Digital technology in the construction of Norwegian house

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Abstract. This work shows the development and implementation of digital technology in the production of wooden houses using the “Norwegian carriage”. The methodology of all stages from designing a house, developing control programs and manufacturing a house with minimal human participation is considered. This approach can significantly reduce the human factor and increase productivity and quality of products. The equipment designed and manufactured for the implementation of this technology is described. The results of experimental processing and assembly of house elements according to the “Norwegian technology” are shown. The cutting modes were worked out and a tool was selected to obtain a high-quality surface.

1. Introduction
Construction is one of the largest and most capital-intensive sectors of the global economy. According to McKinsey and CB INSIGHT, the construction industry is one of the last in terms of digitalization, second only to agriculture [1]. Solving the problem of digitalization in the construction industry, within the framework of the Federal Project "Digital Technologies" [2], can become one of the important competitive advantages and a powerful source of growth. Currently, the greatest successes are associated with the automation of design processes, the development of CAD-CAM packages, allowing the architect to provide detailed design to any level with visualization and all strength calculations.

2. Relevance
In real construction production, the share of “digital technologies” is critically small. In the production of wooden houses, there are no large volumes and a large proportion of individual projects makes it difficult to introduce innovations. At the same time, the Ministry of Construction of Russia has developed proposals for the development of wooden housing construction - a draft Action Plan to support and develop the demand for wooden housing construction products. [3]

This is especially true in the framework of regional programs for the resettlement of citizens from emergency housing in small towns, as well as in the elimination of natural and emergency situations that are associated with the commissioning of a large volume of individual housing.

According to the rating agency of the construction complex, over the past ten years, wooden housing has accounted for 9-10% of housing being built in Russia, while in the United States a similar figure is 40%. It should be noted that most of the American housing construction is based on the
construction of frame houses, while in Russia, especially in the Siberian region, the construction of solid logs and timber is the most relevant and natural. [4]

3. Formulation of the problem
Based on the relevance of the problem, the task was set to develop and introduce new digital technologies in the construction of wooden houses by achieving the highest possible level of automation of production of house kits in the factory and developing high-speed processing methods to obtain maximum efficiency. This paper discusses the "digital technology" of design and production of houses based on the Norwegian joint.

4. Theoretical part
The Norwegian compound (Figure 1) is wedge-shaped and has a smooth surface. The edges of the joint are squeezed at a certain angle and when drying the logs of the carriages under their own weight begins to sag, preventing the appearance of cracks between the cups of the joint. Also, a spike is made at the bottom of the bowl, under which a corresponding groove is machined in the log. Due to the wedge-shaped shape and smooth surfaces, the connection is reliably jammed under load in the lock, and the spike eliminates blowing of the lock. Due to the density of the compound, water does not enter, this reduces the risk of wood decay [5-7].

Figure 1. Norwegian joint.

The technology of cutting “wedge into wedge”, due to the high density of the connection, will not allow the carriage to rotate and limit crowns from deformation due to stresses. The corner connection of the carriage of the “Norwegian house” has a minimum blowing capacity, eliminates the direct ingress of outside air into the room, and prevents heat loss in the corner joints [8-10]. This type of joint is widely used in the countries of Scandinavia, but in Russia its use is still rarely used due to complexity.

Due to the design features of the joint itself, the Norwegian logging process is very time-consuming, many operations are performed manually, which determines the high complexity of manufacturing and the cost of the log house [11-14]. In addition, the quality of the joint depends on
the professionalism of the carpenter and his experience. An analysis of open sources showed that at present in Russia there is no technological equipment for the manufacture of "Norwegian joint " in the factory, and specialized firms make it manually.

In this work, we propose one of the approaches to the implementation of digital technology for manufacturing from a carriage all the components of a log house under the "Norwegian joint ". A production system has been developed that includes a multi-axis CNC milling machine integrated with a CAD / CAM system.

The architect creates a project of the future home in any convenient CAD program (ARCHICAD, WoodCon, etc.), in the form of a 3D model and transfers it to the technologists.

At the stage of preparing the management program for the project, an individual 3D model of each structural element is developed (Figure 2), its shape, dimensions, spatial position in the log house are determined and attached to the position on the log. Further, in the CAM-system SPRUTCAM [15], a processing program for each individual element is automatically prepared and transferred to the machine.

This approach allows us to provide technological support for production, regardless of the individual characteristics of the house project. We believe that any project consists of almost the same elements, differing only in the thickness of the carriage and the different relative positions of the locks on the carriage, which is easily manufactured using the developed equipment.

5. Practical implementation
For testing and practical implementation of the developed digital technology, we designed and manufactured a woodworking machine with CNC, which allows you to automatically process the log carriage with locks, with all the necessary technological transitions.

Our team has extensive experience in the design and modernization of equipment, including metal-cutting machines based on standard units (linear drives, spindles, guides, etc.) and control systems [16-19].

The machine for carriage processing is built on the basis of the modular principle [20], which is widely used in the design of metal-cutting machines with the maximum use of standard elements. The milling machine “Norwegian joint” joint (Figure 3) is a welded construction on which the spatial
frame (Z axis) moves up / down. A table is installed on the spatial frame, which moves in the longitudinal (X axis) and transverse (Y axis) directions. On the table there is a positional rotary device (axis C), in the upper part of which a two-sided motor spindle ET120x103-6.0 with an ACD200 frequency converter is installed. The operation of this unit is controlled by a four-axis CNC controller. All movements are carried out along HIWIN linear guides with ball bearings, through a rolling screw-nut and a 110ST-M060 servomotor in all axes, which ensures kinematic rigidity and positioning accuracy during processing.

As the software control of the DDCSV2.1 CNC controller, the Mach3 CNC [21] application is used in the standard three-axis version for the milling machine. The fourth axis C is positional, it does not participate in interpolation and serves only to rotate and install the spindle at a certain angle relative to the axis of the carriage, according to the geometry of the Norwegian joint.

![Figure 3. A machine for milling a Norwegian joint.](image1)

The working feed during milling of the lock elements (Figure 4) reaches 6 m/min, the accelerated feed reaches 15 m/min. The milling time of one element of the “Norwegian joint” (Figure 5) is no more than one minute, and all elements on the carriage are processed no more than 5 minutes.

![Figure 4. Milling elements of a Norwegian joint.](image2)
This allows you to make up to 200 joints with a full load of equipment, which is enough for an average wooden house with an area of 50 to 80 sq.m. Thus, the equipment allows you to get a «house kit» for 1 work shift.

All processed logs are marked and assembled in the house kit, according to the specification of the log house, which is delivered to the place of construction of the house. On a prepared foundation, according to a special scheme, the house is assembled within 1-2 days.

The experiments showed that the automation of the manufacture of a log house (Figure 6) from a carriage using the Norwegian technology based on digital engineering CAD / CAM technologies with end-to-end network support allows us to implement digital technology in the production of wooden houses, which guarantees high productivity and quality of log house production. The new technology eliminates the “human factor”, and the final quality of the house depends only on the woodworking program, the condition of the equipment and the raw materials used.

6. Conclusion:
1. The use of digital engineering CAD / CAM-technologies in construction and the development of specialized CNC equipment for this technology will allow in the future to create digital production in wooden housing construction with a full production cycle.
2. The use of the developed equipment not only increases the productivity by an order of magnitude in combination with a sharp decrease in the overall costs of manufacturing, but also allows you to significantly reduce the production cycle of construction, by eliminating fitting operations.
3. During the experiments, the technical characteristics of the equipment were confirmed and the optimal modes and parameters of the woodworking process were found.
4. Identified "weaknesses" that need to be addressed when implementing this technology in real production. In particular, to increase the rigidity of the frame, increase the power of the spindle, to ensure the supply of the carriage up to 8 m long.

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