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THE WATER VAPOUR PERMEABILITY OF THE COATED MEDIUM DENSITY FIBERBOARD

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ABSTRACT

The use of foil-faced medium-density fibreboard (MDF) in wood surface finishing enables a reduction in surface finishing time and an enhancement of specific properties of coated surfaces. The objective of this study was to evaluate the differences in water vapour permeability between foil-faced MDF and standard MDF panels (without foil), coated with polyurethane (PU) coating. Both types of coated MDF were exposed to water vapour for a period of 14 days, during which period differences in water vapour absorption and subsequent desorption (for the next 14 days) were examined. The results show that facing the wider face of MDF panels with foil reduced the water vapour absorption of the coated samples. Considering the results of water vapour permeability results, the use of MDF double-faced with ground foil prior to finishing shows the advantages for the use of furniture components in indoor environments with elevated moisture levels.

Keywords: medium-density fibreboard, polyurethane coating, foil-faced, water vapour permeability.

1. INTRODUCTION

Medium-density fibreboard (MDF) is the second most used wood-based composite in overall furniture production and interior decoration (Akbulut and Ayrilmis 2019). For applications in kitchen and bathroom furniture, especially in doors, MDF represents the primary material engaged today (Kúdela 2020). MDF is considered more isotropic when compared to particleboard, which has lower density and lower production costs (Akbulut and Ayrilmis 2019). Its compact, voidless structure also provides better surface quality (Lee et al. 2019), which is one of the key parameters for the surface finishing effect. In comparison to natural wood, MDF exhibits higher strength due to its higher density (Sedleckỳ and Gašparík 2017).

Despite these benefits, MDF is highly sensitive to moisture. Swelling of MDF happens due to water absorption from both liquid water and water vapour (Kibleur et al. 2022). Prolonged exposure to water causes significant swelling and, in severe cases, material degradation. The irreversible swelling affects the aesthetics and mechanical properties of MDF, resulting in a reduced service life under moist conditions (Kibleur et al. 2022). Although water-resistant MDF is available on the market, besides being more expensive, this type of MDF can show signs of dimensional and structural changes under long-term moisture exposure.

Exposure to water vapour of furniture and other products made of MDF in kitchens and bathrooms can weaken joints, alter dimensions, and lead to material failure. The swelling of MDF is most pronounced at narrow, uncoated edges, such as the bottom of panels or doorframes, where water can most easily penetrate to the material.

MDF can be prefinished (primed) with double-faced foils on the wide surfaces, which prevents the excessive coating absorption that leads to uneven and visually unwanted results. Using MDF with a coating carrier (ground) foil that offers a consistent foundation for the spreading and levelling of the subsequent coating layer results in an even and smooth finish. The total time and expense of surface finishing can sometimes be decreased by reducing the number of coating layers needed to achieve through-coloured opacity. The slightly textured surface of the ground foils can promote film coating adhesion that is particularly important, knowing that standard MDF exhibits low surface free energy, which can negatively affect the adhesion of applied film-forming materials (Kúdela 2020).

Since ground foil serves as a physical barrier to coating penetration, the aim of this study was to investigate whether the water vapour adsorption could be reduced by using prefinished MDF as a substrate. This paper investigates the resistance of ground foil-faced (so-called prefinished MDF) and uncoated MDF (so-called raw MDF) to water vapour.

2. MATERIAL AND METHODS SECTION

Two groups of samples were used: "Group A" – raw MDF samples (manufacturer Kastamonu) and "Group B" – prefinished double-sided MDF samples with ground foil (manufacturer DDL). The dimensions of the samples were 150x70x18 mm. Within each group, 20 samples were tested: 10 control (C) and 10 that were surface finished (F), making the total number of samples 40. All samples were dimensioned on a CNC panel saw-cutting machine (manufacturer SCM, model Sigma Prima 50). To guarantee that the coating material remained on the edges, all samples had their edges rounded using a router with a 3 mm radius. Sanding of the samples before coating was performed manually with a disc sander (manufacturer Festool). Sanding was performed in two stages using P120 and P180 grit sanding paper.

All of the samples (except the control ones) were surface finished using the following coating system: 1. layer polyurethane (PU) sealer (Milesi LBR21811: Milesi LNB42=2:1), 2. layer white pigmented PU base coating (Milesi LBR102: Milesi LNB42=2:1 + 30% Milesi LZC70) and 3. layer white pigmented PU topcoat (Milesi RAL 9016: Milesi LNB623=2:1 + 30% Milesi LZC70). All of the used coating materials are based on organic solvents. PU sealer was applied to the entire surface (both the wide and narrow sides) of the raw samples without foil (Group A), while for the prefinished samples (Group B) it was applied only to the narrow sides (Figure 1). The following layers of base and top PU coating were applied to the entire surface of both groups of samples.

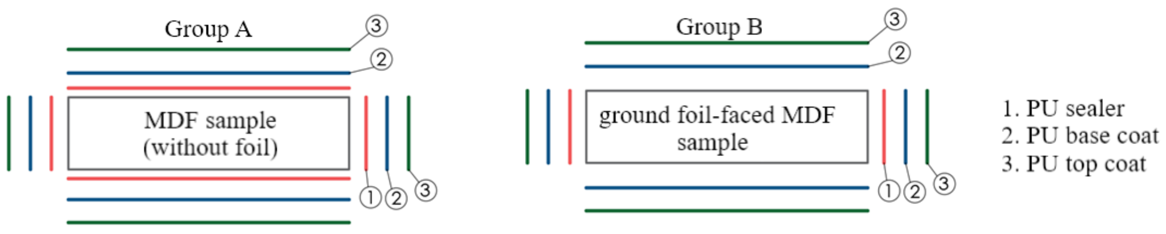

Figure 1. *Layers of coating system applied on wide and narrow sides of: a) raw MDF samples (Group A) and b) ground foil-faced MDF samples (Group B).*

A brush was used to physically apply the sealer, then P240 grit sandpaper was used to manually sand it after it had dried. The base coat and topcoat were applied by air spraying in a pressurised spraying booth, using the following parameters of the spraying gun: nozzle diameter 0.6 mm and air pressure 3 bar. The coatings were applied to the wider sides (front and back) in one layer and in two layers to the narrower sides.

In compliance with SRPS EN ISO 2808:2019, an ultrasonic film thickness gauge (made by DeFelsko, model PosiTector 200) was used to measure the dry film thickness of the coating system.

Every sample's surface that had been coated was measured for dry film thickness at three different points. On the wide side of the coated surface, measurement sites were chosen at random. Each group received thirty measurements in total.

The coated samples were manually sanded with P320 grit sandpaper after the base coating had dried in the open. The samples were preconditioned and then subjected to water vapour permeability tests after being dried in the open for 24 hours after the top coating was applied (according to EN 927-4:2001). Preconditioning of the samples consisted of several phases: immersing of the samples in water for 24 hours; drying of the samples under ambient conditions for 3 hours; drying of the samples at a temperature of 50°C for 3 hours; and drying of the samples under ambient conditions for 18 hours (Figure 2).

a) *b)*

Figure 2. *Preconditioning of the samples: a) immersing of the samples in water for 24 hours and b) drying of the samples at a temperature of 50°C for 3 hours.*

The testing of the samples was done by placing the samples above water for 14 days, using plastic containers filled with water with a grid frame on top (Figure 3). The samples were then allowed to dry at room temperature for 14 days. The mass of the samples is measured immediately after preconditioning, after exposure to water vapour, and 14 days after the ending of water vapour exposure. The mass of samples was measured using an analytical balance (manufacturer CAS, model Kern EW), accuracy 0.01 g. The water vapour permeability of the samples was expressed by mass gain (after 14 days and after 28 days).

a) *b)*

Figure 3. *Testing the water vapour permeability: a) containers filled with water with a grid frame on top and b) samples placed face down to the water by the wide side*

3. RESULTS

Table 1 shows the dry film thickness of the coating system of MDF samples with and without ground foil.

Table 1. *Dry film thickness of coated samples.*

	Group AF	Group BF
Dry film thickness of system of coatings [μm]	202	153

*Group AF – surface finished raw MDF; Group BF – surface finished ground foil-faced MDF

The difference in dry film thickness between coated MDF samples with and without ground foil is attributed to the imprecision of the measurement method and inclusion of the ground foil thickness in the results of the coating system thickness. The differences in dry film thickness between these two groups were not statistically significant ($t(58) = 2.00$, $p > 0.05$).

The percentage of mass gain during the water vapour absorption and desorption cycle (after 14 and after 28 days of the experiment) is given in Table 2.

Table 2. *ass gain of samples during water vapour absorption from the 1st to the 14th day and during water vapour desorption from the 14th to the 28th day.*

Mass gain of samples [%]	**During water vapour absorption**				**During water vapour desorption**			
Group of samples	AC	BC	AF	BF	AC	BC	AF	BF
Average value	**10,38**	**7,97**	**0,99**	**0,71**	**6.40**	**4,65**	**0,15**	**-0,06**
Standard deviation	0,06	0,09	0,42	0,24	0,19	0,29	0,03	0,02

* Group AC – control (unfinished) raw MDF; Group BC – control (unfinished) ground foil-faced MDF; Group AF – surface finished raw MDF; Group BF – surface finished ground foil-faced MDF

From Table 2 it can be seen that surface-finished samples faced with ground foil (group BF) absorbed less water compared to the samples without foil (group AF) in the period from the 1st to the 14th day of the experiment. This result confirms that foils on MDF surfaces reduce penetration of the liquid and vapour materials into the core of the boards. These findings are in line with the implication from previous research that the high-density surface layers should be stabilised to achieve dimensional stability of the MDF panels (Candan et al. 2012). The research results of MDF resistance to different cold liquids (Slabejová, Vidholdová, and Iždinský 2023), in which coated samples faced with ground foil had better grade results in comparison to the samples without foil coated with different coating systems, confirm the role of ground foil as a barrier to the penetration of liquids and vapours. Even though the difference in mass gain during the absorption cycle between groups AF and BF was not statistically significant ($t(18) = 0.873$, $p > 0.05$), the use of ground-foil-faced MDF as a substrate can reduce the moisture uptake of the coated panel. A similar trend applies to the control samples that were not surface finished (groups AC and BC). The difference between these two groups was statistically not negligible ($t(18) = 0.907$, $p > 0.05$).

Regarding the water vapour desorption cycle from day 14 to day 28 of the experiment, the mass of all of the samples decreased, as expected. According to earlier studies, MDF panel thickness swelling was greater than thickness shrinking at all densities (Ganev et al. 2005). While all samples experienced water vapour desorption, the mass of the uncoated samples (groups AC and BC) was higher than the initial mass, indicating that water vapour was not completely lost from the samples and that the uncoated samples should not be used when panels are expected to be exposed to high humidity during use. However, the slightly lower water vapour release during the desorption cycle of uncoated samples with ground foil was statistically significant ($t(18) = 3.272$, $p < 0.05$). The samples double-faced with ground foil before coating had even shown a slight decrease in the mass of the samples (group BF) compared to their mass at the end of absorption time, indicating the higher rate of water vapour release, which can be important for the use of the product in real conditions. The use of ground foil significantly enhanced water vapour desorption of surface-finished samples ($t (18) = 18.173$, $p < 0.05$).

Table 3 summarises the total mass gain of all groups of samples after 28 days of experiment. In comparison of the initial mass of the samples (1st day of experiment), all of the samples had shown an increase in their mass at the end of the experiment.

Table 3. *Mass change of samples after 28 days (absorption cycle: from 1st to 14th day; desorption cycle: 14th to 28th day).*

	Mass gain of samples [%]			
Group of samples	AC	BC	AF	BF
Average value	3,98	3,32	0,84	0,77
Standard deviation	0,10	0,19	0,07	0,06

* Group AC – control (unfinished) raw MDF; Group BC – control (unfinished) ground foil-faced MDF; Group AF – surface finished raw MDF; Group BF – surface finished ground foil-faced MDF

The mass gain (g) of uncoated MDF (groups AC and BC) was 4.97 to 4.25 times higher in comparison to coated samples (groups AF and BF, respectively). The overall mass gain of double-faced ground foil samples was lower in comparison to the raw sample, with and without surface finishing. This result indicates that raw MDF "breathes" more easily compared to MDF with melamine foil. The facing of wide sides of samples with ground foil reduces the water vapour permeability of MDF. The difference in mass change between samples with and without ground foil, at the end of the desorption cycle, was statistically significant for uncoated and coated samples ($t (18) = 2.561$, $p<0.05$ and $t (18) = 6.866$, $p<0.05$, respectively).

Based upon results of water vapour permeability, it makes sense to use MDF double-faced with ground foil prior to finishing for furniture parts in indoor environments with increased moisture.

Along with quantitative differences in resistance to water vapour permeability between surface-finished MDF samples with and without ground foil, qualitative distinctions between these two groups of samples were noticed. The raw samples (without coating) showed a considerable increase in thickness; however, the samples faced with ground foil showed film coating cracks after the thickness shift (Figure 4). These cracks appeared on the thin sides and were visible to the naked eye. This type of defect of a coated surface is not allowed in final products since it can affect the strength and durability of the product (if cracks occur near the joining elements). In addition, cracks significantly reduce the visual impression and surface quality of the final product. The formation of the cracks can be related to the higher mass loss rate of coated samples with ground foil during the desorption cycle in comparison to coated samples without foil. The faster release of water vapour through the narrow edges could cause stress and cracking in the coating film.

Figure 4. *Cracks on narrow edges of coated MDF samples double-faced with ground foil.*

4. CONCLUSIONS

From the results of this study, the following can be concluded:

- Surface finishing of MDF with coatings reduces water absorption.
- The ground foil has a significant effect on water absorption, leading to reduced water vapour uptake in MDF.
- Higher water vapour desorption resistance is demonstrated by MDF double-faced with ground foil; this is especially noticeable when the surface is coated.
- The use of surface-finished MDF faced with ground foil is more suitable in environments with elevated air humidity, although there is a risk of check formation on the narrow edges.

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