UDC 674.047.3

D. P. Babich, junior researcher (BSTU);
V.B. Snopkov, PhD (Engineering), assistant professor, head of department (BSTU)

THERMAL ENERGY CONSUMPTION AT DRYING SAW-TIMBER IN PERIODIC CONVECTION DRYING CHAMBERS

Calculation of thermal energy consumption is executed at drying saw-timber in periodic convection chambers. It is established, that with the mode rigidity increase the total drying heat consumption decreases. It is recommended to apply more rigid modes to reduce the thermal energy consumption.

Introduction. Saw-timber drying is an important stage in massive wood processing. At drying there is removal of free and bound moisture from wood that leads to considerable improvement of wood service properties. Process of wood moisture removal requires considerable consumption of thermal and electric energy.

In work [1] the following data are given: thermal energy makes 84.23% of the total drying power consumption, and electric energy makes 15.77%. It testifies the priority of the problem solution of the thermal energy consumption in comparison with the electric energy consumption.

Thermal energy consumption consists of three components: saw-timber warming up energy consumption, wood moisture evaporation power consumption, drying chamber railing energy losses.

The main factor influencing the thermal energy consumption is the mode of saw-timber drying. Modes of saw-timber drying in periodic drying chambers are regulated by STATE STANDARD 19773-84 [2]. In addition to standard modes the majority of enterprises of our country use nonstandard drying modes which are recommended by foreign manufacturers of drying chambers.

The purpose of the given work was determination of the thermal energy consumption during saw-timber drying using various modes, and also determination of the mode parameters influence on the power consumption.

Research procedure. Researches were carried out with regard to the drying chambers of Cathild firm, VS1E90ACC model. Thermal energy consumption was determined while drying pine, birch, and oak saw-timber with thickness of 25, 32, 50 mm. Calculations were made for the following drying modes: standard of normal and soft categories, modes recommended by the manufacturer of drying chambers. Power consumption determination was made for average annual conditions.

Thermal energy consumption was determined in the following sequence. At first duration calculation of saw-timber drying process was done with the help of graphic-analytical method [3, p. 116–121]. After that the actual chamber capacity for each kind of saw-timber and volume of the circulating drying agent were determined. Weight of moisture removed from wood was calculated on i^{th} stage of drying D_{1_i}, kg/m^3, according to the formula:

$$D_{1i} = \frac{\rho_b \cdot (W_{i_i} - W_{f_i})}{100}, \qquad (1)$$

where ρ_b – base wood density of the rated material, kg/m^3, W_{i_i}, W_{f_i} – initial and final humidity for i^{th} drying stage, %.

Then the specific consumption of saw-timber warming up thermal energy was calculated q_{th}, kJ/m^3, according to the technique given in the literature [4, p. 25–26]. The total heat consumption on saw-timber warming up Q_{th}, MJ, was determined according to the formula:

$$Q_{th} = \frac{q_{th} \cdot E_k}{1000}, \qquad (2)$$

where E_k – the chamber capacity for the rated saw-timber, m^3.

The specific consumption of thermal energy on moisture evaporation from wood q_{test}, kJ/kg, was determined according to the technique given in the literature [4, p. 26–27] for each stage of the drying mode being investigated. The total evaporation power consumption of moisture from wood for i^{th} mode stage (Q_{test_i}, MJ) and for all drying period (Q_{test}, MJ) were determined according to the formulas:

$$Q_{\text{test}i} = \frac{q_{\text{test}i} \cdot D_{1i}}{1000}; \quad Q_{\text{test}} = \sum_{i=1}^{n} Q_{\text{test}i} \qquad (3.4)$$

where n – stages quantity of the drying mode, units.

Railing heat losses for i^{th} mode stage Q_{lim_i}, MJ were determined according to the technique given in the source [4, p. 27–30]. Total railing losses of the drying chamber for the drying cycle Q_{lim}, MJ, were determined according to the formula:

$$Q_{\text{lim}} = \sum_{i=1}^{n} Q'_{\text{lim}i}, \qquad (5)$$

Thermal energy consumption for drying Q_{sum}, MJ, was determined according to the formula:

$$Q_{\text{sum}} = Q_{th} + Q_{\text{test}} + Q_{\text{lim}}. \qquad (6)$$

Research results. Calculation results of the thermal energy consumption are given in the Table.

Let us analyse them. The thermal energy total consumption varies in a wide range (from 43,189.8 MJ to 113,158.1 MJ) depending on thickness, saw-timber species and applied drying modes. Let us consider in detail the influence of each of these factors.

In Fig. 1 there is the diagram on which thermal energy consumption is represented while drying saw-timber of various species and thickness using standard normal modes.

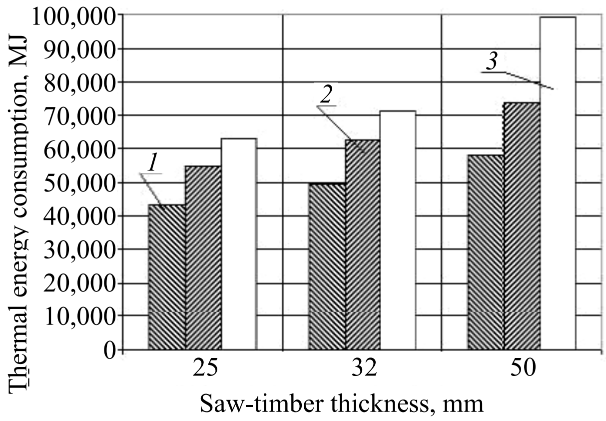


Fig. 1. Thermal energy consumption for drying saw-timber of various wood species by normal modes: 1 – pine; 2 – birch; 3 – oak

From the given diagram it is clear that with increase in thickness of saw-timber the thermal energy consumption for their drying also increases. This regularity is valid for all investigated wood species and drying modes.

It is also clear from the given diagram that the maximum quantity of thermal energy is expended in drying oak saw-timber, less heat is required for drying birch saw-timber, the minimum quantity of thermal energy is expended in drying pine saw-timber. Thermal energy consumption dependence on wood species while using other examined modes has the same nature. On the basis of the above-mentioned we conclude that the drying thermal energy consumption increases with the density increase of the wood being dried up.

In Fig. 2, 3 there are diagrams on which drying thermal energy consumption of pine and birch wood saw-timber by various modes is shown.

It follows from the diagram of Fig. 2 that for pine wood saw-timber the maximum quantity of thermal energy is expended while using standard soft modes, the minimum heat quantity – while using standard normal modes. Thermal energy consumption while using Cathild modes is slightly bigger than energy consumption for normal modes.

Thermal energy consumption while drying saw-timber in periodic convection drying chambers for various modes

Wood species	Saw-timber thickness, mm	Drying mode	Drying duration, h	Thermal energy consumption, MJ			
				for warming up	for moisture evaporation	railing losses	total
Pine	25	2-M	143.2	6,673.5	36,056.4	4,209.4	46,939.4
		2-H	67.0	9,858.3	30,544.3	2,787.1	43,189.8
		112	102.4	6,445.1	33,773.8	3,465.7	43,684.6
	32	3-M	172.5	7,493.1	39,785.4	5,101.0	52,379.5
		3-H	104.8	11,069.0	34,044.0	4,403.4	49,516.5
		112	132.9	7,236.6	37,858.1	4,512.7	49,607.4
	50	5-M	195.7	8,434.0	48,075.1	5,562.6	62,071.8
		5-H	128.6	11,685.6	41,551.5	4,977.9	58,215.0
		112	165.3	8,275.1	45,023.6	5,595.7	58,894.5
Birch	25	Б2-М	147.4	8,477.5	45,392.5	4,744.4	58,614.4
		Б2-Н	106.1	10,367.8	40,419.4	4,088.6	54,875.8
		22	148.8	6,923.7	46,978.6	4,336.3	58,238.7
	32	Б-2М	165.4	9,518.6	50,894.8	5,309.9	65,723.4
		Б-2Н	137.0	11,641.0	45,375.0	5,378.1	62,394.1
		22	179.5	7,773.9	52,852.6	5,212.9	65,839.6
	50	Б-5М	174.4	10,864.2	60,617.8	5,390.4	76,872.5
		Б-5Н	151.0	11,984.2	56,605.4	5,155.4	73,745.1
		22	188.6	8,841.4	63,985.8	5,180.1	78,007.4
Oak	25	Д2	190.8	7,058.1	50,385.8	5,331.3	62,775.3
		30	205.5	5,234.5	63,707.2	4,626.9	73,568.7
	32	Д2	237.7	7,924.9	56,659.7	6,510.5	71,095.2
		30	300.5	5877.3	72,286.5	6,706.5	84,870.5
	50	Д4	902.1	8,305.5	69,521.9	21,123.6	98,951.1
		30	742.3	6,614.0	90,568.1	15,976.1	113,158.1

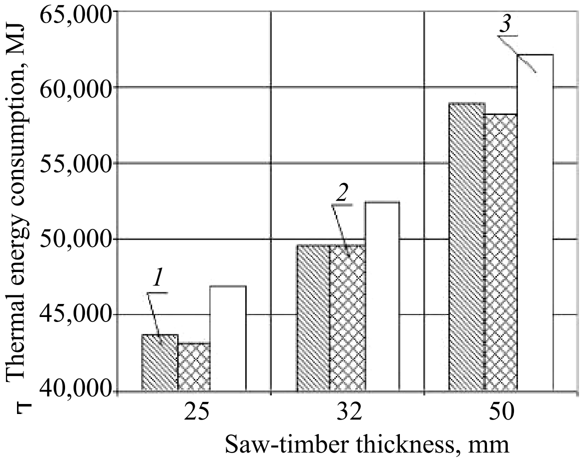


Fig. 2. Thermal energy consumption for pine wood saw-timber drying:
1 – Cathild mode; *2* – standard normal mode;
3 – standard soft mode

Diagram given in Fig. 3, shows that for birch wood saw-timber the minimum quantity of thermal energy is expended while using normal modes. For soft modes and Cathild modes approximately the same quantity of heat is required while drying saw-timber with thickness of 25 and 32 mm. For saw-timber drying with thickness of 50 mm Cathild mode is more energy-consuming.

For drying oak wood saw-timber the thermal energy consumption is bigger while using Cathild modes than while using standard modes (see the Table).

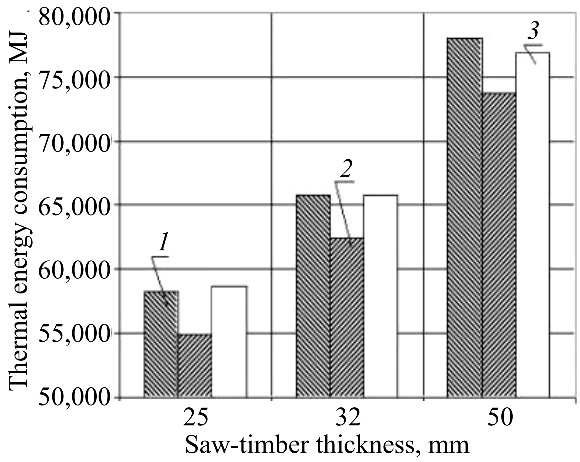
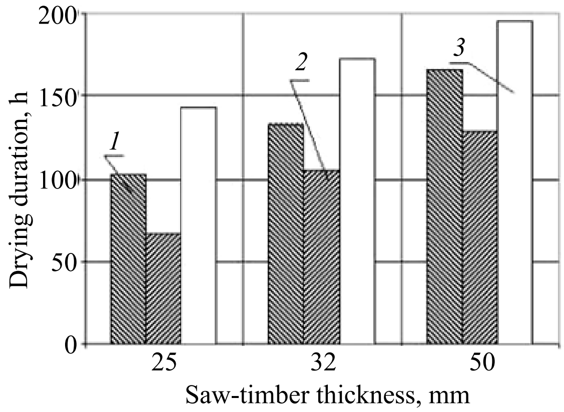
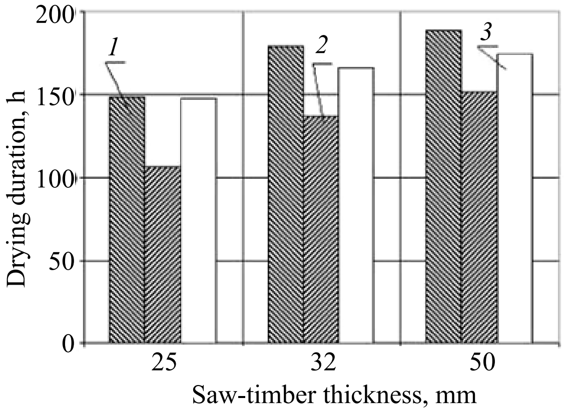


Fig. 3. Thermal energy consumption for birch wood saw-timber drying:
1 – Cathild mode; *2* – standard normal mode;
3 – standard soft mode

The major criterion characterising the drying mode is its rigidity. From the point of view of drying process kinetics the mode duration is defined first of all by its rigidity. The more rigid is the mode, the less time is spent for wood moisture removal. In Fig. 4 there are diagrams showing the drying duration of pine and birch saw-timber.



a



b

Fig. 4. Saw-timber drying process duration:
a – pine; *b* – birch;
1 – Cathild mode; *2* – standard normal mode;
3 – standard soft mode

It is obvious that the change nature of drying duration depending on the applied mode on the given diagrams corresponds to the change nature of thermal energy consumption in diagrams of Fig. 2 and 3. Therefore we conclude that the heat consumption is more influenced by the drying process duration or by the used mode rigidity: thermal energy consumption increases with the duration increase. In other words, the more rigid is the drying mode, the less thermal energy is necessary.

As it was mentioned above, thermal energy consumption at saw-timber drying consists of three components. Having made use of the Table data, we will determine the contribution of each heat component into the total drying consumption. In Fig. 5 and 6 there are diagrams on which the contribution of each heat component into the general drying consumption is shown percentage wise while using various modes.

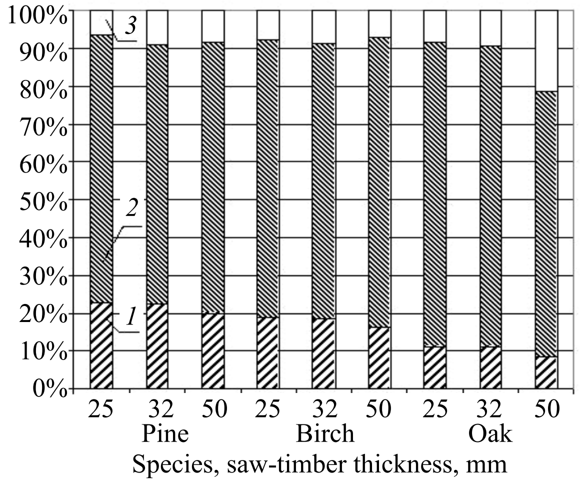


Fig. 5. Distribution of thermal energy consumption for saw-timber drying on components for Cathild modes:
1 – saw-timber warming up energy consumption;
2 – wood moisture evaporation energy consumption;
3 – energy losses through drying chamber railing

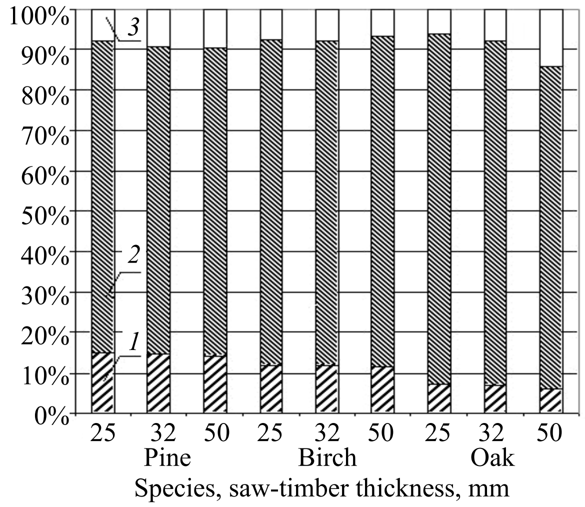


Fig. 6. Distribution of thermal energy consumption for saw-timber drying on the components for standard normal modes:
1 – saw-timber warming up energy consumption;
2 – wood moisture evaporation energy consumption;
3 – energy losses through drying chamber railing

As it is clear from the given diagrams the heat consumption share on saw-timber warming up is from 7 to 22% of the total heat consumption, on evaporation – from 68 to 86%, losses through railing – from 6 to 21%. The heat consumption increase while warming up is characteristic of quick-drying materials and of rigid modes usage.

Average losses value through railing is 7–9% of the total heat consumption, big values (14–21%) are valid at very long drying of saw-timber.

Conclusion. Calculation of the thermal energy consumption at saw-timber drying in periodic convection drying chambers is done. It is established that energy consumption depend on rigidity of the drying modes used. The minimum quantity of thermal energy is spent while using standard normal modes.

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Received 14.03.2012