

TECHNOLOGY OF PROCESSING OF GREEN VERDURE OF CONIFERS IN THE WOOD CUTTING AREA

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Green verdure of conifers having a rich reserve of biologically active substances such as essential oils, vitamins, carotene, carbohydrates, trace elements, and proteins is a valuable raw material for wood-chemical production. The technology for the manufacture of any kind of products from the fir-needles includes such operations as the collection of green verdure, the separation of the fir-needles from the branches, and grinding of it. Currently about 3-4% of potential fir-needles resources are used which is due to the lack of processing technologies for this type of raw material in the wood cutting area. An analysis of existing technologies for preparing and processing green verdure of conifers has shown that they all involve the export of softwood knots and branches to the consumers of this type of raw material, which entails not only transport losses, but also a reduction in the qualitative indicators of the fir-needles. The most difficult and hard operation mechanization in the process of harvesting green verdure is the separation from the woody parts of the branch. It basically determines the quality of the final product. Development of technology for processing fir-needles in the cutting area requires the use of a new mobile unit. The design of the proposed unit allows performing the operations of separating and grinding the green verdure of conifers, and further packaging of the product while the unit itself is able to move around the territory of the cutting area. It will allow to make coniferous semi-finished product of the required fractional composition and to preserve all the useful substances.

Key words: green verdure, processing, fir-needles, mobile unit

INTRODUCTION

Green verdure of conifers (fir-needles) is a specific type of forest raw materials. Living cells of fir-needles, young shoots and bark predominate in the composition of it. These plant cells contain proteins, carbohydrates, vitamins, enzymes, yellow, and green pigments, sterols, microelements, and other substances which are necessary for the life of plants, animals, and humans. Green verdure of conifers is used to make coniferous-vitamin flour, chlorophyll-carotene paste, potions, concentrates, etc. It is of great practical importance to adhere the storage conditions to obtain high-quality products from the fir-needles. The storage of fir-needles should assume the safety of biologically active substances. The storage period of green verdure of conifers in summer should not exceed 1 day, in winter - 5 days. Longer storage leads to a sharp decrease in the content of biologically active substances [1]. That is why it is important to process fir-needles in the places of its greatest accumulation. That is directly on the cutting area or at loading point. The factors that affect the safety of biologically active substances in the fir-needles are air humidity, light, wind, season, storage place, whether needles are separated from branches.

With the current technologies in the process of logging up to 65% of the total biomass of wood is used which is the stem part. The remaining 35% is waste, 17% of which is green verdure. For common pine with a diameter of 40 centimeters the mass of green verdure from the whole tree is 36 kilograms [2]. In most cases it is

left in the cutting area, which is a loss in the production of consumer goods. At present in the course of logging coniferous trees and shrubs are fallen to the ground, and the process of cutting branches with fir-needles takes place. Industrial wood is taken away and the branches are laid on the skidding, burned or left in place of logging for rotting [3, 4]. Therefore, the development of innovative technologies for integrated wood processing at the logging stage is relevant [2, 5, 6].

The purpose of this work is to develop the technology of harvesting and processing of green verdure of conifers on the territory of the cutting area.

THEORY AND EXPERIMENTAL

To achieve the objectives of the study systematic and comprehensive approaches are used. A complex of modern research methods as applied to scientific issues has been used: numerical modeling, mathematical planning, and statistical analysis.

Analysis of existing technologies has shown that the separation of branches with fir-needles during felling to the tree length stage can be performed with stationary drum separators [7]; mobile green verdure separators [8]. During the cut-to-length harvesters and processors are used [9]. The technology of processing fir-needles includes stationary equipment in the territory of wood-chemical enterprises in order to obtain biologically active and chemical components [10-13].

Today in Russia there is an increasing interest in cut-to-length method for logging. One of the main reasons

for the development trend of cut-to-length method in the world is the success of Scandinavian machine engineers. They developed and introduced to the market high-performance and reliable multi-operation machines for the production of cut-to-length process in the cutting area [9]. However, machines and technologies for processing fir-needles in the cutting area can hardly be found on the market.

The proposed process of harvesting with the processing of green verdure in a cutting area is based on the process of felling to the full tree stage. It includes the following operations: felling of trees - skidding of trees on the upper landing - bucking of trees - loading of branches into a mobile unit - assortment hauling.

The technological process of the mobile unit, when installed on the loading point, includes the following set of operations: preparatory work - loading knots and branches with fir-needles into the compartment of the conifer foliage stripper - separation of needles - sieving of needles - grinding of needles - body loading estimation - unloading of the body - vacuum packaging - final works. A worker performs loading of branches with needles manually. The processed fir-needles are located in a 60 liter unloading body, the coniferous semi-finished product is packed in bags with a vacuum unit.

In this case, the felling is performed by a feller-buncher then fallen trees are trilled to the upper storage with a skidder. At the loading point the trees are bucked with the help of a delimeter-crosscutter, the branches develop into heaps, and the assortments in stacks. Branches and small trees are loaded into the receiving part of the mobile unit, in the separation compartment the fir-needles are separated from the branches and knots and then crushed. Under the screen of a green verdure chipper there is a package holder and a vacuum packaging machine. The mobile unit allows the operations of separating the needles from the branches, chopping the needles and packing the crushed products on the territory of the wood cutting area. In addition, this unit allows to chop-green verdure without pre-drying which reduces the cost of the final product.

The operational principle of the mobile unit is as follows: the raw material in the form of branches and small-sized trees is loaded butt end first into the receiving part of the unit. After that, the mass is grabbed with finned rolling presses that take it into the working area of the green verdure separation unit.

Under the action of pins hinged on the drum shell the fir-needles are separated from the branches. Upon further movement the cleared branches are brought out, and the fir-needles under the action of gravity are taken to the cutting unit. The green verdure trapped in the cutting zone is processed by a rotating rotor which creates an air flow to the walls of the working chamber and is taken by knives in a circular motion. Moving in aerodynamic environment knives hit the particles with their working surface and grind them. Grinded raw materials

the dimensions of which are smaller than the size of the cell sieve are removed from the cutting zone and through a turning mechanism enter the packing bag, which is on the scales. Scales are connected to the swivel mechanism with the help of the lever. The swivel mechanism determines which of the two bags will receive shredded fir-needles. Through the neck of the bag a tape connected to a vacuum packing machine is passed. When the bag is completely filled the turning mechanism turns, and the filling of the second bag begins, at the same time the vacuum bagging machine of the first bag pulls in the tape, evacuates the air and seals the bag. The received bags are transported to the upper landing from where they are sent to the consumer.

Figure 1 shows the process flow diagram of the unit operation at the terminal of loading.

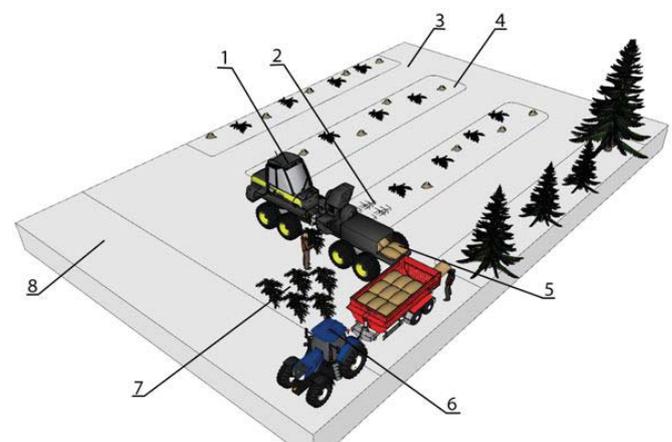


Figure 1: The process flow diagram of the unit operation

- 1 – vehicle with the fir-needle processing unit;
- 2 – proceeded branches (without needles);
- 3 - logging road;
- 4 – block;
- 5 – bags filled with fir-needle powder;
- 6 – vehicle for transportation bags filled with fir-needle powder;
- 7 – branches;
- 8 – logger road

The operation of shredding green verdure can be performed on a plot, on a loading platform near a logging road, in a transshipment terminal, or on the territory of a consumer enterprise [1].

Consider the work of a mobile unit at the loading point. Loading of branches with fir-needles is performed manually by the worker. Proceeded fir-needles are loaded into the 60 liters body.

For a visual review of the operations an information-logical model of the technological process [14] of the mobile unit was created (Fig. 2).

On the basis of the information-logical model a mathematical model of a mobile unit has been created (Fig. 3). The rectangles show the execution time of the main operations, the quadrangles indicate the transition of the state of one operation to another at $(t_i \geq t_{i-1})$; the number

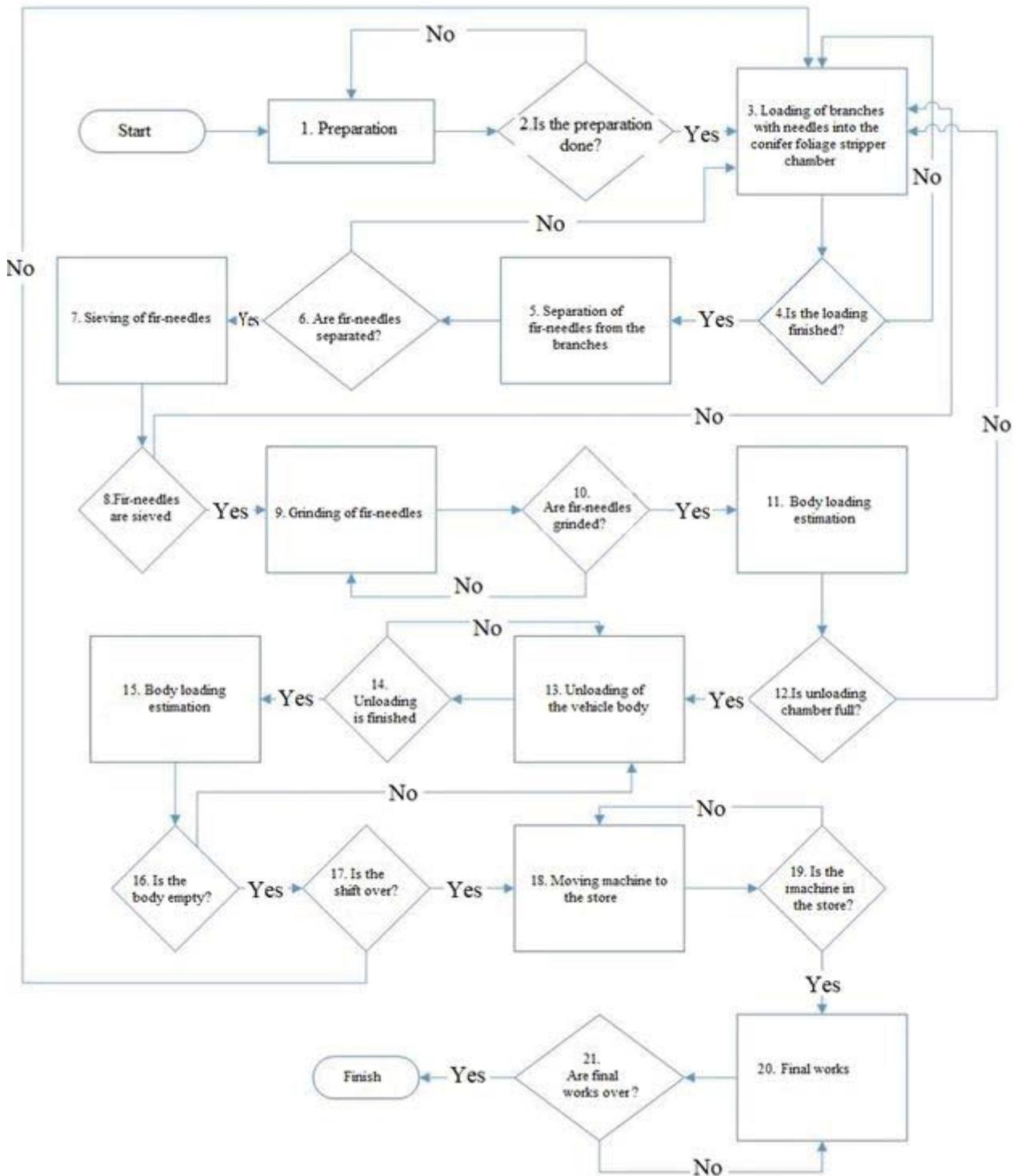


Figure 2: Information-logical model of the mobile unit process

of branches with fir-needles (n_1); the maximum possible number of branches for loading (n_2); the number of unloaded logging residues (n_3); amount of logging residues loaded (n_4); time to complete the main operations (n_5)

$$\left(\left((t_3 + t_{11} + t_{13} + t_{15}) \cdot n_{bem} + (t_5 + t_7 + t_9) \cdot n_{cp} \right) \cdot n_u \right) + t_1 + t_{18} + t_{20} = T_{cm} \quad (1)$$

We need to make a formula for determining the performance of the unit. First, let us make a formula for determining the cycle of the unit using a mathematical model. Let us designate the cycle of operations for loading and unloading the body of a mobile unit ($t_3 + t_{11} + t_{13} + t_{15}$) as T_1 . The cycle of operations of the unit work ($t_5 + t_7 + t_9$) is designated as T_2 . The cycle of preparatory - final work ($t_1 + t_{18} + t_{20}$) is designated as T_3 .

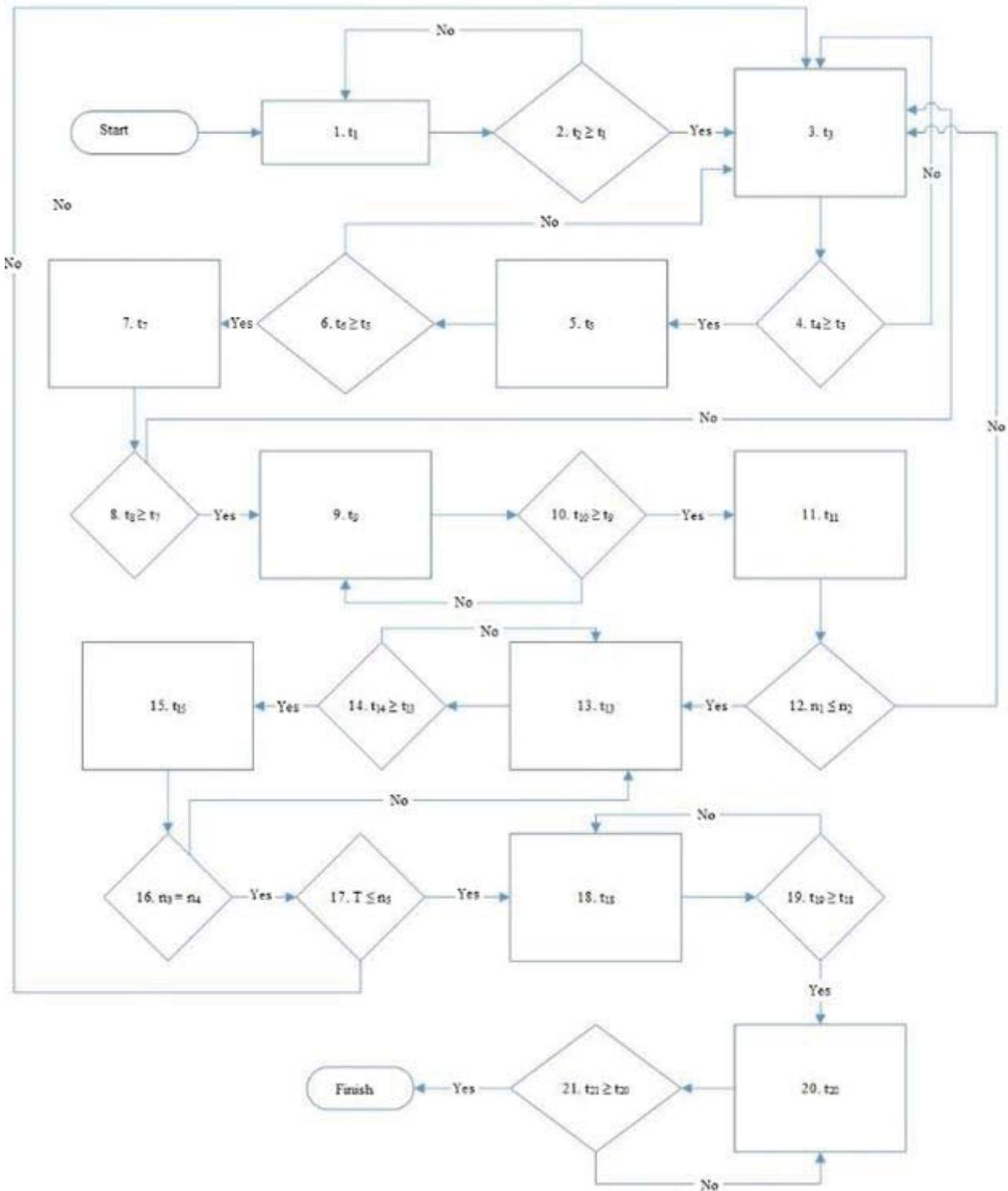


Figure 3: Mathematical model of the technological process of harvesting and processing green verdure of conifers
Then the formula will look like

$$\begin{aligned}
 & ((T_1 \cdot n_{bem} + T_2) \cdot n_{cp}) \cdot n_u + T_3 = T_{CM} & (2) & n_{bem} \cdot n_{cp} \cdot n_u \cdot (T_1 + \frac{T_2}{n_{bem}}) = T_{CM} - T_3 & (6) \\
 & ((T_1 \cdot n_{bem} + T_2) \cdot n_{cp}) \cdot n_u = T_{CM} - T_3 & (3) & n_{bem} \cdot n_{cp} \cdot n_u = \frac{T_{CM} - T_3}{T_1 + \frac{T_2}{n_{bem}}} & (7) \\
 & (T_1 \cdot n_{bem} \cdot n_{cp} + T_2 \cdot n_{cp}) \cdot n_u = T_{CM} - T_3 & (4) & n_{bem} \cdot n_{cp} \cdot n_u = \frac{(T_{CM} - T_3) \cdot n_{bem}}{T_1 \cdot n_{bem} + T_2} & (8) \\
 & T_1 \cdot n_{bem} \cdot n_{cp} \cdot n_u + T_2 \cdot n_{cp} \cdot n_u = T_{CM} - T_3 & (5) & &
 \end{aligned}$$

Where $n_{\text{вет}}$ is the average number of branches per loading, pcs; $n_{\text{ср}}$ - the average number of branches per work cycle, pcs; $n_{\text{ц}}$ - the average number of cycles per shift, times.

The left side of the equation ($n_{\text{вет}} \cdot n_{\text{ср}} \cdot n_{\text{ц}}$) is equal to the number of branches with fir-needles processed per shift, $N_{\text{ср/см}}$, pcs.

Output per shift formula of the mobile unit will be

$$П_{\text{см}} = V_{\text{ср}} \cdot \varphi \cdot N_{\text{ср/см}} \quad (9)$$

Where $V_{\text{ср}}$ - the average number of fir-needles on one branch, m^3 ; φ - coefficient of working time used, 0.8.

To assess the factors affecting the output per shift of the unit the time ranges of each operation are determined (Table 1). The number of branches of Siberian pine to the diameter outside bark for the IV height category varies from 10 to 18%. The average and maximum sizes of the branches when the volume of stem (in the bark) m^3 are 2.5 cm, with the volume of 0.76 m^3 the diameter of the branches is 4.3 cm [1].

According to the formulas 1–9 and the minimum and maximum values of the performing time of the operation of the technological cycle of the unit (Table 1), the de-

Table 1: The duration ranges of each operation conifers

Operation	Time range, sec	Influencing factors
t_1	1200 – 2000	The level of fuel, the state of the spokes, knives
t_3	10 – 20	Weather conditions, branch length, distance in the working area
t_5	3 – 8	The diameter of the branches, humidity, condition of the drum spokes
t_7	1 - 3	Humidity, bulk specific gravity
t_9	180 - 240	Condition of knives, humidity, needles size
t_{11}	1-2	Weather conditions, season conditions
t_{13}	5-10	Weather conditions, package position
t_{15}	1-2	Weather conditions, season conditions
t_{18}	360-540	Weather and season conditions
t_{20}	1500-2500	The state of the main components, wheel-base, refueling method

pendence (Fig. 4) of the output per shift on the average number of fir-needles (kg) per 1 m^3 of tree stem under favorable and unfavorable conditions was obtained.

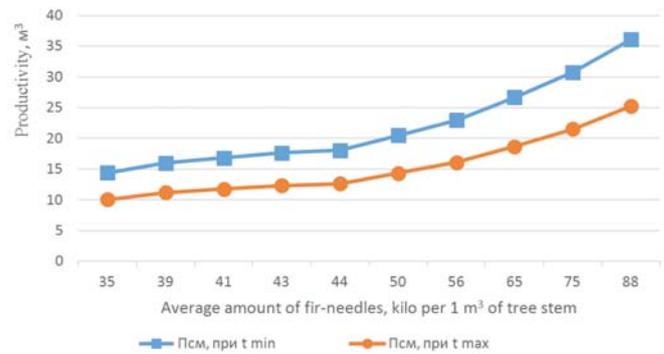


Figure 4: Dependence of the output per shift of the mobile unit on the average number of fir-needles kg, per 1 m^3 of tree stem under favorable and unfavorable conditions

CONCLUSIONS

As a result of the research current technologies were studied; taking into account the advantages and disadvantages a technological process for preparing and processing green verdure of conifers using a designing mobile unit was developed. The unit is able to separate and process green verdure in the wood cutting area; the formula of productivity was deduced. The output per shift depends on the average number of fir-needles per 1 m^3 of a tree stem at minimum time costs and minimum number of fir-needles the productivity will be 14.3 m^3 . At minimum time costs and maximum reserve, the productivity will be 36.1 m^3 . At maximum time costs and the minimum reserve, it will be 10 m^3 . At maximum time costs and maximum reserve, it will be 25.3 m^3 .

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REFERENCES

1. Baranov, N. F., Fufachev, V. S. & Stupin, I. V. (2018). The study workflow chopper coniferous paws mixed working body. Bulletin of NGIEI. no. 3.

2. Zyryanov M.A., Syromyatnikov S.V. & Borin K.V. (2019). Innovative system of complex processing of waste of plant origin at the stage of logging. Innovations in the chemical-forest complex: trends and prospects of development. pp. 179-183.
3. Zajceva M.I., Robonen E.V., Cherno-brovkina N.P. & Kolesnikov G.N. (2013). Recycling of waste recycling of needles of Scots pine. Wooden low-rise housing construction: economy, architecture and resource-saving technologies. Pp. 25-30.
4. Mokhirev, A., Zyryanov, M., Ryabova, T., & Vititnev, A. [2019]. Evaluation of possibility of obtaining woodchips from wood residues. *Journal of Applied Engineering Science*, 17(2), 140-143.
5. Zyryanov M.A. & Syromyatnikov S.V. (2019). Development of measures to improve the efficiency of processing of industrial waste of plant origin. *Forest engineering journal*. T. 9. No 2 (34). Pp. 164-171. <http://lestehjournal.ru/journal/2019/no-2/razrabotka-meropriyatiy-po-povysheniyu-effektivnosti-pererabotki-promyshlennyh> DOI: 10.34220/issn.2222-7962/2019.2/18
6. Mokhirev A.P. (2016). Simulation of the machine operation process for sorting and transporting felling residues in the cutting area. *Systems. Methods. Technologies.* No 1 (29). pp. 89-94. https://brstu.ru/static/unit/journal_smt/docs/number-29/89-94.pdf DOI: 10.18324/2077-5415-2016-1-89-94
7. YUrchenko A.E. (2004). Secondary material resources of forest and woodworking industry
8. Safina, A.V., Timerbaev, N.F., Ziatdinova, D.F. & Arslanova, G.R. (2018). Extraction of valuable components from cutting waste. *News Universities. Forest journal*. no.1 (361). Pp. 109 – 119. <https://elibrary.ru/item.asp?id=32367565> DOI: 10.17238/issn0536-1036.2018.1.109
9. Syunyov, V.S., Seliverstov, A.A., Gerasimov, YU.YU. & Sokolov, A.P. (2011). Cutting machines in the focus of bioenergy: design, design, calculation. http://www.idanmetsatiето.info/ru/document.cfm?doc=show&doc_id=1617
10. Posmet'ev, V. I. & Makarenko, A.V. (2015). Assessment of the appropriateness of the use of wood greenery in the national economy. *Voronezh scientific and technical Bulletin*. no. 4. Pp. 52 – 65. http://vestnikvglta.ru/arhiv_nomerov/4_14_15/12.pdf
11. Gorobec, A. I. (2012). Non-wood forest products. *Fundamentals of forest chemical production*.
12. Borin, K.V. & Petrusheva, N.A. (2018). The production of pine flour in a logging site. *FORESTENGINEERING*. Pp.18-20.
13. Matrosov, A. V. (2006). Technological processes of harvesting in a method of their simulation. *Bulletin of the MSFU. Forest Herald*. no. 6. 191 -196. https://les-vest.msfu.ru/les_vest/2006/Les_vest_6_2006.pdf
14. Mokhirev A.P., Mammatov V.O. & Urazaev A.P. (2015). Modeling of the technological process of logging machines. *International scientific research*. No 3 (24). Pp. 72-74. <https://elibrary.ru/item.asp?id=24859443>

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