Impregnation of lumber due to the pressure of the impregnating liquid

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Abstracts. Storage of the container is one of the most serious problems faced by the manufacturer. At temperatures above 5 °C, the fungus and blue stain affect the container board. Because of this, enterprises suffer losses, which most often occur due to the fact that customers reject wooden containers, since it is important to use wooden pallets without mold and mildew in food and packaging industries. The article describes the methodology and results of experimental studies on the impregnation of wood due to the hydrostatic pressure of the impregnating liquid. Graphic dependencies are made to determine the main technological parameters of the impregnation process - its duration. We studied wood samples of spruce, birch, alder and aspen, the main species from which container sets and pallets are made. A description is given of the use of a densitometer of a fundamentally new design, which makes it possible to determine the density of samples with positive buoyancy.

1. Introduction

Enterprises involved in sawing round wood are aimed at increasing the volume of products, one of which is the container board, which is widely in demand in the production of pallets, crates, flooring. Most often, such lumber is sawn from slabs, low-grade boards, or when finalizing unclaimed lumber. Moreover, some factories focused on the production of pallets are cutting only the container board.

Storage of the container is one of the most serious problems faced by the manufacturer. At temperatures above 5 °C, the fungus and blue stain affects the container board [1]. Because of this, enterprises suffer losses, which most often arise due to the fact that customers reject wooden containers, since it is important to use wooden pallets without mold and mildew in food production and packaging production.

The requirements for wooden pallets are regulated by GOST 33757-2016 [2], which states that only mushroom sapwood colors of wood that are not resulting from storage of wood are allowed. Also, large recipient plants of pallets compose their own technical specifications, which indicate that fungus and any manifestations of mold are unacceptable. Therefore, manufacturers of pallets need to responsibly approach the storage of raw materials for the production of pallets.

The main measures that are used when storing a container board cut from freshly cut wood can be attributed [3]:

- stacking boards crosswise so that the bulk of the surface of the lumber is ventilated. The method is the most common, but ineffective, because with prolonged storage in the places of contact, the juice forms with each other.
- surface treatment with antiseptics by spraying them on the surface of the board. This technique is the most time-consuming, but at the same time the risk of mold is reduced. The disadvantage of this method is that the antiseptic solution is not deeply absorbed, and during long-term storage the container board is also covered with mold.

- heat treatment of the packaging board, providing a reduction in humidity up to 25-30%. This processing method is the most reliable, provided that the board is no longer damaged by the fungus. The downside of the drying process is its energy consumption. Therefore, the production of dry wooden containers often becomes economically inexpedient.

- impregnation of the packaging board by immersion in an antiseptic solution. This is a method in which the ability to store a container increases to several months.

The main objective of the impregnation process is to achieve an optimal temporary impregnation mode, during which the raw materials for the production of pallets can be stored for a long time.

2. Methods and Materials
The experimental technique. To solve this problem, an experimental setup was used, figure 1.

![Figure 1](image)

Figure 1. Scheme of the experimental setup. $H$ - height of the column of impregnating liquid, $H = 4000$ mm; 1 - reservoir, 2 - impregnating liquid, 3 - sample, 4 - cargo.

Prototypes (10 pieces each) were made from the sapwood of freshly cut wood species most commonly used in the manufacture of pallet boards, table 1.

| Wood species | Aspen | Birch | Alder | Spruce |
|--------------|-------|-------|-------|--------|
| Size, mm     | 22×100×1 200 | 22×100×1 200 | 22×100×1 200 | 22×100×1 200 |
| Average humidity, % | 80 | 70 | 70 | 90 |

Samples were immersed in an aqueous solution of methylene blue for temporary periods that were multiples of 5 minutes. The amount of liquid absorbed due to hydrostatic pressure was determined by the increase in the mass of the liquid when extracting samples from the installation, tables 2-5.

The mass gain $\Delta m$ is determined by the equation [4]:

$$\Delta m = \frac{m_1 - m_0}{m_0} \times 100 \%,$$

where, $m_0$ – weight before impregnation, g; $m_1$ – weight after impregnation, g.

Table 1. Characteristics of the samples.
Table 2. Impregnation of aspen wood samples.

| Sample number | Duration, min | Initial mass, g | Mass after impregnation, g | Weight gain, % |
|---------------|---------------|-----------------|-----------------------------|----------------|
| 1             | 5             | 2.100           | 2.140                       | 2%             |
| 2             | 10            | 2.070           | 2.170                       | 5%             |
| 3             | 15            | 2.065           | 2.200                       | 7%             |
| 4             | 20            | 2.140           | 2.270                       | 6%             |
| 5             | 25            | 2.120           | 2.330                       | 10%            |
| 6             | 35            | 2.120           | 2.370                       | 12%            |
| 7             | 40            | 2.100           | 2.420                       | 15%            |
| 8             | 45            | 2.090           | 2.445                       | 17%            |
| 9             | 50            | 2.080           | 2.480                       | 19%            |
| 10            | 55            | 2.110           | 2.570                       | 22%            |

The data in Table 2 is illustrated in figure 2.

![Mass gain versus time](image)

**Figure 2.** The increase in mass of the impregnating fluid over time. Aspen.

Table 3. Impregnation of birch wood samples.

| Sample number | Duration, min | Initial mass, g | Mass after impregnation, g | Weight gain, % |
|---------------|---------------|-----------------|-----------------------------|----------------|
| 1             | 5             | 2.510           | 2.570                       | 2%             |
| 2             | 10            | 2.530           | 2.630                       | 4%             |
| 3             | 15            | 2.490           | 2.630                       | 6%             |
| 4             | 20            | 2.460           | 2.705                       | 10%            |
| 5             | 25            | 2.580           | 2.965                       | 15%            |
| 6             | 35            | 2.520           | 2.970                       | 18%            |
| 7             | 40            | 2.390           | 2.890                       | 21%            |
| 8             | 45            | 2.540           | 3.125                       | 23%            |
| 9             | 50            | 2.560           | 3.225                       | 26%            |
| 10            | 55            | 2.700           | 3.450                       | 28%            |

The data in Table 3 is illustrated in figure 3.
Figure 3. The increase in mass of the impregnating fluid over time. Birch.

Table 4. Impregnation of alder wood samples.

| Sample number | Duration, min | Initial mass, g | Mass after impregnation, g | Weight gain, % |
|---------------|---------------|------------------|----------------------------|----------------|
| 1             | 5             | 1980             | 2010                       | 2%             |
| 2             | 10            | 1920             | 2010                       | 5%             |
| 3             | 15            | 2050             | 2150                       | 5%             |
| 4             | 20            | 2045             | 2145                       | 5%             |
| 5             | 25            | 1990             | 2110                       | 6%             |
| 6             | 35            | 1985             | 2145                       | 8%             |
| 7             | 40            | 2000             | 2170                       | 9%             |
| 8             | 45            | 2000             | 2210                       | 11%            |
| 9             | 50            | 2055             | 2300                       | 12%            |
| 10            | 55            | 2010             | 2290                       | 14%            |

The data in table 4 is illustrated in figure 4.

Figure 4. The increase in mass of the impregnating fluid over time. Alder.
Table 5. Impregnation of spruce wood samples.

| Sample number | Duration, min | Initial mass, g | Mass after impregnation, g | Weight gain, % |
|---------------|---------------|-----------------|-----------------------------|----------------|
| 1             | 5             | 1 700           | 1 730                       | 2%             |
| 2             | 10            | 1 670           | 1 720                       | 3%             |
| 3             | 15            | 1 650           | 1 730                       | 5%             |
| 4             | 20            | 1 695           | 1 780                       | 5%             |
| 5             | 25            | 1 725           | 1 845                       | 7%             |
| 6             | 35            | 1 715           | 1 850                       | 8%             |
| 7             | 40            | 1 700           | 1 860                       | 9%             |
| 8             | 45            | 1 695           | 1 890                       | 12%            |
| 9             | 50            | 1 705           | 1 910                       | 12%            |
| 10            | 55            | 1 690           | 1 960                       | 16%            |

The data in table 5 is illustrated in figure 5.

Figure 5. The increase in mass of the impregnating fluid over time. Spruce.

After the experiments, the samples were split along the fibers and the depth of the zone dyed with methylene blue was measured [5, 6]. Based on the graphs in Figures 2-5, the technological parameters of the impregnation process were determined for each of the tested wood species.

The second stage of the experiments was their conduct for samples of $3 \times 3 \times 3$ cm in size using a new construction densitometer designed and manufactured at St. Petersburg State Forest Technical University (SPbFTU).

The objective of the experiment was to determine the density of the samples before and after impregnation. The determined density value was an indicator of the amount of impregnating liquid in the sample after completion of the impregnation process.

The density of a substance is determined by the well-known formula:

$$\rho = \frac{m}{V},$$

(2)

where, $m$ – mass of the sample, $V$ – volume of the sample.

The mass of the sample is easily determined by weighing it. The volume of the sample in the case of its irregular shape (after impregnation and swelling, the shape of the samples is incorrect) is determined by known devices, based on measuring the volume of liquid displaced by the sample when it is immersed in a reservoir with liquid. So, for example, a pycnometric method of measuring density is carried out, which consists in the following [7, 8].

A pycnometer (a glass vessel, the volume of which is known with great accuracy), is filled with distilled water (up to the mark) and weighed. The mass of the pycnometer with water $M_0$ is equal to:
where, \( \rho_0 \) – density of water, \( V_p \) – volume of the vessel, \( m_p \) – mass of the vessel.

Then weighed the test sample. Its mass \( m \) is equal to:

\[
m = \rho V
\]

Where \( \rho \) – desired density of the sample, \( V \) – volume of the sample.

Then the weighed sample is immersed in a pycnometer with water and the excess water is removed so that its level again coincides with the mark on the pycnometer vessel.

Then determine the mass \( M \) of the pycnometer with water and a sample:

\[
M = \rho V + \rho_0 (V_p - V) + m_p = m + \rho_0 (V_p - V) + m_p,
\]

Then, subtracting (4) from (2) and adding (3), the mass of displaced water is determined and, having determined the volume \( V \) from this, we obtain the expression for the desired density:

\[
\rho = \frac{m}{V} = \frac{m_0 - m}{M_0 - M - m},
\]

The technique for carrying out such measurements is simple; the results obtained are accurate. But all this applies to the studied samples with negative buoyancy [9, 10]. Samples with positive buoyancy (in our case, wood) are not completely immersed in the liquid of the measuring instruments, that is, they displace a liquid volume smaller than its own volume. And their forced complete immersion with the help of additional devices immersed in the liquid of the device together with the sample sharply reduces the measurement accuracy [7, 11].

The density meter design is shown in figure 6.

![Density meter design](image)

**Figure 6.** Density meter, a - view of the density meter with the sample placed in it before determining the volume of the sample, b - the same when determining the volume of the sample.

The use of a new universal densitometer provides the ability to measure volumes of solids with both negative and positive buoyancy relative to the liquid used in the device without the use of additional devices designed to ensure their complete immersion in the liquid, as well as simplifying the measurement process and achieving opportunities to work in the field (outside the laboratory) conditions with the involvement of unskilled personnel.

Conducting experiments to determine the density of wood samples before and after impregnation is as follows.
Having installed the densitometer on a horizontal surface, they achieve a horizontal position in the space of its bed «12» using a standard horizontal level «13» and height-adjustable legs «14».

Liquid «2» is poured into the vessel «1», vertically fixed by the retainer «7», with the threaded upper sealed stopper 6 removed, in an amount equal to half the capacity of the vessel «1». A test sample «3» is placed on the rigid partition «4» and the vessel «1» is sealed with the stopper «6», Figure 6, (a).

Turning the vessel «1» in a vertical plane by 1 800 mm on the cylindrical fingers «9» located on the supports of rotation «10» of the uprights «11», the vertical position of the vessel «1» is fixed with the help of the retainer «7» of the upper tube «6» turned upside down.

Upon completion of the rotation of the vessel «1», the liquid «2» through the hole «5» in the rigid partition «4» flows into the cavity of the vessel «1», where the test sample is located.

In this position, figure 6, (b), in the upper cavity of the vessel «1» there is a volume of liquid displaced by sample «3» from the opposite cavity of the vessel, and, obviously, equal to the volume of the sample. The value of this volume is determined visually by the reading of the scale of the vertical ruler «8», graduated in units of volume. Sample «3» floats in the fluid volume of the lower cavity of the vessel «1», or rather, is pressed by the buoyancy force to the lower plane of the rigid partition «4».

The density of the substance ρ of a pre-weighed sample «3» with a mass m is determined by the Formula (2), where V is the reading of the scale of line «8».

At the end of the process of examining the sample, the densitometer, turning the vessel «1» to 1 800, is returned to its original position, remove the plug «7», remove the sample and proceed to the next study.

The condition for the axis of the fingers «9» to pass through the center of gravity of the vessel «1» must be satisfied to ensure reliable operation of the latches «7». The lower sealed plug «6» is removable to allow periodic cleaning of the vessel «1».

The fluid used in the densitometer can be opaque or tinted in order to more accurately visually fix its level in relation to the risks of graduation of the ruler «8». The fluid was replaced when it was contaminated by particles that separated from the sample during the study period.

The frame «12» of the device can be mounted on a scale, which allows measurement of the mass of the samples simultaneously with the determination of their volume.

The capacity of the vessel «1» with the installed partition «4» was determined before its first operation with the help of the measured capacity.

The densitometer used by us is a fairly accurate instrument, easy to manufacture and convenient to operate.

3. Results and Discussion
It is possible to carry out experimental studies of the degree of impregnation of wood samples of the impregnating liquid on the basis of an experimental setup simulating the impregnation process due to the hydrostatic pressure of the impregnating liquid. The degree of impregnation of wood, as a body with positive buoyancy, is proposed to be carried out using a new construction densitometer.

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