Spectral analysis of various types of wood as the basis of low-temperature drying technology in vacuum conditions

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Abstract. The research was carried out at the expense of the grant of the Russian Science Foundation No. 23-76-01090, https://rscf.ru/project/23-76-01090 /. The characteristics of various types of wood (oak, aspen, pine) were obtained in the laboratory on the basis of the South Ural State Agrarian University using the infrared Fourier spectrometer FSM 2201. For these rocks, the wavelengths at which the maximum absorption of radiation occurs are determined, which is consistent with the operating modes of the film electric heater. The obtained result will become the basis for further research aimed at developing and creating a prototype of an infrared vacuum drying plant and an automatic control system for regulating and investigating the process in a discharged environment.

1 Introduction

Lumber has been in demand for a long time, they are in demand now, in our opinion, in the coming decades the demand will only grow, both in furniture production and in construction. Despite the latest developments of unique synthetic polymers, on the basis of which building materials, household items, and other products necessary for human life are made, the environmental friendliness and beauty of natural wood does not go out of fashion. This, in turn, dictates to woodworking enterprises the need for equipment that meets the requirements of environmental friendliness and energy saving for the manufacture of high-quality competitive products.

All of the above formed the basis of the tasks facing the scientific community: the improvement of existing technologies and the search for breakthrough solutions to create new ones in the field of wood processing. One of such solutions is the use of a low-temperature film electric heater for drying lumber in vacuum conditions.

The film electric heater was invented not so long ago, its classic application is heating systems [1-5]. Nevertheless, the improvement of the materials and technologies used for its manufacture made it possible to expand the areas of its application, including due to the positive effect of dehydration recorded during irradiation of objects [6-11]. To date, research is being actively conducted on the use of low-temperature IR generators for drying various crops, and there are even applications for drying wood in combination with a convective

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method of moisture removal [12,13].

The research presented in this article is aimed at creating an energy-saving technology for drying lumber using low-temperature IR radiation generators in a vacuum chamber to combine the advantages of two drying methods, expressed in the absence of an intermediate medium of IR radiation absorption, followed by an unobstructed water outlet from the lumber, condensation on the walls of the chamber and its removal outside, which will reduce the drying time and energy costs when high-quality lumber is released.

The primary task is to study the optical properties of the IR radiation generator and the spectral characteristics of wood of various breeds, followed by their coordination into a single system "emitter-receiver" [14-17]. The IR spectroscopy method was used to measure the interaction of infrared radiation with matter.

2 Materials and Methods

Currently, IR spectroscopy has been widely used in various industries. Each object under study has its own individual IR spectrum character, which makes it possible to use them for qualitative and quantitative analysis, and also allows to obtain data on the peaks of absorption and transmission of radiation, which can be used to increase the efficiency of the drying process by increasing the concentration of radiation dose in the volume of raw materials. Knowing the depth of radiation penetration, it is possible to effectively control the thickness of the lumber laying and influence productivity.

One of the most important characteristics of raw materials is the absorption capacity. Coordination with this characteristic makes it possible to effectively select an IR radiation generator for the drying process, considering the electromagnetic field as an information flow of energy that is perceived by a biological object and triggers phase increments inside of it.

The IR spectrum is obtained when the object of study is continuously exposed to the energy of the infrared radiation flux. With the help of a spectrometer, the light flux that passes through the raw material is decomposed by wavelengths. With continuous exposure to the spectrum with a certain intensity, the absorption bands of infrared radiation from the breakdown of raw materials become pronounced.

The band intensities at certain wave numbers are different and make it possible to estimate the transmission (1) or absorption (2) of radiation by raw materials, expressed as a percentage:

$$T = \frac{I}{I_0} \cdot 100\% \quad (1)$$

$$T = \frac{(I_0 - I)}{I} \cdot 100\% \quad (2)$$

In the course of the work, an experiment was conducted to obtain spectral characteristics of different types of wood: pine, oak, aspen [18].

The experiment took place in the laboratory on the basis of the South Ural State Agrarian University with the use of the infrared Fourier spectrometer FSM 2201 (Fig. 1). This device allows to obtain spectral characteristics of samples in a wide range of wavelengths from 0 to 25,000 nm.

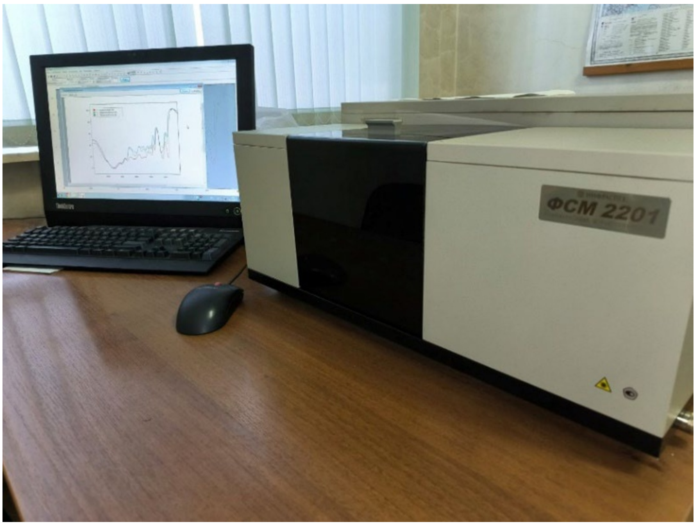

Fig. 1. Workplace in the laboratory on the basis of the South Ural State Agrarian University.

Sample preparation was carried out according to the methodological recommendations. KBr tablets were used as a solvent, since when working with biological objects, the solvent must have transparency, be inert with respect to the sample and not relate to toxic substances. The analysis of the methods showed that when conducting spectral studies, it is necessary to take samples of the same mass to obtain a generalized interferogram of five repetitions.

3 Results and Discussion

Samples of wood of such species as oak, aspen, pine were selected for the experiment. The generalized interferogram is shown in Figure 2 in the wavelength range from 5000 to 11000 nm.

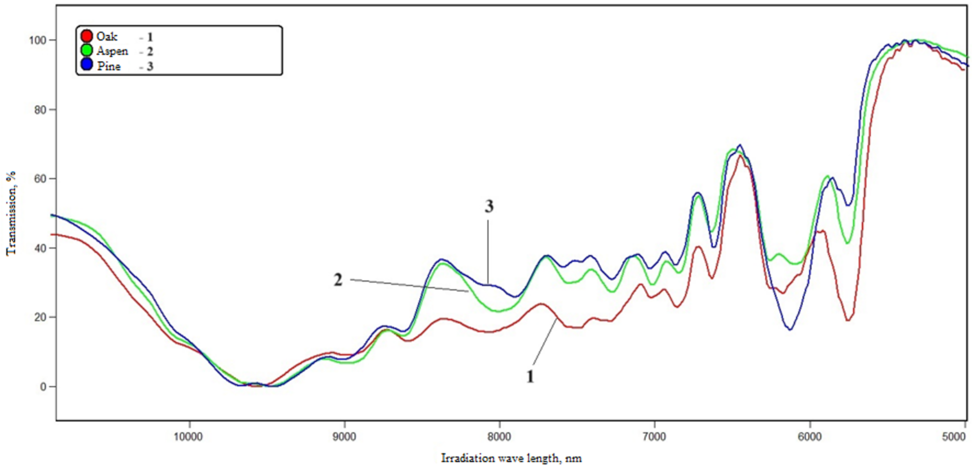

Fig. 2. Generalized interferogram of wood samples.

Analyzing the spectral characteristics of different types of wood (Fig. 2), it was revealed that they have differences in interferograms, but their nature is similar to each other and the spectra are subject to one characteristic range with varying percentages of absorption and transmission of radiation. The extremes in the range from 9400 nm to 9700 nm are of the greatest interest, since the transmission in this range is 0%. Therefore, the operating modes of the radiation generator should be selected with an operating range in this area. The film electric heater is able to provide heating of the board to the specified values, since they are consistent with its optical radiating parameters, and due to its low inertia, the process of influencing the object can be organized "pointwise" [7]. To do this, Figure 3 shows a more enlarged view of this section of the interferogram.

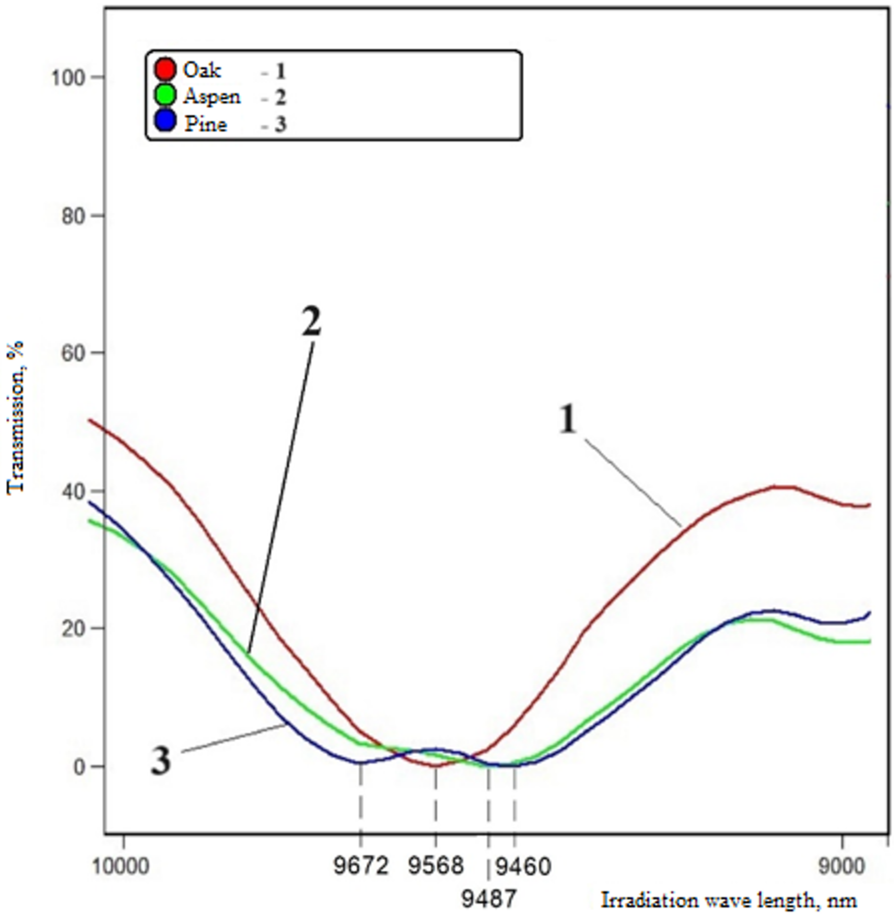

Fig. 3. Interferogram of wood samples in the range from 9000 nm to 1000 nm.

When organizing the drying process by infrared radiation in combination with convection, it is important to consider the microclimate in the chamber, namely the work of ventilation, which inevitably leads to the utilization of part of the heat when removing moisture from the chamber and the influx of cooler air from outside, therefore maintaining a set temperature is a difficult task. Manufacturers of drying plants using this technology recommend the temperature of softwood – 42-44°C; hardwoods – 33-35°C [12,13]. It follows from the interferogram (Fig. 3) that this will lead to a shift to shorter wavelengths of radiation, where the transmission is 20%. This means that the process will be less intensive, and energy costs will increase. Nevertheless, manufacturers thereby solve the issue of microclimate in the chamber, that is, 20% of the energy not absorbed by the wood in the stack provides the temperature of the air around it, the difference of which should be 7-10°C, which will ensure an effective exit of moisture from warm wood to colder air.

In vacuum conditions, maintaining a temperature microclimate around the stack is not required, in this regard, maintaining the set values (determined by the interferogram at 0% transmission) is a feasible task, together with the fact that when the pressure in the chamber decreases below the vapor pressure of water, its boiling occurs at lower temperatures, all this will contribute to the process intensification.

4 Conclusion

The obtained spectral characteristics of oak, aspen, pine, in coordination with a film electric heater, allow to find the optimal heating temperature of wood, while maintaining which in a vacuum chamber will reduce energy costs, time costs when producing high-quality wood.

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