Target-specific change in the liquid permeability of wood

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Abstract. The article presents the findings of the study on the possibility of using the wound reaction of wood for controlled formation of the material's texture. It was determined that the wound reaction of the living wood cells is an effective mechanism for artificial decrease in the natural permeability of birch. Herewith, the process of decreasing the wood permeability can be controlled and selective due to the local removal of free moisture in the parts of the material designed for treatment.

1. Introduction

Currently, artificial materials imitating wood gain broader application. At the same time, the manufacturers of such materials almost do not have technological limitations in the choice of colors and textures when forming the range of products. However, despite this fact, a significant share of the market still belongs to natural wood products, which is due to their greater prestige in comparison with the products manufactured from artificial materials.

At the same time, the current demand for natural wood products does not comply with the supply available on the market. And the main deterrent factor of the supply growth is the limited availability of valuable species of wood with high decorative properties.

One of the ways to solve this problem is to expand the use of less valuable wood of widespread soft-leaved species that do not have natural decorative properties [12]. In the literature, there are quite a few examples of wood modification that allow it to be brightly colored and demonstrate an inexpressive texture due to full treatment with coloring solutions [2, 3, 4, 5, 6, 9, 11]. At the same time, such methods provide only a narrow range of opportunities for forming the texture based on the different intensity of coloration of the annual layer and wood ray areas. Local impregnation of wood using devices similar to those described in the work [10] is justified only to some extent. While when introducing a coloring solution it is difficult to avoid the approach or even closure of the impregnation fronts due to the redistribution of the solution. This in turn leads to a significant distortion of the designed texture and makes it impossible to form the same pattern along the entire length of the assortment.

In our opinion, a better controlled formation of the texture can be achieved by a target-specific change in the liquid permeability of wood in its individual sections. The mechanism of changes in permeability can be a wound reaction that occurs in the wood in case of the damage caused to the tree or any significant disturbance of the water-gas regime of the tree trunk. The essence of the wound reaction is the gradual death of living parenchymal cells with the formation of colored gum-like wound substances. The wound reaction is aimed at protecting the living sections of wood from drying out or fungal attack and leads to a significant decrease in the permeability of wood [1, 8]. As is known, living cells in heart and ripe woods are found only in the peripheral part of the trunk and only in sapwood along its entire section. Therefore, the formation of the wood texture with the use of wound reactions along the entire thickness of the assortment is possible only when using a sapwood such as birch.

2. Materials and methods

Uniform wound reaction along the entire length and section of the assortment is ensured by a moderate positive temperature while maintaining a high moisture content of the wood [1, 8]. However, to form the texture of the material, it is necessary to preserve local permeable areas for the subsequent introduction of the dye, which
implies the need to inhibit the wound processes in the specific designed zones. In this study it was decided to use
the wood moisture content out of the factors determining the duration of the wound reaction.

Special studies were carried out to determine the technological methods that would allow to targetedly form
permeable and impermeable zones in the wood. For this purpose, 9 samples with the length of 1.2 m with the
diameter from 27 to 41 cm were made from 3 freshly cut round birch timber materials (Betulapubescens).

After multi-layer waterproofing of the ends and places of the damaged bark, three samples (one from each
timber) were placed as a control for storage for 60 days at the temperature of 22°C.

In the three samples of the second batch the free moisture was removed locally in the areas designed for
impregnation according to the scheme depicted in Figure 1a.

![Figure 1. Preparation of the wood samples by means of local removal of the free moisture](image)

The free moisture from cell cavities was removed locally using the device shown in Figure 1b. An injector
with a hole diameter of 10 mm was inserted into the end face of the sample to the depth of 20 mm, then air was
fed into the wood through the injector at the pressure of 0.5 MPa. The wood was blown through with air until the
exudation of water from the capillaries at the opposite end of the sample stopped.

The remaining 3 samples were subjected to partial debarking of the assortments by removing the strips of
bark with the width of 50 mm and leaving unbarked 100 mm sections between them (Figure 2).

After special preparation, the samples of the second and the third batches similar to the ones of the first batch
were subjected to multi-layer waterproofing of the ends and placed for storage for 60 days at the temperature of
22°C.

![Figure 2. Scheme of the wood samples preparation by means of partial barking of the assortment](image)

On completion of the 60 day period of keeping the assortments at the positive temperature, the samples
were trimmed by 50 mm at each end. They were further impregnated in an autoclave at the overpressure of 0.5

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3. Results and discussions

The conducted experimental research has revealed the following peculiarities of the formation of impregnated and non-impregnated zones in birch samples depending on the preparation method.

The study of the wood samples the preparation of which included local removal of bound moisture showed the following. The main scope of the assortment was, as expected, impermeable to the aqueous solution of the dye, except for local areas prepared for impregnation. When considering the localized permeability areas in the cross-section, the formation of more than one permeability zone, as planned, was observed for all samples (Figure 3 (IW)). The first zone of the impregnated wood, as planned, was formed along the wood section with previously removed free moisture and showed a uniform impregnation of the dye along the entire length of the assortment. The shape of such areas was practically the same as that of the injector, and the diameters exceeded the opening of the injector by less than 3-4 mm. The preservation of the wood permeability in this case was explained by the rapid death of living wood cells in this area of wood due to their contact with the air medium without a prolonged wound reaction.

The second permeability zone was formed as a ring with slightly uneven edges separated from the first impregnated zone by a ring of non-impregnated wood. The thickness of the impregnated wood ring reached 10 mm, and that of non-impregnated wood ring 5 mm. The rings were elliptical in shape, and in all cases the larger thickness of the rings was observed in the tangential direction (in relation to the structural directions of the wood). The formation of these rings, apparently, can be explained by the fact that when the air penetrates into certain layers of the wood, the process of wound reaction begins to violently proceed in adjacent layers, leading to the formation of the non-impregnated wood ring. In this case, the layers of wood adjacent to the wound reaction zone are the suppliers of substances necessary for the implementation of this process. And later, when the process of the wound reaction starts across the entire section of the sample, these areas are already "depleted" and do not actually participate in the process remaining permeable to liquids and gases.

The study of the samples prepared according to the scheme in Figure 2 did not reveal the designed stellular pattern in the cross section. The assortment was impregnated evenly over the entire section, except for two small sections (with the length of no more than 300 mm and a diameter of up to 40 mm) in the central part of the assortment. Presumably, the preservation of the wood permeability throughout the entire section of the sample is due to excessively rapid decrease in the moisture content of the wood and, consequently, early termination of the wound reaction.

Control samples showed insignificant penetration of the impregnating solution at slitting - not more than 20-30 mm from the ends into the depth of the assortment. The main part of the assortment though remained non-impregnated, which corresponds to the data given in the work [8].

4. Conclusions

Taking into account the findings obtained, we can make the following conclusions:
1. The wound reaction of the living wood cells is an effective mechanism for artificial decrease of the natural permeability of birch.

2. The process of reducing permeability using the wound reaction of wood can be controlled and selective due to the application of a simple and technological method of wood preparation: local removal of free moisture from the cavities of wood cells by introducing air.

3. With the appropriate adjustment and optimization of the processes, the developed method of preparation and impregnation of wood can be successfully applied for the targeted change in the decorative properties of birch wood.

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