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CONTRIBUTION TO THE METHOD FOR DETERMINATION OF DEGREE OF COMPACTION OF WOOD PARTICLES IN COMPOSITE BOARDS

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ABSTRACT

A mathematical model (algorithm) and a nomogram for determination of the compression ratio in flat-pressed composites on the basis of urea-formaldehyde resin as a binding agent and addition of paraffin have been presented in the investigation.

By means of an algorithm (KD), the compression ratio of the wood mat during its piezothermal treatment is taken into account.

As input data, following parameters are included in the algorithm for KD: bulk densities of the input wood raw material and the composite board; the specific weights of the paraffin and the binding agent; the moisture content of the composite board; the percentage of resin and paraffin; the volumetric swelling of wood.

Key words: compression ratio, composite board, wood component, wood mat.

INTRODUCTION

The composite particleboard (CPB) is a wood-polymer product technologically formed by means of piezothermal treatment of a multilayer mat of glued wood particles. As a result of the applied technological modes of treatment, a board-type composite product with preset thickness and density, which in terms of its physical and mechanical properties shall meet the requirements of the respective standardization norms, is obtained. For the purpose, in the case of the flat-pressing method, modes of piezothermal treatment of the wood mat, which to a highest degree ensure the necessary compaction of the wood particles in the composite, are applied.

To determine the degree of compaction of the particles in the wood mat or in the composite board, various methods are used for the time being, but not well theoretically founded and with low accuracy.

That is why, the goal of the present investigation is to develop an algorithm with relatively high accuracy and a respective nomogram (diagram) for quick and reliable determination of the degree of compaction of the wood particles in the flat-pressed composites.

1. THEORETICAL PREREQUISITES

The structure formation of the flat-pressed CPBs takes place during the technological stage of piezothermal treatment of wood mats, preliminarily formed layer by layer, of glued (most often with urea-formaldehyde binder) wood particles. This technological operation is performed by means of the use of hot-platen presses, during which compaction of the wood particle mat takes place across its cross-section under the influence of external pressure (Fig. 1).

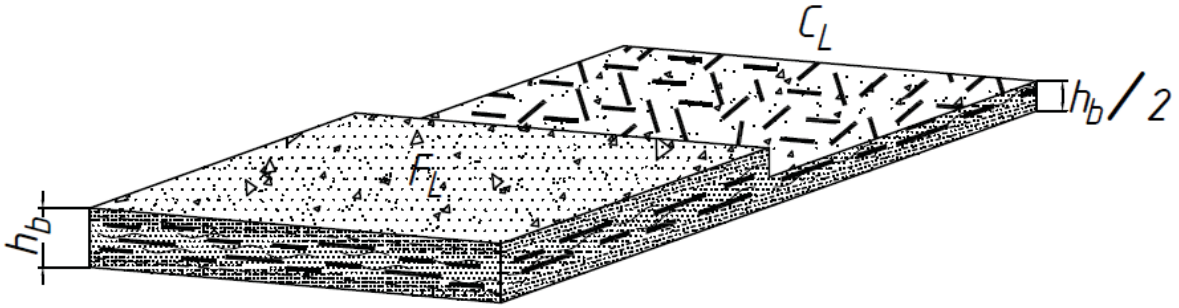

Figure 1: Macrostructure of cross section of the WPB

As a result of the densification of the wood particle mat and partially of the particles themselves, the desired thickness (δ_b), on the one hand, and, on the other hand, the technologically set bulk density (ρ_b) of the composite board are achieved. Therefore, the compaction is mostly at the expense of reduction of the percentage of the macroporous space between the wood particles (C_b) and of the percentage of the cell lumina in the wood substance (C_v), i.e.

$$(C_b + C_v) \rightarrow min \qquad \textbf{(1)}$$

According to Kollmann 1975, the relative volume of the cell lumina in wood is

$$C_v = \left(1 - \frac{\rho_w^0}{\rho_{ws}}\right) \cdot 100 = \left(1 - \frac{\rho_w^0}{1500}\right) \cdot 100 \text{ or } C_v = 100 - 0.0667\rho_w^0, \% \qquad \textbf{(2)}$$

where ρ_w^0 and ρ_{ws} are respectively the densities of the wood raw material and the wood substance in oven-dry state, kg.m^{-3}.

As a criterion for assessment of the degree of compaction of wood particles in the boards, the coefficient of compression (K_C) or of densification (K_D) was adopted (Yosifov 1989). In the present paper, the designation "coefficient of densification" is used below. For the numerical determination of K_D, Kollmann, Maloney, Yosifov, Liiri, Stark and extr. propose various modifications of the algorithm, but, in our opinion, most appropriate is the following one:

$$K_D = \frac{V_m^0}{V_b - V_a^0} = \frac{\rho_b}{\rho_w^0} \cdot G = \frac{\rho_b}{\rho_w^0} \cdot \left(\frac{1}{AB - C_h}\right), \qquad \textbf{(3)}$$

where $V_m^0 = 0.98 - 0.000667\ \rho_w^0$ – volume of the solid substance, kg.m^{-3};

- V_b, V_a^0 are respectively the current volumes of the composite board and binder (adhesive), kg.m^{-3},

where the coefficients A, B, C_h and G are respectively the values of the technological factors.

The determination of the values of the coefficients is performed by means of the mathematical expressions:

$$A = (100 + U_b) \cdot (100 + P_a^0) \cdot 10^{-4}, \qquad \textbf{(4)}$$

$$B = (100 - \chi_b) \cdot 10^{-2}, \qquad \textbf{(5)}$$

$$C_h = \left(\frac{\rho_b}{\rho_a}\right) \cdot \left(\frac{P_a}{100}\right), \qquad \textbf{(6)}$$

where U_b is the average moisture content of the composite board, (8 ± 2%);

- P_a – the average adhesive (hardened resin) content, %;

- χ_b – the maximum densification of the wood substrate at the wood fibre saturation point ($U = 28\%$);

- ρ_a – the density of the hardened resin, for urea-formaldehyde resin (UFR) 1280 kg.m^{-3}.

The maximum densification of the wood substrate (χ_w) may be determined by the expression (Enchev 1984):

$$\chi_w = 0.28\beta_v \cdot U_w \qquad (7)$$

where β_v is the volumetric swelling of the wood substance, %.

For example, t_c values of $U_w = U_b = 8\%$ for wood species At $U_w = U_b = 8\%$ (8) and $\chi_b = 0.72\,C_v$ beach and poplar it is obtain values for χ_w respectively 39,6% and 50,4%.

The value of the coefficient C_h is within 0.05 to 0.06 and may be adopted in the most general case as 0.055.

2. METHOD OF WORK

For the graphic determination of the value of the coefficient for the degree of compaction of the wood particles in the composite boards, K_D, the nomogram presented in Fig. 2 was developed. The use of the nomogram to determine K_D is illustrated with several examples for CPBs made of various raw materials, i.e. with various values of averaged densities as follows: broad-leaved hardwood – ρ_w^0 = 680 kg.m^{-3}; heavy coniferous - ρ_w^0 = 560 kg.m^{-3}; broad-leaved softwood - ρ_w^0 = 420 kg.m^{-3}.

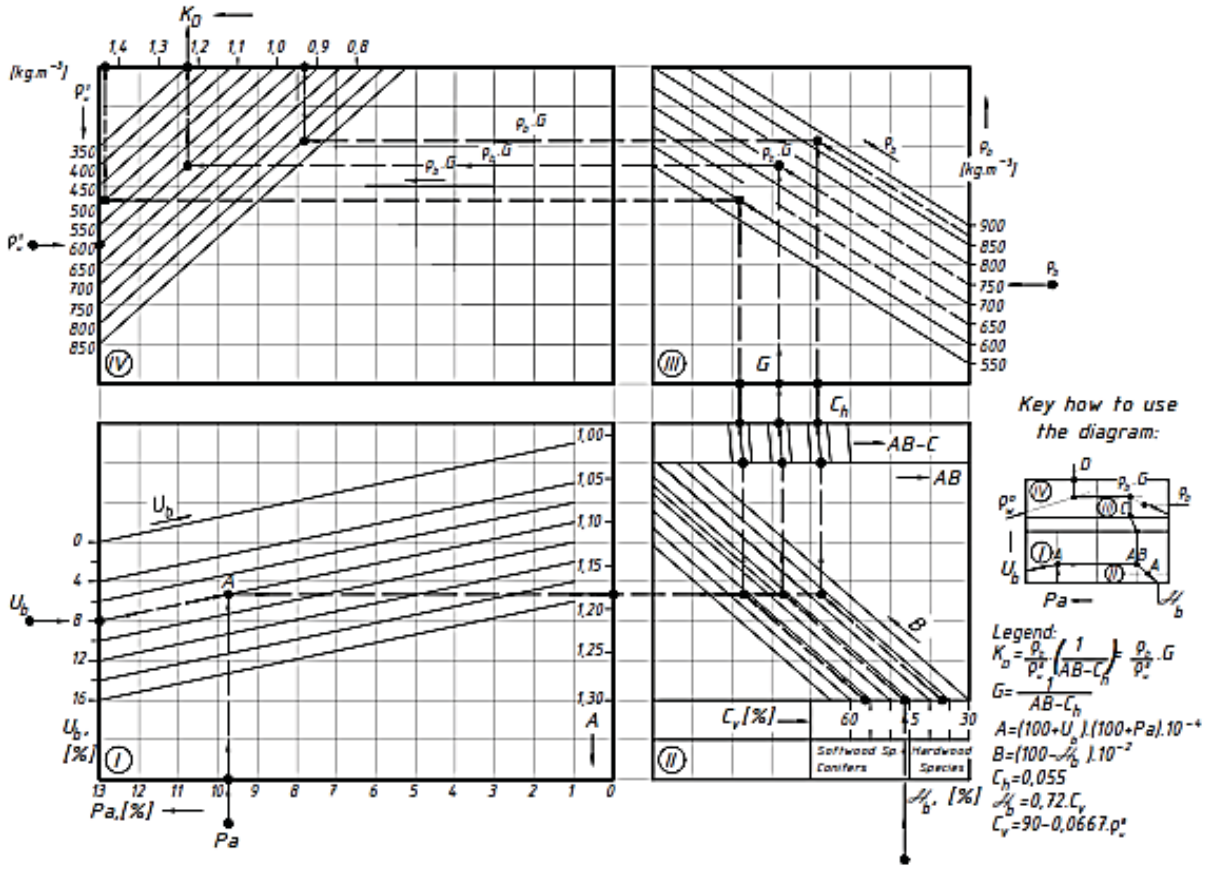

Figure 2: Diagram for determination of Densification ratio K_D

The nomogram in Fig. 2 is composed of four parts (quadrants). In quadrant I, on the basis of the percentages of water content U_b and binder P_a in the composite board, the

value of the coefficient A is determined. In quadrant II, depending on the type of the wood raw material used, the values of the coefficients χ_b and B, as well as the comprehensive coefficient $G = \frac{1}{(AB - C_h)}$ are determined. In the 3rd quadrant, with a view to taking into account the macroporous spaces C_p and C_v, the adjusted value of the composite density, ρ_b, is determined. In the 4th quadrant, on the basis of the values for ρ_b and ρ_w^0, the degree of compaction of the wood particles in the composite board, K_D, is determined.

At the same time, for faster and easy determination of K_D when working with the nomogram, the respective key included in the explanatory part of the figure was developed.

3. RESULTS AND ANALYSES

The developed algorithm and nomogram for determination of the degree of compaction of the wood particles in the composite may be used with success to prognosticate and assess the physical and mechanical characteristic of the composite particleboards. It has been established (Kollmann 1968, Maloney 1976, Yosifov 1989 et Liiri) that high physical and mechanical properties of CPBs may be only achieved in case of provision of good adhesion between the particles, i.e. at high degree of compaction ρ_b » ρ_w^0 at lower limiting condition $\rho_b \geq 1.2\ \rho_w^0$.

From Fig. 2 is seen that the type of the wood raw material exercises essential influence on the density of CPBs and, hence, on the value of K_D. The capacity of the wood to be compacted, expressed with the indicator $\chi_b = \frac{\varphi}{\rho_w^0}$, has been graded as: hard hardwood with χ_b = 38 ± 3%; heavy softwood with χ_b = 45 ± 3%; soft hardwood with χ_b = 52 ± 3%. This also predetermines the differences in the degree of compaction of the particles of the various tree species at given density of the boards, ρ_b.

The degree of compaction of the wood particles in the composite also depends to a great extent on the total macroporous space between the particles in the middle layer, C_b, and the percentage of the cell lumina, C_v. At the same time, $(C_b + C_v) = \varphi(\rho_w^0 + \rho_b)$. In the practice, it is assumed $C_b < 2\%$ of the current volume of the solid substance, V_m^0. The value of C_v depends on the density of the tree species and is determined by the expression $C_v = 100 - 0.0667 \cdot \rho_w^0$.

CONCLUSION

The proposed formula and nomogram for determination of the degree of compaction of the wood particles in the composite boards have been developed on the basis of profound theoretical analysis and are in conformity with the world practice in this field.

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