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# ANALYSIS OF IMPROVING THE EFFICIENCY OF WOOL FIBER MECHANICAL CLEANING EQUIPMENT BY OPTIMIZING THE FEEDING MECHANISM

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**Annotation**

This article presents the optimization of the feeding roller diameter, teeth structure, tooth inclination, and installation of rollers in the wool fiber mechanical cleaning equipment. A vibrating mesh grid was integrated into the base of the feeding roller, enabling the removal of light impurities from the fiber composition before entering the working chamber. Additionally, improvements to the feeding mechanism ensured the continuous and regulated supply of wool fiber to the machine, significantly enhancing operational efficiency.

**Keywords**

wool, fiber, conveyor, feeding roller, raw material hopper, cleaning, carding, pins, equipment.

## INTRODUCTION

Among textile fibers, wool fiber has a significantly higher level of contamination compared to other fibers. While cotton fiber contains two types of impurities—organic and mineral—wool fiber, in addition to these, also includes contaminants derived from the animal itself. These impurities mix within the fiber, causing it to form small and large clumps. In the feeding mechanism, such fiber clumps of varying sizes can lead to blockages, disrupting the process [1, 3].

Wool fiber cleaning is carried out using several methods:

- mechanical method: The wool fiber is cleaned by loosening and carding through the mechanical impact of pins.
- chemical method: The wool is washed using various chemical solutions and alkalis to remove impurities.
- biological method: Impurities and plant residues in the wool fiber are removed by burning them off with electric radiation.

Due to the tendency of wool fiber to form clumps, mechanical cleaning equipment often faces significant challenges in its feeding mechanisms.

## RESEARCH METHODS

Currently, wool processing enterprises in our country utilize ТП-90-Ш1, 2БТ, and 2БТ-150Ш models of carding and cleaning machines [1, 2, 5]. The 2БТ model carding and cleaning unit consists of a feeding conveyor, a shaped bracket, two pairs of feeding rollers, two carding drums, a ribbed grid, and a fiber discharge section (Figure 1).

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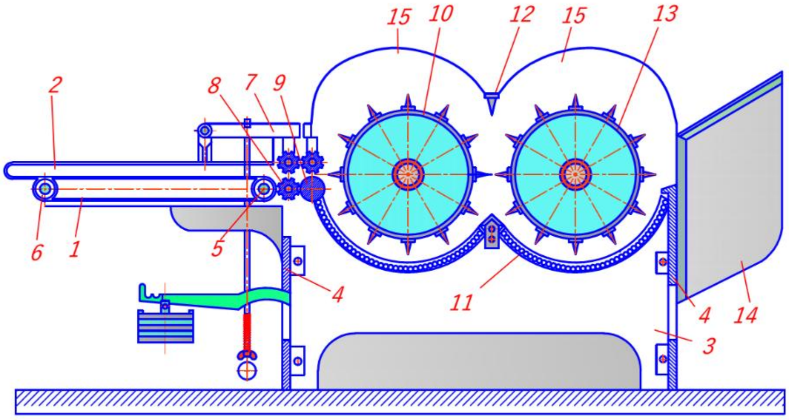


**Figure 1. Schematic diagram of the 2БТ carding unit**
**1 - feeder, 2 - bracket, 3 - unit base, 4 - rear bridge, 5 - driving shaft, 6 - driven shaft, 7 - shaped bracket, 8-9 - two pairs of feeding rollers, 10-13 - carding drums, 11 - ribbed grid, 12 - pinned prism, 14 - fiber chamber, 15 - cover.**

The drawback of this unit is the inconvenient structural design of the feeding section (Figure 2). This issue leads to wool fiber clogging and entanglement, disrupting the fiber feeding process. As a result, the uniform supply of fiber to the machine is compromised, leading to unnecessary energy consumption [3, 6, 7].

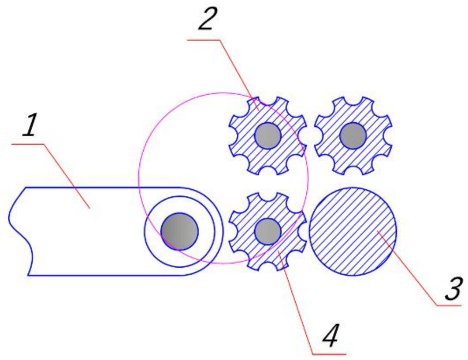


**Figure 2. Feeding mechanism of the 2БТ carding and cleaning unit**
**1 - feeding conveyor; 2,4 - feeding rollers; 3 - leveling cylinder.**

The feeding mechanisms are among the most critical and delicate components of wool fiber carding and cleaning equipment. The efficiency of these machines largely depends on the continuous and uniform supply of fiber, ensuring optimal energy and time consumption. The importance of feeding mechanisms is therefore significant in maintaining the overall performance of the system [ 5, 8]. Carding and cleaning equipment feeding mechanisms are installed using three different methods:

- vertical feeding mechanism;
- horizontal feeding mechanism;
- inclined feeding mechanism.

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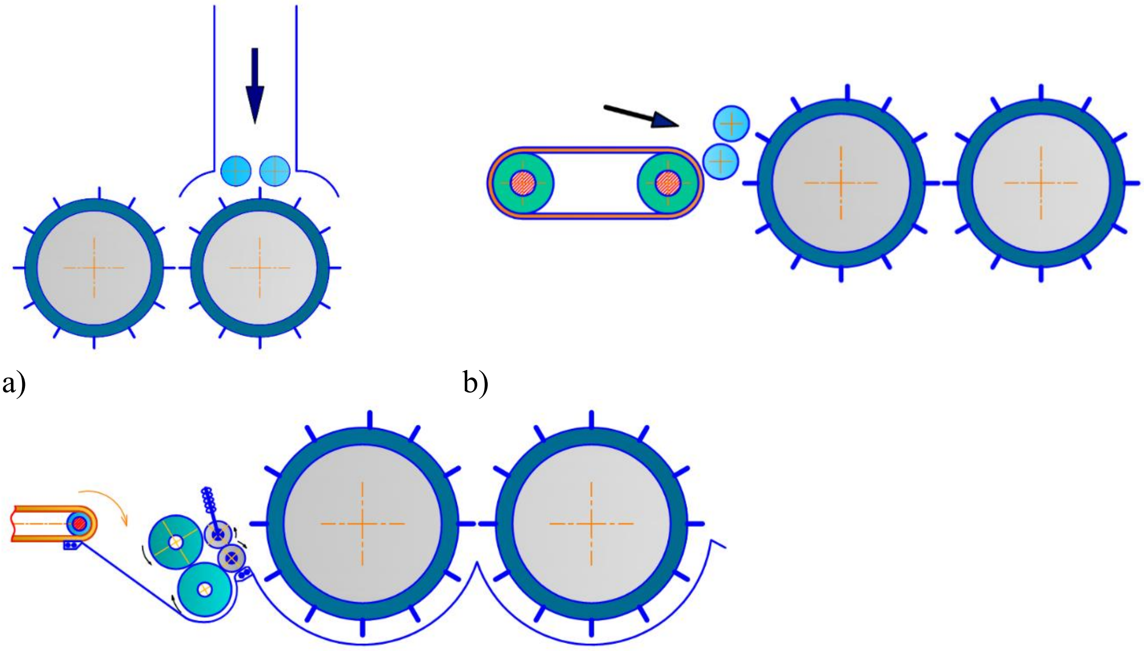


a) b) c)

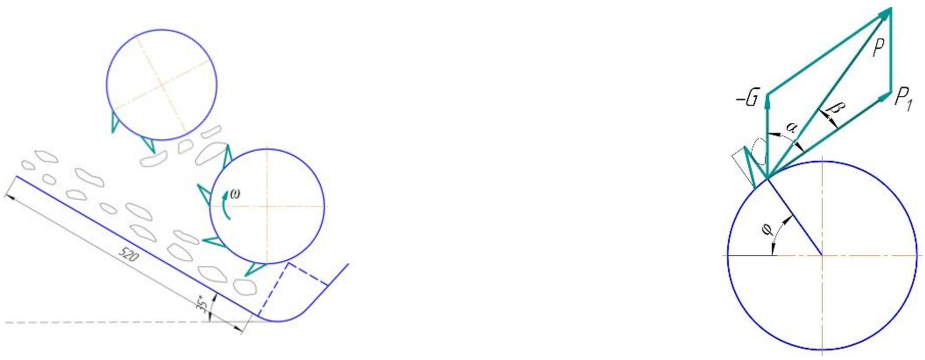
**Figure 3. Installation methods of the feeding mechanism in the carding and cleaning machine: a - vertical feeding mechanism; b - horizontal feeding mechanism; c - inclined feeding mechanism.**

## RESULTS

For textile fibers with relatively low contamination, the vertical feeding mechanism is used. The feeding mechanism of the 2BT carding and cleaning machine is installed in a horizontal position [5, 8, 10]. To address the identified issues and improve performance, the diameter of the feeding roller was doubled. As a result, the fiber gripping surface increased, preventing clogging. The teeth were installed at an inclination of 40° relative to the roller, with each roller containing 28 teeth. The inclined feeding installation method was chosen, positioning the rollers at a 60° angle to the machine (Figure 4). This modification enhances the fiber gripping efficiency, partially pre-cards the wool, reduces energy and time consumption, and ultimately improves the overall performance of the equipment [8, 9].

By integrating a raw material hopper between the conveyor and the feeding roller in the feeding mechanism, issues such as wool fiber clogging and interruptions in fiber supply were effectively eliminated. The base of the raw material hopper is designed as a mesh grid, made from 5 mm thick steel sheet. The mesh holes are oval-shaped, allowing the removal of 3.5–4.2% of short, unusable fibers and light impurities from the raw material composition [9, 11, 12]. This improvement enhances the overall efficiency of the fiber feeding process and contributes to better cleaning performance.

The inclined-toothed feeding rollers, with a diameter of 200 mm, rotate towards each other at a speed of 0–14 revolutions per minute, gripping and transporting the wool fiber from the hopper. Due to the increased diameter of the feeding rollers, the number of revolutions has been reduced, while the fiber gripping surface has expanded. As a result, the risk of wool fiber entangling around the rollers has been effectively eliminated [7, 11, 13].




a) b)

**Figure 4. a) proposed feeding mechanism; b) wool fiber movement scheme on the feeding roller.**

The differential equation describing the movement of wool fibers between the feeding rollers is:

$$m\frac{d^2y}{dt^2} = C\ \ y - G\cos\varphi \qquad (1)$$

(1) expression is divided by mass and the inhomogeneous second-order differential equation is integrated. $\varphi = \omega\ \ t$, $G = m\ \ g$, C - the binding coefficient between wool fibers is determined experimentally [10, 12].

$$\frac{d^2y}{dt^2} - \frac{C}{m}\ \ y = -g\ \ \cos\varphi \qquad (2)$$

(2) The general solution of the equation is sought as follows.

$$y_{ум} = A\ \ \cos\sqrt{\frac{c}{m}}t + B\ \ \sin\sqrt{\frac{c}{m}}t \qquad (3)$$

$$\dot{y}_{ум} = -A\sqrt{\frac{c}{m}}\ \ \sin\sqrt{\frac{c}{m}}t + B\sqrt{\frac{c}{m}}\ \ \cos\sqrt{\frac{c}{m}}t \qquad (4)$$

Using the initial condition, we determine the constant values A and B.

t =0, $y_2 = 0$, $\dot{y}_2 = 0$

$$A = -\frac{mg}{c}, B = -\sqrt{\frac{m}{c}} \qquad (5)$$

Substituting expression (5) into equation (4), we determine the general solution.

$$y_{им} = \frac{mg}{c}\ \ \cos\sqrt{\frac{c}{m}}t - \sqrt{\frac{\mathrm{m}}{c}}\ \ \sin\omega t \qquad (6)$$

(6) The motion equation is analyzed using Maple software to study the movement of wool fibers during gripping by serrated rollers. The given parameters are: g=9.81 m/s$^2$, C=0.05, m=15 kg,. $\omega = 0{,}14\,rpm.$

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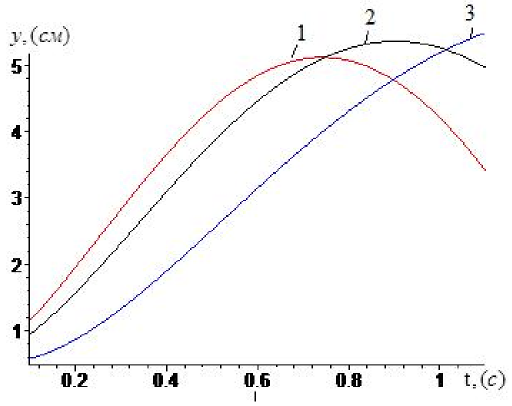



**Figure 5. The time-dependent graph of the angular velocities of the rollers during the transfer of wool fibers between the feeding rollers at different values:** $\omega_1 = 22\ rpm$, $\omega_2 = 18\ rpm, \omega_3 = 14\ rpm.$

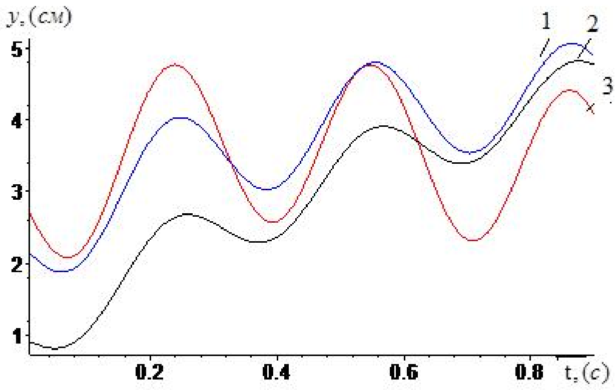
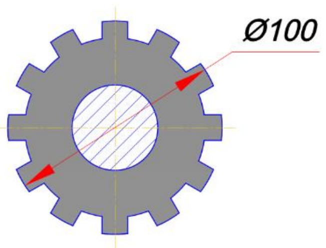
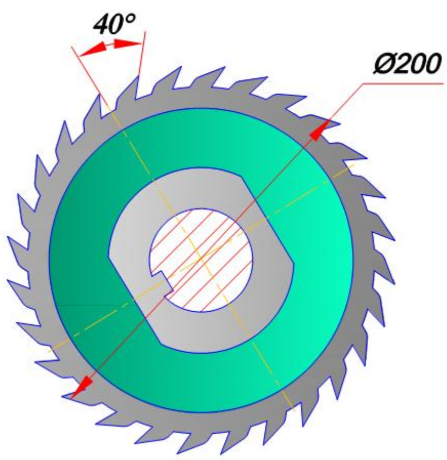



**Figure 6. The time-dependent graph of wool fiber transfer between the feeding rollers at different fiber mass values:** $m_1 = 15\ g, m_2 = 25\ g, m_3 = 35\ g.$

Carding machines operate based on continuous and periodic processing principles. Coarse wool is processed using periodically operating carding machines, where wool is carded and cleaned by rotating it over a ribbed surface with pinned teeth. Afterward, the wool is transferred to a washing machine [8, 11]. The wool fiber is fed into the carding and cleaning equipment through a feeding device. Installing a properly matched feeding roller in the raw material hopper enhances the machine’s efficiency. The uniform extraction of fibers from the hopper depends on selecting the appropriate feeding roller and installing it correctly in the machine. The existing machine's feeding roller has a diameter of 100 mm, 12 teeth, a 90° placement angle, and a rotation speed of 25–30 rpm. In experiments with the 2БТ-150Ш machine, several significant drawbacks were observed: the feeding roller had a high rotational speed, a small diameter, and a limited fiber gripping surface, causing wool fibers to wrap around the roller (Figure 8a). To address this issue, the feeding rollers were installed at an inclined angle, and the teeth were positioned at a 40° inclination relative to the roller (Figure 8b) [7, 9].




a) b)



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**Figure 7. a) existing feeding roller; b) proposed feeding roller.**

The rotational speed of the feeding rollers is determined using the following formula:

$$n=\frac{30v}{\pi R}=\frac{30\cdot 0,24}{3,14\cdot 45\cdot 10^{-3}}=50\ r/min \quad (7)$$

The linear velocity of the small feeding rollers is determined using the following formula:

$$v=\frac{\pi\cdot R}{30}=\frac{3,14\cdot 42\cdot 0,045}{30}=0,24\ m/s \quad (8)$$

o determine the rotational frequency, we use equation 3.3, which is given as:

$$n_m = n_{sml} \cdot u_{chd} \cdot u_g \quad (9)$$

Here:

- $n_{dv}$ – rotational speed of the motor (rpm);
- $n_{sml}$ – rotational speed of the small feeding roller (rpm);
- $u_{chd}$ – transmission ratio of the chain drive;
- $u_g$ – transmission ratio of the gearbox.

The performance indicator of the equipment is determined using the following formula:

$$Q = v \cdot h \cdot l \cdot \rho \cdot 3600$$

and

$$Q = 0,24 \cdot 42 \cdot 10^{-3} \cdot 0,42 \cdot 50 \cdot 3600 = 762\ kg/h.$$

The results of the conducted experiment indicate that an increase in the gap and linear density of the feeding rollers enhances the operational efficiency of the equipment [8, 11,13]. However, excessive increases negatively affect the cleaning efficiency.

When the linear velocity of the feeding rollers was set to **0.24 m/s**, the equipment's productivity reached **762 kg/h**. The cleaning efficiency for wool fibers from autumn and spring shearing was recorded at **17.9%**.

## CONCLUSION

By integrating an improved **raw material hopper** and **inclined-tooth rollers** into the feeding mechanism of the wool fiber carding and cleaning machine, the following advantages were achieved:

- The installation of a **raw material hopper** in the feeding mechanism eliminated fiber clogging and interruptions in fiber supply.
- The **inclination angle** and **mesh grid hole shape** were theoretically calculated for effective separation of light impurities from wool:
  - The hopper inclination was set to **35 degrees**.
  - The mesh grid holes were designed in an **oval shape** to optimize impurity removal.

- The separation trajectory of **light impurities** in the wool fiber was optimized based on the **vibration amplitude** and **inclination angle**, ensuring efficient impurity removal.
- The **continuous transfer** of wool flow from the hopper to **smooth-surfaced pressing rollers** was ensured by adjusting the feeding rollers' **angular velocities** and maintaining an adequate **fiber mass balance** in the hopper.
- In other cases, fiber entanglement around the rollers and subsequent clogging were observed, emphasizing the importance of precise **roller speed** and **hopper feed rate**.

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