Improving the performance characteristics of glued materials based on thermally modified veneer

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Abstract. The performance characteristics of glued materials based on thermo-modified veneer depend on the heat treatment mode. The choice of a mode that does not lead to a decrease in the strength of plywood allows reducing water absorption and swelling by a value from 20.4 to 33.5%. Plywood based on thermo-modified veneer acquires higher strength and water resistance, which significantly expands the range of application of laminated wood based on urea-formaldehyde resins.

1. Introduction

The first studies in the field of high-temperature wood processing were conducted in the 30s of the last century in Germany Stamm A J. and other scientists. Further development of technologies for thermal modification of wood received in the United States and several European countries. A large amount of research in this area was conducted by the VTT Center in Finland [1]. A review of studies on the thermal modification of wood by Russian scientists is given in [2].

A common element of all technologies of thermal modification is the heating of wood in the temperature range of 150-230 °C in environments: water vapor, inert gas, flue gas or liquid.

Researchers [3-6] note a positive change in the physico-mechanical and decorative properties of the material. Treated wood acquires resistance to the effects of wood-destroying fungi and insect larvae, has low moisture absorption, dimensional stability of products, high thermal insulation characteristics and aesthetics. After heat treatment, the color changes, the texture is more clearly and effectively detected. Wood of low-value species (birch, aspen, etc.) acquires a resemblance to the wood of valuable hardwood.

But in the process of thermal modification, exposure to high temperatures leads to a decrease in a number of mechanical and operational properties of wood, which limits its scope. So Kollmann F. observed violations in the microstructure of spruce wood heated to 150 °C. It has been found that a reduction in the volume of wood occurs due to the loss of a substance [7]. In [8], it was found that heating wood in the presence of moisture at temperatures of 180-200 °C leads to a significant decrease in resistance to shock loads, modulus of elasticity, tensile strength at stretching and compressive strength. Researchers [9] found that the tensile strength at break decreases as the temperature of heat treatment decreases, whereas the temperature affects the modulus of elasticity only slightly. In [10], the relationship between loss of strength and darkening of wood when exposed to high temperatures during processing is shown.
A review of the work of researchers shows the different directions of changes in the properties of thermally modified wood. Strength properties are reduced, but the characteristics of the material are increased, allowing it to be operated in conditions of high humidity of the environment.

2. Experimental part and discussion
At the Department of Woodworking Technology SibGU them. Mf Reshetnev for the experiment on thermal modification of the veneer was mounted and tested the experimental setup. Taking into account that a birch veneer with a thickness of 2.0 mm was chosen for the study, the temperature range for heat treatment was adopted from 160 to 200 °C. The duration of the heat treatment process was 2 and 4 hours. Thermal modification consisted of the following stages: heating-high-temperature drying, heat treatment, cooling-conditioning.

For research was used plan full factor experiment. The required accuracy was ensured by a tenfold duplication of measurements.

After the termination of the thermal modification process, the veneer was packed in batches in batches and kept for 24 hours under a small load to level out possible stresses.

The plywood samples were pressed on the basis of thermally modified birch veneer using the standard method. A preliminary experiment showed that the pressing mode of plywood based on thermally modified veneer using urea-formaldehyde resin does not require additional adjustments and corresponds to the pressing mode of general-purpose plywood: specific pressure \( P = 1.6 \) MPa; temperature \( T = 120 \) °C; specific pressing time \( \tau = 0.7 \) min/mm.

The size of the pressing for all samples of plywood corresponded to that adopted for birch plywood and ranged from 9.8 to 10.6 %.

Testing of the physicomechanical characteristics of plywood samples based on thermally modified veneer was made after exposure for 48 hours. The state-of-the-art testing machine UTS-30 was used for the test.

A summary report of the results of static bending and shearing strength on the adhesive layer is presented in tables 1-2.

For a comparative assessment of the strength characteristics of plywood based on modified birch veneer, samples of plywood were made from the original birch veneer. Birch veneer was selected from the same batch of veneer that was used for processing. The results of testing the physico-mechanical properties of plywood based on the original veneer are presented in table 3.

| Processing temperature / processing time | Strength at static bending, MPa |
|-----------------------------------------|---------------------------------|
|                                        | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
| 160/2                                   | 74.22    | 72.75    | 69.8     | 73.9     | 72.96    |
| 160/4                                   | 75.77    | 78.058   | 76.42    | 77.03    | 76.12    |
| 200/2                                   | 75.86    | 78.6     | 81.36    | 77.62    | 79.33    |
| 200/4                                   | 57.12    | 53.609   | 65.83    | 56.7     | 59.36    |

| Processing temperature / processing time | Strength at spallation, MPa |
|-----------------------------------------|-----------------------------|
|                                        | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
| 160/2                                   | 1.761    | 1.972    | 1.821    | 1.798    | 1.902    |
| 160/4                                   | 2.309    | 2.401    | 2.362    | 2.296    | 2.106    |
| 200/2                                   | 1.994    | 2.257    | 2.012    | 1.990    | 2.106    |
| 200/4                                   | 1.584    | 1.163    | 1.265    | 1.369    | 1.401    |
Table 3. The results of the testimony of ordinary plywood.

| Name of the indicator                              | Value of the indicator |
|---------------------------------------------------|------------------------|
| Strength at static bending, MPa                   | 58,2                   |
| Strength of splitting on the adhesive layer, MPa   | 1,75                   |
| Water absorption, %                               | 65,6                   |
| Swelling, %                                       | 18,2                   |

From the presented data it is clear that all the samples of plywood, made on the basis of thermally modified veneer, have high strength and meet the requirements of the standard. Samples of plywood made of modified veneer with the following parameters have the highest durability at static bending: T = 160 °C, τ = 4 h and T = 200 °C, τ = 2 h.

A comparative analysis of the strength of plywood samples shows that the greatest increase in strength during static bending is observed for samples of plywood made of modified veneer at T = 200 °C, τ = 2 h. The average tensile strength is 78,6 MPa. The smallest strength value in static bending for samples of plywood made of modified veneer at T = 200 °C, τ = 4 h. The average tensile strength is 58,9 MPa. In this case, the strength of the samples is close to the strength of the samples based on the original birch veneer. Such changes in strength properties are probably associated with changes in the properties of wood in the process of thermal modification. As a result of thermal modification, the veneer surface becomes more dense and solid, the influence of irregularities and roughness of the surfaces being joined on the bonding strength is reduced, and the cellular structure of the wood changes.

For the indicator of the strength when splitting on the adhesive layer, a dependence similar to the ultimate strength in static bending is observed. Samples of plywood made of modified veneer at T = 160 °C, τ = 4 h and T = 200 °C, τ = 2 h have the highest rates of cleavage on the adhesive layer for the samples of plywood made of veneer modified at T = 200 °C, τ = 2 h. The average shear strength at spallation is 2,1 MPa, with the required standard 1,5 MPa. The smallest splitting strength of the adhesive layer in samples of plywood made of modified veneer at T = 200 °C, τ = 4 h. The average tensile strength is 1,4 MPa, which is lower than the standard requirements (1,5 MPa). This feature can be explained by the formation of a more dense layer on the veneer surface, which prevents the veneer surface from being wetted by glue, an increase in the so-called inactivation of the surface layer of wood, a decrease in roughness and, therefore, a decrease in adhesive contact between glue and wood. This assumption confirms the type of destruction of the sample of plywood under test. If in the first three types of samples the mixed type of failure was most often observed, then in the case of testing plywood based on veneer sheet modified at maximum heat treatment parameters, the type of separation was observed to be cohesive in the adhesive layer.

The obtained plywood samples were also tested for water absorption and swelling. In many works on thermal modification of wood, it is noted that thermal modification allows reducing the water absorption values of wood several times. The test results are presented in table 4.

Table 4. The results of tests for water absorption and swelling.

| Processing temperature / processing time | Water absorption in 24 hours, % | Swelling in 24 hours, % |
|----------------------------------------|--------------------------------|------------------------|
| 160/2                                  | 62,06                          | 16,6                   |
| 160/4                                  | 52,22                          | 12,1                   |
| 200/2                                  | 51,32                          | 10,77                  |
| 200/4                                  | 48,09                          | 10,3                   |

The maximum value of water absorption and swelling is observed for samples made of modified veneer at T = 160 °C and τ = 2 h – 62,06 % and 16,6 %, respectively. The minimum value for samples made of modified veneer at T = 200 °C and τ = 4 h is 48,09 % and 10,3 %, respectively. The water
absorption of thermally modified samples is reduced by 5.4 to 33.5% compared with general-purpose plywood. Swelling is reduced by a value of from 8.8 to 43.4%. Thus, plywood based on thermally modified veneer acquires higher water resistance, which significantly expands the scope of application of urea-formaldehyde-based plywood.

High-temperature processing of wood is one of the ways to improve the physicomechanical properties of general purpose plywood through the use of thermally modified veneer for bonding.

The implementation of the PFE allowed to establish that the strength of plywood depends on the heat treatment mode of the veneer. The highest indicators of strength in static bending (78.6 MPa) and when shearing over the adhesive layer (2.1 MPa) have samples of plywood made of modified veneer with the following parameters: T = 160 °C and τ = 4 h; T = 200 °C and τ = 2 h.

Heat treatment of veneer, not leading to a decrease in the strength of plywood, reduces the water absorption and swelling by an amount from 20.4 to 33.5%.

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