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Reduction of Time Consumption for Wood Impregnation

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Seeking to expand the range of employment and durability of wood articles, in many cases they must be impregnated in correspondent materials. To increment the depth and speed of impregnation, different technologies are used. In the present research the method of wood impregnation by vibration is presented. The testing process of wood scantlings involved an original stand and a measuring instrument. It was established that scantlings exposed to water. Vibrate in analogous vibration modes identical to those in air. After the impregnation the scantlings with smaller density contain 4 times larger water quantities within the same period of time. It was found that as the quantity of penetrated water continues to increase, the resonant frequency of the scantling tends to decrease up to 10 %, whereas the coefficient of damping rises by 1.5 times. It was established that transversal vibrations were not influenced, while impregnating wood along the fiber. The tests showed that while impregnating across the fiber, vibrations can accelerate the whole process: within the same period of time scantlings contain water quantities larger up to 37 % in the presence of vibration.

Keywords: scantlings, coefficient of damping, resonance vibration, pine and birch wood assortments, wood impregnation.

INTRODUCTION

Being one of the widely used materials, wood has a few disadvantages that include low resistance to fire, harmful insects, physical, mechanical and other factors. To expand usage areas of wood products and to extend their lifetime, timber products undergo impregnation with respective materials that tend to be water soluble on a frequent basis and show physical properties similar to water properties. Impregnation leads to wood property changes: wood is under modification, there are chemical linkages with wood elements and others. Such wood assortment shows more resistance to the mechanical effect, absorbs smaller quantity of moisture and has more stable measurements and shape. In other cases modified assortments tend to be softer and more plastic [1–3].

Tracheids are the fundamental structural elements in coniferous wood and constitute up to 95 % of all wood volume. Earlywood tracheids are thin-wall elements and serve for conduction of fluids, whereas latewood tracheids perform the function of supporting elements. Libriform fiber is the basic constituent part of deciduous wood and makes up to 75 % of wood volume. Libriform fiber is reminiscent of thick-wall tubes, which means that while dealing with impregnation, wood can be treated as the capillary system of tubes arranged along the stem and connected in pairs.

There is a number of wood impregnation methods, however, increasing the volume of impregnated wood or reducing the impregnation time requires a great deal of energy consumption and expensive equipment [1–3].

It is a well-known fact that vibrations are used for impregnating nonwoven textile materials [4]. Latex-impregnated materials show better physical and mechanical properties. In addition, such impregnated nonwoven materials tend to better transmit gases and liquids.

The method of resonant vibrations is applied to test wood products and textile fabrics. By evaluating their amplitude-frequency characteristics, dynamic rigidity and coefficients of damping can be determined [5–7].

Vibrations are also used for dying wood [8], since a vibrant assortment allows dyes to penetrate deeper into it and ensures low material consumption. The only disadvantage of this method is that a small amount of dyes remains on the top layer.

Thus, by using vibrations, it becomes possible to increase work efficiency and to reduce expenditure.

The main objective of this work is to assess how transverse resonant vibrations influence the impregnation duration of wood scantlings.

STUDY METHOD AND EQUIPMENT

The testing process of wood scantlings involves an original stand and a measuring instrument. Figure 1 shows the scheme of measuring complex.

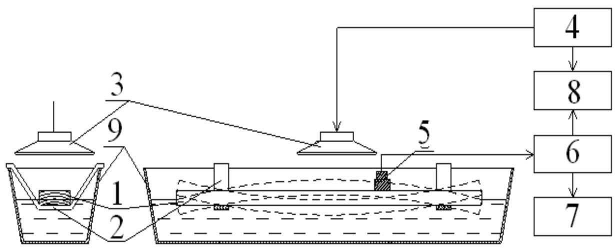

Fig. 1. The scheme of measuring complex: 1 – wood assortment and its bending; 2 – elastic elements; 3 – acoustic vibrator; 4 – vibration generator; 5 – vibration detector; 6 – measuring instrument; 7 – oscilloscope; 8 – phase meter; 9 – water container

A wood scantling being on test (1) is loosely attached to the elastic elements (rubber strips) (2). The acoustic vibrator (3) controlled by the vibration generator (4)

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excites resonant vibrations in the scantling (1). The vibration detector (5) senses these vibrations and the measuring instrument (6) measures their amplitude. The phase meter (8) measures the signal phase of the vibration detector with regard to the signal phase of the generator. The oscilloscope (7) screen records the shape of vibration signal.

There is approximate correspondence between the “attachment” method of the scantling and the freely vibrating scantling.

In order to ensure the full contact between the scantling surface and water, the container is filled with water (roughly 1/3 of scantling thickness is immersed).

The description of the measurement process is provided below.

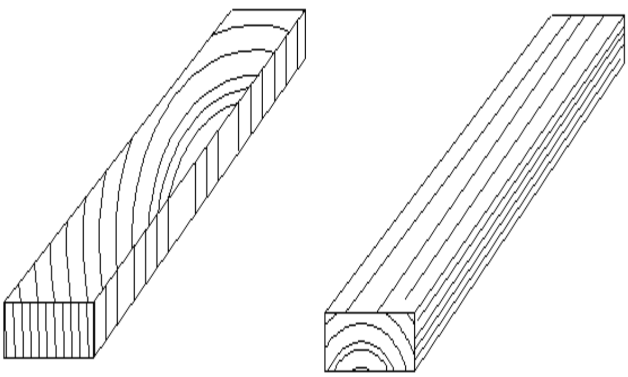
The wood scantling is attached to the elastic elements (2), its transverse vibrations are excited and the resonant frequency together with the coefficient of damping, which correspond to the first mode, are set.

By using the resonant frequency, the scantling undergoes vibration in water for a certain period of time, which allows determining the quantity of absorbed water. Subsequently, the established quantity is compared with the quantity of absorbed water specific to the scantling that does not undergo vibration and obtained in advance during the same period of time.

It was determined that, the same as in the air, scantlings have an analogous vibration mode in water, which approximately corresponds to the first mode of the isotropic rod undergoing deformation [9]. Furthermore, it was found that in water the frequency of scantlings tend to decrease up to 40 %, meanwhile their coefficient of damping increases up to 60 %.

EXPERIMENTAL RESULTS AND DISCUSSION

The tests involved coniferous and deciduous – pine and birch wood – scantlings that were prepared for the impregnation process along and across the fiber (Fig. 2).

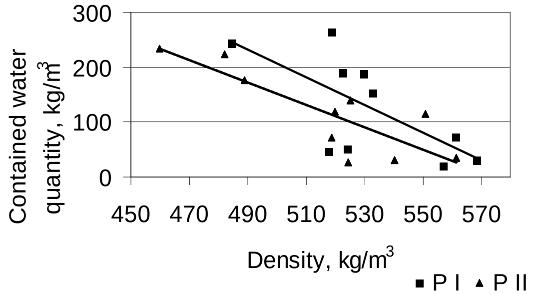


a b

Fig. 2. Scheme for scantlings undergoing impregnation: a – along the fibre; b – across the fibre

The following measurements were selected for pine scantlings undergoing impregnation across and along the fiber: $(600 \times 55 \times 20)$ mm and $(330 \times 45 \times 15)$ mm, respectively. Their moisture and density varied from 7.8 % to 9.3 % and from 460 kg/m^3 to 570 kg/m^3, respectively. The respective measurements of birch scantlings were as follows: $(450 \times 55 \times 15)$ mm and $(270 \times 50 \times 15)$ mm. Their moisture and density ranged between 8.4 % and 10.0 % and between 560 kg/m^3 and 850 kg/m^3, respectively. Tests included the number of 20 – 30 units for each type of scantlings that were devoid of branches, cracks and other clearly visible shortcomings.

All the scantling types were divided into two subgroups: the first one included scantlings undergoing impregnation under vibration, meanwhile the second one consisted of scantlings without applying vibrations. The impregnation process across the fiber lasted for 4 hours.



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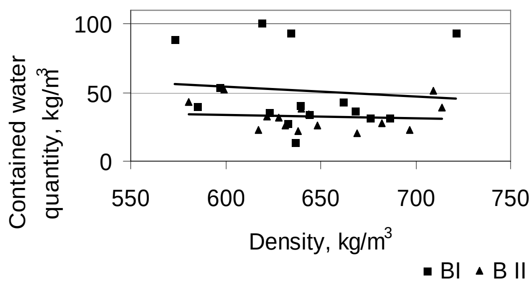

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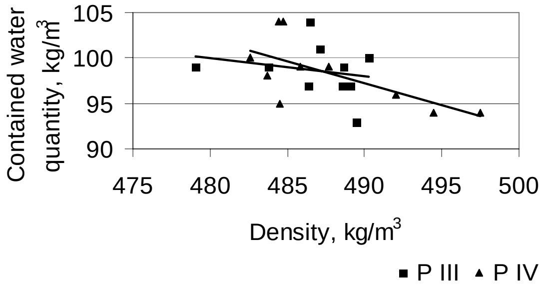
Fig. 3. The dependency between the water quantity while impregnating across the fiber and the wood density: a – pine wood; b – birch wood; I – scantlings with vibration application; II – scantlings without vibration application

It was established that the following water quantities entered through pine scantlings with 1 m^3 volume in and without the presence of vibration: up to 250 kg/m^3 and 230 kg/m^3, respectively. In the case of birch scantlings values were as follows: (20 – 100) kg/m^3 and (30 – 50) kg/m^3, respectively. It is evident that scantlings with small density contained larger water quantities.

It is an established fact that due to its peculiarities in the anatomic structure water passes through wood along the fiber within a shorter period of time. As a result of this, scantling impregnation along the fiber lasted 10 minutes.

It was determined (Fig. 4) that the following water quantities entered through pine scantlings in and without the presence of vibration: (94 – 102) kg/m^3 and (92 – 100) kg/m^3, respectively. In the case of birch wood there was higher value spread: (60 – 92) kg/m^3 and (60 – 88) kg/m^3, respectively. It was found that, the same as in the previous case, scantlings with small density tended to contain larger water quantities.

During the impregnation process, changes in mechanical properties of scantlings were recorded as well (Figs. 5 and 6).



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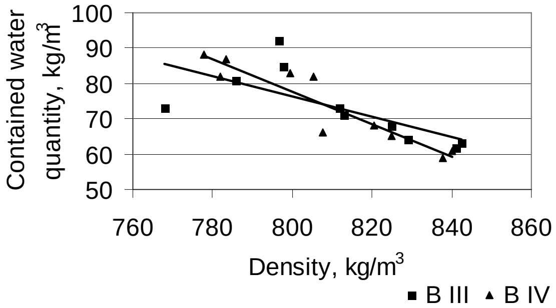

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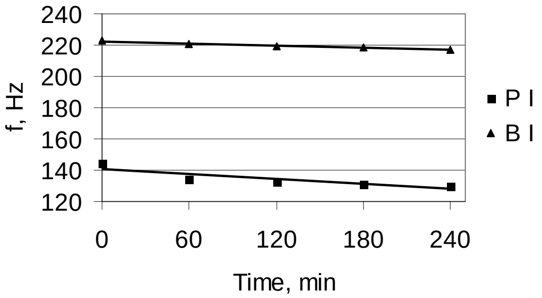
Fig. 4. The dependency between the water quantity while impregnating along the fiber and the wood density: a – pine wood; b – birch wood; III – scantlings with vibration application; IV – scantlings without vibration application



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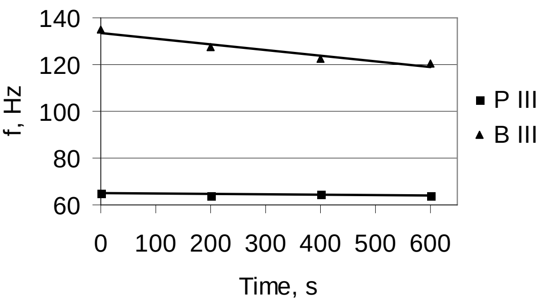

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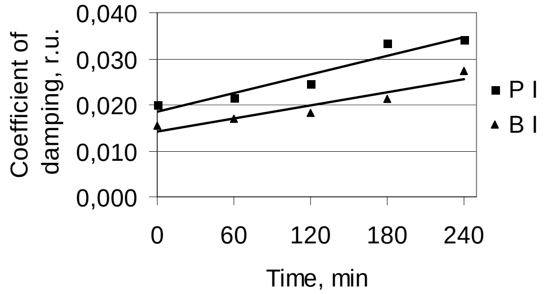
Fig. 5. Changes in the resonant frequency of scantlings during the impregnation process: a – impregnation across the fiber, b – impregnation along the fiber; "P" means pine wood; "B" birch wood

It was established that as the quantity of penetrated water continues to increase, the resonant frequency of the scantling tends to decrease. Tests showed that during the impregnation across the fiber, the average resonant frequency of pine scantlings declined from 144.5 Hz up to 129.8 Hz (with 10.2 % difference), whereas in the case of birch scantlings it fell between 223.2 Hz and 216.9 Hz (2.8 %). During the impregnation along the fiber, the average frequency of pine scantlings varied from 65 Hz to 63.9 Hz (with 1.5 % difference), meanwhile in the case of birch scantlings it ranged between 134.8 Hz and 120.6 Hz (10.5 %).

Figure 6 shows general pattern of changes in the coefficient of damping during the impregnation process.



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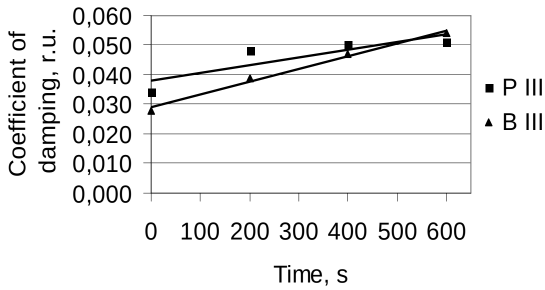

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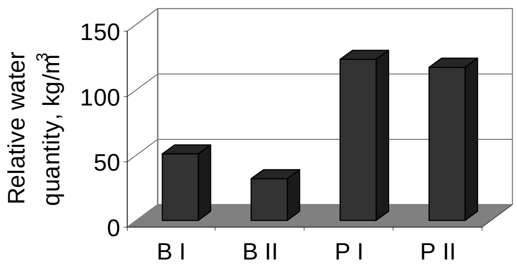
Fig. 6. Changes in the coefficient of damping of scantlings during the impregnation process: a – impregnation across the fiber, b – impregnation along the fiber; P means pine wood; B stands for birch wood

It can be observed that as the quantity of penetrated water continues to increase, the average coefficient of damping tends to rise as well. It was found that during the impregnation across the fiber, the average coefficient of damping of pine wood scantlings grew from 0.020 r. u. to 0.034 r. u. (with 70 % difference), meanwhile in the case of birch wood it reached 0.015 r. u. – 0.027 r. u. (80 %). During the impregnation along the fiber, these changes were as follows: 0.034 r. u. – 0.054 r. u. (in the case of pine) and 0.028 r. u. – 0.051 r. u. (in the case of birch) with value differences being 59 % and 50 %, respectively.

It was determined that the water quantity absorbed by scantlings leads to significant changes in their mechanical properties.

Subsequently, the evaluation on the quantity of water penetrated into the scantling volume with and without vibration application was also performed (Fig. 7).

It was found that when scantlings were undergoing vibration, larger water quantities entered through across the fiber, differently from cases when vibration was absent. In the case of pine wood the average quantity of water passed through 1 m^3 in and without the presence of vibration was 123 kg and 117 kg, respectively, meanwhile in the case of birch wood it was 51 kg and 32 kg, respectively, with difference being 5 % and 37 % accordingly. While impregnating along the fiber, vibration had no significant influence on the whole process. It was determined that in and without the presence of vibration pine scantlings contained the following water quantities: 99 kg/m^3 and 98 kg/m^3, respectively. In the case of birch wood scantlings the contained water quantity was 73 kg/m^3.



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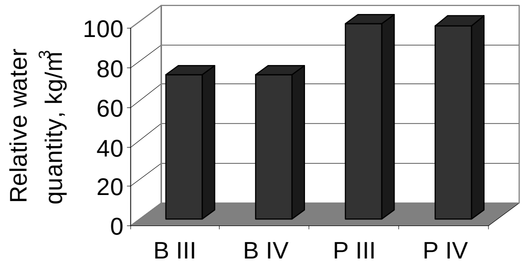

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Fig. 7. Comparing the relative water quantity during the pine and birch wood impregnation: a – across the fiber; b – along the fiber; P means pine wood; B stands for birch wood; I, III – with vibration application; II, IV – without vibration application

Our results are in good accordance with [10], where the impregnation method with high – frequency vibrations in liquid for timber and wood ware impregnation was proposed. According to [10], sound energy helps to remove gas and impurities from wood elements and in the same time facilitate the access of fluid. The influence of ultrasonic vibrations on wood impregnation is research [11]. It was found that to 8 % – 10 % moisture birch wood in the 0.3 mm to 0.6 mm depth the fluid took within 5 to 7 times faster. Ultrasonic vibrations are efficient for impregnation of polymer composite as well [12]. It was found that these vibrations using, resin ratio in glass polymer composite on 3 % – 4 % was boosted and other properties were improved. Our research results show, that the transverse vibrations can accelerate the whole process: within the same period of time scantlings contain water quantities larger average up to 11 % in the presence of vibration.

The introduced impregnation method can be widely used in the industrial area.

CONCLUSIONS

1. It was established that when scantlings are exposed to water, they vibrate in analogous vibration modes identical to those in air.
2. It was determined that scantlings with smaller density contain 4 times larger water quantities within the same period of time.
3. It was found that as the quantity of penetrated water continues to increase, the resonant frequency of the scantling tends to decrease up to 10 %, whereas the coefficient of damping rises by 1.5 times.
4. It was established that transversal vibrations were not influential, while impregnating wood along the fiber.
5. Tests showed that while impregnating across the fiber, vibrations can accelerate the whole process: within the same period of time scantlings contain water quantities larger up to 37 % in the presence of vibration.

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