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PRESSURE EFFECTS ON POLYVINYL ACETATE JOINTS IN HEMP-SHIVE PARTICLEBOARDS – A COMPARATIVE STUDY

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ABSTRACT

This work presents one of the first systematic, ISO-aligned assessments of PVAc-bonded joints in laboratory-made hemp shive particleboards, benchmarked directly against industrial P2 particleboard under identical processing conditions (adhesive type and spread, surface preparation, and three nominal pressing pressures). By holding all bonding variables constant and varying only the substrate and pressure, the study isolates the effect of the substrate on shear strength. It offers actionable data for furniture construction with emergent hemp-based panels.

The key achievement is a consistent approximately 45% increase in PVAc shear strength for hemp shive panels across the tested pressures, with mean values rising from 1.23 to 1.53 N/mm², compared to 0.68 to 0.83 N/mm² for P2 (ISO 6237:2017). This result demonstrates that hemp shive particleboards can deliver markedly stronger adhesive joints without changing adhesive type or application rate, directly supporting their use as a higher-performance alternative in PVAc-bonded furniture assemblies. The observed variability at the highest pressure level highlights a practical optimization window for balancing pressure with adhesive spread and substrate permeability.

Key words: hemp-shive particleboards; shear strength; furniture joints; PVAc bonding; ISO 6237.

INTRODUCTION

Several factors, including moisture content, wood anatomy, surface energy/roughness, machining and sanding parameters, adhesive chemistry, film thickness, and the curing environment, influence adhesive performance on wood and wood-based substrates. For good adhesion, wood moisture is typically kept near 8 ± 2% for furniture and 12 ± 2% for construction (Sandak *et al.*, 2005; Sönmez *et al.*, 2011; Onegin, 2015). In composite panel manufacturing, the wood species and anatomical structure – specifically, fiber length, cell-wall thickness, pore density, and density – strongly influence surface roughness and surface energy (Ayrilmis *et al.*, 2010). More porous anatomies tend to produce rougher surfaces that enhance capillary uptake and surface absorption; pressing and sanding conditions further modulate roughness and absorption (Akbulut *et al.*, 2000). The wood species used in MDF has been shown to affect overall bond strength (Dilik *et al.*, 2015).

Water used as a thinner in water-dispersed systems penetrates deeper, maximally swelling fibers and altering wetting/curing behavior (Zhukov *et al.*, 1993; Onegin, 2015; Yakovlev, 2020). Owing to high surface tension and evaporation energy, coupled with low boiling point and evaporation number, waterborne systems can be sensitive to ambient conditions, displaying limited shelf life and modest heat resistance (Novakov *et al.*, 1997; Müller *et al.*, 2011; Landry & Blanchet, 2012; Kesik & Akyıldız, 2015; Salcă *et al.*, 2016). High-quality bonding generally requires a liquid with good wetting of the wood surface (Hse, 1972; Good, 1992; Jennings *et al.*, 2005). Microscopic surface irregularities increase real contact area and can raise bond strength, though they may necessitate more finishing (Richter *et al.*, 1995; Hazir *et al.*, 2017).

Optimizing adhesive joints requires attention to adhesive type (Williams *et al.*, 1994; Coelho *et al.*, 2008; Landry *et al.*, 2013; Kúdela, 2014; Slabejova *et al.*, 2017; Vasilevich *et al.*, 2018), applied layer thickness (Coelho *et al.*, 2008; Slabejova *et al.*, 2017), sanding grit (Magoss, 2008), and bonding method (Vasilevich *et al.*, 2018). As with solid wood, smaller abrasive grains on MDF yield lower roughness (Ayrilmis *et al.*, 2010). Adhesive chemistry defines service properties such as durability, viscosity, pot life, toxicity, and bonding capability; selection depends on service environment and substrate physicochemistry (Jaffe *et al.*, 1990; Panayotov, 2002). PVAc and urea-formaldehyde are widely used for wood bonding (Vick, 1999). PVAc shows strong adhesion to polar lignocellulosic substrates, but unmodified PVAc is unsuitable for structures in high humidity; modification with thermosetting resins via hardeners introduces (partial) chemical cure and improved resistance (Rosenberg, 1983; Panayotov, 2002).

Process conditions also shape performance. Higher ambient temperatures during bonding improve flow and accelerate solvent evaporation, but overly rapid loss can cause non-uniform films, poor adhesion, and defects. PVAc adhesion drops sharply above ~90 °C, and the film degrades above ~180 °C (Panayotov, 2002). Conventional PVAc's advantages include one-component handling, low toxicity/flammability, and colorless joints with relatively high strength; its elastic film can help redistribute stresses (Altinok, 1995). Fundamentally, bonding occurs as the liquid film hardens between solids: adhesion forces act across dissimilar interfaces, while cohesive forces within each phase also influence the joint quality (Panayotov, 2010; Dunky, 2017).

Wettability and spreading govern film formation and adhesion. On MDF, contact-angle changes reflect penetration and roughness; higher penetration and roughness often correspond to better apparent wetting (Ayrilmis *et al.*, 2010). Spreading – the growth of the liquid–solid contact area – depends on surface energy, adsorption, and wetting kinetics, often evidenced by a rapid decrease in contact angle over time (Shi & Gardner, 2001; Kavalov *et al.*, 2014; Zhukov *et al.*, 1993). In both bonding and finishing, adhesion strength and film uniformity hinge on wetting/spreading (Sinn *et al.*, 2009; Landry & Blanchet, 2012). During curing, the liquid layer can be idealized as three strata (outer/environment, inner/substrate, and intermediate), each hardening at a different rate due to environmental exposure, volatile evaporation, and substrate interactions (Müller & Poth, 2011; Panayotov, 2002).

Adhesive penetration into wood occurs through the surface filling of cells and the penetration of cell walls/microcracks; the degree of mechanical interlocking scales with penetration depth (Marra, 1992). Waterborne systems often deliver better mechanical adhesion than solvent-based ones due to increased roughness (Hernández & Cool, 2008; Salcă *et al.*, 2017). Increased roughness generally improves adhesion by enlarging the contact area, but it also raises material consumption. Excessive roughness can cause over-penetration and non-uniform films, while overly fine sanding may reduce adhesion (Sulaiman *et al.*, 2009; Lewis & Forrestal, 1969; Landry & Blanchet, 2012). Coatings on hardwoods often show higher adhesion than on softwoods, highlighting species effects (Sönmez *et al.*, 2011; Kesik & Akyıldız, 2015; Söğütlü *et al.*, 2016).

Adhesion strength remains a key quality criterion for both adhesive joints and coatings, reflecting interfacial intermolecular/chemical interactions, as well as resistance to peeling/delamination under service conditions (Landry & Blanchet, 2012). It evolves during curing as chemistry, structure, stresses, and environmental exposures change (Zhukov *et al.*, 1993). For MDF and related substrates, the dominant factors include surface treatment, material surface properties, coating/film type and thickness, and the number of layers. Higher surface density and homogeneity increase adhesion, which is a function of both roughness and moisture content (Dilik *et al.*, 2015).

Within this context, the present work examines PVAc-bonded joints in hemp shive particleboards in comparison to conventional particleboards under controlled bonding parameters. By coupling standardized testing with careful control of surface preparation, adhesive spread, and pressing conditions, the study provides comparative data relevant to furniture applications where PVAc remains a predominant adhesive system.

Despite extensive research on adhesion to wood and MDF, the literature provides little standardized (ISO 6237) evidence on PVAc-bonded joints for hemp shive particleboards, particularly in a direct benchmark against industrial P2 particleboard under identical bonding conditions (uniform surface preparation, adhesive type/spread, and controlled pressing pressure). The systematic evolution of shear strength with pressing pressure in the practical range for furniture joints also remains unresolved, as do questions about resulting variability and dominant failure modes for this emerging substrate. This study addresses these gaps through a controlled, statistically supported comparison of PVAc shear strength for hemp panels versus a P2 reference, mapping the pressure–strength relationship and deriving actionable guidance for PVAc-bonded furniture assemblies using hemp-based boards.

MATERIALS AND METHODS

Single-layer particleboards from hemp shives were produced under laboratory conditions at 500 × 500 × 18 mm. Shives were dried to 11% moisture prior to mat formation. Melamine–formaldehyde (MF) resin was applied at 10% (based on oven-dry shives). Physical and mechanical properties were determined by EN standards: density ρ by EN 323:2001; modulus of elasticity (MOE) and bending strength (MOR) by EN 310:1999; and internal bond (IB) by EN 319:2002. An industrial 16-mm P2 particleboard ("Kronospan – Bulgaria") served as the reference substrate. The choice of a P2 board reflects its widespread use in furniture applications, providing a relevant industrial baseline. Using EN methods ensures the comparability and traceability of board properties across studies, aligning with common practice in wood-based panels research and product control (EN 323/310/319).

Lap-shear specimens were prepared from each board type, consisting of two adherends (150 × 20 × 18 mm). Bondline areas were controlled by machining to a consistent overlap. Prior to bonding, adherend surfaces were sanded with P120 abrasive using an orbital sander. The ISO 6237:2017 method specifies the shear strength of wood-to-wood adhesive bonds under tensile loading and was adopted to standardize the geometry, loading, and data reduction procedures. The P120 grit is within the range shown to yield reproducible, moderate roughness that promotes wetting without excessive fiber damage or over-penetration, and is commonly recommended for wood/MDF prior to bonding or coating (Magoss, 2008; Ayrilmis *et al.*, 2010; Landry & Blanchet, 2012; Sulaiman *et al.*, 2009; Richter *et al.*, 1995). PVAc is a standard adhesive for wood and wood-based materials due to strong adhesion to polar substrates and safe, single-component handling (Vick, 1999; Panayotov, 2002; Rosenberg, 1983). Spread levels in the 120–200 g/m² range are typical for furniture joints and are consistent with recommendations that balance wetting/coverage with risks of starved or overly thick bonds (Vick, 1999; Panayotov, 2002).

Maintaining a constant spread isolates the effects of substrate and pressure on bond performance (Marra, 1992).

Specimens were pressed in a laboratory hot press at nominal pressures of 100, 150, and 200 bar for 60 minutes, then conditioned for 24 h before testing. Pressure is a primary control variable affecting wetting, intimate contact, and adhesive penetration/anchoring in porous substrates (Marra, 1992; Shi & Gardner, 2001; Panayotov, 2002). A three-level pressure design enables mapping of the pressure–strength response while keeping other parameters fixed. A one-hour press time with a 24-hour conditioning period provides sufficient time for PVAc film formation and strength development before testing, aligning with standard practice for PVAc joints (Vick, 1999; Panayotov, 2002) and minimizing the confounding effects of incomplete cure or post-press set.

Shear strength by tensile loading was measured in accordance with ISO 6237:2017 using a WDW-50E universal testing machine (HST, China, 2022), as shown in *Figure 1*. Maximum load at failure (adhesive or cohesive) was recorded and converted to shear strength $f_v = F_{\max}/A$, where A is the bonded area. Failure modes were classified qualitatively as either adhesive (at the interface) or cohesive (within the adhesive). ISO 6237 provides a standardized, widely accepted protocol for wood-to-wood adhesive bonds, ensuring that results are comparable and reproducible across laboratories and substrates.

Figure 1: ISO 6237 shear-by-tensile setup on the WDW-50E universal testing machine; crosshead speed 2 mm/min to target failure within 60 ± 30 s. a – hemp shives used for laboratory panel fabrication; b – test setup with centered PVAc-bonded specimen.

For each series and pressure level, five replicate specimens (n = 5) were tested to achieve measurement precision with <5% target error for the mean, where variability allowed. Data were processed using the least-squares method; reported statistics include mean ($\bar{\chi}$), maximum, minimum, median, standard deviation (s), coefficient of variation (v), and the probability (p) for the corresponding property. Replicate numbers of 5–10 per condition are common in wood adhesion and coating studies to capture inherent material variability (e.g., Dilik *et al.*, 2015; Landry & Blanchet, 2012; Salcă *et al.*, 2016). Reporting dispersion metrics is recommended given the known sensitivity of adhesion to surface preparation, moisture, and microstructure (Ayrilmis *et al.*, 2010; Williams & Feist, 1994; Sönmez *et al.*, 2011).

RESULTS AND DISCUSSION

The physical and mechanical properties of the single-layer laboratory particleboards made from hemp shives were determined in accordance with the relevant European Standards (EN). The measured parameters were as follows: density (ρ) = 650 kg/m³ (EN 323:2001); modulus of elasticity (MOE) (E_m) = 2479 N/mm²; bending strength (MOR) (f_m) = 19.35 N/mm² (EN 310:1999); and internal bond (IB) strength (f_t) = 0.71 N/mm² (EN 319:2002). These baseline properties define the stiffness and cohesion of the substrate against which the adhesive joint operates and are used when interpreting the measured shear strength.

Table 1 (HEMP) and Table 2 (PB) summarize PVAc shear strength $f_v$per ISO 6237. For HEMP, the mean f_v increases from 1.23 to 1.53 MPa as pressure rises from 100 to 200 bar (+19.6%); for PB, it increases from 0.68 to 0.83 MPa (+18.1%). At any given pressure, HEMP outperforms PB by roughly 45% on average. Notably, at 100 bar, the HEMP joint already exceeds the panel's internal bond (IB = 0.71 MPa) by ~73%, reaching ~2.2× IB at 200 bar; thus, within this window, the bondline is not the limiting element for the hemp substrate.

Table 1: Shear PVA adhesive strength of hemp panels

№	*Series*	*Shear strenght, fv (N/mm²)*						
		Average (mean value), χ̄ (N/mm²)	*Max. value, f_{max}. (N/mm²)*	*Min. value, f_{min}. (N/mm²)*	*Median, med. (N/mm²)*	*Standard deviation, s (N/mm²)*	*Coefficient of variation, v (%)*	*Probability, p (%)*
1	*HEMP_100*	***1,23***	*1,60*	*1,00*	*1,20*	*0,19*	*15,20*	*1,27*
2	*HEMP_150*	***1,37***	*1,70*	*1,10*	*1,30*	*0,23*	*17,11*	*2,85*
3	*HEMP_200*	***1,53***	*2,20*	*1,10*	*1,40*	*0,36*	*23,41*	*1,95*

Table 2: Shear PVA adhesive strength of PB panels

№	*Series*	*Shear strenght, fv (N/mm2)*						
		Average (mean value), χ̄ (N/mm²)	*Max. value, f_{max}. (N/mm²)*	*Min. value, f_{min}. (N/mm²)*	*Median, med. (N/mm²)*	*Standard deviation, s (N/mm²)*	*Coefficient of variation, v (%)*	*Probability, p (%)*
1	*PB_100*	***0,68***	*0,90*	*0,50*	*0,60*	*0,13*	*19,57*	*1,63*
2	*PB_150*	***0,76***	*1,10*	*0,40*	*0,70*	*0,22*	*28,92*	*2,41*
3	*PB_200*	***0,83***	*1,10*	*0,70*	*0,80*	*0,12*	*14,70*	*1,63*

The regressions shown in Figures 2–3 yield R^2values close to unity for both materials, indicating that within 100–200 bar, nearly all variation in $f_v$is explained by pressure alone; there is no sign of curvature or saturation, so a linear model is appropriate. The slope of the fitted line represents the absolute sensitivity $\Delta f_v/\Delta P$(MPa per bar). Interpreting the fits, a 100-bar increase raises the HEMP joint strength by approximately 0.30 MPa, whereas PB increases by approximately 0.15 MPa; hence, the hemp substrate is about twice as pressure-sensitive as PB under identical adhesive, spread (160 g·m⁻²), and surface preparation (P120). In relative terms, around the mid-range (≈150 bar), a 10% pressure increase leads to a ≈3.3% strength gain for HEMP and ≈3.0% for PB – close in percentage response. Still, the absolute gain remains decisively larger for HEMP, which is what matters for design allowables.

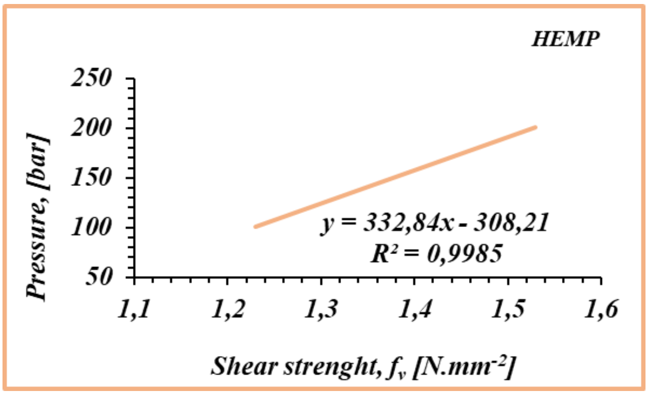

Figure 2: Relationship between the adhesive joint strength and the pressing pressure of hemp shive panels

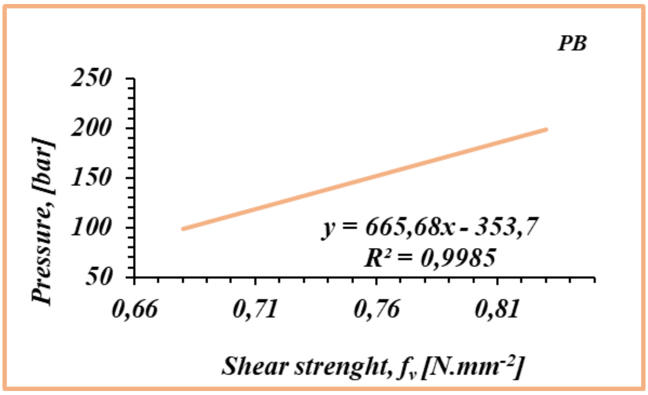

Figure 3: Relationship between the adhesive joint strength and the pressing pressure of particleboard panels

Scatter behavior is consistent with substrate microstructure. For *HEMP*, the coefficient of variation increases with pressure (15.2% to 23.4%), suggesting that higher pressure promotes deeper penetration and micromechanical anchoring in an open, heterogeneous network, but can also induce locally starved bonds if the adhesive is drawn too far into the lumina. For PB, variability peaks at 150 bar and drops at 200 bar, consistent with a denser, more homogeneous surface where higher pressure primarily improves intimate contact. These mechanisms align with established models of wetting, spreading, and mechanical interlocking in porous lignocellulosic substrates and with the role of controlled surface roughness in promoting wetting without excessive fiber damage or over-penetration (Marra, 1992; Shi & Gardner, 2001; Magoss, 2008; Ayrilmis *et al.*, 2010; Richter *et al.*, 1995; Landry & Blanchet, 2012).

Relative to comparable MDF/solid-wood studies, the present results follow the same direction of effect – stronger bonds at higher pressure – but add two points specific to hemp-shive boards with PVAc: at equal adhesive and spread the hemp substrate consistently delivers higher strength than the industrial P2 reference, and the linear fits reveal a distinctly steeper pressure response for HEMP than for PB in the same processing window. This finding directly informs process tuning: manufacturers can achieve higher joint strengths on hemp panels without changing the adhesive type or application rate, provided that pressure is balanced with spread/time to avoid variability growth at the upper end of the range. Future work should quantify failure-mode fractions, extend the design to pressure × spread × surface-prep response surfaces, and include moisture/temperature cycling to translate the observed strength advantage into verified long-term performance.

CONCLUSIONS

This study addresses a clear gap: there is a lack of ISO 6237 evidence on PVAc-bonded joints in hemp shive particleboards, particularly under a direct, like-for-like benchmark with industrial P2 particleboard. We held all bonding parameters constant (surface preparation, adhesive type and spread, press time, and conditioning) and varied only the substrate and pressing pressure within a practical range of 100–200 bar. This controlled, ISO-aligned design shows that the mean shear strength rises linearly for both materials (hemp: 1.23 to 1.53 MPa; P2: 0.68 to 0.83 MPa), with hemp outperforming P2 by approximately 45% on average and exhibiting approximately 2 times higher pressure sensitivity (approximately 0.30 MPa vs. 0.15 MPa gain per 100 bar). Hemp joints already exceed the board's IB at 100 bar and reach approximately 2.2 times the IB at 200 bar, indicating that the bondline is not the limiting element in this range.

Practically, manufacturers can achieve substantially stronger PVAc joints on hemp panels without changing adhesive chemistry or application rate. The high linearity (see R^2 on the figures) supports predictable strength gains through pressure tuning, although the increased scatter for hemp at 200 bar suggests balancing pressure with spread and time to avoid starved bonds from over-penetration.

Despite the encouraging results, this work is an initial step. It has apparent limitations: a single adhesive chemistry and spread (PVAc, 160 g/m^2), one surface preparation (P120), a fixed loading rate (2 mm/min), and a bounded pressure window (100–200 bar).

Future studies should quantify failure-mode fractions (adhesive/cohesive/substrate), expand the experimental space to include pressure × spread × surface preparation, and assess durability under cyclic moisture and temperature conditions. Comparative trials using crosslinked PVAc classes and alternative systems (e.g., PUR, epoxy), combined with surface-energy and penetration analyses, would help translate these findings into robust process guidelines for hemp-based furniture panels.

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REFERENCES

AKBULUT T., HIZIROGLU S., AYRILMIS N. 2000. *Surface absorption, surface roughness, and formaldehyde emission of Turkish medium density fiberboard*. Forest Products Journal, 50 (6), 45–48.

ALTINOK M. 1995. *Sizing the strength components according to the tension analysis in chair design*. Gazi University Institute of Sciences, Ankara, 1–33.

AYRILMIS N., CANDAN Z., AKBULUT T., BALKIZ O. D. 2010. *Effect of Sanding on Surface Properties of Medium Density Fiberboard*. Drvna industrija, 61 (3), 175–181.

COELHO C. L., CARVALHO L. M. H., MARTINS J. M., COSTA C. A. V., MASSON D., MEAUSOONE P. J. 2008. *Method for evaluating the influence of wood machining conditions on the objective characterization and subjective perception of a finished surface*. Wood Science Technology, 42, 181–195.

DILIK T., ERDINLER S., HAZJR E., KOÇ H., HIZIROGLU S. 2015. *Adhesion Strength of Wood Based Composites Coated with Cellulosic and Polyurethane Paints*. Advances in Materials Science and Engineering, Article ID 745675.

DUNKY M. 2017. *Adhesives in the wood industry*. In Handbook of Adhesive Technology, 511–574.

GOOD R. J. 1992. *Contact angle, wetting, and adhesion: a critical review*. Journal of Adhesion Science and Technology, 6 (12), 1269–1302.

HAZIR E., KOC K. H., HIZIROGLU S. 2017. *Optimization of sanding parameters using response surface methodology*. Maderas. Ciencia y tecnología, 19 (4), 407–416.

HERNÁNDEZ R. E., COOL J. 2008. *Evaluation of three surfacing methods on paper birch wood in relation to water- and solvent-borne coatings performance*. Wood and Fiber Science, 40 (3), 459–469.

HSE C. Y. 1972. *Wettability of Southern Pine Veneer by Phenolic Formaldehyde Wood Adhesives*. Forest Products Journal, 22 (1), 51–56.

ISO 6237:2017. *Adhesives. Wood-to-wood adhesive bonds*. *Determination of shear strength by tensile loading*.

JAFFE H. L., ROSENBLUM F. M., DANIELS W. 1990. *Polyvinyl Acetate Emulsions for Adhesives*. In: Handbook of Adhesives. Springer, Boston, MA. https://doi.org/10.1007/978-1-4613-0671-921.

JENNINGS J. D., ZINK-SHARP A., KAMKE, FRAZIER C. E. 2005. *Properties of compression densified wood. Part 1: Execution of bonds*. Journal of Adhesion Science and Technology, 19 (13–14), 1249–1261.

KAVALOV, A., & ANGELSKI, D. 2014. *Furniture Technology*. Sofia: Publishing House of the University of Forestry. 390 pp. ISBN 978-954-332-115-5. (in Bulgarian)

KESIK H., AKYILDIZ M. 2015. *Effect of the heat treatment on the adhesion strength of water based wood varnishes*. Wood Research, 60 (6), 987–994.

KÚDELA J. 2014. *Wetting of wood surface by liquids of different polarity*. Wood Research, 59 (1), 11–24.

LANDRY V., BLANCHET P. 2012. *Surface preparation of wood for application of waterborne coatings*. Forest Products Journal, 62 (1), 39–45.

LANDRY V., BLANCHET P., CORMIER L. M. 2013. *Water-based and solvent-based stains: Impact on the grain raising in Yellow Birch*. BioResources, 8 (2), 1997–2009.

LEWIS A. F., FORRESTAL L. J. 1969. *Adhesion of coatings. In Treatise on Coatings. Characterization of Coatings.* Physical Techniques, 2, 57–98.

MAGOSS E. 2008. *General Regularities of Wood Surface Roughness*. Acta Silvatica et Lignaria Hungarica, 4 (1), 81–93.

MARRA A. 1992. *Technology of Wood Bonding: Principles in Practice*. 1st ed. Van Nostrand Reinhold, New York, 454 p.

MÜLLER B., POTH U. 2011. *Pigment dispersions*. In Coatings Formulation: An International Textbook, Vincentz Network GmbH & Co. KG, Second edition.

NOVAKOV, P., ILIEV, I., & MILOSHEV, ST. 1997. *Chemistry and technology of paint-and-varnish materials and coatings*. Sofia: University of Chemical Technology and Metallurgy (HCTM). 444 pp. (in Bulgarian)

ONEGIN, V. I. 2015. *Wood properties considered in forming protective–decorative coatings on wood and wood-based materials*. Lesnoy Zhurnal (Forestry Journal), 6(348), 116–127. (in Russian)

PANAYOTOV, P. 2002. *Adhesives and materials for protective–decorative coatings*. Sofia: Publishing House of the University of Forestry. 230 pp. (in Bulgarian)

PANAYOTOV, P., GOCHEV, ZH., & BORISOV, D. 2010. *Effect of surface roughness on the adhesion of film-forming protective–decorative coatings*. Woodworking and Furniture Manufacturing, No. 1, Sofia, 8–19. ISSN 1311-4972. (in Bulgarian)

RICHTER K., FEIST W., KANEBE M. 1995. *The effects of surface roughness on the performance of finishes*. Forest Products Journal, 45 (7–8), 91–97.

ROZENBERG M. E. 1983. *Polymers based on vinyl acetate*. Leningrad: Khimiya, pp. 106–113. (in Russian)

SALCĂ E. A., KRYSTOFIAK T., LIS B., MAZELA B., PROSZYK S. 2016. *Some coating properties of black alder wood as a function of varnish type and application method*. BioResources, 11 (3), 7580–7594.

SALCA E. A., KRYSTOFIAK T., LIS B. 2017. *Evaluation of selected properties of alderwood as functions of sanding and coating*. Coatings, 7 (10), 176.

SANDAK J., MARTINO N. 2005. *Wood surface roughness – what is it?* Proceedings of the 17th International Wood Machining Seminar (IWMS 17), Rosenheim, Germany, 26–28.

SHI S. Q., GARDNER D. J. 2001. *Dynamic adhesive wettability of wood*. Wood and Fiber Science, 33 (1), 58–68.

SINN G., SANDAK J., RAMANANATOANDRO T. 2009. *Properties of wood surfaces – characterization and measurement: A review*. Holzforschung, 63, 196–203.

SLABEJOVA G., ŠMIDRIAKOVÁ M., MORING M. 2017. *Surface roughness of water-based finishes on aspen poplar wood*. Ann. WULS-SGGW, Forestry and Wood Technology, 98, 126–131.

SÖĞÜTLÜ C., NZOKOU P., KOC I., TUTGUN R., DÖNGEL N. 2016. *The effects of surface roughness on varnish adhesion strength of wood materials.* Journal of Coatings Technology and Research, 13, 863–870.

SÖNMEZ A., BUDAKÇI M., PELIT H. 2011. *The effect of the moisture content of wood on the layer performance of waterborne varnishes*. BioResources, 6, 3166–3177.

SULAIMAN O., HASHIM R., SUBARI K., LIANG C. K. 2009. *Effect of sanding on surface roughness of rubberwood*. Journal of Materials Processing Technology, 8, 3949–3955.

VASILEVICH, V. G., & MAZANIK, N. V. 2018. *Domestic and foreign methods for analyzing the quality of paint-and-varnish coatings for exterior wood finishing*. (in Russian)

VICK C. B. 1999. *Adhesive bonding of wood materials*. In: Wood Handbook: Wood as an Engineering Material. U.S. Department of Agriculture Forest Products Laboratory, Madison, WI.

WILLIAMS R. S., FEIST W. C. 1994. *Effect of preweathering, surface roughness, and wood species on the performance of paint and stains*. Journal of Coatings Technology, 66, 109–121.

YAKOVLEV, A. D. 2020. *Chemistry and technology of paint and coatings*. Saint Petersburg: Khimizdat. 448 pp. ISBN 978-5-93808-360-8. (in Russian)

ZHUKOV, E. V., & ONEGIN, V. I. 1993. *Technology of protective–decorative coatings for wood and wood-based materials*. Moscow: Ekologiya. 304 pp. ISBN 5-7120-0443-7. (in Russian)

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