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INVESTIGATION OF BEECH LUMBER DRYING PROCESS BY THE LOW TEMPERATURE MULTI-STAGE REGIMES

This paper presents the results of experimental study of convective drying process of beech lumber under production conditions. Processed drying process cards, built drying curves and drying rate curves for beech lumber with the actual thickness 32mm. Duration of drying process for multi-stage low-temperature regime of beech timber have been investigated; obtained the value of moisture conduction coefficient at given conditions.

Keywords: wood drying, low-temperature drying regime, beech timber, drying curve, moisture conduction.

The current state of the issue. Convective chamber drying of lumber is complex, energy-intensive process. Modern production realities require obtaining high quality products as a result of drying. However, there is a need for efficient use of heat and electricity. Therefore, the research process of timber drying does not lose its relevance. The experimental investigations in the laboratory are important, but equally important is the generalization of manufacture experience for timber drying to further improvement of drying regimes, increasing resource and energy effectiveness.

The aim of the investigation. The aim of the study is to establish the duration of the convective drying of beech lumber with the actual thickness 32 mm for the studied low-temperature multi-mode regime under production conditions; identifying of drying coefficient and moisture conductivity.

Investigation methodology. Experimental production studies were conducted in convective drying chamber with a vertical transverse circulation of drying agent.

The chamber was loaded by stacks of length 6.5 m, width 1.8 m, height 3 m. Six experimental drying process of beech lumber with thickness of 32 mm, width 200 mm and length 3.5m have done. The use of adaptive automatic control process allowed to obtain the results of moisture content in stack at 6 points. The rate of circulation drying agent in the chamber was near 3 m/s.

During the drying process change of regime parameters occurred stepwise depending on the change of the current moisture content. Process of drying from the initial moisture content up to 25% moisture content was carried out by the rate of the sample with the highest moisture content, due to decline the current moisture content of the sample down to 25% – with average estimated moisture on the stack.

Ambient temperature during the drying process in the first stage at a dry bulb was t = 53°C, relative humidity – φ = 84%; at the last stage – t = 64°C and φ = 30% accordingly.

Results and Disscutions. According to the results of the drying process of beech lumber, drying curves and drying rate curves for each experiment at all points of measurement of humidity were built.

In Fig. 1 shows the drying curves in six points of the stack (experiment №2), from which is also visible regime parameters of drying agent. In Fig. 2 illustrated the curves of drying rate, which shows that the process occurs in a period of slowing down rate of drying.

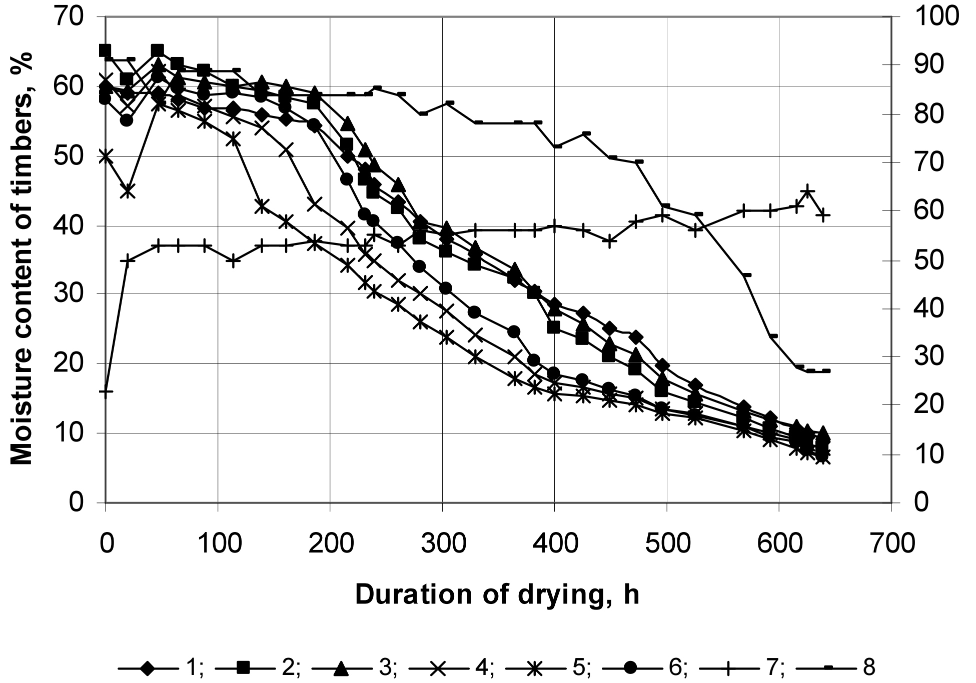

Fig. 1. Drying curves (study number 2) in stacks of six points:

1, 2, 3, 4, 5, 6 – drying curves under measurement at points 1, 2, 3, 4, 5, 6;

6 – temperature of drying agent, °C; 7 – relative humidity og drying agent, %.

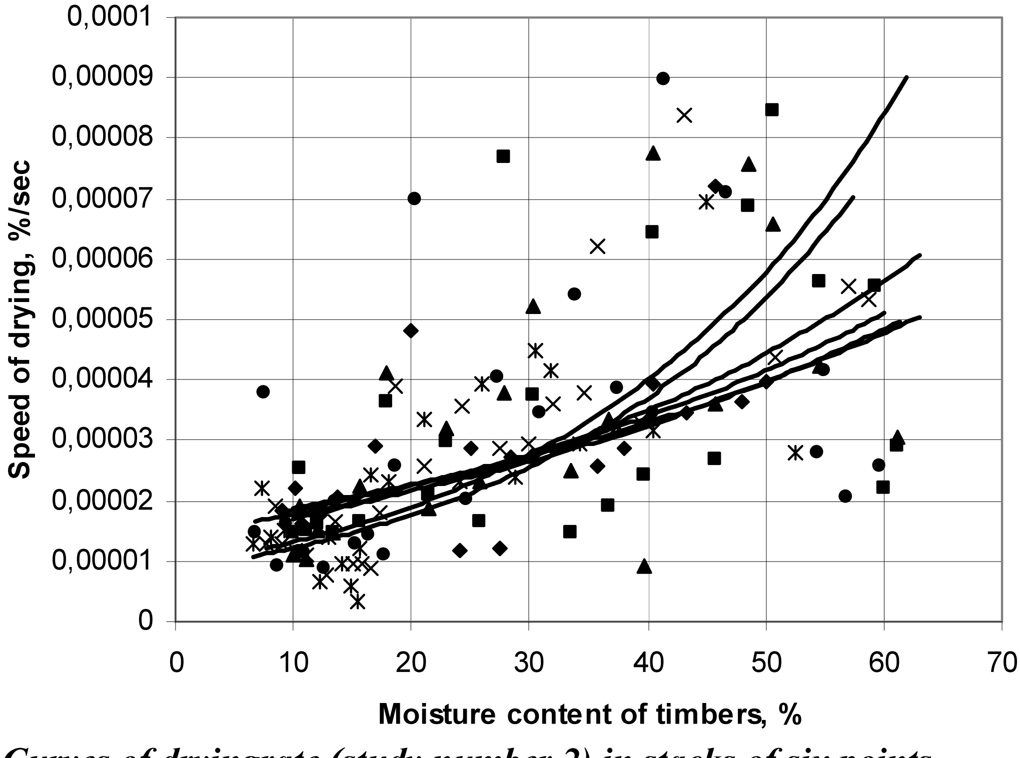

Fig. 2. Curves of dryingrate (study number 2) in stacks of six points

Since under industrial conditions the initial humidity of lumber, which are loaded into the chamber, varies considerably the drying curves were built in moisture at which the process was carried out reduced to the same initial moisture content by moving them along the x-axis as long as they cross the y-axis at the point at the initial moisture content.

Experimental drying curves are given at initial moisture content of about 60% and the final moisture content about 8% (see Fig. 3).

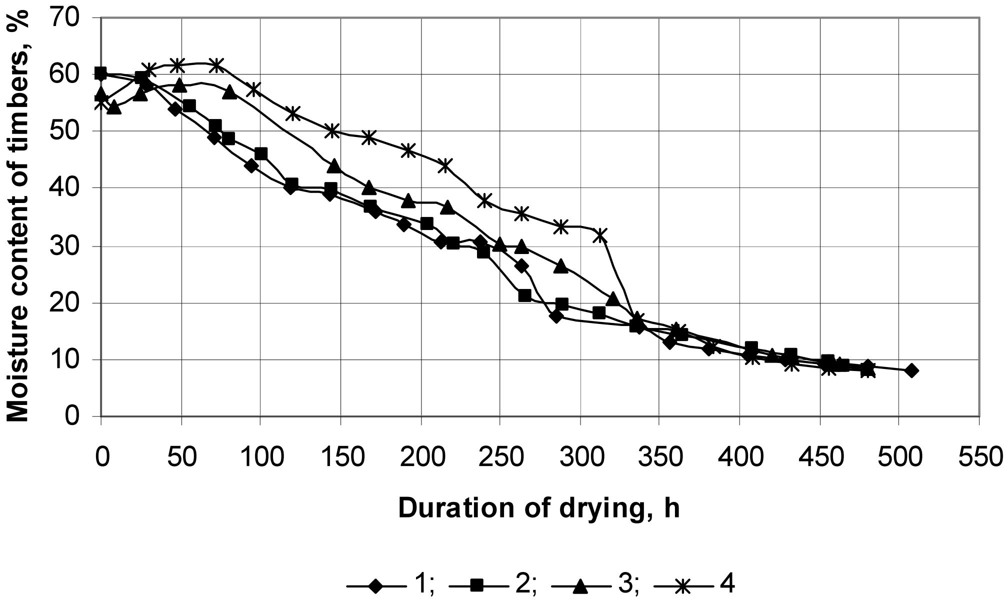

Fig. 3. Drying curves fitted to the same initial moisture content:
1, 2, 3, 4 – drying curves for experiments № 1, 2, 3, and 5.

Thus, the duration of beech lumber chamber drying after correction to the same initial moisture content are as follows: 1st experiment - 507,3 hours; 2nd – 479,92 h; 3rd – 480,5 h; 4th– 429,9 h; 5 th – 480 h; and 6 th – 447,75 hours. The arithmetic mean value of the duration of drying process is 470.9 hours. The accuracy of the experiment, according to [1] is 2.39%. Since in woodworking the reliability of the experiment accuracy rate does not exceed more than 5%, found average duration can be considered a reliable result. With the drying curves mass transfer coefficients can be investigated.

Approximate equation of drying curve for a period of slowing down rate expressed as follows [2, 3]:

$$\ln \frac{W_i - W_{eq}}{W_f - W_{eq}} = -K \cdot \tau \ , \qquad (1)$$

where: W_i, W_f, W_{eq}–respectively the initial, final and equilibrium moisture content,%; K – coefficient of drying (depends of the type and size of material, mass transfer, slowing downrate of the drying process) s^{-1}; τ – the drying period, s.

From equation (1) can determine the rate of drying:

$$K = \frac{\ln\left[(W_i - W_{eq}) / (W_f - W_{eq})\right]}{\tau}, \qquad (2)$$

According to the investigated multi-mode regime average rate of drying coefficient is = $2{,}332 \cdot 10^{-6}$, s^{-1}.

The coefficient of moisture conductivity was determined by the method of pilot dryers. Duration of the low-temperature drying process by graphoanalitical method determined at each stage mode by the formula [3]:

$$\tau_{1 \ldots n} = C_{\tau 1 \ldots n} \cdot \frac{65 \cdot S_1^2}{a'_{1 \ldots n} \cdot 10^6} \cdot C_{1 \ldots n} \cdot A_{c.} \cdot \lg\left(\frac{W_{i1 \ldots n} - W_{eq.1 \ldots n}}{W_{f1 \ldots n} - W_{eq.1 \ldots n}}\right), \qquad (3)$$

where: $W_{i1 \ldots n}$, $W_{f1 \ldots n}$, $W_{eq.1 \ldots n}$– initial, final and equilibrium moisture content of lumber at each of drying stages; C_τ –amendment to the multidimensionality that takes into account the width of the lumber; S_1 –width of the lumber; C –factor of the slowdown of drying process in stacks of different widths; A_c – coefficient for the reversibility circulation (for reverse circulation – 1.0); $a`_{1..n}$– coefficient of moisture conductivity of wood at each of the stages of the drying, cm²/s.

The amendment to the multidimensionality accepted - 1 as the width of lumber were 200 mm and more, as well as the ratio of thickness to width ratio is 0.16 or less. Factor considering slowing the drying process in the stacks was took according to the method described in [4].

According to our calculations for the study of these conditions it is 1.04.

The average coefficient of moisture conductivity for these drying conditions is $2{,}526\cdot10^{-6}$ cm²/s.

Conclusions. By the results of this study in a production environment and statistical processing of the experimental data the average time for the convective drying process of edged beech lumber with thickness 32 mm have been obtained.According to the investigated multi-mode low-temperature regime average duration of drying is ≈ 470,9 hours. Obtained the value of drying coefficient – $2{,}332\cdot10^{-6}$ s^{-1}, and the coefficient of moisture conductivity –$2{,}526\cdot10^{-6}$ cm²/s undergiven conditions.

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УДК 674.047
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Дослідження процесу *сушіння букових пиломатеріалів низькотемпературним багатоступеневим режимом*

Проведено експериментальні дослідження конвективного низькотемпературного сушіння букових пиломатеріалів у виробничих умовах. Опрацьовано картки обліку процесу сушіння і побудовано криві сушіння та швидкості сушіння для букових обрізних пиломатеріалів товщиною 32 мм. Досліджено тривалість процесу сушіння букових пиломатеріалів низькотемпературним багатоступеневим режимом; встановлено коефіцієнти сушіння та вологопровідності для даних умов дослідження.

Ключові слова:сушіння деревини, низькотемпературний режим сушіння, деревина бука, крива сушіння, коефіцієнт сушіння, вологоперенесення