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Modelling of interaction processes of a fibrous mass with a grate in the saw generation

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ABSTRACT: A modernized saw gin with a new design grate for fiber cleaning has been developed. The rational number of grates, their location with the effective extraction of the beetle and trash impurities in the process of fiber cleaning has been determined theoretically.

KEY WORDS:fibrous material cleaner, saw gin, saw cylinder, fibers, speed, pressure, density, trash, cleaning effect, qualities.

I. INTRODUCTION

At present, in the Republic, the share of difficult-to-clean selection cotton varieties, such as C-6524, An-Bayaut-2, Omad, Namangan-77 and others, is more than 80% of the total amount of harvested raw cotton. In addition, to facilitate manual labor and reduce additional costs, the volume of harvesting of raw cotton by machine collection increases every year. Analysis of the quality of the harvested raw cotton showed that the contamination of raw cotton by machine picking, compared with manual picking, is higher and amounts to 10-15% on average in the republic [1].

The results of earlier research works showed that it is impossible to significantly improve the quality of fiber due to repeated and intensified cleaning of raw cotton, since the cleaning effect of the regulated cleaning process reaches 80 ÷ 90%, and its further increase is irrational [2].

In addition, some of the fiber defects, such as fiber skins, broken seeds and nodules are formed during the ginning process and therefore can only be removed by ginning raw cotton.

In the mid - 80 years, to clean the fiber in the gin itself, the serial sawing gin 4DP-130 was modernized and released under the brand name 5DP-130, on which two individual grates were installed. The gin consists of a working chamber 1, a seed comb 2, a cantilever grate 3, a saw cylinder 4, a grate for cleaning fiber 5, a scavenger auger 6, a windshield 7 and an air chamber 8 (Fig. 1). Installed two individual grate bars 5 of a trapezoidal shape, carried out cleaning of the spent fiber, increasing its quality. But due to the shortcomings of fastening individual grates on the sidewalls of the gin, it was impossible to establish the required clearances between the saw teeth and the edges of the grates, which reduced the release of the beetle and trash[3].

At the same time, the cleaning effect on the fiber decreased to 12-14%, the fiber content of the waste increased to 16-19% when cleaning high- and low-grade fibers, respectively [4].
Considering the positive effect on the fiber quality, despite the decrease in the cleaning effect, these individual grates are still used on 5DP-130 and DPZ-180 gins.

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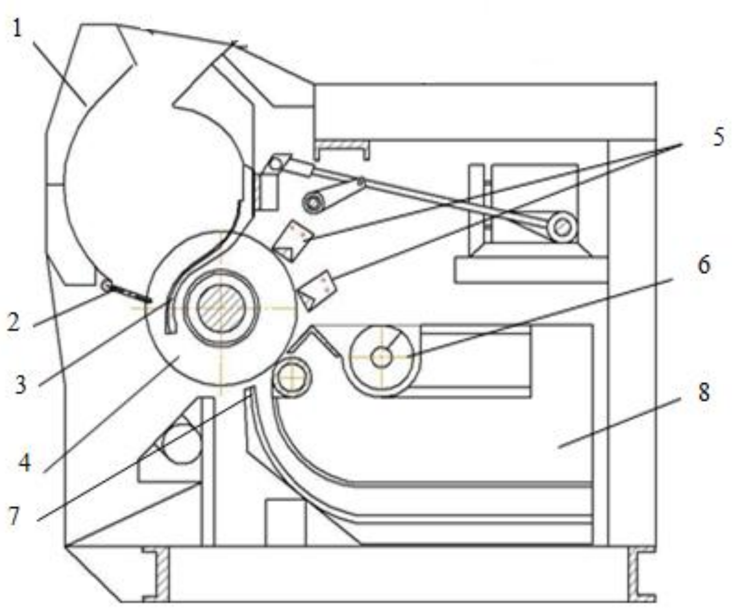

1- working chamber, 2- seed comb, 3- cantilever grate,4- saw cylinder, 5- individual grates, 6- worm auger, 7- snake goat, 8- air chamber
Fig. 1. Diagram of a 5DP-130 sawing gin with two individual grates

II. ACTUALITY OF THE TOPIC

In developed cotton growing countries such as the USA, China, India, etc., fiber cleaning sections are not used in the construction of gins (Fig. 2, 3). They clean the fiber on aerodynamic and condenser fiber cleaners [1].

At the same time, the fiber undergoes enhanced cleaning according to the combing principle, which increases the fiber content of the waste, thereby reducing the amount of fiber produced by grade.

Studying the dignity of individual grates and considering their shortcomings, a grate diagram was developed. For the effective extraction of the beetle and trash from the fiber and the reduction of fibrous content in the waste, we theoretically determine the rational number of grates, their location and their angle of inclination to the radius of the saw cylinder.

III.THEORETICAL PART

Cleaning the pulp occurs as a result of impact interaction with the grate, where the pulp is loosened by increasing its initial volume. If the mass enters the cleaning zone continuously with a flow rate Q and interacts with the $S = \varphi_0 R$ -th fractional part of the surface, where n is the drum rotation frequency, then due to the stationarity, the same fiber mass $m = QSn$ enters the chamber during period $T = Sn$.

Let us make an equation to describe the change in this mass during the passage through the cleaning zone. The mass of the fiber decreases over time dt as a result of the escape of particles of trash impurities $m - dm$, where m - is the mass of fibers over time t.

According to [5], the change in mass during this time is proportional to the change in the volume occupied by the mass dm, ie.

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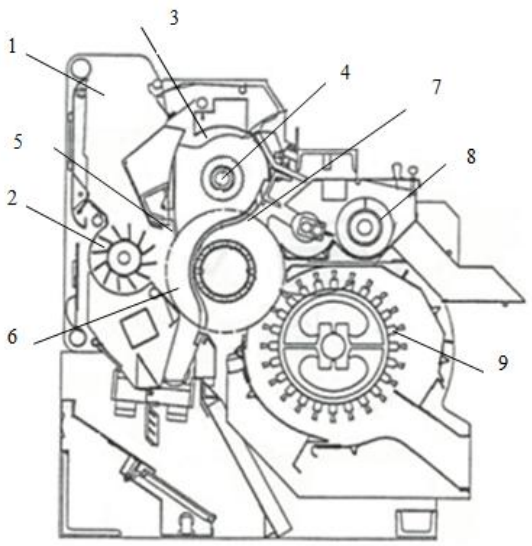
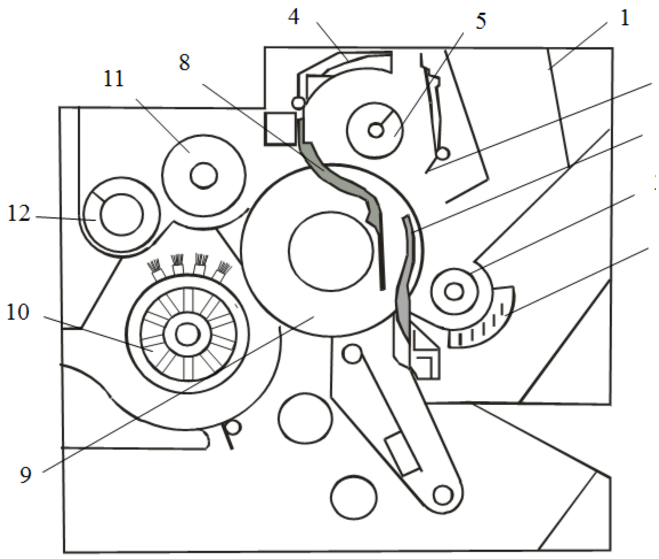
$$\frac{dm}{m}=\frac{1}{a}\frac{dV}{V} \quad (1)$$

Where, $V-$ the volume of pulp in time t, dV - change in volume over time dt, a- proportionality coefficient, which is a function of time, since during the cleaning process, the removal of impurities from the mass due to impact on the grate is uneven in time.



1 - peeling chamber, 2 - throwing drum, 3 - working chamber, 4 - accelerator, 5 - seed comb, 6 - saw cylinder, 7 - seed grate, 8 - auger, 9 - brush drum.

Fig. 2. The scheme of the sawing gin of the Lummus company - USA.



1 - peeling chamber, 2 - throwing drum, 3 - grate, 4 - working chamber, 5 - accelerator, 6 - seed grate,7 - peeling grate, 8 - cantilever grate, 9 - saw cylinder, 10 - brush drum, 11 - scraper, 12 - auger.

Fig. 3. The scheme of the saw gin brand MY-171 Swan company - China.

If we consider dependencies $V=\frac{m}{\rho}, V+dV=\frac{m-dm}{\rho-d\rho}$, then we get

$$\frac{dV}{V}=\frac{m-dm}{\rho-d\rho}\cdot\frac{1}{V}-1=\frac{m-dm}{\rho-d\rho}\cdot\frac{\rho}{m}-1=\frac{1-\frac{dm}{m}}{1-\frac{d\rho}{\rho}}-1=(1-\frac{dm}{m})(1+\frac{d\rho}{\rho})-1=-\frac{dm}{m}+\frac{d\rho}{\rho}$$

Substituting expression $\frac{dV}{V}$ in formula (1), we obtain

$$\frac{dm}{m}=\frac{1}{1+a}\cdot\frac{d\rho}{\rho} \quad (2)$$

Equality (2) establishes a relationship between the relative change in the fiber mass and its density. If we take a separate piece (fibers) as a pulp, then on the right side of equality (2) it is necessary to establish a change (decrease) in the density of the piece over time as a result of its interaction with the grates and the release of some part of trash impurities. This change is presented as a linear function of the angle of rotation of the piece along the arc of its contact with the grate and their number.

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Vol. 8, Issue 1 , January 2021

1. If we assume that the scrap rotates jointly with the serrated drum at an angular velocity and periodically contacts the grates, then in accordance with the accepted interaction scheme, the change in the weight of the scrap over time can be written in the form

$$\frac{d\rho}{\rho} = -b\omega dt \qquad (3)$$

Where *b*- proportionality factor.
Considering (3), dependence (2) can be represented as:

$$\frac{dm}{m} = -\frac{b\omega}{1+a}dt \qquad (4)$$

We assume that over time, the rate of weight reduction due to the release of trash impurities decreases. In this case, the coefficient in the simplest case can be taken as

$$a = a(t) = a_0 + a_1\omega t \qquad (5)$$

By supplying the expression $a(t)$ into the equation (4) and integrating it under the condition $m(0) = m_0$, obtain

$$m = m_0(1+\lambda_1\omega t)^{-\lambda_0/\lambda_1} \qquad (6)$$

Where $\lambda_0 = b/(1+a_0)$, $\lambda_1 = a_1/(1+a_0)$
The efficiency of cleaning the pulp is determined by the formula

$$\varepsilon = \frac{m_0 - m}{m_0} = 1-(1+\lambda_1\omega t)^{-\lambda_0/\lambda_1} \qquad (7)$$

The amount of separated trash impurities during the interaction with the grates $t = \varphi_0/\omega$ (φ_0 - is the angle of coverage of the grate along the cleaning arc) will be equal to:

$$\Delta m = m_0 - m = m_0 - m_0(1+\lambda_1\varphi_0)^{-\lambda_0/\lambda_1} = m_0\varepsilon(\varphi_0/\omega) \qquad (8)$$

In fig. 4 shows the curves of the dependence of the cleaning intensity $\varepsilon = 100\varepsilon(\tau)$ on the dimensionless time at various values of the coefficients λ_0 and λ_1. It can be seen that with an increase in the coefficient ε it also increases, while an increase in the second coefficient λ_1, which leads to a decrease in the rate of release of trash impurities, can lead to a significant decrease in the cleaning efficiency. In this regard, we note that to ensure a uniform release of trash impurities, it is necessary to change the nature of the interaction of the scrap with the grate, for example, by increasing the coefficient λ_0.

In fig. 5 shows the graphical dependences of the amount of separated trash impurities (in% and referred to the mass m_0) on the coefficient λ_0 for different values of the parameter λ_1. Analysis of the results shows that the mass M linearly depends on the coefficients λ_0 and λ_1 at their small values.

2. The piece interacts pointwise with the grates. Suppose that when the pulp passes through the cleaning zone, point contact with the surfaces of the grate occurs. When drawing up the equation of motion of the scrap at the points of contact with the surfaces of the grate, we consider the weight of the scrap and the friction between the scrap and the grate.

The equations of the circular motion of a piece are written in the form:

$$mR\ddot{\varphi} = m\sum_{i=1}^{k}[g\cos\varphi_i - f\sin\varphi_i) - fm\dot{\varphi}_i^{\,2}R)\delta(\varphi-\varphi_i) \qquad (9)$$

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 8, Issue 1 , January 2021

Where, $\varphi_i = i\varphi_0$, f - coefficient of friction between the scrap and the grate surface, $\delta(z)$ - is the Dirac function

Introducing the function $y = \frac{d\varphi}{dt}$, equation (9) is reduced to the form:

$$\frac{1}{2}\frac{dy^2}{d\varphi} = \sum \frac{g}{R}(\cos\varphi_i - f\sin\varphi_i) - fy_i^{\,2}]\delta(\varphi - \varphi_1)$$

I integrate the last equation under the condition $y = \omega$ for $\varphi = \varphi_0$, we obtain

$y = 2y_0^2 = 2\omega^2$ at $\varphi_0 \angle \varphi \angle 2\varphi_0$

$$y^2 = 2\omega^2 + \frac{2g}{R}(\cos\varphi_1 - f\sin\varphi_1) - 2fy_1^2 \text{ at } 2\varphi_0 \angle \varphi \angle 3\varphi_1 \quad (10)$$

$\lambda_0 = 0.05$ $\qquad$ $\lambda_0 = 0.1$

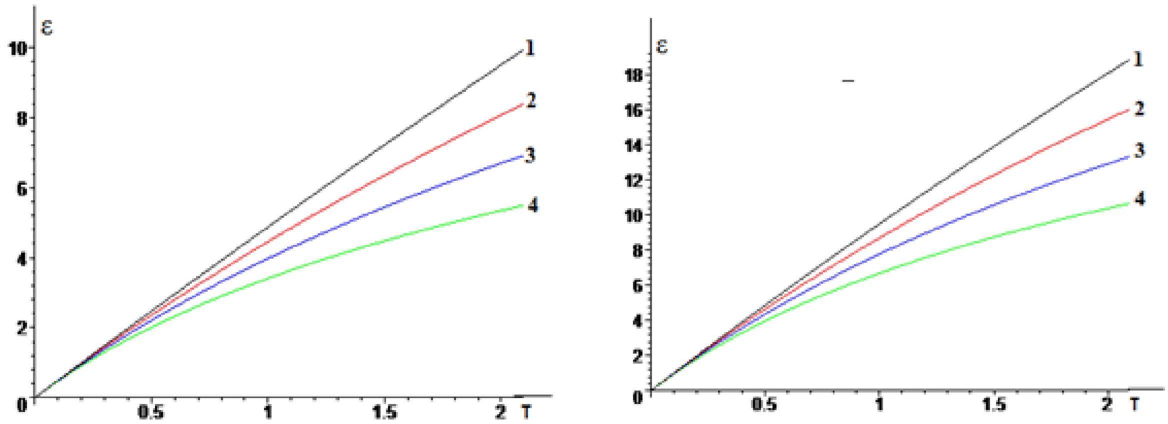

Fig. 4. Dependences of the relative change in mass $\varepsilon = 100(m_0 - m)/m_0$ of precipitated impurities by dimensionless time $\tau = \omega t$ for different values of parameter λ_1: $1 - \lambda_1 = 0$, $2 - \lambda_1 = 0.2$, $3 - \lambda_1 = 0.5$, $4 - \lambda_1 = 1$.

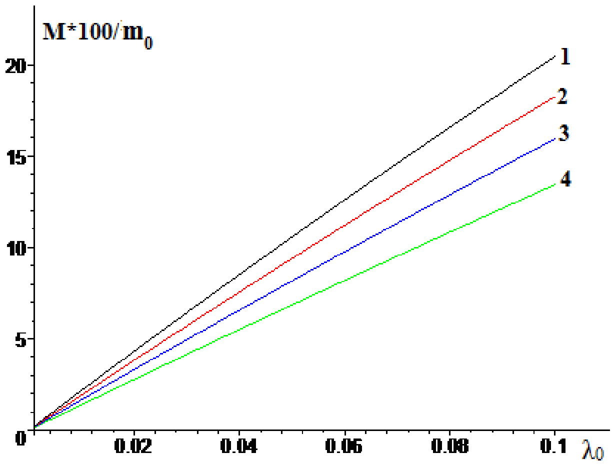

Fig. 5. Dependences of the mass of the emitted trash impurities in% (referred to the value m_0) on the coefficient λ_0 for different values of the parameter

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$$\lambda_1 : 1-\lambda_1 = 0,\ 2-\lambda_1 = 0.2,\ 3-\lambda_1 = 0.5,\ 4-\lambda_1 = 1.$$

$$y^2 = 2\omega^2 + \frac{2g}{R}(\cos\varphi_1 - f\sin\varphi_1) - 2fy_1^2 + \frac{2g}{R}(\cos\varphi_2 - f\sin\varphi_2) - fy_2^2 \text{ at } 3\varphi_0 \angle \varphi \angle 4\varphi_0$$

$$y^2 = 2\omega^2 + \frac{2g}{R}(\cos\varphi_1 - f\sin\varphi_1) - 2fy_1^2 + \frac{2g}{R}(\cos\varphi_2 - f\sin\varphi_2) - fy_2^2 + ... + \frac{2g}{R}(\cos_i - f\sin\varphi_i) - fy_i^2$$

at $(i+1)\varphi_0 \angle \varphi \angle (i+2)\varphi_0$, $i = 0,1,2....k-1$

Assuming $y = y_1^2$ at $\varphi = 2\varphi_0$ find

$$y_1^2 = \frac{g(\cos\varphi_1 - f\sin\varphi_1)}{2(1+f^2)R} + \omega^2$$

Similarly, we find

$$y_i^2 = \omega^2 + \frac{g}{R}\sum_{j=1}^{i} \frac{g(\cos\varphi_i - f\sin\varphi_i)}{(1+f^2)},\ \ i = 1,2....k-1$$

The shred speed expression is determined by the formulas (9). Change in the mass of a piece according to the model of A.G. Sevastyanov is determined by the equation $\frac{dm}{m} = -\frac{by_i dt}{1+a}$

Integrating under the condition $m(0) = m_{00}$ we obtain for the moments of time:

$$m = m_1 = m_0 \exp(-\lambda_o y_1 t) \quad \text{at } 0 < t < t_1$$

$$m = m_2 = m_1 \exp[-\lambda_o y_2 (t - t_1)] \text{ at } t_1 < t < t_2$$

$$m = m_i = m_{i-1} \exp[-\lambda_0 (t - t_{i-1})] \text{ at } t_{i-1} < t < t_i\ i = 1,2....k-1$$

IV. CONCLUSION

The designs of saw gins with cleaning sections for cleaning fibers have been studied. The influence of the design and arrangement of grates on the cleaning effect, fiber quality and waste fiber content are determined.

A variant of a grate for cleaning fibers in saw gins is proposed. The change in the mass of fibrous material due to the release of trash impurities in the process of impact interaction with the grate has been studied theoretically.

With an increase in the parameter λ_0 associated with an increase in the intensity of the release of impurities, an increase in the parameter λ_1 leads to their significant decrease.

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