Using microwave irradiation to increase permeability of Siberian larch wood

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Abstract. The paper presents the research results of the microwave radiation effect on the Siberian larch heartwood. The collected experimental data show that microwave treatment increases the larch wood permeability not only longitudinal but also transversely the fibres. The most significant increase of the transversely fibre wood permeability is found in the tangential direction.

1. Introduction

In the last several decades, the interest for wood as an environmentally friendly renewable natural resource has been consistently growing. This is facilitated both by the unique wood properties and the growing welfare level of the developing countries ensuring the increasing consumption of natural wood as a more expensive and prestigious material.

The range of wood on the global market is represented by a broad variety of different wood species. Some wood species are sought for more than others due to their attractive colour, texture or good physical and mechanical properties. This creates the deficit of supply and, therefore, an increase in prices.

One of the ways to satisfy the demand for wood with the sought-for properties is a modification of less precious species growing in the northern latitudes, not remarkable for their high physical and mechanical properties, bright colour or distinctive texture.

One of the promising species for wood modification is Siberian larch wood (Larix sibirica) widely spread in the Siberian region [1]. Larch wood is known for its good physical and mechanical properties equal to those of such popular species as oak, ash, or beech [2] but has a pale colour and plain texture which can be successfully corrected with the modification methods depending on the purpose.

The majority of the wood modification methods are based on the treatment of wood with a modifying solution under excessive pressure. However, the larch wood treatment is almost impossible, as the major part of the trunk volume consists of the heartwood with low liquid and gas permeability [3].

The permeability-reducing mechanism in the softwood core formation process has been studied by numerous researchers [3-5]. In those studies, the low permeability of the heartwood is explained by the changed position of the toruses in the vertical tracheid pores and the deposition of the extractive substances in the marginal zones of the radial tracheid pores.

Increasing permeability of wood is one of today's important scientific and technological tasks. By the present time, a number of wood material permeability-increasing methods have been developed, including injection, alternating pressure treatment, wood-staining fungi implantation etc. [4-7].
listed methods have their drawbacks, such as disintegration of wood structure, low energy efficiency, or technical complicatedness when applied in industrial conditions etc.

In recent time, scientists from all over the world are actively working on the methods for increasing the permeability of wood by means of microwave (MW) irradiation radiation treatment. For instance, the works [8-13] remark the high efficiency of (MW) radiation treatment of wood to increase its permeability with an acceptable reduction of its mechanic properties. The authors of [10] have found that the MW treatment of Chinese fir wood increases the treating solution absorption rate to 308% compared to the untreated reference sample; according to [11], the absorption rate increases to 156%. In the research [12], the MW radiation influence on the beech wood increased its longitudinal permeability by 28%, and in some cases — up to 156%.

In the quoted works [8-12], the MW radiation-induced permeability-increasing mechanism is explained, first of all, with the effect of heating and evaporation of the water contained in wood, producing steam-gas pressure. As a result, the cell walls of the wood elements are partially destroyed, softening the material and enforcing the movement of the extractive substances.

Noticeably, in the majority of the studied materials, the authors mostly focus on improving the longitudinal permeability. However, the determining factor for treatment of elements over one meter long is the transverse permeability of wood [3].

With all the collected data of the MW radiation treatment potential, it was decided to study the possibility of increasing the Siberian larch (Larix sibirica) heartwood permeability.

2. Experimental and Results
For the research, from a part of the 110-year-old larch tree log, 1.2 meters away from the butt, a block with the diameter of 40 cm was cut. From the block core, along the fibres, some samples of 50x50 and 150 mm with the similarly oriented growth rings were produced. The samples were divided into three groups of 10 pieces each. The first two groups were treated with MW radiation; the third one was the reference group.

To simulate the industrial batch amount, the longitudinal permeability of the samples was blocked. For this purpose, the sample ends were coated with a layer of silicon sealant and covered with plastic caps with rubber seals inside. Before placement into the MW chamber, the opposite caps were tightened with a heat resistant plastic clamp strap (figure 1).

The SHF treatment of the samples was carried out in the microwave chamber at the frequency of 2.45 GHz with a fixed power of 0.9 kW. At the moment of treatment, the humidity of samples was 55%. The duration and method of treatment were selected based on the published research data [10-12]: Group 1: MW treatment of 5.5 min; Group 2: MW treatment of 4 min; Group 3: untreated reference samples.

After that, the MW treated and untreated samples were thoroughly waterproofed (to exclude the end permeability) with PF-115 and silicon sealant applied in multiple layers. Then, the samples were treated in an autoclave under the pressure of 0.5 MPa for one hour. The treatment solution was the water solution of FeSO₄ which allows observing the treatment infiltration due to its wood colouring properties.
As a result of the studies, the MW treated samples were discovered to feature a larger treatment solution infiltration depth in the radial direction compared to the reference samples (figure 2). In the given conditions, the samples from Group 1 show over a 1.5-time increase in the treatment infiltration front depth progress, while the infiltration value of Group 2 exceeds that of the reference samples by 6% only. The infiltration depth of the samples from Group 1 (exposed to longer MW treatment) exceeded that of the samples from Group 2 by almost 60%.

For the tangential infiltration (figure 3), the MW treated samples from both Group 1 and 2 show an almost double increase in the progress of the treatment infiltration depth. However, the longer MW treatment of the Group 1 samples did not induce a dramatic change in the treatment infiltration depth compared to those of Group 2. The difference between the samples of Groups 1 and 2 lies within the experiment accuracy limits.

Generally, at the maximum lasting exposure (Group 1), among the structural directions, the greatest permeability was observed in the radial direction with the treatment solution infiltration depth being
12% higher than that of the tangential direction. At the same time, tangential treatment infiltration depth progress value of the samples of Group 2 (shorter MW exposure) exceeded that of the radial infiltration depth progress by almost 1.4 times.

![Figure 3. Treatment front depth progress in the tangential direction.](image)

3. Conclusion
The collected experimental data showed that the MW treatment of the Siberian larch wood facilitates the increase of the wood transverse permeability. After MW treatment of the larch wood, the treatment solution infiltration depth progress was found to increase by 1.5 times in the radial direction and by 2 times in the tangential direction. The collected data prove the high efficiency of the MW radiation treatment as a way of increasing transverse permeability of the Siberian larch heartwood.

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