Conditions for Obtaining Finishing Materials from Wood with a Relief Pattern on the Front Surface

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Abstract. In the article the questions devoted to the study of the process of bonding a new type decorative material embossed plywood, substantiated the possibility of improve the appearance by creating a volumetric pattern on its front surface when using molds with different thickness in cross section. Use as raw materials little used at the present time of wood of soft deciduous species will enhance the resource base of woodworking and building industry. The causes of occurrence of cracks when bonding the embossed plywood. Proved that the highest tensile stresses occur at the contact edges with the wood. Invited to sluglett edges of the mold to reduce tensile stresses. On the basis of theoretical research of processes of formation of deformations and stress relief when gluing plywood wood whose texture-defined conditions, ensuring its integrity, the formation of three-dimensional pattern on the front surface of the finishing material.

1. Introduction
Development strategy for the forest complex of the Russian Federation for the period until 2020 is aimed at the development of capacities for deep mechanical, chemical and energy wood processing [1]. Stocks of wood of soft deciduous breeds in Russia amount to 16.5 billion m³. Annual allowable cut of this wood is over 200 million m³ and annual allowable cut is used only by 15%. [2, 3]. Therefore, the involvement in processing of wood of soft hardwoods is relevant and meaningful. The homogeneity of the texture of the soft wood of deciduous trees [4] complicates its use as finishing materials. The aim of the research study the possibility of improving the appearance of finishing materials from wood with uniform texture. Scientific novelty have discussed in the article questions of modeling of process of formation of relief. Theoretically substantiated conditions of creating relief on the front surface of the new finishing material without breaking. The practical significance of the research is to study the possibility of improving the appearance of finishing materials with a homogeneous texture to the wide use of wood of soft hardwoods in the timber and construction industry.

2. Experimental

2.1 Materials and methods
The studied material was the wood of soft hardwoods. Method of research is the analysis of physical-mechanical and performance of this wood.

3. The results
For bonding of new material - embossed plywood is used rees-form with varying thickness in the cross section [5]. In some cases, when bonding occurs the destruction of the surface of the front sheet. For the theoretical study developed a mathematical model of the stress-strain state of layered material in the pressing process [6]. The calculations were performed with different widths of the cavities of the mold, various radiiuses of a rounding off its edges, and different forces of compression. In Figure 1 shows a diagram of a deformable system. In Figure 2 shows the contact model of the package and the mold in the area of scrutiny.

![Figure 1. Diagram of the deformable system](image)

![Figure 2. Contact Model of the package and the mold in the area of scrutiny](image)

Scheme of deformation of the plywood mold with different thickness in cross section (Fig. 3). Analyze the stress in the bonded package to ensure the integrity of the surface layer. Move the layers into the mold determines the height of the relief pattern. Under pressure from the upper plate wood on the 3 phase is compressed (Figure 3).

![Figure 3. Scheme of deformation of plywood in the mold and with a sharp edge](image)

At site 2 under pressure the layers of wood are moved into the mold 2. Due to the elongation of the surface layer there arise normal stresses $\sigma$. Moving layers of wood inside the cavity between the projections of the mold 2 in wood also occur shear stresses $\tau$. If the maximum stress exceeds the tensile strength of wood in tension, it is the destruction of the front surface of the embossed plywood.
Reduction of normal and shear stresses is achieved by rounding the edges (Fig. 5B). Elastic properties of veneer are given in tab. 2, where $E_x$, $E_y$ – the moduli of elasticity, $G_{xy}$ – the shear modulus, $\mu_{xx}$, $\mu_{yy}$ – the Poisson's ratios. In the analysis of the object in a dynamic setting are responsive to the changing design scheme design associated with the displacements [7]. In accordance with the d'alembert principle consider a system of equations of dynamic equilibrium for the finite element model of the object with remote connections in a.

$$
\begin{bmatrix}
M & Z
\end{bmatrix}
\ddot{Z} + 
\begin{bmatrix}
C & Z
\end{bmatrix}
\dot{Z} + 
R \ Z = F ,
$$

(1)

where $M$, $Z$, $C$, $R$ – the mass matrix, the damping matrix and the vector of nodal reactions that depend on the generalized nodal displacements.

Take zero initial conditions $Z(0) = 0$; $\dot{Z}(0) = 0$. We consider the solution of this initial problem on the basis of the preconditions of a method Newmark on the permanent values of the accelerations at each step of integration. To implement this approach to the solution of nonlinear problems, building the finite element model, taking into account the geometry of the system in a deformed state. The vector of nodal reactions for the finite element $e$ can be written as follows [8-13]:

$$
R_e = \int_{V_e} [B_e]^T S_e \ dV ,
$$

(2)

where matrix $B_e$ associating the virtual increment of the vector of generalized deformations $\chi_e$ vector and increments its virtual nodal displacements $Z_e$:

$$
\delta \chi_e = B_e \delta Z_e ;
$$

(3)

$S_e$, $V_e$ – vector of generalized strains and the volume of the final item.

We introduce the tangent stiffness matrix $K_{e\tau}$ of the final item.

$$
\tilde{d} \ R_e = K_{e\tau} \tilde{d} Z_e ,
$$

(4)

where $\tilde{d}$ used to denote differential characteristics of the stress-strain state of the object.

Get the dependency for finding matrix $K_{e\tau}$ in the deformed state of the system. From equality (2) will have

$$
\int_{V_e} \tilde{d} [B_e]^T S_e \ dV + \int_{V_e} [B_e]^T \tilde{d} S_e \ dV .
$$

The first integral in the expression (5) is usually represented in the form [8]

$$
\int_{V_e} \tilde{d} B_e^T S_e \ dV = K_{e\tau} \tilde{d} Z_e ,
$$

(6)

where $K_{e\tau}$ – the initial stress matrix or geometric matrix. Since we consider the rejected state, the second integral can be taken $B_e = B_{eo}$, where $B_{eo}$ – matrix defining infinitesimal deformations. Then you can record

$$
\int_{V_e} B_e^T \tilde{d} S_e \ dV = K_{eo} \tilde{d} Z_e ,
$$

(7)

where $K_{eo}$ – built for this condition the stiffness matrix of the infinitesimal strain finite element taking into account physically nonlinear material:
\[ K_{eo} = \int_{V} B_{eo}^T D_{et} B_{eo} \, dV ; \]
\[ D_{et} \quad \text{tangent elasticity matrix.} \]

Considering the relations (4)-(8), we have
\[ K_{et} = K_{eo} + K_{et} . \]  

On the basis of matrices \( K_{et} \) can be formed by a corresponding tangent matrix \( K_r \) for the finite element model of the whole system. We assume that at each step \( \Delta t \) numerical integration is solved by linear problem. For the initial time \( t_{n-1} \), some step \( n \) discusses the mass matrix \( M(t_{n-1}) \), the damping matrix \( C(t_{n-1}) \) and tangent stiffness matrix \( K_r(t_{n-1}) \). Vector \( RZ \) for time \( t_n \) he end of the n-th step of integration can be defined approximately by:
\[ RZ_n = \sum_{k=1}^{n} K_r(t_{k-1}) \Delta Z_{k-1} , \]  

where \( \Delta Z_k \) – the vector of displacement increments at the k-th step:
\[ \Delta Z_k = Z(t_k) - Z(t_{k-1}) . \]  

Given the dependence of (10), we write the equation (1) for time \( t_n \):
\[ M(t_{n-1}) \ddot{Z}(t_n) + C(t_{n-1}) \dot{Z}(t_n) + \int_{k=1}^{n} K_r(t_{k-1}) \Delta Z_k = F . \]  

In accordance with the approach of the method Newmark have
\[ \dot{Z}(t_n) = a_1 Z(t_n) - Z(t_{n-1}) - \ddot{Z}(t_{n-1}) ; \]
\[ \ddot{Z}(t_n) = a_0 Z(t_n) - Z(t_{n-1}) - a_2 \dot{Z}(t_{n-1}) - \ddot{Z}(t_{n-1}) , \]  

where the integration parameters \( a_0 = \frac{4}{\Delta t^2} ; \ a_1 = \frac{2}{\Delta t} ; \ a_2 = \frac{4}{\Delta t} . \)  

Substituting the equality (13), (14) in equation (12), we obtain the system of equations:
\[ \begin{bmatrix} K' \end{bmatrix} \Delta Z_n = R' , \]  

where
\[ \begin{bmatrix} K' \end{bmatrix} = a_0 M(t_{n-1}) + a_1 C(t_{n-1}) + K_r(t_{n-1}) ; \]
\[ R' = F - \int_{k=1}^{n-1} K_r(t_{k-1}) \Delta Z_k + a_0 M(t_{n-1}) + a_1 C(t_{n-1}) + a_2 M(t_{n-1}) + C(t_{n-1}) \dot{Z}(t_{n-1}) + M(t_{n-1}) \ddot{Z}(t_{n-1}) . \]  

After step n, the displacement vector is defined as
\[ Z(t_n) = Z(t_{n-1}) + \Delta Z_n , \]
a vector of the internal forces expression
\[ S(t_n) = S(t_{n-1}) + \Delta S_n , \]
where \( \Delta S_n \) – the vector of increments of effort are calculated from vector \( \Delta Z_n \) and tangent matrices of elasticity finite elements. The vector \( S(0) \) determined in the calculation of the original design, and the product \( M(0) \hat{Z}(0) \) – from the expression,

\[
\begin{bmatrix}
M & 0
\end{bmatrix}
\hat{Z}(0) = F .
\]

Research of process of deformation of the layered material was carried out by analyzing nine estimated models in this range the radii of curvature (R=0 mm; R=1 mm; R=2mm) and the distance (l=20mm l=40mm l=80mm). The characteristics of the plate elements of the materials are presented in table 1.

| Table 1 - Characteristics of plate elements |
|---------------------------------------------|
| \( E_x \) , MПа | \( E_y \) MПа | \( G_{xy} \) , H/см² | \( \mu_{xy} \) | \( \mu_{yx} \) |
| 9,14 | 0,01 | 3,57 | 0,4 | 0,00007 |
| | | | | 35 |

The modulus of elasticity E and Poisson's ratio is chosen according to [2]. The moments of inertia of torsion, bending and the cross-sectional area of the rod \( (J_x, J_y, J_z, A) \) considered in local coordinate axes; \( E_x, E_y, G_{xy}, \mu_{xy}, \mu_{yx}, t \) – the moduli of elasticity, shear modulus, Poisson's ratios and the thickness of the plate. The tensile strength of the samples of birch peeled veneer along the grain of the wood was taken equal to 130 MPa, tensile strength in the tangential stress directed across the grain, – 4 MPa [14]. The conditions that ensure the integrity of the surface layer are given in table 2.

| Table 2 - terms of gluing embossed plywood |
|-------------------------------------------|
| characteristic | Options |
|-----------------|---------|
| The span between the projections, m | 1 | 2 | 3 |
| | 0,02 | 0,02 | 0,04 |
| The edge fillet radius, m | | | |
| | 0 | 0,00 | 0,002 |
| | | 1 |
| Pressure, MPa | 1,5 | 2 | 1,5–2 |

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4. Conclusion.

Literature he dependences of the duration of glueing relief plywood from its thickness and the temperature of the press plates [15]. Based on the study of the penetration of the adhesive into the wood while glueing relief plywood [16] and study of layer-by-layer strength relief of plywood [17] substantiated quality control methods of the relief on the front surface and assess the quality of gluing plywood relief [18]. During long-term operation of the relief plywood retains its properties [19].

1. Proven ability to improve the appearance of finishing materials with a homogeneous structure, which allows more widely to apply wood of soft hardwoods in the timber and construction industry.

2. Developed the conditions for obtaining relief on the front surface of the new finishing material without destroying its integrity.
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