Improving the technology of sorting wood chips obtained from stump and substandard wood by resin content

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Abstract. The paper considers the issues of the most complete use of wood biomass through the widespread use of a secondary type of raw material - stumps and substandard wood, which under current conditions of logging is 15-25 % of the total volume of harvested wood. The issues of sorting technological wood chips obtained from stumps and substandard wood in an electrostatic field by resin content. Existing methods for sorting technological wood chips by resin content. A new method of sorting technological wood chips for low and high resin in a constant high voltage electrostatic field has been proposed, which can be recommended for industrial implementation. A mathematical model of the deviation of technological wood chips in an electrostatic field depending on the distance between the electrodes and the voltage between them has been obtained. The amount of deviation of the technological wood chips is directly proportional to the amount of voltage generated between the electrodes of the electrostatic separator and inversely proportional to the weight of the wood chips and the distance between the electrodes. The optimal straightened sinusoidal voltage for the separation of wood chips into high resin and low resin has been determined. An experimental setup has been developed and experimental results are presented. The main modes of operation of the plant for sorting process wood chips in an electrostatic field are determined. The dependences of the effect of tar and moisture of technological wood chips on its deviation in a constant electrostatic field with a free fall are obtained. With an increase in resin content, an increase in the deviation of wood chips in an electrostatic field occurs. It has been established that the moisture content of process wood chips in the range from 7 % to 22 % significantly affects the chip deviation, and in this range it is possible to sort technological wood chips using constant voltage to high and low resin. Technological schemes for sorting wood chips obtained from stump and substandard wood at the enterprises of the wood chemical industry are proposed. The main conclusions and recommendations are made; the main dependencies are given.

1. Introduction

One of the most important conditions for the successful implementation of tasks in the field of forest industry is the introduction of advanced resource-saving technology based on the full use of biomass of all types of raw materials. One of the directions of full use of wood biomass is the use of stump wood, the lateral part of the log remaining after the manufacture of the board, twigs, tree tops, etc., which under modern conditions of logging is 15-25 % of the total volume of harvested wood. In addition, the full use of waste wood processing enterprises is one of the factors of waste-free production technology [1-3].
Maximum processing of wood waste for technological wood chips, as well as stumps in sawmilling, woodworking, is of great importance.

2. Purpose of research
Improving the efficiency of sorting technological chips from stumps for colophony and pulp and paper enterprises by using the properties of the electrostatic field.

3. Setting and solving the problem
In the domestic and foreign practice of industrial production there are various ways of sorting solid and bulk materials. However, the specific features of sorting technological wood chips by resin content are considered eliminates the use of existing methods for its separation into high and low resinous. The only way to achieve a positive result in our opinion is the separation of process wood chips using an electrostatic separator [4, 5, 6].

A method has been developed for separating bark particles from shavings mass in an electric field [7] in a special separator with a bipolar corona. The main components of the separator are wire and plate electrodes. The principle of the separator operation is to create a corona discharge field by applying a high polar voltage to the electrodes. The chip mixture is evenly dropped from the conveyor belt along a guide into a field with a bipolar corona. In this case, the particles of the cortex acquire an excess negative charge and move towards the positive electrodes, gathering in the receiving bin section. Wood particles acquire a positive charge and move to the negative electrodes.

The Kirov Research and Design Institute of Forest Industry has developed a method for sorting technological wood chips according to resin, based on a method of electrostatic separation of materials, including bringing the raw material to the same degree of moisture and processing it in an electric field [8].

This method [8] is carried out in a free-fall separator, which includes electrodes 1000x1000 mm in size, placed at an angle to the vertical, and the distance between the electrodes at the top and bottom is respectively 100 mm and 200 mm. A voltage of 100 kV is applied to the electrodes, and an electrostatic field is formed in the interelectrode space, the intensity of which is in the range from 5 to 10 kV / cm. Chips stump containing two types of wood, such as sapwood and heartwood, is crushed, adjusted to the same degree of moisture 4.3 %, sorted by size and sent to the electrostatic space. Since the content of colophony in these types of wood is different, their dielectric properties at a moisture content of 4.3 % are significantly different, which leads to the fact that particles with different amounts of colophony receive charges of different sizes and are attracted to different electrodes, thus there is a separation of sapwood from the core. The main disadvantage of this method is its high energy intensity.

4. Mathematical modeling
We have found that in a uniform electric field for the emergence of ponderomotive force responsible only free electric charges, therefore, from the electric field intensity \(E\) on the dielectric loaded ball subject to the force

\[
F = NeE, \tag{1}
\]

where \(e\) - electron charge; \(N\) – the number of free electric charges.

As is known [9], the field strength of a flat capacitor is

\[
E = \frac{U_0}{d}, \tag{2}
\]

where \(U_0\) – potential difference between the plates, \(d\) – distance between plates.
Projection on axis Ox (figure 1) of forces acting on wood chips in an electrostatic field

$$\sum X = 0 \quad F - R \sin \alpha = 0.$$  

In the projection on the y-axis has:

$$\sum Y = 0 \quad R \cos \alpha - G = 0.$$  

From where we directly find

$$\tan \alpha = \frac{F}{G} = \frac{N e U_0}{G d} = \frac{\rho U_0}{G (l_1 + l_2)},$$  \hspace{1cm} (3)  

where $\rho = eN$ - volumetric charge of wood chips; $d = l_1 + l_2$ - the distance between the electrodes.

If the length of the filament $l_0$ is specified, then the displacement of wood chips in the electric field will be

$$l = l_0 \sin \alpha = l_0 \sin \left[ \arctg \frac{\rho U_0}{G (l_1 + l_2)} \right].$$  \hspace{1cm} (4)  

Or replacing the volume charge, we get

$$l = l_0 \sin \left[ \arctg \frac{4 \pi F (l_2 - l_1)^3}{3 G (l_1 + l_2)} \right].$$  \hspace{1cm} (5)  

where $F$ – the force of gravity chips to the plate wood.

5. Research results

To study the separation of technological wood chips by resin content are considered into separate fractions, samples of wood chips of the same size and weight (350 mg), but different resinousness were selected: 8 %, 10 %, 13 %, 17 % and 22 %. Each sample was labeled with its own label. In the experiments, the moisture content of the wood chips was varied from 7 % to 26 %. The studies were conducted on an experimental setup of Figure 2, which gives a rectified sinusoidal voltage electric field.
To enhance the effect of sorting wood chips by the resin content are considered, the wood chips was pre-charged negative charges. Chip was charging on the feed conveyor when it was fed into the electric field of the separator. For this purpose, the conveyor was made of a copper elastic mesh and connected with a bus to a negative electrode, and a metal plate connected to the positive electrode was placed above the conveyor. At a given speed of movement of the conveyor mesh, the charge time of the chip was 3 minutes.

Voltage from 44 to 91 kV was applied to the separator electrodes. In the experiments, samples of technological wood chips were loaded onto a recharge conveyor, where wood chips were charging, then, with its further movement in an electric field, the wood chips were separated by the resin content are considered and the experimental samples fell into the separator pockets located in its lower part.

The movement and sorting of process wood chips is significantly influenced by the position of the electrodes (plates). During the experiments, flat electrodes (having mobility due to the developed mounting) were installed at different distances from the vertical axis of the separator, as well as at different angles to the axis. The most effective separation of wood chips by the resin content are considered (having mobility due to their fixation) occurred at the following position of the plates in space: $a = 5\, \text{cm}$, $b = 20\, \text{cm}$, $c = 15\, \text{cm}$, $d = 40\, \text{cm}$.

Experimental studies on the separation of technological wood chips in an electric field according to the degree of the resin content are considered content were carried out with wood chips with a previously known percentage of resin content and humidity. The research results for a resin content of 22\%, 17\% and 13\% with a voltage between the electrodes at a voltage of 75 kV are given in table 1. The graphical dependence of the influence of the amount of tarry of technological wood chips on the value of its deviation is shown in figure 3. Experimental separation studies table 1.
Table 1. The influence of the resinousness of the wood chips on the value of its deviation from the vertical axis of the separator.

| Resinousness, K, % | 13 | 15 | 17 | 20 | 22 |
|-------------------|----|----|----|----|----|
| Deviation, L, m   | 0.025 | 0.04 | 0.05 | 0.075 | 0.1 |

A significant impact on the sorting of technological wood chips has its moisture. The investigated wood chips were moistened in a separate vessel to a moisture content of more than 60 %. Then, in the course of the experiments, it was dried to a moisture content: 60 %, 24 %, 23 %, 22 %, 15 %, 14 %, 7 %. Chip moisture was measured with an electronic moisture meter. Chip volume was measured by weight method. Weighing wood chips was carried out on scales with an accuracy of 0.1 grams.

As studies have shown, the wood chips of high humidity (60 %) more strongly deviates towards the negative electrode. In this case, the effect of moisture on the chip deviation affects more than the amount of tar. With a decrease in humidity of up to 22 %, this effect is significantly reduced - wood chips are deflected into the pocket № 2 area, just like at 7.3 % humidity. As well as for natural resinous wood chips, humidity ranging from 7 % to 22 % has little effect on the chip deviation, and in this range it is possible to sort technological wood chips with a constant voltage of high and low resin (figure 4).

6. Interpretation of results and their analysis

During the experiment, the position of the electrodes relative to the axial line and the magnitude of the high voltage applied to the electrodes changed. During the experiments, it was found that when the moisture content of wood chips is from 13% to 28%, the best separation of wood chips occurs at a voltage of 75 kV and the position of the electrodes, characterized by the following parameter values: a = 5 cm, b = 20 cm, c = 15 cm, d = 40 cm, e = 17 cm (figure 2). With the given initial parameters, high-resinous wood chips were mainly deviated to the negative electrode, and low-resin wood chips to the positive electrode.
Figure 4. The influence of the moisture of the technological wood chips on its sorting:

- **G** - the weight of the technological wood chips;
- **η** - the moisture content of the wood chips;
- **k** - chipping resin.

As shown by experimental studies, wood chips with a high resinous content (more than 13%) deviate towards 3 and 4 pockets, and technological wood chips of lower resinousness (less than 13%) in pockets 1 and 2. Thus, in the process of sorting wood chips, it is necessary to provide in the installation design shutter, for the separation of technological wood chips on the high and low resinous. Dividing shutter must be installed between pockets 2 and 3, and in the lower part of the installation two bunkers for collecting process chips.

Taking into account the experimental studies carried out, a technological scheme for the processing of stump wood has been developed using chip sorting equipment.

Cleaning the stump wood is carried out as follows (figure 5).

Whole stumps (ripe osmol), harvested by uprooting, are brought by loading and transport vehicle to the site to the loading conveyor. Using the manipulator 1, the stumps are fed to the loading conveyor 2 and the conveyor to the hydro-pulse cleaning unit 3. Entire stumps, when passing along the LO-107 unit, are exposed to the hydraulic pulse jets created by the hydraulic pulsators.

Due to this, they are cleaned of soil and rot. The waste enters the vibrating screen, where the water separates, and then is removed by a belt conveyor 4. The cleaned stumps are unloaded from the hydro-pulse cleaning unit, fall on the discharge conveyor 5 and are fed to a LO-109 receiving bin.

The crushed stump of the unloading conveyor 7 and belt conveyor 8 are fed to the chipper 9 MRNP-30 for processing into process chips. The resulting chips scraper conveyor 10 is fed to a recharge conveyor 11, and then in installation 12 for sorting process wood chips on the high and low resinous LO-115. Pneumatic pipes 13 and 14 divided wood chips are supplied for further processing.
Figure 5. Technological scheme for the processing of stump resinous wood: 1 - manipulator; 2 - double-chain loading conveyor; 3 - installation of hydro-pulse cleaning LO-107; 4 - conveyor belt waste collection from under the installation; 5 - double-chain loading conveyor; 6 - unit for grinding whole stumps LO-109; 7 - chain conveyor scraper for removing pieces of stumps from under the machine LO-109; 8 - double-chain loading conveyor; 9 - chipping machine MRNP-30; 10 - scraper conveyor; 11 - recharge conveyor; 12 - equipment for sorting technological chips LO-115A; 13, 14 - pneumatic pipeline; 15 - swimming pool; 16 - pressure pipe; 17 - discharge tray for waste liquid; 18 - waste storage area.

7. Conclusion
- A new method has been developed for sorting technological wood chips for low-and high-resin in a constant high-voltage electrostatic field with pre-charging with a negative charge.
- Based on the laws of physics and mechanics, the dependences of the deviation of process wood chips with a free fall in an electrostatic field are obtained.
- The optimum value of the rectified high sinusoidal voltage for the separation of wood chips into high and low resin (13 % criterion) is 75 kV. DC voltage can vary from 65 kV to 85 kV. Voltages beyond these limits do not effectively separate the technological wood chips wood.
- Technological wood chips of high humidity (60 %) more strongly deviates towards the negative electrode. In this case, the effect of moisture on the chip deviation affects more than the amount of tar. With a decrease in humidity of up to 22 %, this effect is significantly reduced. Therefore, the moisture content of process wood chips in the range from 7 % to 22 % significantly affects the deviates of wood chips in an electrostatic field, and in this range it is possible to sort technological wood chips with a constant voltage of high and low resin.
- When installed in a free-fall separator at the level of the lower edges of the flat electrodes of a vertical solid shutter, it separates the technological wood chips into two fractions, respectively, below and above 13 % of the resin content.
• Schemes have been developed for the technological process of logging enterprises using the proposed installations for the processing of stump wood into process wood chips.

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