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The effect of mechanical treatment of beech wood surface on quality of surface finish

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Abstract: *The effect of mechanical treatment of beech wood surface on quality of surface finish.* The paper deals with the quality of three surface finishes intended into interior. Three types of coating materials were tested (polyurethane, waterborne, wax). Each type of the surface finish was created on beech wood surface in three various coating thicknesses. The coating thicknesses differed in number of coatings of the coating material. The surface finishes were evaluated according to the impact resistance and the resistance to abrasion. The polyurethane surface finish showed the lowest resistance to abrasion. If the film thickness was increasing, the resistance to abrasion was decreasing. The greatest differences in the resistance to abrasion, depending on the wood surface treatment, were found on the wax surface finish. In general, the waterborne surface finish showed the best resistance to abrasion. Pressing the wood surface before finishing increased the impact resistance of all three surface finishes. The damage of the surfaces was only of grade 2 (No cracks on the surface and the intrusion was only slightly visible). The lowest impact resistance of the surface finishes was found on grinded wood surface; the damage was graded as 4 (Visible large cracks at the intrusion). At the drop height of 400 mm, the effect of the film thickness on the impact resistance was no longer present on all differently mechanically treated surfaces.

Keywords: beech veneer; coating material; coating thickness; impact resistance; resistance to abrasion

INTRODUCTION

Wood is a material often used to produce interior products. Especially beech wood is significant in production of furniture, flooring, and staircases. The wood texture is unmistakable and unique. Nowadays, there is a trend to finish the wood surface with transparent surface finishes and so to keep the wood colour and texture. The surface finishes not only have an aesthetic function but also a protective function. Surface finish quality is assessed according to physical, mechanical, and resistance properties (Jaic and Zivanovic, 1997, Tesařová et al. 2010, Scrinzi, et al. 2011, Bekhta et al. 2014, Salca et al. 2017, Yong et al. 2017). The main properties assessed at flooring, staircases, and highly stressed furniture surfaces are: the resistance to abrasion and the impact resistance. The mechanical treatment of wood surface before finishing and the coating film thickness have an effect on physical and mechanical properties of the surface finish.

The coatings can be modified by technological parameters or with added nano-technological products (Lee et al. 2003, Kaygin and Akgun, 2009, Tesařová et al. 2010, Kumar et al. 2015, Weththimuni et al. 2016, Cataldi et al. 2017, Miklečić et al. 2017, Salca et al. 2017, Yong et al. 2017).

The aim of this work was to monitor the effect of mechanical treatment of wood surface done before finishing on mechanical properties of the surface finish: the resistance to abrasion and the impact resistance.

MATERIALS AND METHODS

In the experiment, beech test specimens (*Fagus sylvatica L.*) were used. The dimensions of test specimens were 100 mm ×100 mm × 3 mm, moisture content of 8 % ± 2 %, and the average density at zero moisture content ρ_0 = 676 kg/m^3.

The surface of the test specimens was mechanically treated as follows:

1. Cut surface – using a band saw.
2. Grinded surface – using a belt sander. The surface was sanded gradually with sand papers with a grain size of P60, P80, P100, and P120.
3. Pressed surface – using a press with two heated pressing plates. The surface was pressed at the pressure of 1 MPa, temperature of 120 °C, and time 5 minutes.

The test specimens were finished on one side. Three different surface finishes were created: surface finish based on polyurethane, waterborne surface finish, and wax based surface finish. The following representative coating materials were selected:

- PUR-Strong 26303 (PUR) – transparent polyurethane varnish,
- Aqua-Step Professional 30153 (AQUA) – waterborne varnish on a polyurethane-acrylic-copolymer dispersion basis,
- Naturnah Hartwachs 96050 (WAX) – hard wax on the basis of natural oils and wax, solvent free.

The coating materials were spread pneumatically on tangential-radial surfaces of the test specimens. Three various coating film thicknesses were created for each surface finish (Table 1).

Table 1. Paint coating materials used for surface finishing.

Label	**Coating Material**	**Thickness Mark**	**Thickness of Cured Film**	
			Number of Coats	**Average Thickness [µm]**
PUR	PUR-Strong 26303	H1	1	50
		H2	2	100
		H3	3	150
AQUA	Aqua-Step Professional 30153	H1	1	40
		H2	2	70
		H3	3	100
WAX	Naturnah Hartwachs 96050	H1	1	60
		H2	2	80
		H3	3	100

The resistance to abrasion of surface finish was determined according to the standard STN EN ISO 7784-3 (2016). The coefficient of the resistance to abrasion K_T was calculated according to the formula:

$$K_T = (m_1 - m_2)/F \tag{1}$$

Where: m_1 – specimen weight before sanding (g),
m_2 – specimen weight after sanding (g),
F – correction coefficient of the used pair of abrasive papers (F = 1,36).

Technical requirements according to the STN 91 0102:

- Surface finish resistance to abrasion (K_T)
  - Worktops – loss of the surface finish max. to 0.12 g/100 rev. (furniture in public areas), max. to 0.15 g/100 rev. (household furniture)
  - Other worktops – loss of the surface finish max. to 0.15 g/100 rev. (furniture in public areas), max. to 0.20 g/100 rev. (household furniture)
  - Other surfaces are not evaluated.

The impact resistance of the surface finishes was determined according to the standard STN EN ISO 6272-2 (2011). The intrusion (diameter of the intrusion) was measured and the surface finish was evaluated subjectively according to Table 2.

Table 2. Impact resistance: degree and evaluation.

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

RESULTS AND DISCUSSION

Resistance to abrasion:

Comparison of all tested surface finishes is shown in Fig. 1. The lowest resistance to abrasion was found for the polyurethane surface finish with the thickest coating film (PUR-H3) on grinded wood surface (K_T = 0.114). The best resistance to abrasion was found for wax surface finish with the thinnest coating film (WAX-H1) on pressed surface (K_T = 0.04). The biggest differences in the resistance to abrasion on differently mechanically treated wood surfaces were observed on the wax surface finish (K_T from 0.04 to 0.084). In Fig. 1, one can see that the best level of resistance to abrasion, in terms of different surface treatment and different film thickness, was found on the surface finish created by waterborne coating material (AQUA).

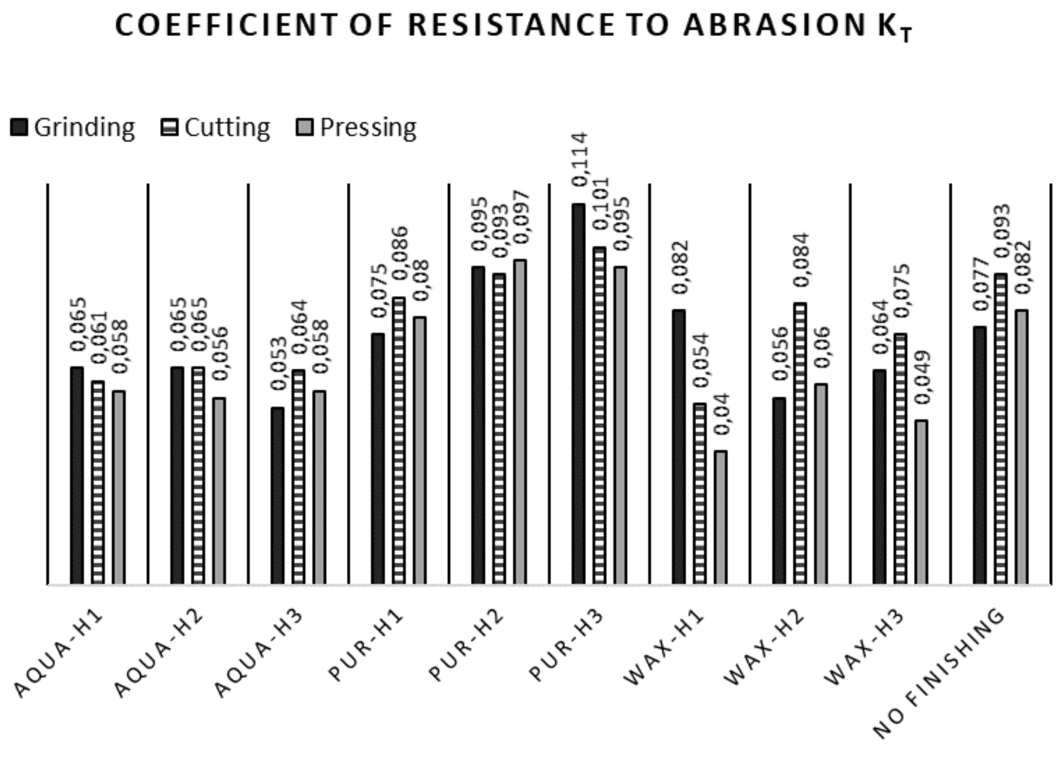

Figure. 1. The coefficient of the resistance to abrasion K_T – of all the tested surface finishes for three various film thickness (H1, H2, H3) and three ways of mechanical treatment of wood surface (grinding, cutting, pressing).

From the comparison of results with technical requirements, it is obvious that all of the three surface finishes met the technical requirements for both furniture in public areas and household furniture.

If evaluating the results according to the weight loss, the surface finishes met the technical requirements, but according to visual examination there were visible damages of the surface finishes (Fig. 2). The same was described by Slabejová and Šmidriaková (2018b).

CUT GRINDED PRESSED

Figure 2. The traces after abrasion resistance test visible on the thickest coating film of WAX surface finish on cut, grinded, and pressed wood surfaces.

Impact resistance:

Figures 3 through 5 show the impact resistance of all the tested surface finishes on differently mechanically treated wood surface for three film thicknesses at four various drop heights. In Fig. 3, the impact resistance of surface finishes on cut surfaces is presented graphically. At the highest drop height of 400 mm, all the surface finishes showed the degree of surface damage of 3. At the drop height of 50 mm, the best impact resistance (degree 1) was found for waterborne (AQUA) and polyurethane (PUR) surface finishes for all three thicknesses of the coating films. The thickest coating films (H3) of waterborne and polyurethane surface finishes reached degree of 1 also at the drop height of 100 mm.

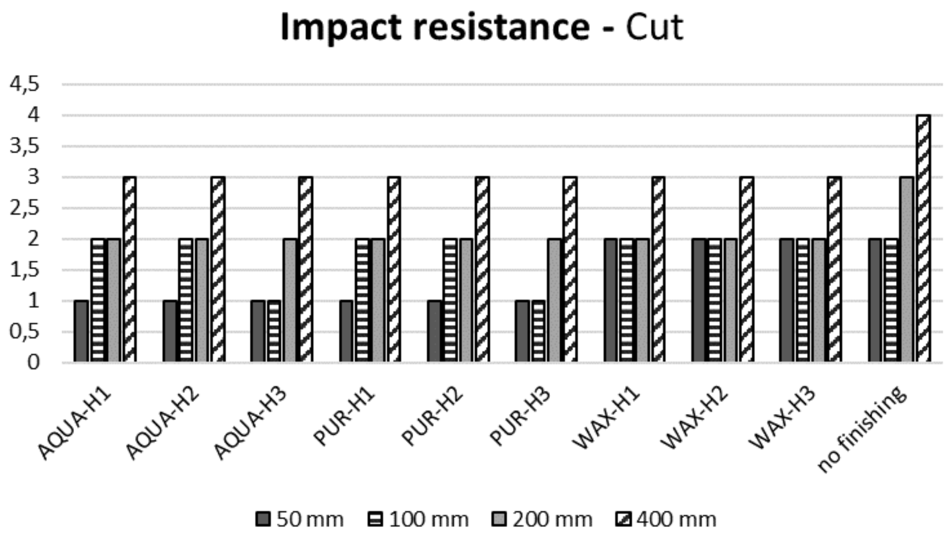

Figure 3. Impact resistance of the surface finishes on cut wood surface.

In Fig. 4, the impact resistance of surface finishes on grinded wood surface is presented graphically. At the highest drop height (400 mm), all the surface finishes showed the degree of damage of 4. At the drop height of 50 mm, the best impact resistance (degree 1) was found for polyurethane (PUR) surface finish with coating film thicknesses of H2 and H3.

The impact resistance of a surface finish increases with increasing thickness of the coating to some extent (Slabejová 2012). The important factor is a degree of surface damage. A thicker coating results in a greater risk of cracking under test conditions.

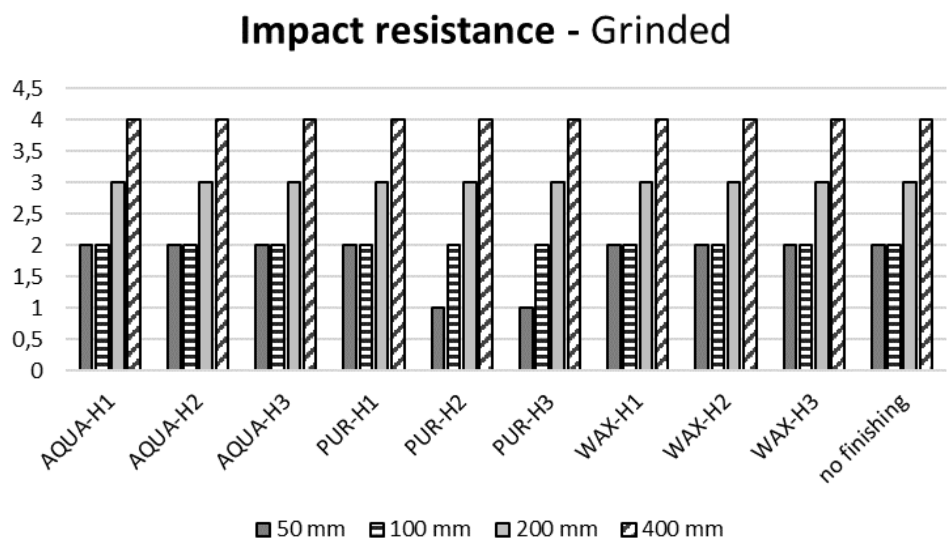

Figure 4. Impact resistance of the surface finishes on grinded wood surface.

In Fig. 5, the impact resistance of surface finishes on pressed wood surface is presented. At the highest drop height (400 mm), all the surface finishes showed the degree of damage of 2. At the drop height of 50 mm, all the surface finishes showed excellent impact resistance (degree 1). Pressing resulted in increased impact resistance of all the surface finishes for all film thicknesses.

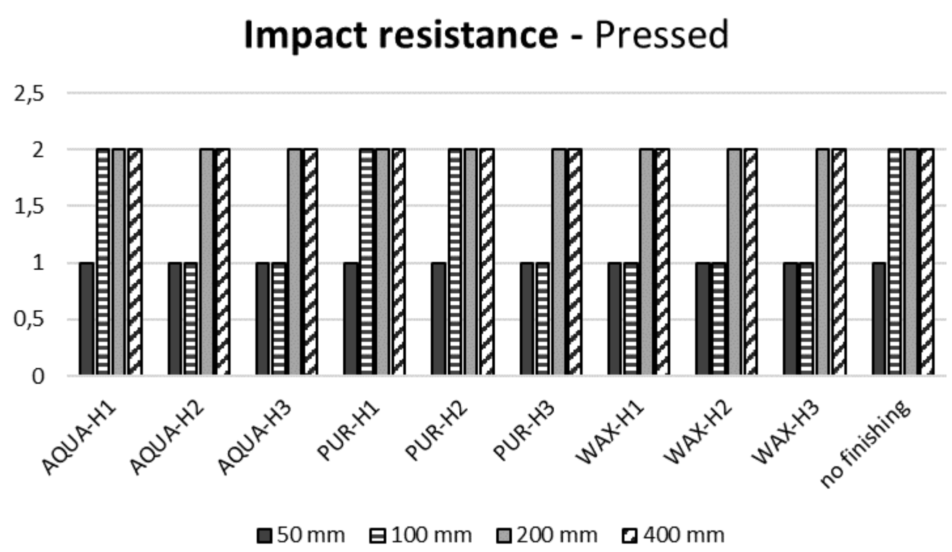

Figure 5. Impact resistance of the surface finishes on pressed wood surface.

At impact resistance test, the degree of damage was evaluated and the intrusion (a pinhole diameter) was measured. The biggest intrusions were visible on grinded surface and the smallest intrusions were on pressed surface (Fig. 6). With increasing thickness of the coating films the diameter of intrusions was decreasing for all the surface finishes. Similar fact has been described by Slabejová and Šmidriaková (2018a) for glossy polyester-polyurethane surface finish. The wax surface finish (WAX) with film thicknesses of H2 and H3 showed this tendency only on pressed surface.

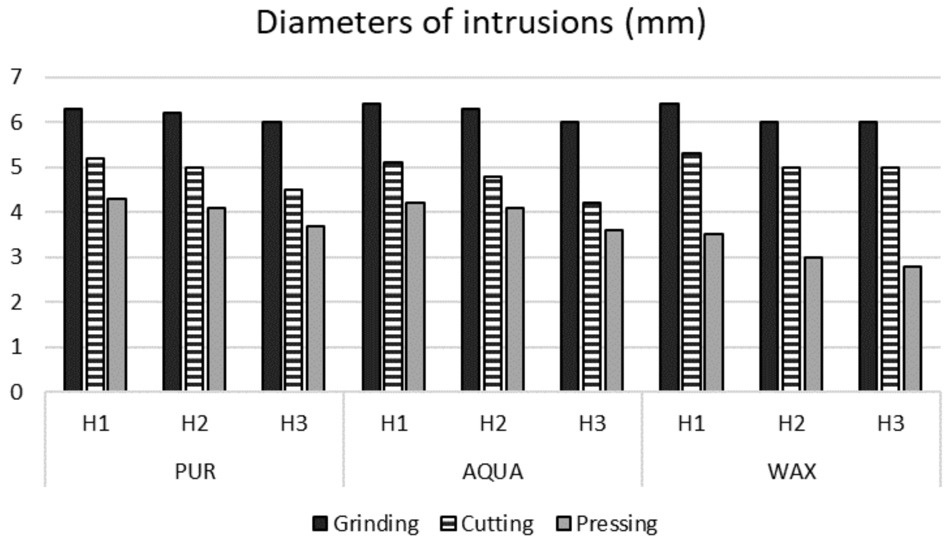

Figure 6. Diameter of intrusions on all surface finishes with three film thicknesses on grinded, cut, and pressed wood surfaces at the drop height of 400 mm.

Diameters of intrusions measured on the tested surface finishes were bigger than the diameters of intrusions on silicon coatings on beech veneer described by Slabejová et al. (2018). The impact resistance of the silicone coating on veneer surface was evaluated on veneers freely placed on medium density fibreboard. The diameters of intrusions measured in this experiment were comparable with the diameters of intrusions on a polyester-polyurethane surface finish described by Slabejová and Šmidriaková (2018).

CONCLUSIONS

Based on the analysis of the results, one can draw the following conclusions:

- The lowest resistance to abrasion was found on polyurethane surface finish (PUR).
- The greatest differences in resistance to abrasion, from the view point of mechanical treatment of wood and the thickness of the coating film, were found on wax surface finish (WAX).
- The best impact resistance was measured on pressed surface for all the tested surface finishes.
- Impact resistance of the coating film increased with increasing thickness of the coating film. With increasing film thickness, the diameter of intrusion was decreasing.

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REFERENCES

1. BEKHTA, P., PROSZYK, S., LIS, B., KRYSTOFIAK, T. 2014. Gloss of thermally densified alder (*Alnus glutinosa* Goertn.), beech (*Fagus sylvatica* L.), birch (*Betula verrucosa* Ehrh.), and pine (*Pinus sylvestris* L.) wood veneers. In European Journal of Wood and Wood Products, 2014, 72(6): 799–808.
2. CATALDI, A, CORCIONE, C.E., FRIGIONE, M., PEGORETTI, A. 2017. Photocurable resin/nanocellulose composite coatings for wood protection. In Progress in Organic Coatings, 106: 128–136, DOI: 10.1016/j.porgcoat.2017.01.019
3. JAIC, M., ZIVANOVIC, R. 1997. The influence of the ratio of the polyurethane coating components on the quality of finished wood surface. European Journal of Wood and Wood Products, 55(5): 319–322.
4. KAYGIN, B, AKGUN, E. 2009. "A nano-technological product: An innovative varnish type for wooden surfaces," In Scientific Research and Essays 4(1): 1–7. ISSN 1992-2248
5. KUMAR, A., PETRIČ, M., KRIČEJ, B., ŽIGON, J., TYWONIAK, J., HAJEK, P., ŠKAPIN, A.S., PAVLIČ, M. 2015. Liquefied-wood-based polyurethane-nanosilica hybrid coatings and hydrophobization by self-assembled monolayers of orthotrichlorosilane (OTS). In ACS Sustainable Chemistry and Engineering [online] 3(10): 2533–2541. DOI: 10.1021/acssuschemeng.5b00723
6. LEE, S. S., KOO, J. H., LEE, S. S., CHAI, S. G., LIM, J. CH. 2003. Gloss reduction in low temperature curable hybrid powder coatings. Progress in Organic Coatings [online], 2003, 46(4): 266–272. [online] http://thirdworld.nl/gloss-reduction-in-low-temperature-curable-hybrid-powder-coatings.
7. MIKLEČIĆ, J., TURKULIN, H., JIROUŠ-RAJKOVIĆ, V. 2017. Weathering performance of surface of thermally modified wood finished with nanoparticles-modified waterborne polyacrylate coatings. In Applied Surface Science, 408: 103–109.
8. SALCA, E. A., KRYSTOFIAK, T., LIS, B. 2017. Evaluation of Selected Properties of Alder Wood as Functions of Sanding and Coating. In COATINGS. ISSN 2079-6412. 2017, vol. 7, no. 10, art. no. 176.
9. SCRINZI, E., ROSSI, S., DEFLORIAN, F., ZANELLA, C. 2011. Evaluation of aesthetic durability of waterborne polyurethane coatings applied on wood for interior applications. In Progress in Organic Coatings [online], 2011, 72(1□2): 81–87. [online] www.sciencedirect.com.
10. SLABEJOVÁ, G. 2012. Vplyv vybraných faktorov na stabilitu systému drevo – tuhý náterový film. In Acta Facultatis Xylologiae Zvolen, 54(2): 57–65.
11. SLABEJOVÁ, G., ŠMIDRIAKOVÁ, M., PÁNIS, D. 2018. Quality of silicone coating on the veneer surfaces. In BioResources.2018, (13)1: 776–788. URL: https://bioresources.cnr.ncsu.edu
12. SLABEJOVÁ, G., ŠMIDRIAKOVÁ, M. 2018a. Quality of Pigmented Gloss and Matte Surface Finish. Acta Facultatis Xylologiae Zvolen, 60(2): 1–9.
13. SLABEJOVÁ, G., ŠMIDRIAKOVÁ, M. 2018b. Adhesion of Pigmented Surface Finish on MDF Board. Annals of Warsaw University of Life Sciences. 2018. (104), 164–168. ISSN 1898-5912.
14. STN EN ISO 7784-3: 2016, Determination of paint resistance to abrasion by abrasive paper in "Taber-Abraser" apparatus.
15. STN EN ISO 6272-2: 2011, Paints and varnishes. Rapid-deformation (impact resistance) tests. Part 2: Falling-weight test, small-area indenter.
16. STN 91 0102: 1991, Furniture. Surface finishing of wooden furniture. Technical requirements.

17. TESAŘOVÁ, D., CHLADIL, J., ČECH, P., TOBIÁŠOVÁ, K. 2010. Ekologické povrchové úpravy. Monografia. Brno. 2010. 126 p.
18. WETHTHIMUNI, M. L., CAPSONI, D., MALAGODI, M., MILANESE, C., LICCHELLI, M. 2016. Shellac/nanoparticles dispersions as protective materials for wood. In Applied Physics a-Materials Science & Processing 122(12): 1058. DOI: 10.1007/s00339-016-0577-7.
19. YONG, Q.W., NIAN, F.W., LIAO, B., GUO, Y., HUANG, L.P., WANG, L., PANG, H. 2017. Synthesis and surface analysis of self-mattee coating based on waterborne polyurethane resin and study on the mattee mechanism. In Polymer Bulletin 74(4): 1061–1076. DOI: 10.1007/s00289-016-1763-7.

Streszczenie: *Wpływ obróbki mechanicznej na jakość wykończenia powierzchni drewna bukowego*. Artykuł dotyczy oceny jakości trzech wykończeń powierzchni przeznaczonych do użytku wnętrznego. Zbadano trzy rodzaje powłok wytworzonych na drewniw bukowym na bazie: lakieru poliuretanowego, lakieru wodnego i wosku. W każdym z przypadków wytworzono powłoki w trzech różnych grubościach (zróżnicowanych liczbą krotności naniesienia materiału powłokowego). Jakość powierzchni oceniano w oparciu o pomiar odporności na uderzenia i odporności na ścieranie. Powłoki wytworzone na bazie lakieru poliuretanowego charakteryzowały się najniższą odpornością na ścieranie. Wzrost grubości powłoki wpływał na spadek odporności na ścieranie. Największe różnice w odporności na ścieranie, w zależności od obróbki powierzchni drewna, stwierdzono dla powłok wytworzonych na bazie wosku. Ogólnie stwierdzono, że powierzchnie wykończone powłokami na bazie lakierów wodnych charakteryzowały się najlepszą odpornością na ścieranie. Zagęszczenie powierzchni drewna przed wykończeniem zwiększyło odporność na uderzenia dla wszystkich rodzajów wykończeń powierzchni. Odnotowano jedynie 2 stopień uszkodzenia powierzchni (brak pęknięć na powierzchni i ślad po kuli tylko nieznacznie widoczny). Najniższą odporność na uderzenia odnotowano dla próbek drewna o szlifowanej powierzchni; odnotowano 4 stopień uszkodzenia (widoczne duże pęknięcia przy wgłębieniu). Dla wysokości rzutu 400 mm, bez wzgledu na sposób obróbki powierzchni drewna, nie odnotowano wpływu grubości powłok na udarność.

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