

Research of Heating Rate While Thermo Modification of Wood

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Abstract: A technology for thermal processing of hard wood in hydrophobic liquids is worked out in order to increase its biological stability and even colour scheme for the entire cross section of timber. As a result of experimental studies and mathematical modelling there were defined rational mode parameters of the process. There was developed hardware design of the technologies, which due to its constructive solution can be applied both by large and small woodworking enterprises.

Key words: Thermal treatment • Wood • Liquid • Fumed oak

INTRODUCTION

There is an increased interest in thermal treated wood in recent years, due to the introduction of the European Commission in 2004 a ban on the use of chemically treated wood, as well as unique properties of the obtained products, such as environmental friendliness, high bio stability, durability, low equilibrium moisture content, a wide range of colours. Researches in this area are being done in the last 10-15 years in countries such as Finland (Technology- Thermowood®), France (Retification), America (WEST-WOOD), Latvia (Vacuum Plus), Germany (Thermoholz). Problems of research and technology development of thermal treated wood materials in liquids are the subject of many works by foreign scholars. Heat transfer issues in technology, heat treatment of wood, the thermo physical properties of wood, mathematical modeling of heat and moisture of wood were studied by scientist Nencho Deliiski (Bulgaria) [1]; the impact of heat treatment on the physics-mechanical, chemical and performance properties of wood was in works of Danica Kacikova Frantisek Kaci'k (Slovakia) [2], Ladislav Dzurenda (Slovakia) and Vincent Repellin (France) [3], who also studied the patterns of the color score changes in the process of timber thermal treatment; issues on wood thermal treatment could be found in works by Andreas O. Rapp (Hamburg) [4]; the handling of wood in organic oils was in works of Anna Koski

(Finland) [5], Michael Sailer (Germany) [6]. Chemical, thermal and other properties of thermowood were studied by scientist Callum Hill (England) [7]. High temperature and chemical effects on wood stability was in works of Edwin Hillis (Australia) [8]. The results of the studies on mechanical properties of composite materials and the researches of thermal treatment of wood in the flue gases were presented in the works of Ruslan Safin (Russia) [9], [10], [11].

A common characteristic of the known methods of thermal treatment can be called the treatment temperature range from 180 to 240°C, which is explained by the physical and chemical processes occurring in the wood at a given temperature, contributing to the colour change of the material and its physical and mechanical properties. The fundamental differences are the following: the time from 16 to 180 hours and the processing environment, for example, in a protective atmosphere of water vapor (Thermowood, PLATO-Wood, WEST-WOOD), in a vacuum (Vacuum Plus), in a protective atmosphere of inert gas - nitrogen (Retification), in organic oils (Thermoholz) and the fact that many of the technologies used for heat treatment are used only for low-grade timber, which limits the possibility of their application to hard wood.

Thus one of the most neglected technologies still remains thermal treatment of wood in hydrophobic liquids, which is defined by eco- friendliness and is a modern alternative to chemical methods of wood processing and

thanks to a constructive solution can be applied at small enterprises. Existing technology V Ter-moholz, where heat treatment occurs in organic oils, has two significant drawbacks: it has a considerable duration of the process by cooling the material in a natural way and is not intended for the treatment of hard wood. It can be assumed that technology for thermal treatment of wood in liquids is rational for the hardwood thanks to its lowest penetrating power. Therefore, the development of technology designed for the treatment of hard wood species and ensuring the quality of the product, as well as an even colour scheme for the cross section of material is an important task for today.

MATERIALS AND METHODS

We propose a power-saving technology for thermal treatment of hardwood in liquids, including pre-oscillating drying of lumber in liquids, temperatures up to 200-240°C and endurance of wood at these temperatures in a sealed chamber filled with oil with a boiling point above 260°C, cooling by the oil drain plug, vacuum timber, steaming it and re-steam vacuum for 2-3 hours.

To determine the optimal operational parameters of the process the experimental plant was set up and research works were conducted. As an agent for processing while conducting the experimental researches there have been used the hydrophobic liquid with a boiling temperature of 260°C - glycerine D-98. As the samples there have been used different wood species (birch, pine, oak) with 50 mm.

The process of heat treatment of wood in a liquid medium can be represented as a set of stages of heating and thermal treatment of wood as well as cooling, which in turn is divided into draining, evacuation, steaming with water vapour, re-evacuation and exposure to vacuum conditions.

Process of thermal treatment of timber in a liquid medium starts with filling the cavity of the working chamber with the hydrophobic liquid through a vacuum chamber with subsequent heating at its pressure not exceeding atmospheric value and post-heating timber until 200- 240°C. Then, there carried out its exposure in a liquid medium at a given temperature, depending on the desired degree of thermal treatment. Upon reaching the required degree of thermal treatment there happen discharge of all liquid, then with a vacuum pump and condenser vacuum is created and carries out an excerpt of the material to remove the agent from the processing of internal cavities of wood cells. Then the water vapour supplied into the

chamber where it contacts the hot wood and heats up, while to maintain the desired temperature in the chamber an internal capacitor is included in the work environment. After processing the timber in an environment of water vapour vacuum is created again in the chamber and timber is exposed to it. The use of vacuum and steaming stages after thermal treatment of timber aimed at reducing the temperature of the material to 120-130°C and to prevent spontaneous ignition of wood at the specified high temperature conditions, as well as the removal of internal stresses in the material and the smell of burnt thermowood in its further use.

During the process of heat treatment of timber in liquids two inverse flows are observed inside the material: the flow of liquid impregnation from the environment, inward the timber and the flow of gas mixture of decomposition products, which is directed from the timber. The process of impregnation is the movement of wetting liquid in a capillary with trapped gas and a major influence on its progress is by processes of dissolution and diffusion of the gas-vapour mixture in the soaking liquid. The process of impregnation fluid occurs when the velocity of the fluid in the deadend capillary, determined by the rate of dissolution and diffusion of trapped gas in it, will be greater than or equal to the rate of gaseous flow of decomposition products. Otherwise, the steam-gas flow degradation products will result in the expulsion of liquid impregnation of wood.

After completing the stage of thermal modification the material must be cooled without additional oxygen in order to avoid its spontaneous combustion. Lowering the temperature of products is carried out directly in the chamber by feeding steam from steam-generator.

Results. Analysis of the results of experimental research works for samples of different wood species (birch, pine, oak) with 50 mm showed that the rate of flow of liquid impregnation is in direct proportional to the temperature of thermal treatment and the depth of penetration of the agent in the treatment of timber does not depend on penetrating power of natural wood and from its base density. In particular, natural birch penetrating power is higher than penetrating power of natural pine, but the depth of penetration of the agent in the treated pine (pine, heat-treated) was higher than in the case of thermal birch. This can be explained by the fact that during the thermal treatment of wood there happens a release of cavities of macro structural elements of the material from the contained substances (e.g. tar), which in turn, determine the ability of timber to the permeability of liquids. Therefore thermal treatment of wood in

hydrophobic liquids is more rational to be used for hard wood, with greater density and, thus, less depth of penetration of the agent processing, thereby reducing the consumption of a hydrophobic liquid to carry out the process and avoid large losses of material in the process of further mechanical processing. Therefore, further basic research has been focused on the process of thermo modification of oak lumber.

The experimental data of heating fluid and wood immersed into it point out the uneven heating of the material thickness by immersing the sample in a preliminary heated fluid and vice versa, while heating the liquid and placing the material into it there is an even material heat treatment over the cross section. As a result of experimental studies and mathematical modelling the expression for determining the rational rate of temperature increase in the environment was determined, depending on the thickness of the timber, ensuring the quality of the material (oak), obtained during the process of heat treatment

$$\ln(\Delta T/\Delta \tau) = 1,508 - 2,004 \ln (s_m/2)$$

The results of experimental studies, the changes of integral densities of thermal treated wood in hydrophobic liquids have shown that thermal treatment has a direct impact on changes in the density of wood, in addition the higher the processing temperature is, the stronger the reduction in the density of the material. At the same time, wood species has no significant effect on change in this parameter.

Analysis of the results of the kinetics of the relative mass oak sample at different temperature regimes of treatment showed that the mass of the timber in the light soaking substantive and fluid changes depending on the processing temperature as follows: at relatively low temperatures (180°C and 200°C) mass of the sample starts to grow intensively from the very beginning of the process, indicating that the penetration of the agent in the treatment of lumber, while at higher temperatures (220°C, 240°C) there observed intense mass loss of the sample in the first 1-3 hours, which indicates that the active phase of the emission of the products of timber decomposition, preventing the impregnation of timber.

It is established that the thickness of the timber directly affects the duration of the process and the depth of penetration of the handling agent into the material. The depth of impregnation of the material increases in lower proportion to the expected duration of the process, so thermal treatment of wood in liquids should be performed for lumber with greater thickness.

Processing of experimental and theoretical data for emission of vapour-gas mixture out from the wood during thermal treatment made it possible to determine the change in the flux of volatile in time required to calculate the system catches and condensation of products of decomposition of wood. It is established that the performance of the catch and condensation should be regulated during heat treatment, depending on the temperature of heat treatment process, the thickness of lumber and wood.

The simulation results characterizing the dependence of the steam flow during the cooling stage of heat-treated wood showed that the steam consumption increases in rise of material specific surface. The obtained dependences allow to control the flow of steam and gradually low the temperature of the material to 120-130°C, ensuring the quality of the obtained thermo wood.

As a result of experimental studies there have established that thermal treated oak wood may be the best substitute for natural fumed wood, since it opens opportunities for the use of wood as a highly artistic material, superior in quality due to obtained new physical-mechanical, operational and aesthetic characteristics. Analysis of studies on the properties of thermal treated oak showed a decrease in strength properties of lumber. However thermal treated oak exceeds on the performance the characteristics of the natural fumed oak. In particular, the flexural strength for treated oak is 4-30% higher than for natural oak and the compressive strength is 1-5% more, depending on the degree of thermal treatment, the coefficients of shrinkage and swelling on average is five times less and the shock hardness of artificial oak is slightly lower than of the natural. For convenience there were obtained empirical correlations of core physical and thermo-mechanical properties of oak on the temperature, time and duration of any process.

During the process of thermal treatment of wood there observed the chemical processes, running inside the timber, accompanied by a change in its colour throughout the thickness. For unifying the values of colours of the thermal treated samples the colour mode was used in which images are described using 256 shades of gray.

Based on these data there was developed an engineering method of calculation the rational regime parameters of the process depending on the desired level of thermal treatment and physics-mechanical properties of the received thermo wood.

As a result of researches there was designed a pilot plant equipment, which consists of a sealed chamber with a heater, vacuum lines and the system of cooling, including storage capacity of the hydrophobic liquid with

built-in tank filled with water, connected with the chamber by means of steam pipe. After completion of heat treatment stage the hydrophobic liquid is drained out from the chamber is drained into a container, where it gives the heat through the walls of the inner tank to the water, resulting in steaming which is served back to the camera. This action eliminates the need of additional spending on water vapor and intensifies the process of cooling the hydrophobic liquid before the next cycle of thermal treatment.

CONCLUSIONS

A power-saving technology for thermal treatment of hardwood in liquids was presented in this article. The work includes the results of high-temperature treatment of wood materials in hydrophobic liquids, the analysis of the effect of high temperatures on the timber, the physical properties of the agent processing (hydrophobic liquid), physics-mechanical and chemical properties of wood as a heat treatment object.

The presented technology of thermal treatment of wood in liquids, thanks to a constructive solution, can be applied both in large and small woodworking enterprises, while decreasing energy costs, improving quality of thermo treated wood, colouring of the material is even throughout the thickness and colour scheme can be predicted.

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