Composite layered materials from soft hardwood species imitating oak structure

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Abstract. The study substantiates the feasibility of producing composite finishing materials from soft hardwood species that imitate the texture of oak. A method is proposed for manufacturing decorative finishing strips from rotary-cut veneer by alternating layers of veneers of different species and colors, which ensures a vivid and expressive structure resembling oak. It was established that the wave-like structure is achieved through veneer elements shaped like pyramids, placed within the glued veneer package. The degree of veneer layer curvature (waviness) is determined by the size, quantity, and spacing of these additional elements. Research was conducted to examine the relationship between the density of decorative strips and the parameters of the bonding regime, aiming to enable the production of higher-density products. A regression equation was derived to adequately describe the dependence of decorative strip density on bonding conditions, including pressing duration, veneer package thickness, and press plate temperature. Statistical processing and graphical dependencies were developed using computer programs such as PlanExp B-D13, Excel, and SigmaPlot. The study confirmed the possibility of producing decorative strips with increased density.

1 Introduction

The wood of soft deciduous species exhibits lower strength and decorative qualities compared to the wood of hard deciduous species. The growing scarcity of coniferous and hard deciduous species is currently being addressed by processing forests that have not yet reached maturity. The constant increase in raw wood prices exacerbates the situation, leading to an even greater shortage of technically valuable wood and a rise in raw material costs. Reducing the deficit of valuable wood can be achieved through the widespread utilization of soft deciduous wood in production and the creation of products with improved operational properties, as demonstrated in studies [1]. Research [2-4] indicates the possibility of enhancing operational characteristics after modifying such wood. To increase adhesive strength, it has been suggested to optimize the molar ratio of urea and formaldehyde [5]. Studies [6] confirm the feasibility of drying veneer using a conductive method with heated

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plates. The possibility of reducing moisture content by half through mechanical dewatering has been shown in research [7]. Additionally, heating veneer from both sides in heating drums ensures the drying of veneer with a thickness of 0.8 mm [8].

Decorative materials are manufactured from fast-growing softwood species according to the "fine-line" technology [9]. Due to their low density and high porosity, to prevent cracking, it has been noted that veneer with a moisture content not exceeding 8–10% should be used during veneering processes [10-12]. The imitation of aesthetically pleasing, pronounced wood textures is achieved through coloring and alternating layers of rotary-cut veneer of different colors during gluing. The implementation of a method for producing decorative panels from rotary-cut veneer of soft deciduous species (Patent No. 16540, Republic of Belarus) requires the use of complexly designed molds and water-based dyes for coloring the veneer. Therefore, a method has been proposed for manufacturing decorative panels with a wavy, pronounced structure from sheets of rotary-cut veneer made from soft deciduous species. Research has been conducted on the conditions for obtaining high-density decorative planks from soft deciduous wood.

2 Materials and methods

During the study, samples of pine wood with dimensions of 100 × 100 × 20 mm and used machine motor oil were utilized. The water absorption investigation was conducted using a standard methodology.

The water absorption of the wood (ΔW, %) was determined using the formula:

$$\Delta W = 100\ (m_2 - m_1) / m_1, \quad (1)$$

where m_2 is the mass of the sample after immersion in water (g), and m_1 is the mass of the sample before immersion in water (g).

The degree of wood impregnation (ΔP, %) was evaluated using the formula:

$$\Delta P = 100\ (p_2 - p_1) / p_1, \quad (2)$$

where p_2 is the mass of the impregnated sample (g), and p_1 is the mass of the dry sample (g).

Technical scales capable of measurements with an accuracy of up to 0.01 g were employed for weighing. To equalize initial moisture content, pine wood samples were conditioned for 24 hours at a temperature of 20±2°C in desiccators and weighed with a measurement error not exceeding 0.01 g.

3 Results and discussion

A method for manufacturing decorative strips is proposed, wherein additional upper and lower elements made of veneer in the form of pyramids are placed inside the glued package (Fig. 1).

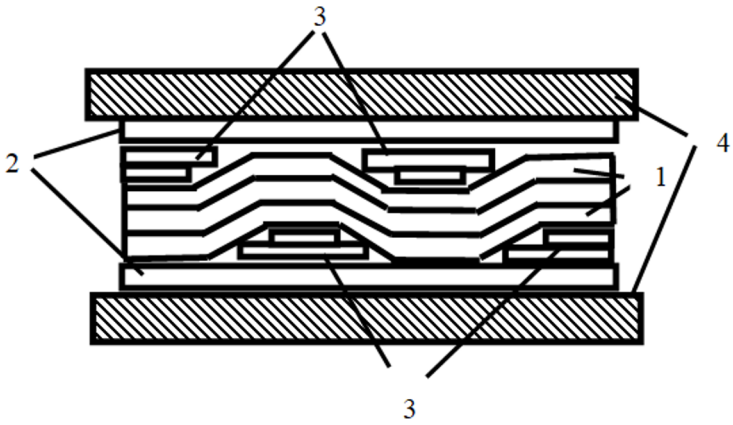

Fig. 1. Assembly diagram of the adhesive package: 1 and 2 - inner and outer layers, respectively; 3 - internal elements in the form of a pyramid; 4 - flat press plates.

Figure 2a illustrates a sample of birch and alder wood with a wavy structure. Figure 2b depicts the texture of oak wood.

a b

Fig. 2. Appearance of the sample: (a) made of birch and alder wood with a wavy structure; (b) made of oak.

A study was conducted to investigate the dependence of the density of decorative strips on the parameters of the bonding regime. The variable factors, the planning matrix, and the experimental results are presented in Table 1 and Table 2, respectively.

Table 1. Variable factors and their levels of variation.

Factors	Designation		The range of variation	Variation levels		
	in kind	in encoded form		lower	main	upper
				-1	0	1
Pressing time, min	τ	X_1	1	6	7	8
Veneer package thickness, mm	Sп	X_2	1,4	10,5	11,9	13,3
Temperature, ^{0}C	T	X_3	5	110	115	120

Table 2. Planning matrix and research results.

N	Code view			Natural appearance			Density, ρ, kg/m^3
	X_1	X_2	X_3	τ, min	Sп, mm	T, ^{O}C	
1	-	-	-	6	10.5	110	678
2	+	-	-	8	10.5	110	724
3	-	+	-	6	13.3	110	678
4	+	+	-	8	13.3	110	758
5	-	-	+	6	10.5	120	589.5
6	+	-	+	8	10.5	120	698
7	-	+	+	6	13.3	120	740
8	+	+	+	8	13.3	120	832
9	-	0	0	6	11.9	115	707
10	+	0	0	8	11.9	115	725
11	0	-	0	7	10.5	115	726.7
12	0	+	0	7	13.3	115	800
13	0	0	-	7	11.9	110	769
14	0	0	+	7	11.9	120	769.7
15	0	0	0	7	11.9	115	726

The results of the statistical analysis of the dependence of the density of decorative strips on the parameters of the bonding regime are presented in Table 3.

Table 3. The significance of the coefficients and the adequacy of the mathematical model of the dependence of the density of decorative strips on the parameters of the bonding mode.

Statistical indicator	Meaning
Variance of reproducibility in parallel experiments	0.25
Number of degrees of freedom	10
Number of degrees of freedom (t_{table})	2.23
Calculated value of Student's criterion (t_i)	4.25
Insignificant coefficient of the model b_0 b_1, b_2, b_3 b_{11}, b_{22}, b_{33} b_{12}, b_{13}, b_{23}	 778,44 34.45; 39.18; 2.22 -45.33; -19.92; -13.32 2.2; 9.3; 31.3
Insignificant coefficient of the model (t_I менее $t_{табл.}$)	b_3 (2.22); b_{12} (2.19)
Adequacy variance (S^2_{ad})	0.56
The number of degrees of freedom with significant coefficients	1
Tabular value of the Fischer criterion ($F_{табл.}$)	4.96
Calculated value of the Fischer criterion (F)	546
Adequacy of the model (F less than $F_{табл.}$)	adequate

The regression model describing the dependence of decorative slat density on bonding process parameters (pressing duration, veneer packet thickness, press plate temperature) is represented by the following regression equation:

$$Y = 778.44 + 34.45X_1 + 39.18X_2 + 2.22X_3 - 45.33X_1^2 - \\ - 16.92X_2^2 - 13.32X_3^2 + 2.19X_1X_2 + 9.31X_1X_3 + 31.31X_2X_3$$

The dependence of the density of decorative slats on the parameters of the gluing regime is illustrated in Fig. 3. Within the investigated range, the most significant influence on the density of decorative slats is exerted by the packet thickness and pressing temperature. According to the equation and nomograms (Fig. 3), increasing the packet thickness and pressing temperature leads to a maximum density value of 830 kg/m³ within the variable factors. This maximum is achieved at the following gluing regime parameters: gluing duration - 8 minutes, veneer packet thickness - 13.5 mm, and press plate temperature of 120°C.

For producing decorative slats using this method, technology and equipment similar to LVL timber production can be employed. The authors' proposed method for manufacturing composite finishing materials proves economically advantageous, as the cost of 1 m³ of oak raw material is 70,000₽ compared to 5,000₽ for 1 m³ of birch raw material.

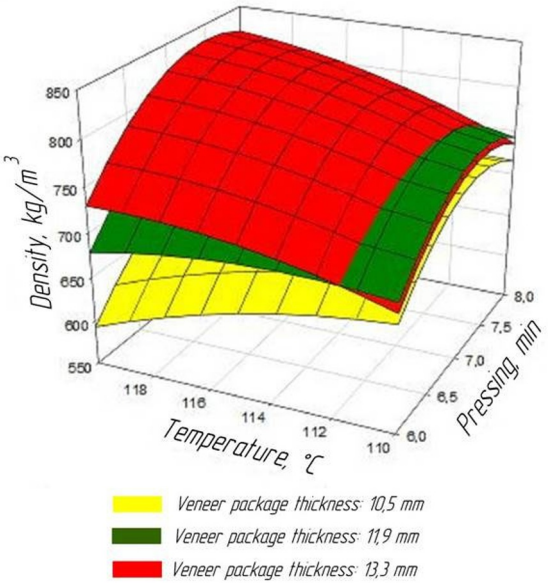

Fig. 3. Density dependence on veneer package thickness, pressing duration and press plate temperature.

4 Conclusion

The method developed by the authors for manufacturing composite finishing materials has been proposed, which enables the imitation of oak texture by alternating peeled veneer of different species and colors. This method serves as an import substitution solution, as it facilitates the production of finishing materials from soft deciduous wood species that mimic the texture of valuable hardwood species.

The waviness of the structure is achieved through veneer elements shaped like pyramids, which are placed within the glued veneer package. The degree of veneer layer curvature (waviness) is determined by the dimensions and quantity of additional elements as well as the spacing between them.

The study was conducted to investigate the dependence of decorative plank density on bonding regime parameters. A regression equation was derived, accurately describing the relationship between decorative plank density and bonding conditions, including pressing duration, veneer package thickness, and press plate temperature. The possibility of producing decorative planks with increased density was established.

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