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Influence of the Perfective Working Body of Fiber Cleaning Machines on the Aerodynamic Parameters

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Abstract: *The modernization of process control methods, the development of automated methods for designing equipment and technologies, and the development of automated control systems for the cotton processing process. Currently, due to the improvement of machines for cleaning cotton fiber, which are developed according to the technology of primary processing of cotton, one of the urgent issues is to ensure the production of high-quality fiber. Taking this into account, it is necessary to conduct a constructive analysis of the fiber cleaning equipment and develop an effective design. In view of this, this study was aimed at improving the aerodynamic parameters of a fiber cleaner on the basis of theoretical and applied research by creating and experimenting new saw blade construction. In process of the research, methods are used optimization by theoretical statistics, evaluation and target electronic programs, theoretical and applied mechanics, higher mathematics and vibration theory. Aerodynamic equilibrium of a freely rotating saw cylinder due to the presence of friction forces arising between the saw blades and air and atmospheric pressure cannot be overcome by centrifugal forces acting on the air mass during rotation. This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min-1 and its transition to 1500 min-1. For the normal operation of the fiber cleaning machine, it is necessary that the saw cylinder, taking air on the cleaning arc.*

Keywords: *fiber cleaner, saw cylinder, saw blade, air flow, and aerodynamic parameters.*

Introduction. In developed countries, the modernization of process control methods, the development of automated methods for designing equipment and technologies, and the development of automated control systems for the cotton processing process [1-9]. Currently, due to the improvement of machines for cleaning cotton fiber, which are developed according to the technology of primary processing of cotton, one of the urgent issues is to ensure the production of high-quality fiber. Taking this into account, it is necessary to conduct a constructive analysis of the fiber cleaning equipment and develop an effective design [10-16].

To maintain the quality of fiber and seeds produced by researchers, cotton is repeatedly cleaned from small impurities up to 32 times [17], although in fact that cotton can be cleaned from large impurities up to four times and from small impurities up to 20 times [18]. Moreover, the cleaning efficiency of the demand level is below 90-95%, and the amount of residual impurities in the fiber is not cleaned at the required level. The complexity of the problem lies in the fact that now the maximum number of cotton cleaners in the equipment for cleaning from small and large impurities in cotton factories largely requires the installation of additional filters that increase the cleaning efficiency, leading to a sharp increase in the number of impurities with fiber defects. Therefore, the efficiency of cotton cleaning should be carried out without additional mechanical impact on it [19, 20].

In one of the scientific studies to improve the efficiency of cleaning cotton, which are on the assembly machine, a special structural guide device is installed on the equipment in order to improve the equipment for cleaning fibers used in cotton-cleaning mill. Recommendations were given for the introduction of a directional device in a special design into production [21-23].

Other study presented the results of a fiber cleaner developed and implemented at the Buz cotton-cleaning mill to determine the technological performance indicators depending on the rotation speed of the saw cylinders and the aerodynamic mode of operation [24].

In addition, fiber cleaning in direct-flow cleaners takes place in aerodynamic flows; the technological parameters of the machine depend on the aerodynamic mode of operation. The saw cylinders of the fiber cleaner not only clean the fiber, but also perform a number of aerodynamic functions associated with the interaction of several different air flows. Therefore, the scheme of movement of air masses inside the fiber cleaner is a rather complex phenomenon and has not been fully studied [25]. In view of this, this study was aimed at improving the aerodynamic parameters of a fiber cleaner on the basis of theoretical and applied research by creating and experimenting new saw blade construction [26, 27].

Materials and methods. The object of research is cotton cleaning mills, fiber cleaner (fig.1), aerodynamic parameters. The properties of fibers in the composition of cotton fibers and semi-finished products are determined using the laboratory equipment of AFIS PRO 2 of the company "Oster". At the same time in the laboratory equipment it is possible to determine the length L(n), endings (Neps/g), the amount of thick fibers (SFC n, SFC w), linear density (Fineness), the amount of mature (ripened) fiber (Muturity), the amount of dead fiber (IFC), the amount of dust (Duct Cnt), pollution (Trash Cnt), visible large impurities (VFM). With the help of the above laboratory equipment, the quality indicators of the cotton obtained from the existing and improved fibers are studied [27].

The effect of the fiber on aerodynamic parameters of the working bodies in t cleaning process is calculated based on the values contained in the tables 1, 2 below [28].

Table 1. Air density depending at different temperatures

t, °C	-30	-20	-15	-10	-5	0	10	15	20	30
ρ, kg/m^3	1,453	1,395	1,369	1,342	1,318	1,293	1,247	1,226	1,205	1,165

Table 2. Kinematic viscosity of air at different temperatures

t, °C	-20	-15	-10	-5	0	10	15	20
$\nu \cdot 10^{-6}$, m^2/s	11,61	12,02	12,43	12,86	13,28	14,16	14,61	15,06

In process of the research, methods are used optimization by theoretical statistics, evaluation and target electronic programs, theoretical and applied mechanics, higher mathematics and vibration theory, theory of mechanisms and machines, mathematical modeling of working processes of technological machines, mathematical statistics and mathematical calculations [31].

Types of variables are independent – cotton fiber, dependent – saw cylinder (fig.2), controlled – fiber cleaning machine 1ВП (fig.1).

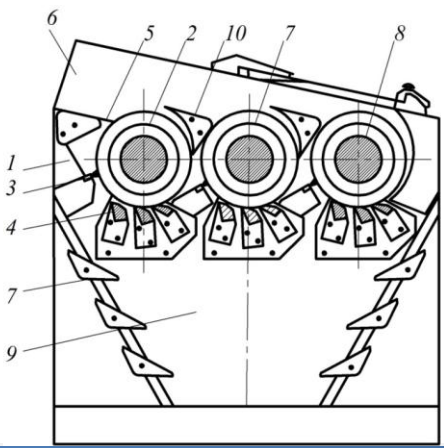
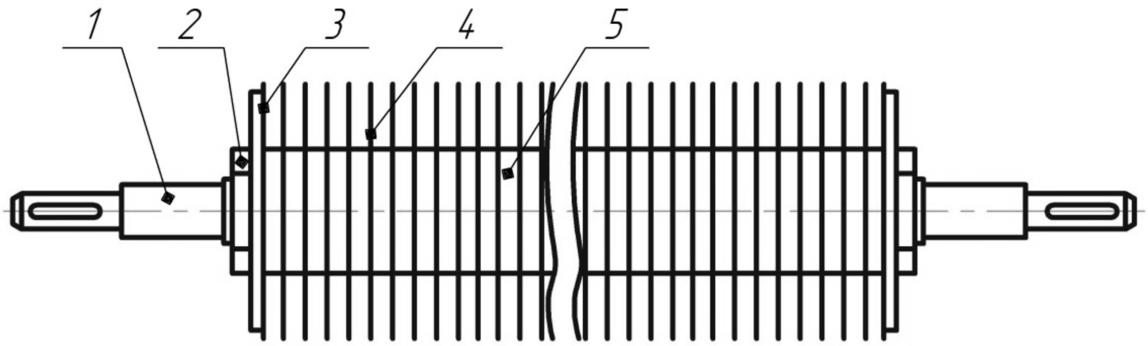


Fig.2. Technological process scheme of 1ВП fiber cleaner

1-inlet pipe of fiber; 2, 7, 8-saw cylinder; 3-grinding brush; 4-fire-grate; 5-separating knife; 6. outlet pipe of fiber; 9-chute of impurity; 10-guide; 11-air blind

Fig.2. Saw cylinder of fiber cleaning machine



1 – shaft; 2 – lock nut; 3 – taper washer; 4 – saw blade; 5 - inlay

Analysis of research results. In the process of studying the effect of working bodies on the aerodynamic parameters of fiber cleaning machines, it is important to calculate the air flow generated around the cylinder with the saw in the process.

The air flows formed in the fiber cleaner have a significant impact on the process of separating weed impurities from the fibers. Consider the air flows created by the saw cylinder during its rotation. The movement of the fiber strand depends on which flow is laminar or turbulent, which will directly affect the cleaning process. During the rotation of the disk, air flows move along its side surfaces. They have a laminar character at low rotational speeds, and at higher velocities – turbulent. Laminar air flow over the disk is possible at a Reynolds number < 100000.

$$Re = \omega r^2/\nu \qquad (1)$$

where ω - the angular velocity of rotation of the disk, rpm; r - the current radius of the disk, m; ν - the kinematic viscosity of the air, m^2/s.

From formula (1), the maximum radius of the laminar flow zone will be

$$r_{max} = \sqrt{\frac{215000 \cdot \nu}{\omega}} \qquad (2)$$

Take $\nu = 15.06 \cdot 10^{-6}$, m^2/s. Knowing that $\omega = \pi n/30$, we rewrite equation (2)

$$r_{max} = \sqrt{\frac{215000 \cdot \nu \cdot 30}{\pi \cdot n}}$$

When the fiber cleaner is in operation, the saw rotates at a frequency of n = 1500 rpm, with r_{max} = 0.153m = 153 mm (Fig.3).

As you can see, there is no laminar flow outside the saw blade Ø310 mm.

n, rpm	1000	1500	2000	2500	3000
r_{max}, m	0.176	0.153	0.124	0.111	0.102

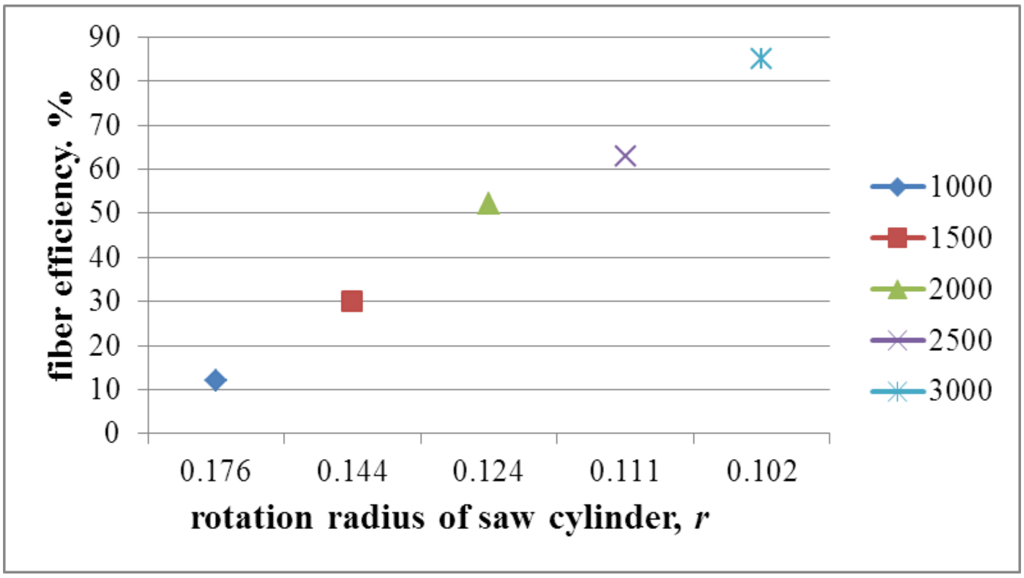


Fig.3. Chart of the number of rotations and the linkage of the chainwheel rotation radius to the fiber cleaning efficiency

This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min^{-1} and its transition to 1500 min^{-1}. An increase in the number of revolutions gives an increase in the cleansing effect, which has been proven by repeated experiments (Fig. 4).

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With the rotation speed of the saw cylinder over 1750 rpm, an unacceptable increase in its vibration is observed.

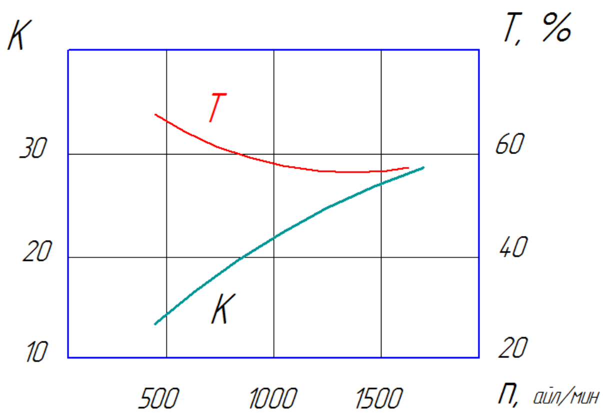


Fig. 4. The increase in the cleaning effect as a result of a change in the number of rotation of the saw cylinder depends on the amount of fiber contained in K and waste B

Equilibrium conditions of the fiber strands on the saw teeth with an arbitrary direction of the air flow to the fiber (Fig. 6).

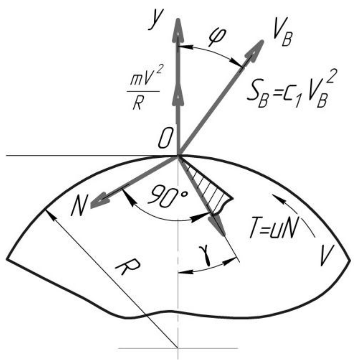
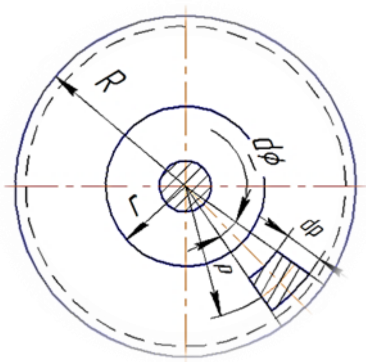


Fig. 5. Determination of self-extracting γ angle of fiber

Applying the d'Alembert's principle and projecting the forces acting on the fiber on the x and y axes, we obtain for uniform rotation of the saw blade [35]

$$\begin{cases} N\cos\gamma \mp Nu\sin\gamma - c_1 V_B^2 \sin\varphi = 0 \\ -N\sin\gamma \mp Nu\cos\gamma + \dfrac{mV^2}{R} + c_1 V_B^2 \cos\varphi = 0 \end{cases}$$

The aerodynamic equilibrium of a freely rotating saw cylinder due to the presence of friction forces arising between the saw blades and air and atmospheric pressure cannot be overcome by centrifugal forces acting on the air mass during rotation. In Fig. 5, the elementary volume of air can be expressed as follows:



$$dV = \rho d\theta d\rho d\delta$$

Fig.5. Scheme for determining the volume of air in the suction cup

For the normal operation of the fiber cleaning machine, it is necessary that the saw cylinder, taking air on the cleaning arc, has the ability to discharge it.

Discussion. With an increase in the rotation frequency of the saw cylinder, the diameter of the laminar flow decreases, therefore, the saw teeth and grates are located in the boundary zone of the turbulent flow. If the strand moved in the zone of a confident turbulent flow, then such a flow would contribute to the unraveling of the strand of fibers, thereby facilitating the release of weed impurities due to the strength of their connection with the fibers. Aerodynamic equilibrium of a freely rotating saw cylinder due to the presence of friction forces arising between the saw blades and air and atmospheric pressure cannot be overcome by centrifugal forces acting on the air mass during rotation.

Conclusion. This paper shows that as a result of the influence of working bodies of fiber cleaning machine on aerodynamic parameters. When the fiber cleaner is in operation, the saw rotates at a frequency of n = 1500 rpm, with rmax = 0.153m ≈ 155 mm. As you can see, there is no laminar flow outside the saw blade Ø310 mm. This justification makes it possible to explain the reason for the industry's refusal of the cleaning rate at 1000 min^{-1} and its transition to 1500 min^{-1}.

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