Forecasting the final moisture of birch lumbers in the process of chamber drying

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Abstract. The paper substantiates a method for predicting the timely completion of the process of convective drying of birch lumber. The results of statistical processing of industrial drying of birch lumber in MJR-150 chambers are presented. It has been established that there is a statistically significant dependence of the final moisture content of the dried batch of sawn timber on the temperature difference and equilibrium moisture content characterizing the intensity of moisture evaporation along the movement of the drying agent through the stacks. Depending on the thickness of the sawn timber in the last period of the drying process, the temperature difference is from 0.9 to 3.1 °C, and the EMC difference is from 0.5 to 0.9%. As the average moisture content of wood \( W_{av} \) in stacks decreases, the difference in temperature and equilibrium moisture content decreases. Graphical dependencies for birch lumber 25 and 50 mm thick were built. These graphs are offered to the camera operator as an additional tool for making a decision about the end of the drying process.

1. Introduction
Currently, there is a strong global demand for furniture and other solid wood products. This is due to their high consumer properties. The most suitable material for meeting the quality requirements of such products is hardwood. In the Siberian region, such a species is birch. Birch wood is characterized by high strength, hardness and impact strength [1]. In view of the increased density, the tendency to warping and damage by mushroom colors, drying of birch lumber is a rather complicated and energy-intensive process.

In works [2-9] the problems of energy consumption and control of operating parameters during wood drying are considered. It is concluded that the improvement of the quality of the dried material and, in general, the productivity of drying plants is associated with the improvement of both the designs of the chambers and the heat supply systems and automatic control of the wood drying process. The issues of improving the systems of automatic regulation of drying chambers are analyzed in works [10, 11].

Thermal requirements for the enclosing structures of drying chambers, data on heat consumption for drying sawn timber, analysis of the heat balance during chamber drying are given in the review [12].

Russian technology for drying birch wood provides for the use of normal and forced modes [13]. But such modes can be implemented only in chambers with steam heat supply, which are practically nonexistent in the forestry industry of the Russian Federation. Most modern batch convection chambers use a water heating system and, accordingly, soft drying modes. These modes allow obtaining high quality material without changing the strength properties and natural color of wood.
However, soft modes have a significant drawback - it is a long duration of the drying process. As a result, the productivity of the chambers decreases, the cost of drying increases, and most enterprises experience a shortage of drying capacities.

It is known that the process of convective drying of birch lumber includes periods of increasing drying speed and a pronounced period of decreasing speed when removing bound moisture. The second period can be up to 50% of the total process duration. Therefore, in the second period, the issue of timely forecasting the end of the drying process when the average moisture content of a batch of sawn timber reaches a given final one becomes especially relevant.

Currently, drying technology uses three methods for determining the current moisture content of sawn timber: the first is the method of control samples based on the weight method for determining the moisture content of wood; the second is electric (using a remote or manual conduct metric moisture meter); the third is analytical (based on the methods for calculating the duration of drying). The first method is laborious, requiring special equipment and personnel qualifications, therefore it is rarely used, mainly in scientific research. The second method is used in most modern cameras. However, it has a number of known disadvantages that reduce the accuracy of determining the moisture content of wood. The third is theoretical, does not allow taking into account the variability of wood properties and the deviation of the current parameters of the drying mode from the specified ones.

Therefore, despite the presence of various methods, the determination of both the current and final moisture content of sawn timber in the process of chamber drying requires additional research.

In [14], a graphical method was developed for determining the final moisture content of wood during impulse drying for various species of standard sections. The method for determining the final moisture content of wood is as follows: according to the diagram of the equilibrium moisture content, depending on the temperature t and the psychometric moisture $\Delta t$ of the drying agent, the value of the equilibrium moisture $W_e$ is found; Further, according to the graph of the dependence of the average moisture content of sawn timber on the equilibrium moisture content in the chamber at the end of the "pause" stage $W_{av} = f(W_e)$, the value of the final average moisture content of the stack is determined. The authors note that this method, with sufficient accuracy for production, predicts the final moisture content of sawn timber in the range of only 6 to 11%. It should be noted that, for a number of technical and organizational reasons, pulsed modes of drying sawn timber have not been widely used in practice.

2. Methods

Modern systems of automatic control of timber drying chambers are quite functional and, in particular, allow obtaining information about the parameters of the drying agent at the entrance and exit from the stacks. For example, figure 1 shows the dTOUCH synoptic menu of the LogicaHSi electronic control system for controlling the process of chamber drying of sawn timber. The blocks of sensors 1 and 2 are highlighted, displaying the temperature and equilibrium moisture content of EMC wood (Equilibrium Moisture Content).

The temperature difference and EMC of the sensor units characterizes the rate of moisture evaporation along the movement of the drying agent through the stacks.

The temperature difference and EMC in the chamber depends on a number of factors:

- rock and section of the material to be dried;
- the value of the initial, current and final moisture content of wood;
- volume and rate of circulation of the drying agent;
- severity of the drying mode;
- compliance with the rules for the formation of packages and stacks;
- technical condition of the camera.

These factors are variable. Depends on the technical characteristics of the camera and partly on the labor discipline. But with due observance of the drying technology, the temperature difference and EMC will be mainly due to the speed and amount of moisture evaporation from the wood. Consequently, there
is a hypothetical possibility of timely completion of the drying process at certain values of these differences.

![Image](https://example.com/image1.png)

Figure 1. dTOUCH synoptic menu page.

On the basis of the above, we propose to predict the end of the chamber drying process by a combination of two methods for determining the final moisture content of sawn timber: the first is technical (according to the indications of a standard remote moisture meter); the second is calculated (based on the temperature difference and EMC at the entrance and exit from the stack). This work is devoted to the development of the latter method.

Since its launch in 2016 and up to the present, we have been performing remote control of drying processes at one of the timber processing enterprises of the Irkutsk region. A block of 10 convection chambers of periodic action MJR-150 with a capacity of 120 m$^3$ conv. Is installed at the drying section. Lumber. Mainly birch sawn timber with a thickness of 25 and 50 mm is dried to a final moisture content of 8 - 10%, which are exported to Asian countries.

![Image](https://example.com/image2.png)

Figure 2. Drying curves for birch lumber 25 mm thick soft mode in the MJR-150 chamber.
The archive of dryers collected over the years of operation of the chambers was analyzed and statically processed in order to identify the dependence of the transfer of temperatures and EMC on the value of the final moisture content of sawn timber and the readings of a remote moisture meter. Figures 2 and 3 show, as an example, the results of industrial drying of birch lumber 25 and 50 mm thick, respectively.

Figure 3. Drying curves for birch lumber 50 mm thick soft mode in the MJR-150 chamber.

The temperature drops and EMC, as previously assumed, significantly decrease as the wood dries. So when drying lumber 25 mm thick (figure 2) at the beginning of the process $\Delta t$ reaches a maximum value of 15 °C, and $\Delta$EMC - 19.7%. At the end of the process, $t$ is minimal and varies in the range 0.3-1.1 °C, and EMC in the range 0.2-1%. When drying sawn timber with a thickness of 50 mm (figure 2), close values are visible: at the beginning of the process, $\Delta t$ rises to 12 °C, and EMC to 18%. At the end of the process, $\Delta t$ changes in the range of 0.1-2.1 °C, and EMC in the range of 0.1-0.7%.

Table 1. An example of primary data processing of industrial dryers of birch lumber 25 mm thick in convection chambers MJR-150.

| S, mm | W$_{av}$, % | n, pcs | $\Delta t$, °C | S, °C | V, % | $S_x$, % | $t_y$, % | $\Delta t$($t_y$, $S_x$), °C | $\Delta t$($t_y$, S), °C |
|-------|-------------|--------|----------------|-------|-------|---------|---------|-----------------------------|-----------------------------|
| 25    | 12±1.5      | 673    | 2.7            | 1.36  | 52.1  | 0.09    | 0.18    | 2.49                        | 2.84                        |
| 25    | 10±1.5      | 911    | 2.0            | 0.98  | 54.3  | 0.06    | 0.12    | 1.85                        | 2.08                        |
| 8±1.5 | 728         | 0.69   | 0.46           | 44.0  | 0.02  | 0.05    | 0.64    | 0.64                        | 0.73                        |

The data in table 1 show that the temperature difference has significant fluctuations due to the influence of the reversible operation of the fans. After compiling the algorithm for statistical data processing in the EXCEL program, we left the temperature measurements in the steady-state thermal regime in the chamber. The data $W_{av} = f(\Delta$EMC) were processed in a similar way. Table 2 shows the results of statistical processing for lumber 25 mm thick. In a similar way, the data of industrial dryers of sawn timber with a thickness of 50 mm were processed.
Table 2. Results of statistical processing $W_{av} = f (\Delta t)$.

| S, mm | $W_{av}$, % | n, pcs | $\Delta t$, °C | S, °C | V, % | $S_x$, °C | t$\rightarrow$S$\rightarrow$ °C | $\Delta t$-(t$\rightarrow$S$\rightarrow$), °C | $\Delta t$-(t$\rightarrow$S$\rightarrow$), °C |
|-------|-------------|--------|----------------|-------|------|----------|------------------|------------------|------------------|
| 50    | 12±1.5      | 485    | 3.1            | 1.56  | 36.5 | 0.09     | 0.17             | 2.88             | 3.22             |
| 8±1.5 | 10±1.5      | 711    | 2.5            | 0.72  | 30.4 | 0.05     | 0.10             | 2.37             | 2.57             |
|       | 8±1.5       | 479    | 1.6            | 0.50  | 32.7 | 0.03     | 0.07             | 1.48             | 1.61             |

Based on the results of statistical processing of experimental data, graphs (figure 3) of the dependence of the average moisture content $W_{av}$ of birch lumber on the values of temperature differences and equilibrium moisture in the range of final moisture content of wood 8 - 12% (taking into account the standard deviation of ± 1.5%) in cameras MJR-150 [13].

![Graph](image1.png)

**Figure 4.** Dependence graph $W_{av} = f (\Delta t, \Delta EMC)$ of birch lumber during convective drying in chambers MJR-150.

It was found that for thinner sawn timber with a thickness of 25 mm, the temperature differences and EMC are slightly higher than for large sawn timber. So for sawn timber with a thickness of 25 mm in the range of average humidity of 8 - 12%, the difference $\Delta t$ was from 1.5 to 3.1 °C, and the change in the $\Delta EMC$ stack was from 0.6 to 0.9%. For sawn timber with a thickness of 50 mm, $\Delta t$ varies from 0.9 to 1.2 °C, and $\Delta EMC$ from 0.5 to 0.8%. This circumstance is associated with a lower intensity of drying of lumber of large sections.

3. Conclusion

Analysis of graphical dependencies $W_{av} = f (\Delta t, \Delta EMC)$ confirmed the hypothesis of the possibility of timely completion of the process of convective drying of birch lumber in MJR-150 chambers. The camera operator, being guided by the readings of the remote moisture meter and the $t$ and $\Delta EMC$ values of the sensor units, receives an additional tool that, with sufficient accuracy for practice, allows him to make a decision about the end of the drying process.

The results obtained in this work are primary and require further research to obtain the dependencies $W_{av} = f (\Delta t, \Delta EMC)$ in batch chambers of various designs, capacities and applied drying modes.

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