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Losses in the manufacture of wooden building structures

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Abstract. Wood properties have successfully established themselves in the building structures. Very important to know expected wood losses in production. Losses are considered throughout the process of woodworking from sawmilling to obtaining glued blank. Research results were an assessment of losses in production of glued window beam as an example and substantiation of recommendations to production of wooden window blocks for choosing the type of primary source material: roundwood or edged sawn timber.

1. Introduction

The history of the use of wood in building structures in most countries of the world goes back many centuries and is lost in the depths of millennia. The richest forest resources of Russia is the reason for the widespread use of wood as one of the main building materials. Timber reserves in Russia are 82 billion m³, and the forested area of Russian territories is more than 777 million ha [1]. Wood is the only building material regenerated on the surface of the earth by the colossal energy of the Sun.

The use of wood as a structural material in the production of building structures contributes to a number of its properties:

- 1) low average density with a sufficiently high strength;
- 2) the manufacturability of the manufacture of structures of various dimensions and shapes;
- 3) high factory readiness of constructions;
- 4) low energy consumption for wood processing and manufacturing of structures (3–4 times lower compared to reinforced concrete structures and 8–10 lower compared to metal structures);
- 5) ease of assembly and processing of constructions at the construction site;
- 6) low costs of transportation and installation of constructions;
- 7) replenishment of the raw material base.

In addition, wood has excellent thermal engineering and decorative properties.

At the beginning of the 20th century, the development of wooden constructions received a new powerful impetus - the production of glued wooden constructions. The removal of areas with natural defects from the wooden structural elements that worsen the physical and mechanical properties of the wood, and the further gluing of the remaining parts of the wood into the blanks, revealed huge reserves of shaping of building structures, both in shape and in geometric characteristics.

The approximate structure of the use of wooden building structures, by type of construction, is as follows: civil engineering - 42%, industrial - 35%, transport - 13%, rural - 10%.



The excellent physical, mechanical and decorative properties of wood have proven successful in the manufacture of wooden stairs of various designs, including spiral, glued window beams [2], wooden facades with ventilated channels [3], reinforced curved wooden beams [4], and others constructive solutions. Moreover, for their constructive calculations, there are various methods of numerical modeling [5].

One of the traditional operational shortcomings of wood in the production of wooden building structures is its natural combustibility, but today the issues of fire resistance of wooden building structure have been successfully resolved [6, 7].

The subject of the research in this scientific article is the estimation of losses in the volume of wood during the production of wooden building structures.

2. Materials and methods

A number of scientific articles [8, 9, 10, 11, 12, 13, 14, 15] have been devoted to questions of assessing the strength characteristics of wood, optimizing sawn timber cutting, modeling sawn timber production processes and the output of sawn timber products, substantiating and calculating various timber cutting patterns [8, 9, 10, 11, 12, 13, 14, 15], in which the named problems have been successfully solved and considered.

However, only in the scientific article of Rukomoinikov K.P. [12] it is written that statistical indicators of wood processing indicate a 50% loss of processed wood into waste. But in all the above scientific articles, the process of losing wood to waste is considered only at the sawing stage, i.e., cutting round timber into lumber, and does not consider the integrated consumption of wood throughout the whole woodworking process from round timber to obtaining a finished glued blank.

The author of this scientific article set out to specifically assess the loss of wood in the production of window blocks, as the most massive building construction, and to give recommendations to manufacturers of wooden window blocks on the choice of the type of main source material: round wood or edged sawn timber. Each manufacturer of wooden window blocks needs to understand the feasibility of creating a deep processing of wood from roundwood to finished products.

Losses were considered by the author of this scientific article throughout the entire process of woodworking from sawmilling to obtaining final glued billets. As an example of a woodworking workshop for glued window timber production, the technological layout of the workshop [2], shown in Figure 1, is adopted.

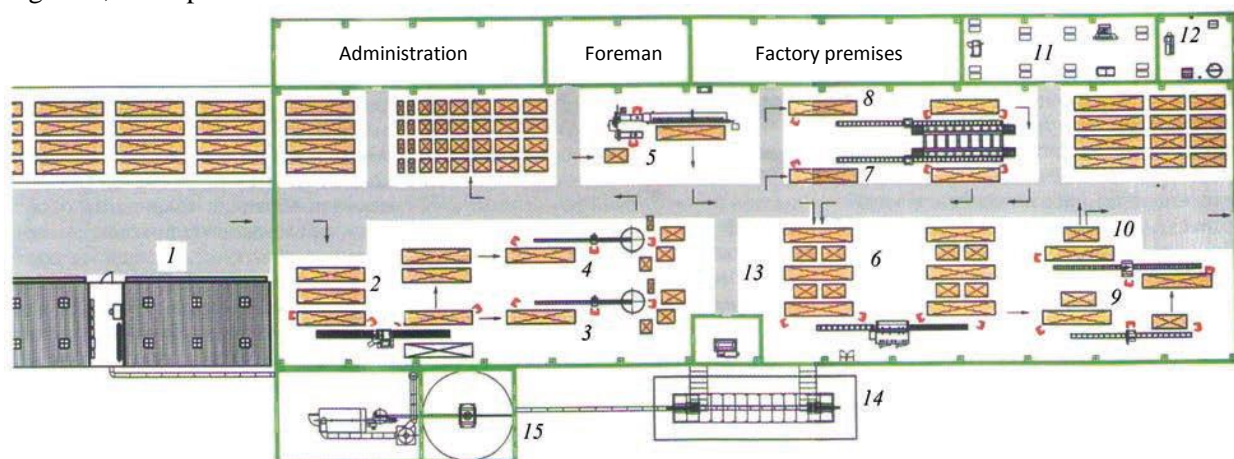


Figure 1. Technological layout of the window timber production workshop (1 - drying chambers; 2 - longitudinal sawing section; 3 and 4 - trimming machines; 5 – work piece splicing line along the length; 6 - four-sided longitudinal milling machine; 7 and 8 - presses; 9 and 10 - packing sections of the finished glued window timber into a film; 11 - tool section; 12 - compressor unit; 13 - grinding unit; 14 - aspiration system; 15 - boiler unit).

The technological process for the production of window timber is considered from sawing round wood to lumber in the lower warehouse of the timber industry enterprise and to obtaining a window timber in the window timber production workshop of a woodworking enterprise.

In the lower warehouse of the timber industry, roundwood is initially spread out on two-edged timber and unedged lumber. Then the two-edged beam is sawn into edged sawn timber, and at unedged sawn timber, the lateral edges are sawn off and edged sawn timber is obtained from them.

Edged lumber comes to the window timber production workshop of the woodworking enterprise (Fig. 1), which is dried in the drying chambers before machining (item 1). Dried to a relative humidity of 12-15%, the lumber comes to the section of longitudinal sawing 2, where the sawn timber is cut to a predetermined width. Then, at the cutting optimization section (items 3 and 4), they are trimmed and the wood affected by natural defects is removed. Sliced stacks of short billets on an automatic splicing line (item 5) are glued along the length into a single-layer glued billet 6 meters long, called the lamella. From the obtained lamellas, window blanks in the form of multilayer glued blanks are glued on the presses (items 7 and 8), which are then processed to a predetermined section of 84x86 mm on a four-sided longitudinal milling machine (item 6).

Assessment of wood losses in the production of window blocks is performed by the reverse calculation from the volume of finished products to the volume of the source material.

The initial data for the calculation is given in table 1.

Table 1. Initial data for estimating wood losses in the production of window blocks

| № | Name of parameter | Value |
|---|---|------------------|
| 1 | Window unit productivity per shift | 90 |
| 2 | Number of work shifts | 2 |
| 3 | Estimated number of working days per month | 21 |
| 4 | Estimated number of working days per year | 12 |
| 5 | The number of window bars in one window block | 16 linear meters |

The initial data for the calculation and the methodology for calculating losses in the production of wooden building structures are taken on the basis of many years of production experience of the author of a scientific article at the enterprises of the woodworking industry. The methodology for estimating wood losses in the production of wooden building structures is considered using glued window beam as an example and is illustrated in the "Research results" section of this scientific article.

3. Research results

The results of the research were the assessment of losses in the production of wooden building structures using the example of glued window beam and substantiation of recommendations to manufacturers of wooden window blocks for choosing the type of main source material: roundwood or edged sawn timber.

The final product in this case is glued window beam with a width of 84 mm and a thickness of 86 mm, which requires 16 linear meters per window unit (table 1). The calculation of the annual demand of glued window beam, according to the initial calculation data (table 1), is given in table 2.

Table 2. Calculation of the annual needs of glued window beam.

| № | The estimated number of window blocks and the time period for their manufacture | Number of window blocks in pieces | The total length of the window beam in linear meters | The volume of glued window beam in m ³ |
|---|---|-----------------------------------|--|---|
| 1 | One window unit | 1 | 16 | 0,1156 |
| 2 | Work shift | 90 | 1 440 | 10,4026 |
| 3 | A working day | 180 | 2 880 | 20,8052 |

| | | | | |
|---|-------|--------|---------|------------|
| 4 | Month | 3 780 | 60 480 | 436,9075 |
| 5 | Year | 45 360 | 725 760 | 5 242,8902 |

The net volume of the annual program for the production of glued window beam with a width of 84 mm and a thickness of 86 mm is 5 242,8902 m³.

The window beam is a three-layer wooden glued structure, which is glued from three layers of lamellas (single-layer wooden glued constructions) with a thickness of 35 mm and a width of 92 mm. The calculation of the annual demand for lamellas is given in table 3.

Table 3. Calculation of the annual demand for lamellas

| № | The estimated number of window blocks and the time period for their manufacture | Number of window blocks in pieces | Total length of lamellas in linear meters | Lamella volume in m ³ |
|---|---|-----------------------------------|---|----------------------------------|
| 1 | One window unit | 1 | 48 | 0,1546 |
| 2 | Work shift | 90 | 4 320 | 13,9104 |
| 3 | A working day | 180 | 8 640 | 27,8208 |
| 4 | Month | 3 780 | 181 440 | 584,2368 |
| 5 | Year | 45 360 | 2 177 280 | 7 010,8416 |

The volume of the annual program for the manufacture of slats with a thickness of 35 mm and a width of 92 mm is 7 010,8416 m³.

The lamels are glued along the length on an automatic splicing line (item 5 of Fig. 1) from short blanks of edged sawn timber with an average length of 350 mm and a width of 95 mm, previously cut at the cutting optimization section (items 3 and 4 of Fig. 1) with natural defects.

The calculation of the annual bonding volume of short pieces of edged sawn timber (sawn timber) with a length of 350 mm and a width of 95 mm on an automatic splice line is given in table 4.

Table 4. The calculation of the annual volume of bonding of blanks on an automatic line of splice

| № | The estimated number of window blocks and the time period for their manufacture | Number of window blocks in pieces | The total length of a running meter on the splice line in linear meters | Volume of a running meter on the line of merging in m ³ |
|---|---|-----------------------------------|---|--|
| 1 | One window unit | 1 | 50,53 | 0,168 |
| 2 | Work shift | 90 | 4 547,37 | 15,12 |
| 3 | A working day | 180 | 9 094,74 | 30,24 |
| 4 | Month | 3 780 | 190 989,47 | 635,04 |
| 5 | Year | 45 360 | 2 291 873,68 | 7 620,48 |

The annual processing volume of short blanks of edged sawn timber is an average length of 350 mm and a width of 95 mm on an automatic splice line is 7 620,48 m³.

Gluing of lamellas along the length is preceded by cutting of defective areas with natural defects from lumber of standard lengths of 4 to 6 m in the cutting optimization section (items 3 and 4 of Fig. 1). This technological operation, like all others, leads to losses. Calculation of the need of wood necessary for cutting defective places in the optimization section of cutting is given in table 5.

Table 5. Calculation of the need of wood necessary for cutting defective places.

| № | The estimated number of window blocks and the time period for their manufacture | Number of window blocks in pieces | Total length of a linear meters at the training optimization site per linear meter | Volume of a linear meters at the training optimization cutting site in m ³ |
|---|---|-----------------------------------|--|---|
| 1 | One window unit | 1 | 59,44 | 0,1976 |
| 2 | Work shift | 90 | 5 349,85 | 17,7882 |
| 3 | A working day | 180 | 10 699,7 | 35,5764 |
| 4 | Month | 3 780 | 224 693,5 | 747,1059 |
| 5 | Year | 45 360 | 2 696 321,98 | 8 965,2706 |

The annual demand for lumber for cutting defective places at the cutting optimization site in order to ensure a given production program is 8 965,2706 m³.

The above technological operations of mechanical processing of wood in the window timber production shop of a wood processing enterprise (Fig. 1) are preceded by chamber drying of lumber (item 1 of Fig. 1) to a relative humidity of 12 - 15%. In the window beam production workshop of the woodworking enterprise, lumber comes from the lower warehouse of the sawmill.

At a sawmill, cutting round wood to edged materials in two stages. On sawmill equipment of the first row of roundwood receive a two-edged beam and unedged lumber. And on the equipment of the second row, the two-edged timber is cut into edged sawn timber, which subsequently goes to the window beam production workshop of the woodworking enterprise.

The calculation of the need of wood to ensure the technological operations of chamber drying of wood, sawing a two-edged timber into edged lumber and sawing roundwood into a two-edged timber and unedged sawn timber is given in table 6.

Table 6. Calculation of the need of wood for chamber drying

| № | The estimated number of window blocks and the time period for their manufacture | The required amount of wood: | | |
|---|---|---------------------------------------|---|---|
| | | For drying chambers in m ³ | for sawing two-edged timber into edged lumber in m ³ | for sawing roundwood into timber and lumber in m ³ |
| 1 | One window unit | 0,2036 | 0,2714 | 0,4524 |
| 2 | Work shift | 18,3219 | 24,4292 | 40,7153 |
| 3 | A working day | 36,6438 | 48,8584 | 81,4306 |
| 4 | Month | 769,5191 | 1 026,0254 | 1 710,0424 |
| 5 | Year | 9 234,2287 | 12 312,3049 | 20 520,5082 |

The required annual volume of wood for chamber drying is 9 234,2287 m³, for sawing two-edged timber into edged sawn timber – 12 312,3049 m³, for sawing roundwood into two-edged timber and unedged sawn timber – 20 520,5082 m³.

4. Conclusion and recommendations

The research results presented in tables two to six are summarized in final table 7. In table 7, the technological operations for the production of wooden glued beams for the manufacture of window blocks are arranged in the order of their execution.

Table 7. Technological operations for the production of wooden glued beams

| № | Name of technological operation | The required amount of wood in m ³ | The required amount of wood in % |
|---|--|---|----------------------------------|
| 1 | Sawing up of roundwood (logs) | 20 520,5082 | 100 |
| 2 | Sawing a two-edged beam into lumber | 12 312,3049 | 60 |
| 3 | Chamber wood drying | 9 234,2287 | 45 |
| 4 | Cutting out defective sections of lumber | 8 965,2706 | 43,7 |
| 6 | Splicing lamellas along the length | 7 620,48 | 37,1 |
| 7 | Lamella machining | 7 010,8416 | 34,2 |
| 8 | Bonding and processing of window beams | 5 242,8902 | 25,5 |

Analyzing table 7, we can draw the following conclusions:

1. In the process of wood processing at a sawmill in the lower warehouse of the timber industry, its losses amount to 55%. For further processing, only 45% of the round timber brought from the forest plot comes to the window timber production workshop. This conclusion is not significantly different from the statement in the scientific article by Rukomoinikov K.P. [12] that statistical indicators of wood processing indicate a 50% loss of processed wood into waste.

2. The yield of finished products is only 25.5% of the roundwood brought from the forest plot, that is, 74.5% of the original wood is not suitable for the production of glued wooden window timber.

3. Considering the source material for the window timber production shop not round timber, but edged sawn timber, we can count on 56.8% of the finished yield and only 43.2% of timber loss.

4. Evaluating the task from a technological point of view, it can be considered that it is advisable for the production of wooden glued window timber to be considered as raw material not roundwood, but edged sawn timber.

In this scientific article, the task of organizing the production of glued wooden window beam is considered from a technological point of view. Entrepreneurs who intend to organize the production of wooden window blocks, the above calculations must be supplemented with economic indicators. A feasibility study should be carried out, which will make it possible to make an informed and balanced decision.

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