Development of a method and equipment for processing wood biomass into flour

M.A. Zyryanov*, and *E.D.* Ivantsova

Reshetnev Siberian State University of Science and Technology, 660037 Krasnoyarsk, Russia

Abstract. The paper assesses the relevance of processing felling residues at logging sites into semi-finished wood products for further transportation and use at enterprises of the forestry and agro-industrial complex. In particular, the expediency of making wood flour from felling residues is justified. An assessment of the effectiveness of using wood flour as a baking powder for adding to depleted soils and plant insulation is given, which will lead to an increase in the yield of cultivated plants. As a result, the purpose of these studies was to increase the efficiency of using wood biomass by introducing a mobile plant for wood flour production into the logging process. To achieve this goal, the design of a mobile installation for the production of wood flour in logging operations, technology and algorithm of its implementation were developed. To substantiate the effectiveness of design and technological solutions implemented in the process of designing the installation, a multifactorial experiment using a laboratory prototype was planned and implemented. An analysis of the results of experimental studies is presented, regression models and graphical dependences of the size of wood particles on the input parameters of the studies are obtained. The optimal values of the moisture content of the wood raw materials, the wear of the teeth of the working bodies and the gap between them were determined. In the course of the research, methods of statistical analysis, modeling and active multifactorial experiment were used. The results obtained can be used by logging, wood processing and agricultural enterprises to obtain additional raw materials for the production of semi-finished products and materials, as well as in the design of new types of equipment.

1 Introduction

Forests in the Russian Federation occupy significant territories and form the raw material basis for the logging and woodworking industries. It is known that during logging operations, a large amount of unused tree biomass accumulates [1-3]. These include branches, twigs, tops and trunk remnants. Previously, researchers [4-7] had already attempted to produce semi-finished products from logging waste for wood processing enterprises. In particular, a system of mobile machines has been developed for the production of wood chips, semi-finished wood fiber and coniferous flour in logging operations [8]. Coniferous boughs with separated needles, branches and branches with a

*Corresponding author: zuryanov13@mail.ru

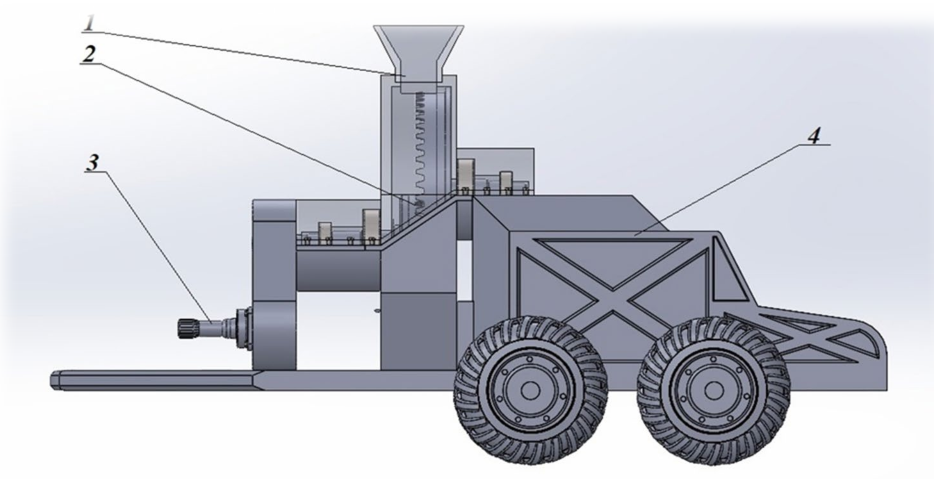
diameter of up to 10 cm remained not involved in the production of semi-finished products. One of the possible ways of processing this type of logging waste is the production of wood flour [9-12]. It has been established that in agricultural activities, wood flour has found its application as a baking powder for soil poor in nutrients and insulation for plants. To produce wood flour from logging waste, a mobile plant and technology for its production have been developed.

2 Materials and Methods

The purpose of this work is to increase the efficiency of using wood biomass by developing a design and introducing a mobile plant for the production of wood flour into the logging process. The research is based on the results of an analysis of the practical experience of operating logging and wood processing enterprises, as well as the works of researchers [13-15] dealing with the issues of complex processing of wood biomass. During the research, methods of statistical analysis, analytical, modeling in the environment of the Compass 3D v.21 program and active experiment were applied.

3 Results and Discussion

To increase the efficiency of using wood biomass, a design of a mobile installation for the production of wood flour in logging operations from coniferous boughs with separated needles, branches and branches with a diameter of up to 10 cm was developed. The 3D model of the installation is shown in Figure 1, and the technical characteristics - in Table 1.



1 – loading compartment; 2 – work chamber; 3 – drive shaft; 4 – vacuum packaging module

Fig. 1. 3D model of a mobile plant for wood flour production.

Table 1. Technical characteristics of a mobile plant for wood flour production.

Indicator	Value
Efficiency, m^3/h	3
Maximum diameter of the processed material, cm	14
Unladen weight, kg	1370
Overall dimensions, mm: - length	2043

https://doi.org/10.1051/bioconf/202410814007

- width	1010
- height	1440

As can be seen from Figure 1, the wood raw material is fed through the feed pipe 1 into the working chamber 2. The processing of wood into flour takes place in the work chamber when stator and rotor teeth create abrasion and pressure effects. The torque is transmitted to the rotor by means of the drive shaft 3. The drive shaft is connected through the power take-off shaft of any self-propelled machine located in the cutting area with an internal combustion engine. The resulting wood flour, which has passed through the calibration holes of the mesh installed in the work chamber, enters the vacuum packaging module 4. By installing a grid with different hole diameters, the size of the wood particles of the semi-finished product can be adjusted.

Figures 2 and 3 show a technological scheme for the production of wood flour in the conditions of logging operations and an algorithm for its implementation.

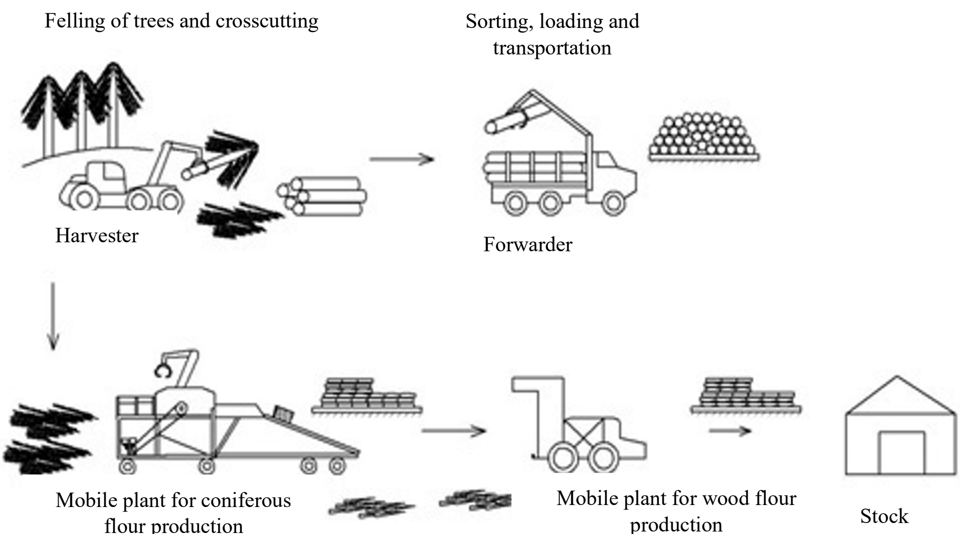


Fig. 2. Technological scheme of the process of processing felling residues into wood flour

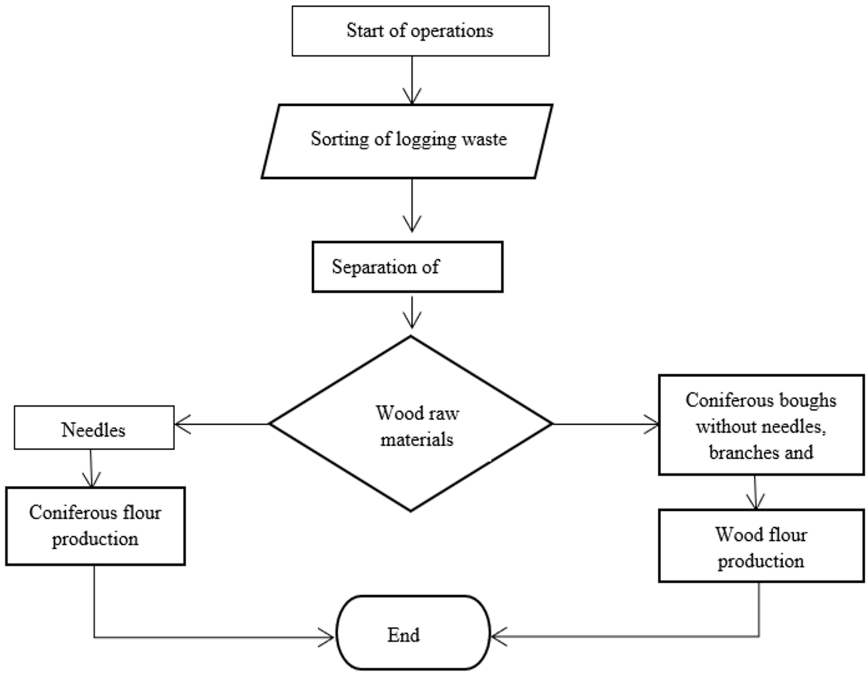


Fig. 3. Algorithm for wood flour production from felling residues

As can be seen from Figures 2 and 3, the process of producing wood flour begins with loading the felling residues into a mobile plant for wood flour production. At the same time, at this stage, the coniferous boughs are sorted with and without needles. If the coniferous boughs are with needles, then they are sent to the plant for the production of coniferous vitamin flour. Coniferous boughs without needles, branches and branches with a diameter of up to 10 mm are supplied to the plant for the production of coniferous flour. After the mobile plant for wood flour production, the packed bags arrive at the warehouse for further transportation.

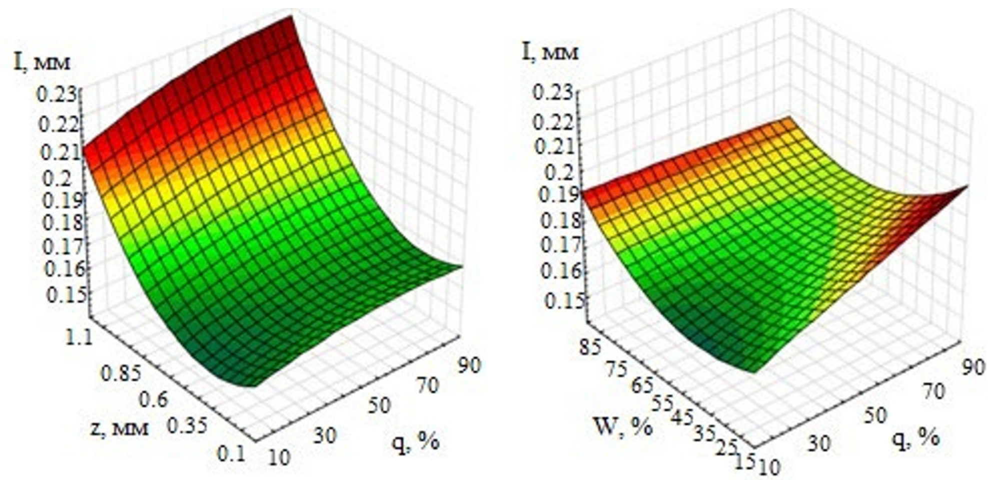
To confirm the plant effectiveness, a multifactorial experiment was implemented on a laboratory prototype. The gap between the rotor and stator teeth (z, mm), wear of the working bodies (q, %), moisture content of the processed wood (W, %) were the input factors of the research. The input parameters of the studies varied in the following ranges: $(0.1) \leq z \leq (1.1)$ mm, $(10) \leq q \leq (90)$ %, $(15) \leq W \leq (85)$ %. Experimental studies were carried out on pine, larch, fir and birch wood. As an example, the results of research on the processing of waste from logging of pine wood are presented below.

Regression dependencies describing the effects of the main technological parameters of the installation on the size of wood particles will look like:

$$\mathrm{I} = 0{,}1699 + 0{,}0054 \cdot \mathrm{q} + 0{,}0216 \cdot \mathrm{z} - 0{,}0027 \cdot \mathrm{q}^2 + 0{,}002 \cdot \mathrm{q} \cdot \mathrm{z} + 0{,}0173 \cdot \mathrm{z}^2 \quad (1)$$

$$\mathrm{I} = 0{,}1735 + 0{,}0057 \cdot \mathrm{q} + 0{,}0017 \cdot \mathrm{W} \cdot 0{,}0004 \cdot \mathrm{q}^2 - 0{,}0065 \cdot \mathrm{q} \cdot \mathrm{W} + 0{,}0102 \cdot \mathrm{W}^2, \quad (2)$$

The graphical interpretation of the equations obtained allows a fairly complete assessment of a wide range of studied dependencies. Figure 4 shows the dependencies obtained from equations (1), (2).



a) from the gap of the size of the working gap and the wear of the working bodies

b) from humidity of raw materials and wear of working bodies

Fig. 4. Dependence of wood particle size.

It can be seen from the graphical and regression dependencies that when the gap is reduced to 0.3-0.35 mm, the resulting wood particles reach 0.15-0.16 mm. If you continue to reduce the gap, the wood particles will become slightly larger. An increase in the wear rate of workers leads to an increase in the size of wood particles and reaches its maximum of 0.2-0.21 mm at 90%. An increase in the moisture content of wood raw materials leads to an increase in the size of wood particles and reaches its maximum of 0.19-0.2 mm at a humidity of 90%.

4 Conclusion

Thus, in the course of the work, an analysis of the processes of formation and actual use of potential wood raw materials in the form of logging waste was carried out. The expediency of wood flour production and the direction of its use in agriculture is substantiated. The design of a mobile plant for wood flour production is proposed, a technological scheme and an algorithm for its operation are developed. Using a multifactorial experiment, the effectiveness of using the proposed plant for wood flour production has been proven. It was found that flour has the smallest sizes of wood particles at a moisture content of 10-30% of the raw material, a working gap of 0.3-0.35 mm and wear of the rotor and stator teeth of 10-20%

Acknowledgements

The research was carried out at the expense of the Russian Science Foundation grant No. 22-78-10002, https://rscf.ru/en/project/22-78-10002/.

References

1. E.S. Belyakova, Ya.Yu. Sevostyanov, *Complex use of wood*, 275-276 (2023).

https://doi.org/10.1051/bioconf/202410814007

2. T.N. Storodubtseva, S.D. Steblovsky, A.A. Fonova, *Issue of integrated use of wood waste in composite material for transport construction,* 341-346 (2020).
3. A.A. Tambi, S.A. Ugryumov, A.R. Birman, I.A. Chernogradskaya, E.M. Runova, V.A. Nikiforova, Justification of the need to introduce processes for the integrated use of wood at sawmills, **2(46)** 47-54 (2020).
4. A.V. Vinogradov, I.S. Ilyin, N.E. Luzgin, *Integrated use of wood through the organization of fuel production*, 255-257 (2023).
5. P.B. Ryabukhin, *Technologies and machine systems to ensure the integrated use of wood*, 5-10 (2021).
6. A.A. Tambi, S.A. Ugryumov, A.R. Birman, I.A. Chernogradskaya, E.M. Runova, V.A. Nikiforova, Justification of the need to introduce processes for the integrated use of wood at sawmills, **2(2)** 18-25 (2020).
7. E.S. Belyakova, S.A. Matveeva, M.N. Zabenkina, Integrated use of wood, 266-268 (2023).
8. V.S. Nepomnyashchy, S.O. Sergaev, M.A. Zyryanov, Mobile woodworking equipment as the basis for the efficiency of logging operations, **4(142)** 110-112 (2023).
9. Ya.O. Khudoshin, T.N. Efimova, Study of the prospects of wood flour, the use of wood flour in various sectors of the national economy, 190-192 (2022).
10. N.R. Galyavetdinov, R.R. Safin, G.F. Ilalova, A.A. Prokopiev, Study of the physical and mechanical characteristics of biocomposites filled with wood flour, **3(59),** 94-99 (2023).
11. V.A. Neznanov, V.V. Glukhikh, A.E. Shkuro, P.S. Krivonogov, Study of the influence of plasticizers on the properties of polymer composite materials based on polyvinyl chloride and wood flour, **2,** 114-122 (2022).
12. D.D. Chirkov, A.E. Shkuro, V.V. Glukhikh, E.I. Vlasova, Physico-mechanical properties of polymer composite materials based on ethylcellulose and wood flour, **25(11),** 122-127 (2022).
13. K.D. Mertsalov, E.V. Kuzmitsky, E.A. Ryzhenkova, Justification of the need to introduce processes for the integrated use of wood at sawmills, 42-44 (2021).
14. A.A. Pobedinsky, M.K. Vakhrusheva, Integrated use of wood, 428-432 (2020).
15. E.E. Kulakov, S.A. Kryukova, A.L. Musievsky, M.A. Semenov, Theoretical foundations of multi-purpose forest management, 350-353 (2023).