Study of the process of processing felling residues in the conditions of logging operations

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Abstract. Until recently, only the trunk was recognized as valuable in the forestry industry, and everything else, including the crown, was considered waste that cluttered the areas of cutting areas, and was also considered a dangerous raw material in the event of possible fires. Currently, only about 700 thousand tons of wood waste is used, which is no more than 4% of the resulting amount of potential raw materials that could be used at wood processing enterprises. Analysis of the processes of formation and use of felling waste showed that today coniferous greenery has found its application as a raw material for the production of coniferous flour, which is produced directly at the cutting area. After the needles are separated, branches remain in the cutting area that have not found further use. One of the promising areas for the use of logging waste after the separation of needles is the production of wood flour, which has found its wide application in many industries. In the course of research, a design of a mobile device for processing felling residues in a felling area into wood floor was proposed and a laboratory prototype was made. In the course of the analysis of the results of experimental studies, the influence of the design and technological parameters of the device for obtaining wood flour from felling residues on the quality indicators of the finished marketable product was revealed. Statistical and mathematical equations and graphical dependencies have been obtained, which make it possible to predict the qualitative characteristics of wood floor for given design and technological parameters.

1. Introduction

Today, in the context of a continuous increase in the demand for wood raw materials, its complex and rational use is of particular importance. In this regard, the key direction in the development of the forestry complex is to increase the use of woody biomass in the production process [1-3]. In order to increase the coefficient of integrated use of wood, technology and equipment have been developed (patents for invention No. 2673858 dated November 30, 2018 and No. 2698059 dated August 21, 2019) for processing large branches and twigs into semi-finished wood fiber, and coniferous greenery into flour. As a result, small branches and legs without needles remained unused logging waste.

Analysis of practical experience and work of modern researchers [4, 5] showed that the most appropriate direction for using the remaining part of logging waste is the production of wood flour, which has found its wide application in the production of materials such as phenolic plastics, explosives, polymer composite and building materials, alkyd linoleums, pigment titanium dioxide, filter elements, catalysts, etc. [6,7].
2. Methods and materials

In order to identify the requirements for the quality indicators of wood flour, an analysis of the areas of application and the geometric characteristics of the particles of the finished product was carried out, which showed that its dimensions should not exceed 0.5 mm. To process small twigs and pine needles without needles into wood flour with a particle size of no more than 0.5 mm, a knife machine was designed and a laboratory prototype was made figures 1, 2.

![Diagram of a device for obtaining wood flour from logging waste](image1)

Figure 1. Diagram of a device for obtaining wood flour from logging waste: 1 - drive shaft, 2 - driven shaft; 3 - sieve; 4 - loading branch pipe.

![Laboratory prototype of a device for obtaining wood flour from logging waste](image2)

Figure 2. Laboratory prototype of a device for obtaining wood flour from logging waste.

The principle of operation of the mobile unit shown in figures 1 and 2 is as follows: the raw material, presented in the form of felling residues, is fed into the loading nozzle 4. The wood raw material is shredded due to the forces of squeezing, crushing and abrasion of the leading crowns 1 and 2 shafts. The raw material crushed to the required size leaves the working chamber through the calibration sieve 3.
With regard to scientific problems, a complex of modern research methods was used: numerical modeling, mathematical planning and statistical analysis. An active multifactorial experiment was adopted by us as the main method for obtaining a statistical-mathematical description of the process under study using the second-order B-plan. As input factors of the experiment were chosen: the size of the working gap \( z \), wear of the working bodies of the device \( q \), the frequency of rotation of the drive shaft \( n \). The average particle size of wood flour \( R \) was selected as an output parameter.

The choice of the main characteristics of the model according to the program of experimental studies is presented in the form of a functional dependence:

\[
R = f(z, q, n),
\]

Based on a series of preliminary experiments, the following intervals of variation of the input parameters of the process under study were selected: \( 1.0 \leq z \leq 3.0 \) mm, \( 10 \leq q \leq 90\% \), \( 1000 \leq n \leq 2000 \) rpm.

3. Results and discussion
As a result of processing experimental data using a modern experimental and laboratory-measuring base at the appropriate level of metrological support of research, equations were obtained that describe the dependence of the particle size of wood flour on the size of the working gap, the degree of wear of the working bodies of the device and the speed of rotation of the drive shaft.

\[
R = 0.39 + 0.33 \cdot q + 0.16 \cdot z + 0.18 \cdot n - 0.13 \cdot q^2 - 0.19 \cdot z^2 - 0.01 \cdot n^2 + \\
+ 0.03 \cdot q \cdot z + 0.01 \cdot q \cdot n + 0.01 \cdot n \cdot z
\]

The calculations confirmed that all the coefficients of the regression equation are significant.

For clarity and a more complete assessment of the influence of the investigated factors on the geometric dimensions of wood flour particles according to equation 2, graphical dependences are built in the form of response surfaces (figure 3).

![Graphical Dependence](image)

\( a \) – on the size of the working gap and wear of the working bodies.

\( b \) – from the speed of rotation of the drive shaft and wear of the working bodies.

Figure 3. Dependence of the influence of the technological parameters of the knife installation on the average particle size of wood flour.

It can be seen from the graphical dependence shown in Figure 3a, with an increase in the size of the working gap to 1.9-2.1 mm and wear of the working bodies to 50-55%, the particle size of wood flour increases and reaches its maximum value of 0.42 mm. With a further increase in the size of the working gap and wear of the working bodies, the particle size of the wood flour tends to decrease. Analyzing the graphical dependence shown in figure 3b, it can be seen that with an increase in the rotational speed of the drive shaft up to 1500-1700 rpm, the particle size of wood flour increases to 0.51-0.53 mm. With a further increase in the rotational speed of the driven shaft, a slight decrease in the particle size of wood flour occurs.
4. Conclusion
Thus, the production of wood flour from branches and coniferous legs without needles will reduce the amount of unused wood biomass left in the felling area, which will have a positive impact on the environment and increase the integrated use of wood. The statistical-mathematical equation and graphical dependencies obtained in the course of research, describing the process of producing wood flour, allow predicting the geometric characteristics of the finished product, depending on the design and technological parameters of the device's operation process. The analysis of the research results showed that the best average particle size of wood flour is obtained with a working gap of 0.9-1.1 mm, a drive shaft speed of 900-1100 rpm, wear of working bodies of 10-30%.

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