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WOOD PARTICLEBOARD COVERED WITH SLICES MADE OF PINE TREE BRANCHES

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ABSTRACT

The article deals with the proposition of wood composite material coated with slices made of natural wood. The aim was to investigate the possibility of production of decorative and formaldehyde low-emission particleboard covered with slices of pine wood branches (*Pinus Sylvestris* L.). The paper describes the technology of slices preparation to create the outer surface layer of particleboard (impregnation, drying), pressing parameters, testing the properties of obtained composite material and formaldehyde emission. Various types of adhesives were used to impregnate the slices: urea-formaldehyde, phenol-formaldehyde, melamine-urea-formaldehyde and bone glue. Obtained results of specific mechanical and environmental properties were comparable with samples of untreated slices and in accordance with the standard requirements. The decrease of formaldehyde emission was observed and the lowest value was measured from the samples with slices impregnated with the bone glue.

Key words: adhesives, bending strength, decorative material, facing, formaldehyde, slices of pine branches, internal bond, wood particles.

INTRODUCTION

The special feature of designed new decorative material is using slices – thin end sections of pine wood, as the facing layer. Slices are produced by cutting of wood branches with well-expressive annual rings. The rings creating 3D effect are stretched. Various combinations of slices on the board surface make the possibility to create different types of designs. Using low quality timber for production of the boards – using wood production wastes for the particleboard middle layer and using slices from branches for facing – could solve the problem of complex exploitation of raw materials (MIRSKI and DZIURKA 2011). Wood composite covered with slices is intended to be used for furniture fronts, panels, cladding of structural elements, etc.

Technology of industrial production of this new material has not been fully worked out yet. It is necessary to solve a number of issues related to technological parameters: definition of cutting, drying-impregnation-drying of slices, parameters of the pressing process of materials with slices of different wood species. In particular, it is necessary to search for environmental adhesives with low-emission of formaldehyde and having reliable adhesion to the slices. For bonding of wood, there are used synthetic adhesives and/or glues of natural origin. The latter are environmentally friendly but they are not waterproof and they cannot prevent biological degradation of bonded material. They are usually specifically used for bonding of solid wood and for veneering.

At present, particleboard are industrially produced with low formaldehyde emission of E1 class (formaldehyde emission is less than 0.124 mg/m^3 stated according to the standard EN 717-1). In the USA, isocyanates are used in particleboard manufacturing. A disadvantage of the isocyanate adhesives is their high adhesion to metal, so particle carpet adheres to the hot press plates or pans, but they have no formaldehyde emission.

Last time, there were carried out studies for production of eco-particleboard which use the following binders: adhesives based on soy protein, which are even cheaper than formaldehyde resins (JANG and LI 2015, SUGHYUN and NETRAVALI 2006), adhesives based on bone glue (KONNERTH *et al.* 2009), adhesives based on tannin and sucrose adhesive (OSMAN 2012). Production of eco-particleboard is still in development.

Nowadays, according to the Fraunhofer Institute (2012), 80–85 % of particleboard is produced using adhesives containing formaldehyde. Despite this fact, the furniture made of particleboard is the most popular. So it is important to use the particleboard facing – such as slices from branches – to reduce the formaldehyde emission.

The aim of this research was to propose the low-emission particleboard covered with pine wood slices. Tests on static bending, internal bond and formaldehyde emission were done on samples of particleboard with end slices of pine wood branches impregnated in different resins.

METHODS

Technology for production of wood composite material with facing slices involves: slices impregnation, placing them above and below a layer of wood particles mat, pre-pressing, hot pressing, cooling and conditioning. For impregnation of pine wood slices, the following adhesives were used: urea formaldehyde (UF) – the control sample, melamine-urea-formaldehyde (MUF) without hardener, phenol-formaldehyde (PF) and bone glue (BG). All selected adhesives were diluted with water in the ratio of 1:1. UF, PF and MUF are industrially applied resins for E1 class wood panels, BG is natural glue without formaldehyde.

Slices with the thickness of 1.5 mm were impregnated by dipping into the resin, and then they were incubated for 5 minutes at a room temperature (Figure 1a). After the draining the rest of the resin, they were dried in a laboratory oven in a clamp state (Figure 1b) at the temperature of 50 °C for the BG, and 60 °C for the other adhesives.

a

b


Fig. 1 Stages of slices preparation before pressing: a – impregnation, b – drying.

The wood based composite was pressed in one cycle in the heated laboratory press FONTIJNE. Wood particles with the size of middle layer were industrially resinated (8 % resinification) by UF or MUF adhesive at Bučina DDD company. The mat of composite was layered as follows: impregnated slices – wood particles – impregnated slices. For all types of adhesives, the same temperature of pressing (t = 130 °C) was used. Time holding pressure for synthetic adhesives and bone glue was different (Table 1). According to the recommendations of KONNERTH *et al.* 2009, during the pressing of board with slices impregnated with the bone glue, the heating was turned off and the sample was left under the pressure until the temperature was lowered down to 80 °C.

Tab. 1 Pressing parameters for particleboard covered with impregnated slices.

Slices not impregnated impregnated with UF impregnated with PF impregnated with MUF	Slices impregnated with BG
Pressing temperature t = 130 °C	
Three-step diagram: 1st = 4,5 MPa, τ = 1,5 min 2nd = 2,5 MPa, τ = 2,5 min 3rd = 1,5 MPa, τ = 1,0 min	Three-step diagram: 1st = 4,5 MPa, τ = 1,5 min 2nd = 2,5 MPa, τ = 2,5 min Heating off 3rd = 1,5 MPa, τ = 57 min Final temperature t = 80 °C

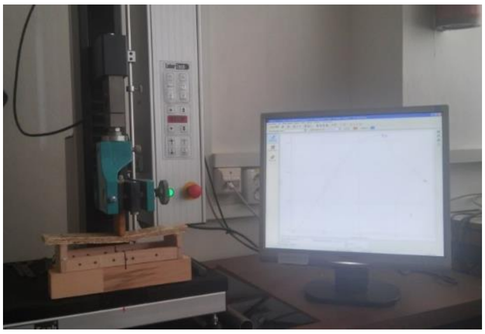
Static bending and internal bond tests were carried out in the laboratory conditions at the temperature of 20 °C according to the following standards:

– EN 310: 2003 Wood-based panels. Determination of modulus of elasticity in bending and of bending strength.

– EN 319: 2001 Particle boards and fibreboards. Determination of tensile strength perpendicular to the plane of the board.

All tested samples were prepared in laboratory conditions. Testing machine LaborTech 4.050 is equipped with the appropriate devices to test the static bending (Figure 2a) and internal bond strength (Figure 2b). Test results were processed by mathematical statistics methods.

a



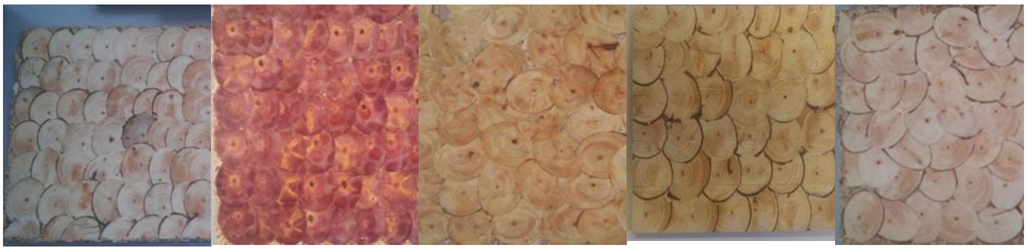
b

Fig. 2 Testing of: a – bend strength, b – internal bond.

The test for determination of quantity of formaldehyde emitted from the boards by desiccator method were carried out by using the glass desiccator according to JIS A 1460. The emitted quantity of formaldehyde is obtained from the concentration of formaldehyde absorbed in distilled water. The test pieces of specified surface area were placed in the desiccator filled with the specified amount of distilled water for 24 h. The principle for determination of concentration of formaldehyde absorbed in distilled water is based on the Hantzsch reaction in which the formaldehyde reacts with ammonium ions and acetylacetone to yield diacetyldihydrolutidine.

RESULTS AND DISCUSSION

Surface covering presents opportunities for changing the mechanical and environmental properties of bonded material. Figure 3 shows the wood particleboards covered with slices impregnated with different adhesives and also the sample with untreated slices. All prepared boards had the thickness of 10 mm.



a b c d e

Fig. 3 Wood particle samples facing with slices impregnated with: a – UF, b – PF, c – BG, d –MUF, e – untreated slices.

In all samples, pine wood slices were placed overlap on both surface layers of the board. The particleboards with impregnated slices had smooth surface because slices were pressed into the mat; thus it is possible to eliminate grinding procedure and apply varnish immediately. UF and MUF adhesives practically did not change the natural colour of the slices; BG caused yellowish colouring. From the aesthetic point of view, the samples with slices impregnated with PF showed the inappropriate result – dark burgundy colour absorbed the natural beauty of pine wood. Table 2 describes the obtained results and basic statistical evaluation of static bending and internal bond strength testing of all the samples.

Tab. 2 Static bending and transverse tensile strength of particleboard samples.

Adhesive for slices impregnation	**Samples density (kg/m^3)**	**Static bending**		**Internal bond**	
		Bend strength (MPa)	**Variability (%)**	**Strength (MPa)**	**Variability (%)**
UF	758	9.32	7.85	0.58	6.41
PF	757	10.17	21.02	0.52	10.17
BG	727	10.50	10.29	0.52	9.65
MUF	856	16.45	4.67	1.31	7.93
Unresinated	769	5.20	9.93	0.15	34.00

Results of static bending and internal bond strength testing showed similar results for the UF, PF and BG types of boards. This can be explained by the same substrate and the same pressing parameters. Fractures on test pieces, when tested for static bending, were on the opposite side from the place of the applied load; all cracks were observed on the slice area of the samples. When tested for internal bond strength, the rupture was occurred inside the particleboard for all samples. Slices impregnation gave more resistance to stress thanks to ongoing polymerization of the adhesives during pressing of the boards.

Crosslinking of impregnation on slices during the pressing of the boards can help to achieve new material properties such as smooth surface of the board, enhanced dimensional stability and lower equilibrium moisture content. All these might prolong the service life of the board. Heat treatment of flakes influences mechanical properties of flakeboard glued with UF adhesive (KWON and AYRILMIS 2015a). The results showed that water resistance and internal bond strength were improved by the heat treatment of flakes, while the modulus of rupture and modulus of elasticity was decreased. KWON and AYRILMIS (2015b) researched physical and mechanical properties of particleboard prepared from treated wood particles. Their results confirmed that bending properties and also mechanical properties of the board are influenced by the treatment of wood particles. What was important, the dimensional stability of the particleboard was significantly improved.

We suppose that treatment of all parts of the proposed wood composite (so wood particles in the board and facing wood slices on the surface) influences the properties of the designed board. This assumption was confirmed by the results measured on test pieces with untreated slices. Creation of the bond between the board and impregnated slices can be categorised as chemical adhesion where the dried resin on slices and liquid resin on the wood particles interact together (CHEN *et al*. 2014). The system can reach better strength properties. The boards with untreated slices on their surface (slices with no adhesive) confirmed this assumption. Both bend strength at static bending and internal bond strength reached the lowest values when compared with all the others boards.

The test pieces with slices impregnated with MUF showed results with the best values. Internal bond strength reached the value 1.31 MPa; it was almost 2.5 higher than internal bond strength of the samples with UF, PF or BG impregnated slices, and 10 times higher than internal bond strength of the samples covered with untreated slices. Probably this was due to the higher density, stronger cohesion of MUF resin and smaller wood particles.

The performance of the covering is stated by the adhesion between the slices and the underlying substrate. Thus, the evaluation of adhesion is critical for the assessment of quality of a coating and its fitness for the service. The performance and reliability of the coating depend on the mechanical integrity of coating-substrate system. Adhesion is the most important property, because it determines the durability and longevity of the whole system. The used mechanical methods for evaluating adhesion have some limitations from the perspective of interfacial fracture mechanics and test pieces preparations. By properly selecting the testing method or a combination of methods, useful and reliable data could be obtained (BEKHTA and MARUTZKY 2007, CHEN *et al.* 2014). Ways to non-destructively assessment of the load capacity and the underlying resin influence could assist manufacturers in designing a structurally safe product. Parameters such dimensions of slices, density of board, decreased finest content, increased internal shear strength, and increased local bending strength and bending stiffness all impact panel resistance to a single point load (VIA 2013).

The testing method used to test formaldehyde emission in the furniture and flooring industries, the desiccator method, is the most basic method. This method is quick, inexpensive and simple to carry out (KIM *et al.* 2010). Results of the desiccator and chamber methods have showed good correlation (PARK *et al.* 2011). The formaldehyde emission measured by chamber method is directly proportional to the desiccator method (KIM *et al.* 2007).

The results of formaldehyde emission measurement are shown in Figure 4. Formaldehyde emission from the board with UF impregnated slices was taken as 100 %.

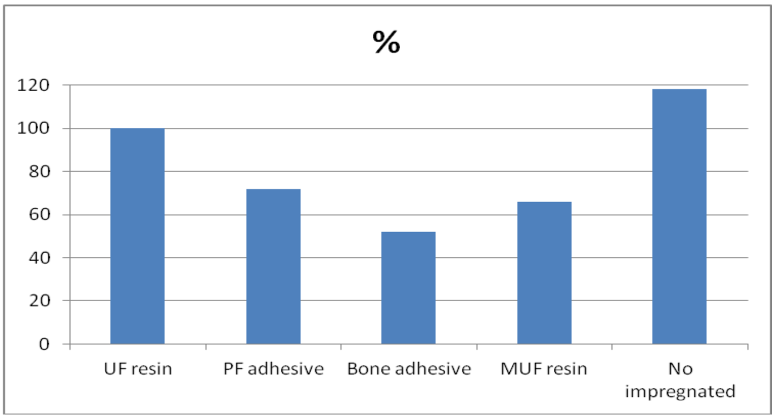


Fig. 4 Results of formaldehyde emission testing by the desiccator method.

The intensity of the formaldehyde release from bonded product is significantly influenced by the density profile of the board. Particleboard covered with wood slices has increased the density of surface layers which inhibits the formaldehyde emission from the inner layer. Although UF resin generally has the highest formaldehyde emission, appropriate surface covering significantly lowers its release from all tested types of boards.

PF, MUF and BG adhesive-treatment of slices reduced the formaldehyde emission determined by desiccator method. The best result showed BG as impregnating adhesive, the formaldehyde emission was reduced down to 50 % in a comparison with the UF sample. There is the mutual reaction between UF adhesive on wood particles and BG on impregnated slices, the reactivity of UF resin with glutin and creation of stronger methylene and peptide links was confirmed by FT-IR spectra, also lowered emissions of formaldehyde down to approx. 40 % were confirmed according to MATYAŠOVSKÝ *et al*. (2011).

Similarly, formaldehyde emissions were reduced down by almost 30 % for samples with MUF resin and PF adhesive. MUF and PF cross-linked resins are chemically more stable and do not release formaldehyde molecules from their structures. However, the PF adhesive considerably reduces decorative properties of the boards, so it couldn't be recommended for production of such the boards. Our results correspond exactly to the results of KIM *et al.* (2007). They measured emissions of formaldehyde and VOC from wood flooring bonded with different adhesive and reached the same ratio in amount of emitted formaldehyde.

All obtained results, formaldehyde emission and strength properties, encourage us to recommend application of BG for slices impregnation to produce the designed particleboard on the basis of UF adhesive. This type of the adhesive makes possible to increase environmental friendliness of boards significantly. Studies of DANNEMILLER *et al*. (2013) have shown that formaldehyde concentration is typically consistent throughout a home environment. That is why the modern woodworking industry should try to improve all bonded materials for furniture production. If BG is used for impregnation of wood slices, the particleboard with the face covered with slices impregnated by BG will be environmentally friendly and can be used even for production of panel elements for children's room furniture.

The highest formaldehyde emission was measured from the boards covered with untreated slices. These outer layers were not compact and formaldehyde was easy releasing from the inner section.

CONCLUSION

Obtained results confirm the possibility to apply pine wood slices for covering of particleboard and/or to replace the veneer for facing of wood based panels. Utilisation of waste wood – slices from wood branches – makes possible to obtain a composite material with high decorative properties. Using a polycondensation adhesive in manufacturing of particleboard covered with slices of different wood species impregnated with non-toxic natural adhesive can be applied for a wide range of wood products. Such wood composites have good mechanical, chemical and aesthetical properties.

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