Selection of controlled parameters of the technological process of obtaining CLT panels with increased sound insulation

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Abstract. The problem of creating high-quality sound insulation materials is an important area of development of the construction industry today. Therefore, at the manufacturing stage, it is necessary to observe many different indicators that affect the quality characteristics of building materials. One of the ways to improve the sound insulation characteristics in the construction of capital walls of buildings is the use of multilayer wooden panels consisting of modernized wooden lamella structures. There are various technologies for the production of multilayer wooden panels, most of which have proven themselves well in the construction industry and allow the use of wood of various breeds and varieties, combine them to achieve optimal characteristics, such as high heat capacity, fire resistance, noise insulation, environmental friendliness, biological resistance, almost complete absence of shrinkage. Mathematical modeling of such multifactorial processes makes it possible to determine the optimal strategy for conducting the technological process. By controlling the technological process in this way, taking into account the specified quantitative and qualitative characteristics, it is possible to obtain a CLT panel with the specified sound insulation properties.

1 Introduction

The production of CLT panels is currently widely developed in the domestic construction industry and is an important direction in the implementation of wooden housing construction [1-9]. Various technologies for the production of multilayer wooden panels make it possible to use wood of different species and grades, combine them to achieve optimal characteristics, such as high heat capacity, fire resistance, noise insulation, environmental friendliness, biological resistance. In addition, due to the fact that the structure is made of packages of vertically and horizontally located wooden lamellas, the shrinkage of wooden panels is excluded, and the ability to absorb vertical and horizontal loads increases from 4 to 16 times.

Depending on the design features and physical and mechanical characteristics, CLT panels can serve as independent vertical load-bearing structures, as well as partitions, walls with the necessary specified properties, including those with increased sound insulation.

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2 Materials and methods

Finding the optimal process conditions is an important task in the production of any product. At each stage, it is necessary to identify certain factors that affect the quality of the material, including strength, wear resistance, thermal conductivity, sound insulation and other characteristics. It is also necessary to take into account the uncertainty of the conditions (there is no sufficient information support about the functional dependence of each parameter) under which the technological process of manufacturing wooden structures will be carried out.

The technological process of obtaining CLT panels with improved sound insulation properties is complex and consists of many interrelated operations (Figure 1).

The main processes necessary for coordination and control:

- determination of the specified properties of the panel, selection of raw materials, equipment, production technology;
- preparation of raw materials; preparation of separate block packages made up of separate cross-arranged vertical and horizontal 2 boards of the same length (lamellas);
- preparation of lamellas with porization (cellular structure);
- assembly, impregnation and pressing of the main unit from block packages and lamellas with porization (cellular structure);
- formatting, including calibration on the plane of the main unit (processing on the plane with simultaneous removal of glue swells);
- checking the performance properties for quality, etc.

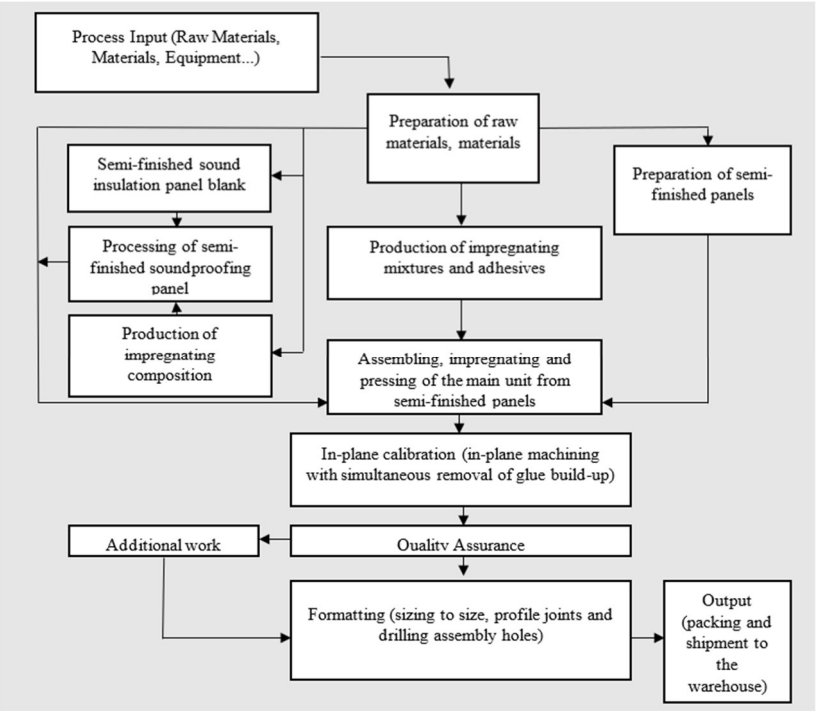

Fig. 1. General scheme of the technological process of manufacturing CLT panels with a sound insulation layer.

A special feature of the process is the inclusion in the main technological process of manufacturing a multilayer wooden building panel: after drying, sorting and harvesting of individual block packages, operations for the preparation of soundproof lamellas with a cellular structure were added [10, 11].

Pine, larch, spruce, birch, furniture panels, OSB, plywood and other board materials of various types of wood, or their multi-layer combinations, can be used as part of a wooden building panel.

In the process of manufacturing lamellas with a cellular structure, parabolic cavities – "sound pockets" – are drilled along the entire plane of the slab (Figure 2).

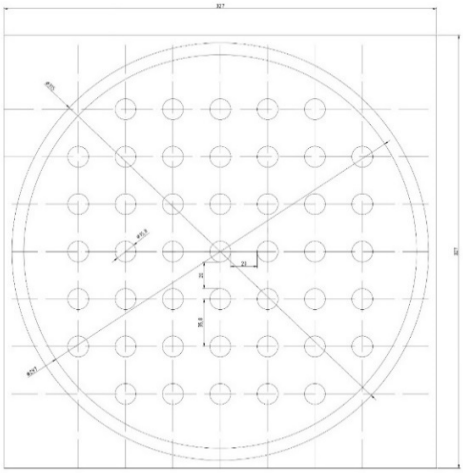

Fig. 2. General arrangement of «sound pockets» in lamellas with a honeycomb structure with the following parameters: d = 15.8 mm, h = 14 mm, l = 20 mm, d – drilling diameter, h – drilling depth, l – pitch between «sound pockets».

Studies have shown that the use of such a lamella with a pore – a device of "sound pockets" – increases the sound absorption of the entire multi-layer wooden building panel.

In the study of sound processes [12] of wooden panels of complex construction, the following assumptions were made: sound vibrations are a non-harmonic signal, the vibration spectrum is 300-3400 Hz, the impedance depends on the frequency, and the structural parameters do not change over time. The sound was decomposed into spectral components using the Fourier transform, then the influence of each spectral component was taken into account. The sum of the responses to the spectral components was equal to the response to the original non-harmonic signal. The fin(t) audio source was previously converted to a complex representation of Ft(s) using a direct Laplace transform:

$$F_t(s) = \int_0^\infty fin\,(t)e^{-st}dt \quad (1)$$

The complex sound impedance of any structure through the converted complex representation of the sound source and the complex transmission function of the building structure H(s) is expressed as follows:

$$F_{t,H}\,(s) = H(s)F_t(s) \quad (2)$$

For the CLT panel design, the Ra value from the equation for inharmonic sound corresponds to the sound resistance and can be calculated experimentally from the sound pressure. The acoustic resistance Xa, which was calculated according to the formula, depends on the sound frequency ω and parameter C – properties of the internal cavities of the resonator structure (geometric dimensions, material density, surface treatment purity, sound absorption coefficient of the building material:

$$X_a = - i/(\omega C) - \frac{i}{\omega C} \quad (3)$$

The technological process of obtaining CLT panels with improved sound insulation is a complex technical system. The study of the problem of determination and improvement, including the selection of N structural and functional characteristics and factors that affect operational properties, is a multi-criteria problem, and its solution is possible with the help of mathematical modeling [13-15].

In this case, the construction of a mathematical model for a complex technical system under conditions of certainty and uncertainty can be represented by the technical characteristics of this process: $X = \{x_1, x_2, \ldots, xN\}T$ or $X = \{x_j, j = 1, \mathrm{N}\}$, with defined value limits: $x_j min \leq x_j \leq x_j max$, где $j = 1,\mathrm{T}$, determining the state of a wood panel, a technological system at a certain point in time.

For mathematical modeling, it is necessary to select certain parameters at each stage of production:

1) Determination of the optimal list of N controllable factors influencing the main quality characteristics of wooden panels:
$$x_i \in [x_1 \ldots, x_N]; \; i \in [1, N] \quad (4)$$
2) Choosing a system for normalizing the units of measurement of factors in order to bring them to a single measurement for all (usually dimensionless numbers from 0 to 1).
3) Construction of functional interdependencies for production process control factors:
$$x_o = a_1x_1 + a_2x_2 + a_n x_n \; x_i = F_i\,(x_j); \; j \in [1, N]; \; i \neq j \quad (5)$$

Where x_o – is a generalized criterion of optimality, provided that all xi simultaneously tend to either a maximum or a minimum.

4) Formalization or acceptance of boundary conditions for both factors and the range of admissible solutions to the technological process problem: $a_i \geq x_i \geq b_i; \; i \in [1, N]$
5) Construction of objective functions with full formalization of their dependence on all selected controlled factors of the technological process: $F_k \rightarrow max; \; k \in [1, N]; \; Fj \rightarrow min; \; I \in [1, N]; \; j \neq k$

Thus, the identification and selection of factors capable of regulating the quality of the product at each stage of production is a very important task to determine the optimal conditions for system improvements.

3 Results and discussions

In the manufacture of CLT panels, there are many factors that affect their performance (Figure 3).

Statistical data processing and mathematical modeling methods are used to process these input parameters, including the required thickness (multilayer), compressive strength, load-bearing capacity, sound insulation coefficient, as well as the parameters of a lamella with a cellular structure (sound pockets).

An important point before the start of the production process is to establish the necessary requirements for the wooden panel in accordance with the subsequent purpose and use: for the wall, load-bearing vertical structure, partition, etc. In accordance with this, the wood is selected, all the main properties are set, as well as the location and diameter of the pores or «sound pockets» in the lamellas, the sound insulation coefficient.

Next, there are the main technological operations for the direct manufacture of individual lamellas. One of the key operations in the creation of a lamella with porization (honeycomb structure), which affects the quality of sound insulation, is the determination of the parameters of «sound pockets»: d – is the drilling diameter, h – is the drilling depth, l – is the pitch between the «sound pockets». The arrangement of the «sound pockets» can be different

and depends on the frequency of the sound wave and the sound pressure under certain conditions. Before assembling the lamellas into a block, it is cleaned of the formed chips and wood dust. At the stage of impregnation, assembly and gluing of the main unit, its quality is greatly influenced by the type and quantity of the impregnating mixture and adhesives, the accuracy of their dosage, temperature and pressing time.

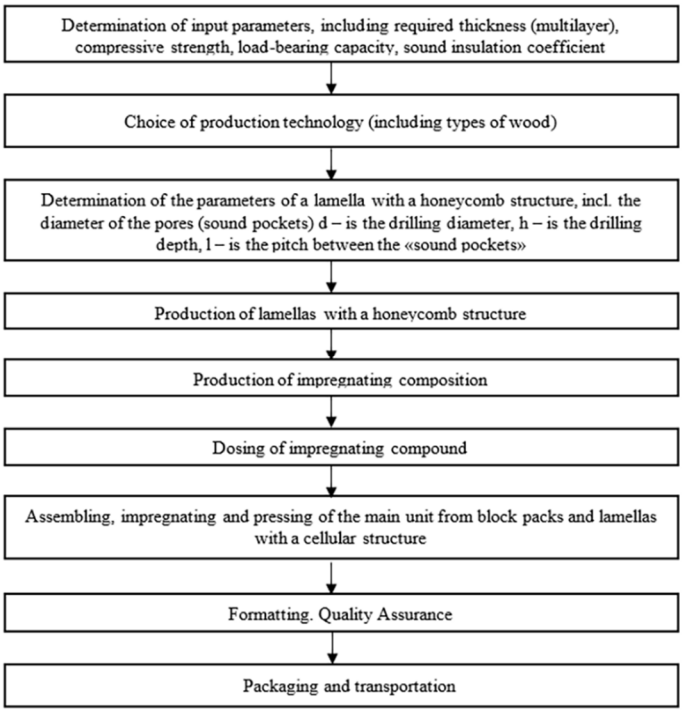

Fig. 3. Factors influencing the processes of obtaining CLT panels with increased sound insulation.

At the same time, all the main quantitative parameters of the technological process are observed. By controlling the process in this way, taking into account the specified thickness of the lamellas, the density of the wood, the location and diameter of the pores, it is possible to obtain a CLT panel with the specified sound insulation properties.

4 Conclusion

Mathematical modeling of such multifactorial processes as the technology of creating wooden panels makes it possible to identify factors that have a significant impact on the technological process, as well as to determine the optimal strategy for the development of complex engineering systems.

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