sample (g) and m_2 is the weight of the sample after a cycle of 100 revolutions (g).

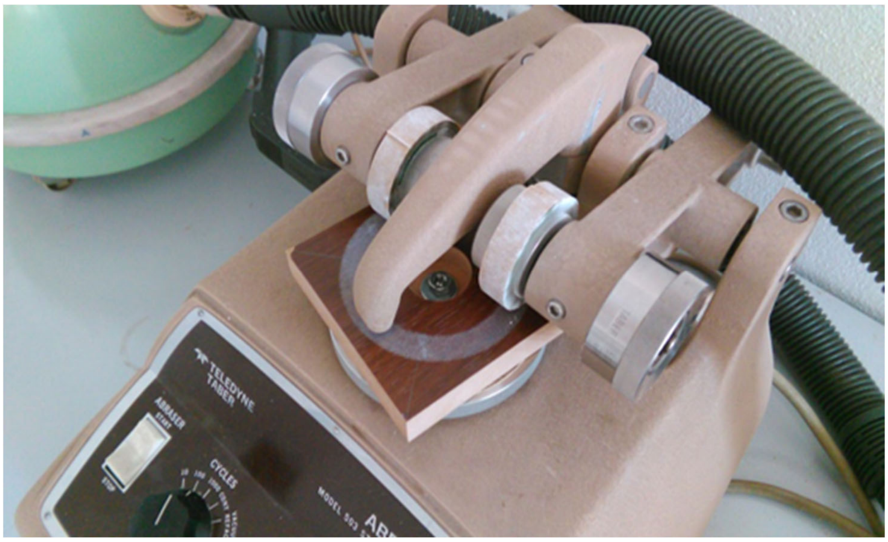

Figure 3. The evaluated resistance-to-abrasion in the Taber abrasion tester model 503.

The abrasion resistance test results were compared to the technical specifications for the quality of wood furniture surface provided by standard STN 91 0102 [34]: worktops—loss of the surface finish max. to 0.12 g/100 cycles (furniture in public areas); max. to 0.15 g/100 cycles (household furniture); and other worktops—loss of the surface finish max. to 0.15 g/after 100 cycles (furniture in public areas); max. to 0.20 g/100 cycles (household furniture).

2.5.4. Resistance to Cold Liquids

The surface resistance to cold liquids was determined according to the standard STN EN 12720+A1 [37]. Table 3 shows the used liquids, which are typical for everyday situations in the household.

Table 3. Used cold liquids selected from the standard STN EN 12720+A1 [37].

Cold Liquid	Characteristic
Acetic acid	10% (*w*/*w*) aqueous solution
Citric acid	10% (*w*/*w*) aqueous solution
Ethanol (p.a.)	96% (*v*/*v*) concentration
Coffee	Dissolved 4 g of instant coffee, medium roasted; freeze-dried in 100 mL boiling water
Wine	Black currant wine
Sanitizer	Chloramine T, 2.5% aqueous solution

After 24 h exposure of the paper immersed in individual liquids (Figure 4), all surfaces were cleaned by gently wiping with an absorbent cloth, soaked first in a cleaning solution and then in water. Finally, the surfaces were carefully dried out with a dry cloth. The appearance of the surface, i.e., discolouration, changes in gloss and colour, and other defects, were visually evaluated in the observation box with direct light and graded according to Table 4.

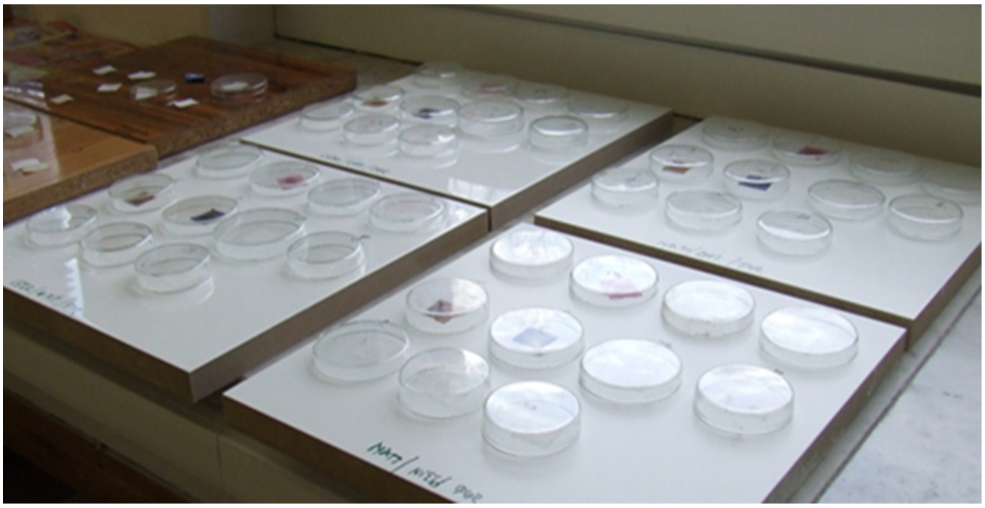

Figure 4. The papers immersed in individual liquids on the surface.

Table 4. Degree of the resistance to cold liquids according to the standard STN EN 12720+A1 [37].

Degree	Description
5	No visible changes (no damage)
4	Slight change in gloss—visible only in reflection of light source
3	Slight traces of damage (gloss)—visible from different directions
2	Strong traces of damage usually without changing the structure of varnish
1	Strong damage with change in varnish structure

2.5.5. Resistance to Moulds

According to the standard STN EN 15457 [38], the resistance of surface treatments against moulds, which are more likely to grow in the indoor environment, was determined. Washing the surface of each 2-week-old Petri plate culture with 10–15 mL of sterile demineralised water produced a mixed spore suspension of two moulds, *Aspergillus niger* Tiegh (strain BAM 122) and *Penicillium purpurogenum* Dierckx (strain BAM 24). Washings were combined in a spray bottle and diluted with demineralised water to a volume of 100 mL to yield approximately 3×10^7 spores mL^{-1}. The samples have circular cross sections with diameters of 50 mm. UV light-sterilised specimens were placed individually on the surface of Czapek Dox agar (HiMedia Laboratories Pvt. Ltd., Mumbai, India) in glass dishes. Then, they were coated by brushing with 1 mL of mixed mould spore suspension and incubated at 24 ± 2 °C and 80 ± 5% relative humidity for 21 days (Figure 5).

(**a**) (**b**)

Figure 5. The evaluated resistance-to-mould growth: (**a**) sample in glass dishes; (**b**) mould growth on surface of test sample treated with transparent natural wax with oil (scale bar = 1 mm).

Following incubation, the samples were visually rated using a scale from 0 to 4 according to Table 5 and using glass with a magnification of 10×.

Table 5. Surface resistance to mould growth: degree and evaluation according to the standard STN EN 15457 [38].

Degree	Description
0	No mycelium on the top surface of the sample
1	Growth up to 10% on the top surface of the sample
2	Growth more than 10% up to 30% on the top surface of the sample
3	Growth more than 30% up to 50% on the top surface of the sample
4	More than 50% on the top surface of the sample

2.5.6. Statistical Evaluation

MS Excel was used to analyse the gathered data. Descriptive statistics deal with the basic statistical characteristics of the studied properties, namely the arithmetic mean and standard deviation.

3. Results

3.1. Film Hardness by Pencil Test

Table 6 shows the measured values of film hardness to pencil (scratch hardness). The results show that only the laminated surface with foil under test met the requirements for worktop hardness for public furniture and household furniture [34].

Gloss surface finishes only met the requirements for the inner surfaces of furniture. It can be seen that the gloss surface was less scratch-resistant than the matte one by contrasting them. Pencil number 5 caused the scratch that was obvious to the unaided eye on the gloss surface finishes. Pencil number 7 created noticeable scratches on the matte surface finishes. The film-forming element, in this case, polyurethane, mostly determines the film's hardness. The same base coating material and a white gloss or matte polyurethane top coat were used to create the surfaces with a gloss or matte finish. Additives (matte ingredients) added directly to the coating material during manufacture give the surface finish its matte appearance. The coating's film hardness, as well as gloss, were both impacted by the additions. It was proved by [36–41] that the shine enhances the product's quality. Contrary to the study in [22], adding a second top coat layer did not increase a coating's resistance.

3.2. Impact Resistance

The findings of the impact resistance of all surface treatments, including the diameters of surface intrusions and the degrees of damage, are shown in Table 6. All transparent coatings suffered damage of at least grade 2 at the highest drop height of 400 mm. There were no surface cracks, and the incursions were barely noticeable. The size of the incursions varied depending on the type of coating used; they were smaller when the surface finish was transparent wax and were roughly the same when the surface finish was water-borne or solvent-borne. We may conclude that representative surface finishes obtained a good impact resistance [35,42,43]. Results of silicate-based formulations' surface finishes on beech wood are shown in study [44]. Incomparably larger intrusion diameters (up to 7.1 mm) than the diameters of intrusions on the surface finishes reported in this work were seen on silicate-based surface finishes where surface degradation could reach grade 3. With increasing coating thickness, impact resistance increases to some extent [22,43]. The hardness of the substrate, as well as the brittleness and elasticity of the film, affect a surface finish's ability to withstand impacts [35,45].

Table 6. Film hardness, impact and abrasion resistance of tested surface treatments of MDF board.

Surface Treatment	Thickness (m)	Film Hardness *	Impact Resistance ** (Using the Different Drop Height (mm))				Abrasion Resistance *** Δm (g)
			50	100	200	400	
I. MDF + coating							
(a) Transparent waterborne polyurethane-acrylate	87.6 (2.8)	3H (7)	0.0 (1)	1.0 (1)	1.3 (2)	3.6 (2)	0.061 (0.006)
(b) Transparent solvent-borne polyurethane	93.8 (3.9)	3H (7)	0.0 (1)	0.6 (1)	2.0 (2)	3.7 (2)	0.095 (0.007)
(c) Transparent, wax	77.3 (3.8)	3H (7)	0.0 (1)	0.9 (1)	2.2 (2)	2.8 (2)	0.052 (0.009)
II. MDF + coating system with polyester (base coat) and polyurethane (top coat)							
(a) Pigment, gloss, 3 layers	113.8 (3.9)	F (5)	2.0 (2)	3.2 (2)	4.0 (3)	5.0 (3)	0.038 (0.006)
(b) Pigment, gloss, 4 layers	133.8 (3.9)	F (5)	2.0 (2)	3.2 (2)	5.0 (3)	5.0 (3)	0.039 (0.009)
(c) Pigment, matte, 3 layers	117.3 (3.2)	3H (7)	2.0 (2)	3.3 (2)	4.0 (3)	5.0 (3)	0.050 (0.009)
(d) Pigment, matte, 4 layers	123.8 (2.9)	3H (7)	2.1 (2)	3.3 (2)	5.1 (3)	5.1 (3)	0.047 (0.008)
III. Veneered MDF + coating system with polyester (base coat) and polyurethane (top coat)							
(a) Pigment, gloss, 3 layers	113.1 (3.1)	F (5)	3.0 (4)	4.3 (4)	5.0 (4)	6.0 (4)	0.039 (0.007)
(b) Pigment, gloss, 4 layers	123.8 (1.9)	F (5)	3.1 (4)	4.4 (4)	4.1 (4)	4.2 (4)	0.041 (0.009)
(c) Pigment, matte, 3 layers	111.7 (2.2)	3H (7)	3.0 (3)	4.2 (3)	5.0 (3)	5.0 (3)	0.049 (0.007)
(d) Pigment, matte, 4 layers	133.8 (2.1)	3H (7)	3.0 (3)	4.4 (3)	4.9 (3)	4.9 (5)	0.048 (0.009)
IV. MDF + Foil							
(a) PVC foil, gloss	400	5H (9)	2.0 (2)	2.1 (2)	2.1 (2)	2.2 (2)	0.001 (0.001)
(b) PVC foil, matte	400	>9H (>13)	1.0 (1)	1.4 (1)	2.1 (2)	2.2 (2)	0.034 (0.002)
(c) high gloss PVC foil	500	4H (8)	3.0 (2)	4.1 (3)	4.4 (3)	5.2 (3)	0.077 (0.003)
(d) high gloss PET foil	500	4H (8)	1.9 (2)	3.1 (2)	3.3 (3)	4.1 (3)	0.006 (0.002)
(e) high gloss lacquered (acryl) film	700	9H (13)	2.0 (2)	2.0 (2)	2.1 (2)	2.1 (2)	0.015 (0.002)
(f) GFE + pigment polyurethane	95.8	5H (9)	2.0 (2)	2.4 (2)	3.1 (3)	4.2 (4)	0.077 (0.002)

* film hardness = pencil hardness (the pencil number is in parenthesis); ** impact resistance = diameter of the pinhole incrustation in mm (the impact resistance degree is in parenthesis); *** abrasion resistance = average (standard deviation is in parenthesis).

As can be seen by the diameter of incursion at a drop height of 400 mm, the gloss pigment surface finish with four layers achieved superior impact resistance at the highest drop height than the three layers (see Table 6 for a comparison between 4.2 mm and 6.0 mm). Grade 4 surface damage—visible large cracks at the intrusion—was the most severe. In the case of matte pigment, grade 5 damage was achieved on the four-layer surface finish, and grade 3 surface damage was achieved on the three-layer finish (Figure 6). The impact resistance of the coating rises to some extent as the coating thickness increases [22,43]. This claim was confirmed for the gloss surface finish but not for the matte one.

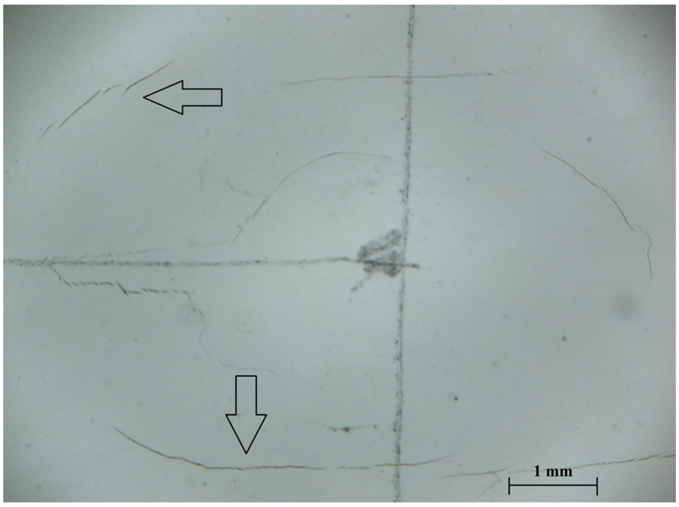

Figure 6. Cracking visible on the surfaces with pigmented surface finish (pigment, matte, 4 layers) after impact resistance testing at the drop height of 400 mm (visible at magnification 17×).

3.3. Abrasion Resistance

When assessing the resistance against scuffing, the weight loss from the surface finish after abrasion and the mass loss Δm were determined (Table 6). Transparent surface coatings exhibited greater abrasion resistance than pigmented polyester–polyurethane surface finishes. We can additionally deduce from the results that the gloss surface treatments proved more scuff-resistant than the matte surface finishes. For both gloss and matte surface finishes, there is little difference in the four-layer coating's resistance to scratching compared to the three-layer coating. Due to the chemicals that give surfaces a matte look, matte surface finishes are less resistant to scratching. The majority of the additives are insoluble powders that are spread throughout the coating substance. The powder can make the surface harder, but it can also make the coating film's polymer bonds weaker [46], which lowers the coating's resistance to scratching. Compared to UV water-soluble polyurethane coatings, which were handled by [47], matte and gloss white polyurethane finishes had less resilience to scratching. Surface system performance is greatly influenced by coating formulations [48] and can be enhanced by the use of additives [49]. None of the four surface treatments (coatings) meet the requirements of resistance against scuffing for worktops and other worktops when compared to the technical requirements by the standard STN 91 0102 [34]. The PVC foil–gloss and high gloss lacquered (acryl) film meet the requirements of resistance against scuffing for worktops and other worktops when compared to the technical requirements of the standard STN 91 0102 [34].

The best resistance against scuffing was reached by the PVC glossy foil. Figure 7 shows that the surface damage after abrasion was visible on all the tested surface finishes. From the viewpoint of the weight loss, the PVC Gloss achieved Δm = 0.001, but from the visual evaluation, the surface was damaged equally to the other surface finishes.

(**a**) (**b**)

Figure 7. The surface finish after abrasion: (**a**) PVC foil, gloss; (**b**) PVC foil, matte.

3.4. Resistance to Cold Liquids

Table 7 shows the results of evaluating the resistance of laminated surfaces and coatings to cold liquids. All liquids left a mark. In the case of sanitising, a significant discolouration occurred on the transparent wax surface (grade 1). Coffee and ethanol showed slight damage to the coating surfaces, which was more intense than on the laminated surfaces. All laminated surfaces proved to be totally resistant to these liquids (grade 5). This proves that, in our case, the resistance to selected liquids was only dependent on the type of finish used. Comparable results were presented in other studies [11,30,35,36,45].

3.5. Resistance to Interior Moulds

The resistance to mould growth of the fungi *Aspergillus niger* and *Penicillium purpurogenum* on the top surfaces' tested surface treatment is summarised in Table 7. The surfaces of the MDF were resistant to moulds if their surfaces were treated with lamination foils, pigment coating system with polyester (base coat) and polyurethane (top coat) and transparent solvent-borne polyurethane; their degree of resistance to moulds was "0" during the laboratory test. From the first seven days of the test, it was clear that mould was growing on the surfaces coated with transparent aqueous polyurethane–acrylate and wax. In contrast, 30% or more of their area was covered in mould hyphae with sporangium (degrees ranging from 3 to 4) on the final 21 days following inoculation. However, there was a lower distribution of mould fungus on all surfaces. On the other hand, surfaces of all raw PB, MDF and OSB without a lamination treatment can be susceptible to the growth of the applied moulds (the degree of the resistance to interior moulds was 3–4) [50]. Mould growth was greater on surfaces covered with wax, oil, or polyurethane with an acrylate-based coating than it was on surfaces coated in polyurethane. They may, however, achieve improved microbial durability when combined with antimicrobial treatments [51–53].

Table 7. Resistance to cold liquids and interior moulds of tested surface treatments of MDF board.

Surface Treatment	Resistance to Cold Liquids						Resistance to Interior Moulds		
	Acetic Acid	Citric Acid	Ethanol	Coffee	Wine	Sanitizer	7th Day	14th Day	21st Day
I. MDF + coating									
(a) Transparent waterborne polyurethane-acrylate	5	5	4	5	5	4	1–2	2	3
(b) Transparent solvent-borne polyurethane	5	5	4	5	5	4	0	0	0
(c) Transparent, wax	5	4	4	3	3	1	3	4	4
II. MDF + coating system with polyester (base coat) and polyurethane (top coat)									
(a) Pigment, gloss, 3 layers	5	5	5	3	5	5	0	0	0
(b) Pigment, gloss, 4 layers	5	5	5	3	5	5	0	0	0
(c) Pigment, matte, 3 layers	3	5	3	3	4	4	0	0	0
(d) Pigment, matte, 4 layers	3	5	3	3	4	4	0	0	0
III. Veneered MDF + coating system with polyester (base coat) and polyurethane (top coat)									
(a) Pigment, gloss, 3 layers	5	5	5	3	5	5	0	0	0
(b) Pigment, gloss, 4 layers	5	5	5	3	5	5	0	0	0
(c) Pigment, matte, 3 layers	3	5	3	3	4	4	0	0	0
(d) Pigment, matte, 4 layers	3	5	3	3	4	4	0	0	0
IV. MDF + Foil									
(a) PVC foil, gloss	5	5	4	5	5	5	0	0	0
(b) PVC foil, matte	5	5	5	5	5	5	0	0	0
(c) high gloss PVC foil	5	5	4	5	4	4	0	0	0
(d) high gloss PET foil	5	5	4	5	5	5	0	0	0
(e) high gloss lacquered (acryl) film	5	5	5	5	5	5	0	0	0
(f) GFE + pigment polyurethane	5	5	5	5	5	5	0	0	0

4. Conclusions

Selected transparent, pigmented polyurethane email finish, thin foils, lacquered acryl film, and coated ground foil, commonly used in furniture, were used for surface treatment of raw or veneer-faced MDF.

According to our research, we can recommend varnished lacquered acryl film with a high gloss and matt PVC foil for highly mechanically stressed vertical front surfaces of furniture. Transparent surface treatments on veneered MDF have standard resistance to mechanical stress and are comparable to thin foils on MDF. Transparent waterborne polyurethane-acrylate and transparent wax are less resistant to cold liquids and interior moulds, so they are not suitable for kitchen and dining room furniture. Pigmented surface treatments on a veneered MDF board are more susceptible to cracking when struck than on raw MDF, so it is more suitable, for example, to use raw MDF with pigmented surface treatment for children's furniture. For children, matte finishes are more suitable, and this also results from the resistance against mechanical stress compared to gloss finishes.

Interactions between the coated film or thin foil and the substrate had a significant impact on both hardness and impact resistance. The choice of surface finish has a significant impact on the resistance characteristics of coating and foil, including resistance to mould and cold liquids.

The usefulness, adaptability, and decorative value of raw veneer-faced MDF boards are increased along with their protective and functional value via various surface treatment techniques.

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