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Development of Design and Substantiation of The Parameters of the Separator for Fibrous Materials

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Abstract**: *The article provides an analysis of existing separators for raw cotton. Their disadvantages are described. The design scheme and the principle of operation of the separator with side grids of the air duct with curved conical holes are presented. The results of theoretical studies to determine the strength of Stripping and justification of the system parameters. The results of comparative production tests of the recommended separator design for fibrous materials are presented.***

Index Terms: fibrous material, separator, air, chamber, Stripping, brush, friction force, hole, curvature, mesh, vacuum valve, quality.

I. INTRODUCTION

Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline. The existing separator is a chamber divided by a mesh partition into two parts cotton and air. In the cotton part there is a deflector and a scraper, which cleans the mesh from the raw cotton, located on the sides, and directs it to the vacuum valve. The vacuum valve is designed for unloading raw cotton from the separator chamber and creating a tightness that prevents suction of outside air into the separator chamber. The air part of the chamber is limited by a mesh surface on the sides and cones of the separator. The raw cotton fed into the separator by the airflow through the pipe hits the mesh surfaces installed on the two sides of the cotton separator chamber. At the same time, the airflow rate in the separator drops sharply, the main part of the raw cotton falls into the vacuum valve, and a certain part reaches the mesh surface and is discharged by a scraper into the vacuum valve [1]. A significant disadvantage of the known separator is the low reliability in operation, due to the fact that during the removal of raw cotton scrapers, the fiber crushed by the airflow to the mesh surface and the seeds are damaged.

In the separator of fibrous material containing a separation chamber, inlet and outlet pipes, a mesh drum installed in front of the outlet pipe and a vacuum valve mounted in the lower part of the separation chamber, the chamber is made expanding in a horizontal plane from the inlet pipe to the mesh drum, with a reflection partition installed inside it, dividing the chamber into a pneumatic conduit located in the upper part of the chamber, and a fibro conduit – in its middle part. In the fiber in the direction of the vacuum valve installed fan guide ribs. The latter can be installed on the upper or lower wall of the fiber, or on the upper and lower walls of the fiber. The height of the guide ribs is from 1/4 to 1/3 the height of the cross section of the fiber [2]. The disadvantage of this separator is the low reliability due to the rigidity of the ribs, which leads to the unloading of raw cotton in the center of the fiber and, in the future, in the middle of the vacuum valve. Due to the overload of the middle section of the vacuum valve, the rubber strip is strongly bent and a gap is formed through which air is sucked into the separation chamber. This leads to a decrease in the rate of absorption of raw cotton through the fiber, which leads to a decrease in the productivity of the separator. The design of the separator for raw cotton, containing a separation chamber with perforated grids in the end walls, the holes of which are cylindrical at an angle 45÷600 to the horizontal, nozzles for input and output of raw cotton, a vacuum valve adjacent to the discs scrapers with elastic blades mounted on the drive shaft [3]. The disadvantage of the separator is the damage of fiber and seed scrapers during removal of raw cotton from perforated discs.

II. EFFICIENT DESIGN OF THE SEPARATOR

In order to reduce the damage of cotton fibers in the interaction of scrapers with perforated discs, a new modernized design of the separator has been developed..

The essence of the design is that the raw cotton separator contains a separation chamber with perforated grids in the end walls, the holes of which are cylindrical at an angle of 45÷600 to the horizontal, the nozzles for the input and output of raw cotton, a vacuum valve adjacent to the discs scrapers with elastic blades mounted on the drive shaft,

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and the holes of perforated grids (discs) are conical in shape with a curved surface, the ratio of the diameters of the holes is selected d2=(1,15÷1,25)d1.

Execution of holes of perforated nets of conical shape with a curved surface allows smooth removal of fibers of cotton bats by scrapers in their interaction with perforated nets [4,5].

The raw cotton separator consists of a housing 1 with inlet 2 and outlet 3 nozzles and, installed in the lower part of the housing 1, a vacuum valve 4. In the case 1, a cylindrical chamber 5 is stirred, at the ends of which perforated grids (disks) 6 are fixed (Fig.1).

For purification of individual briefing of cotton attached to the perforated grids of 6, the scrapers 7 are mounted on the shaft 8. In this case, the holes 9 of the perforated grid 6 are conical with a curved surface, the ratio of the diameters of the bases of the holes 9 is $d_2=(1{,}15\div1{,}255)d_1$ (where d1 is the diameter of the small base, d2 is the diameter of the large base of the conical holes).

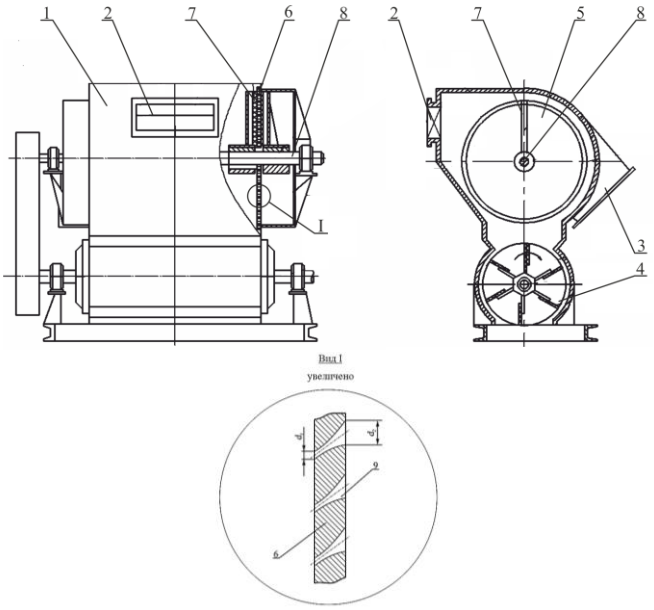


Fig.1. A separator of raw cotton

The separator for raw cotton works as follows. Raw cotton is supplied by air flow through the inlet pipe 2 to the separating cylindrical chamber 5 of the separator. In this case, the air is sucked through the pneumatic perforated mesh 6 and from the outlet pipe 3 is taken out of the separator. The raw cotton hits the grid 6, the air flow rate drops sharply and the bulk of the raw cotton falls into the vacuum valve 4, and part settles on the surfaces of the perforated grids 6. It should be noted that, due to the implementation of the holes 9 meshes, 6 conical, greatly reduced the power of the restraint of the cotton fibers on the surface of the grid 6. Therefore, a part of the mass of cotton deposited on the surface of the nets 6 is reduced.

The evenly rotating shaft 8 drives the scrapers 7, which by moving the cotton bats settling on the surfaces of the perforated grids 6 direct them to the vacuum valve 4. At the same time, due to the conical holes 9, the bulk of the volatiles fibers will mainly be located in the side of the large base of the holes 9 and therefore their pulling out of the holes 9 with clips 7 will be with less force. The curvilinear surface of the holes 9 allows reducing the friction force between the fibers of cotton volatiles and these surfaces due to the coincidence of the forming holes 9 with the direction of the shear force of the scrapers 7. This significantly reduces the damage of raw cotton fibers.

III. METHODS AND RESULTS OF THEORETICAL STUDIES

In order to reduce the free fiber is important to study the process of the scraper to remove cotton volatiles from the mesh separator. In the Fig. 2 the calculated scheme is shown to determine the force and torque on the shaft of the separator. Meanwhile the following forces affect on pappus of cotton subsided on the surface of meshes, when removing fibers of pappus of the holes the clips for the existing and recommended options for grids: peeling force with scraper $\overrightarrow{F_{pe}}$, , the friction force fibers on the surface of the hole grid F_{fr1}, the force of weight of fibers in the hole $\overrightarrow{G_f}$ and seed $\overrightarrow{G_e}$, suction power with airflow $\overrightarrow{F_в}$, the fibers in the cross section in the holes $\overrightarrow{F_a}$, and the force of friction of the seed on the mesh surface $\overrightarrow{F_{fr2}}$.

The friction force of the fibers on the surface of the hole is determined from the expression [4].

$$\overrightarrow{F_{fr1}} = f_1 \cdot N_1 \qquad (1)$$

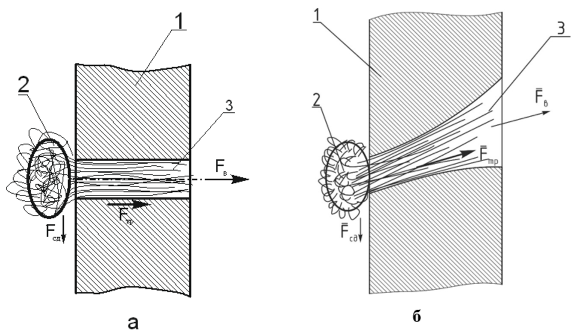
where, f_1 is the coefficient of friction between the fibers and the surface of the hole.

The pressure on the surface of the holes is determined from the expression:

$$N_1 = m_в g + F_a \qquad (2)$$

Meanwhile $$F_a = kV^2$$

where, $m_в$ is the mass of the fibers located in the mesh hole; g – acceleration of gravity, V-the speed of the fibers on the walls of the hole due to the transverse aerodynamic force; k-the coefficient of aerodynamic force in the transverse direction.



a - in the existing scheme; b - in the recommended scheme; 1-grid, 2-seed, 3-fibers

Fig.2. Design scheme for determining the seeding force of cotton pappus.

In this case, taking into account the equilibrium state of the fibers in the hole, we obtain the pressure force of the seed on the surface of the grid:

$$N_1 = f_1(m_в g + kV^2) + F_в + nF_0 e^{f_3 \beta} \quad (3)$$

where, n is the number of fibers in the hole; F_0 - with the rim tension of the fibers in the hole; f_3 – given the coefficient of friction of the fibers on the curved surface of the hole; β – angle curved part of the mesh openings of the separator.

Then the shear, that is, the removing force of the cotton volatiles on the surface of the mesh should actually be greater than the friction force between the seed of the volatiles on the surface of the mesh.

$$F_{cg} \geq F_{тр2} = f_2 N_2$$

$$F_{cg} \geq f_2 [f_1(m_в g + kV^2) + F_в + nF_0 e^{f_3 \beta}] \quad (4)$$

where, f_2 - the coefficient of friction of the seed on the surface of the mesh.

For the recommended option, the pressure of the seed on the surface of the mesh is equal to:

$$N_2^1 = \cos\alpha [f_1(a \cdot m_в g + kV^2) + F_в + nF_0 e^{f_3 \beta}] \quad (5)$$

where, α-the angle of inclination of the axis of the hole, a – coefficient, taking into account the reduction in the number of fibers in the conical inclined hole. Then the shear force of the cotton bat on the surface of the mesh has the form:

$$F_{cg}^{`} = f_2 \cos\alpha [f_1(a \cdot m_в g + kV^2) + F_в + nF_0 e^{f_3 \beta}] \quad (6)$$

Given that the shear force of the cotton bats subsiding on each mesh opening will be the same. However, the moment relative to the axis of the scraper from this force will be different, depending on the radius of the hole relative to the axis of the grid and the scraper. At the same time, the total moment of scraping is determined from the expression for the recommended grid variant:

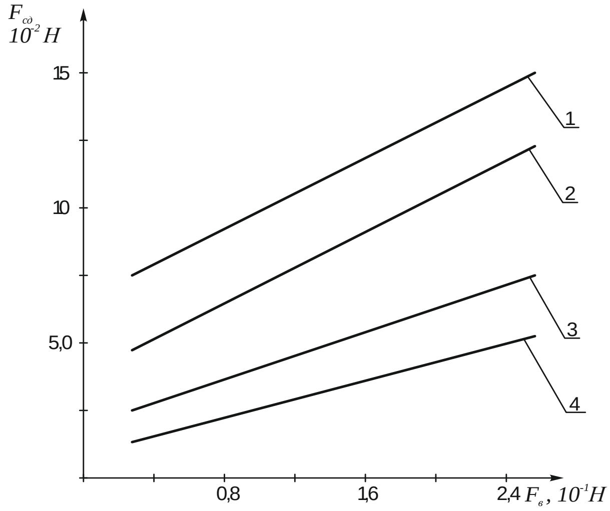
$$M_c = (K_1 R_1 + K_2 R_2 + \cdots + K_n R_n)[f_1(a \cdot m_в g + kV^2) + F_в + nF_0 e^{f_3 \beta}] f_2 \cos\alpha \ (\quad (7)$$

where, $K_1, K_2, \dots K_n$ – number of holes on the same mesh radius, $R_1, R_2, \dots R_n$.

The numerical solution (4), (6) and (7) are produced at the following initial values of the parameters: $m_в$=(0,7 ÷ 0,9) degree; $F_{тр1} = (0{,}24 \div 0{,}34) \cdot 10^{-3} H$; $F_в = (60 \div 150) \cdot 10^{-3} H$; $V_в = (10 \div 20)м/c$; $K = (1{,}0 \div 2{,}5)$; $\alpha = (30^0 \div 45^0)$; $e = 2{,}72 \cdot f_3 = (0{,}35 \div 0{,}5)$; $n = (150 \div 200)$; $F_0 \leq (10 \div 15)cH; f_1 = (0{,}3 \div 0{,}4)$; $f_2 = (0{,}45 \div 0{,}55)$;

IV. TASK SOLVING AND RESULTS ANALYSIS

On the basis of the solution of constructed graphic dependences of change sirusa forces from changes in the force of suction of fibers in the mesh openings of comparable options mesh separator [6,7]. However, the humidity of raw cotton took into account the values of the coefficients of friction. The obtained dependences are shown in Fig.3. The analysis of the graphs shows that with the increase in the force of air absorption of fibers by a linear pattern, the force of removal of fibers from the grid by scrapers increases. It should be noted that an increase in $F_в$ fo *3,0·10*$^{-1}$ *H* leads to an increase in F_{cg} fo *6,2·10*$^{-2}$ *H* in the recommended and to *13,1·10*$^{-2}$ in the existing embodiment, the holes of the grids of the compared separators.



1,2-F_{cg} for existing variant; 3,4-F_{cg} for recommended variant, 1,3- with humidity of cotton for 10,5%; 2,4- with humidity of cotton for 9,0%.

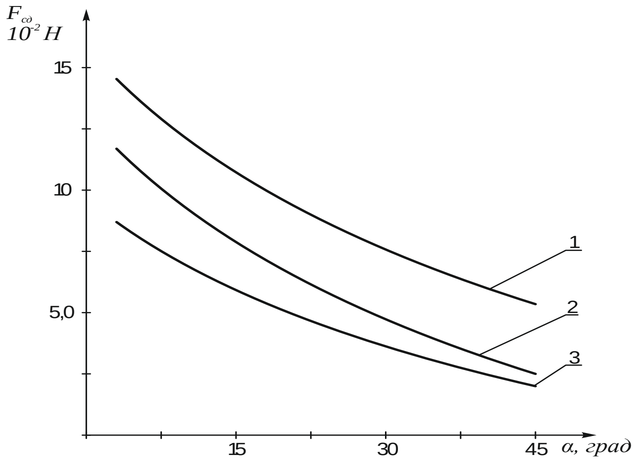
Fig.3. Graphic dependences of seeding force of cotton pappus on changes in the suction force of cotton fibers by air.

It is important that the influence of the angle of inclination of the axis of the grid holes on the force of removal of cotton volatiles from the surface of the grid. Analysis of graphs in Fig.4 shows that an increase in the angle of inclination of the hole from *5*^{0} to *46*^{0} leads to a decrease in the force F_{cg} on a nonlinear pattern from *14,7·10*$^{-2}$ H to *4,82·10*$^{-2}$ H at a coefficient *K=2.5 N/m*, and at a coefficient *K=2.5 N/m*, the value F_{cg} decreases *2,1·10*$^{-2}$ *H* at α=*46*^{0}. It follows that for the warranty removal of adhering to the holes of the raw cotton bats, it is advisable to increase the angle of inclination of the axis of the holes of the grids in the direction of movement of the scraper. The recommended values of the angle of inclination of the grid hole axis is $\alpha = 40^0 \div 48^0$.

The force of pulling out and moving the fibers and seeds of cotton stuck at the holes of the flyers largely depends on the coefficient of friction of the fibers on the surface of the holes of the grid. It should be noted that the increase in the number of fibers in the holes increases the friction force. In the recommended cone-shaped hole, the number of fibers in it is significantly less than in the cylindrical shape of the mesh hole. This decrease in the expressions (6) and (7) is taken into account by the coefficient "a". In the Fig.5 it is shown the variation of seeding force of cotton pappus on mesh surface of separator from the change of the coefficient of friction of the fibers about the surface of the mesh openings.

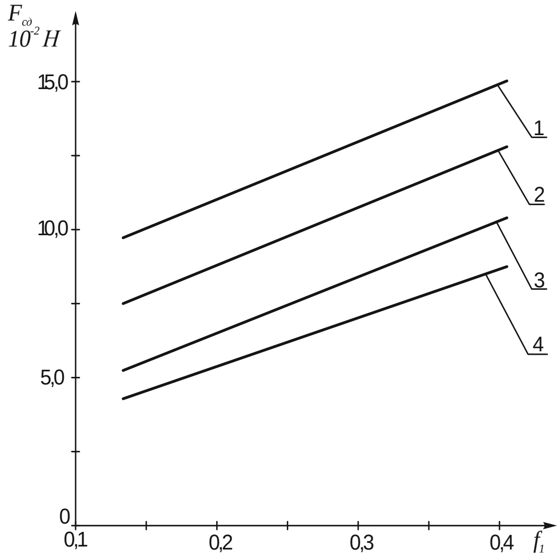
Analysis of the graphs shows that with the increase in the coefficient of friction of the fibers on the surface of the grid holes leads to an increase in the force F_{cg} linear regularity. At high air velocity, *20 m/s* at $f_1 = 0{,}4\, F_{cg}$ power for existing grid option separator comes to *14,65·10^-2 H*, and for recommended option F_cg increases to 8.9·10-2 N. At low air velocity *15 m/s* F_{cg} for the recommended grid option the separator comes to *7,6·10^-2 H*. Therefore, to ensure $F_{cg} \leq 6{,}0 \cdot 10^{-2}$H recommended values are $f_1 = 0{,}25 \div 0{,}35$. Analysis of graphs in Fig.6 shows that to provide $F_{cg} \leq 6{,}0 \cdot 10^{-2}$H it is recommended to choose $f_2 = 0{,}45 \div 0{,}55$.

One of the important objectives of the use of meshes with a conical hole with a tilted axis is the reduction of power consumption of the scraper. To do this, it is necessary to reduce the torque on the shaft of the scraper. Calculations were carried out according to the expression (7) for the recommended version of the separator grid. Fig.7 shows the graphical dependence of change of moment on the shaft of the scraper arm of the total move weight of cotton freezing to the mesh openings of the separator. Analysis of the obtained graphs shows that with an increase in the total weight of cotton in the mesh surface from 1.22 kg to 6.0 kg leads to an increase



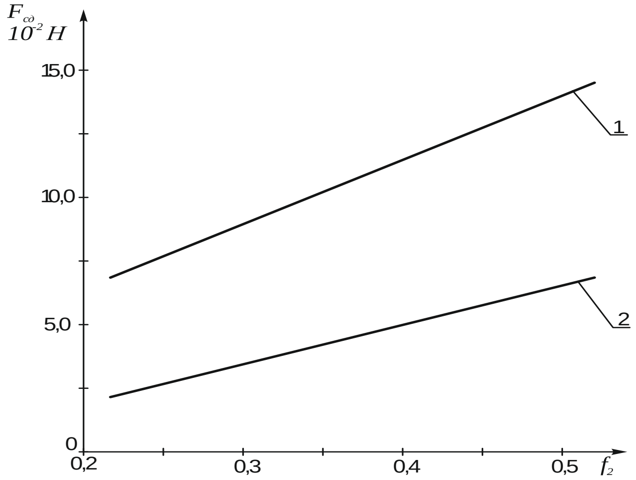
1-at K=2.5 n/m; 2-at K=2.0 n/m; 3-at K=1.5 n/m;

Fig.4. Graphic dependences of the variation of the seeding force of cotton pappus from the grid surface on the variation of the angle of inclination of the hole axis in the grid.



1,2-F_{cg} for existing variant; 3,4-F_{cg} for recommended variant, 1,3- at $v_в$-20 m/s, 1,3- at $v_в$-15 m/s

Рис. 5. Dependences of the variation of the seeding force of cotton pappus on the surface of the separator mesh on the variation of the coefficient of friction of the fibers on the surface of the mesh holes

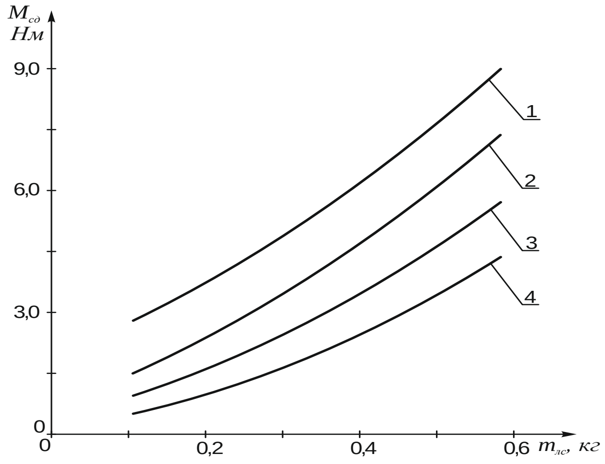


1-for existing variant; 2- for recommended variant

Fig. 6. Graphic dependences of change of seeding force of pappus cotton on mesh surface of separator from the change of the coefficient of friction Pappus cotton on mesh surface

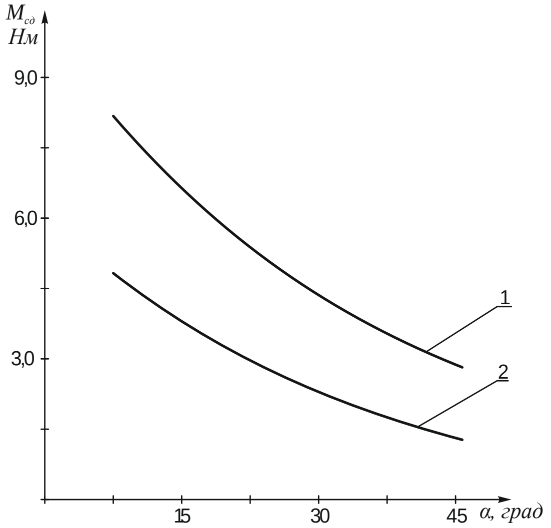
in torque on the scraper shaft from 0.51 Nm to 4.29 Nm in the recommended version of the grid at $V_в$=20 m/s. For existing variant of the grid the torque on the scraper shaft reaches 5.24 Nm. It should be noted that the small value of the moment on the shaft of the scraper for recommended variant of the grid is explained by the fact that the friction force of the fibers on the surface of the mesh opening will be smaller due to the small number of fibers, as well as reducing the projection of the friction force due to the angle α. For Fig.8 graphical dependences of the change in the moment M_{cg} on the variation of the angle of inclination of the axis of the conical holes of the grid are presented.

The greater the angle α, the lower the value of M_{cg}. For the recommended values α=400 ÷480 M_{cg} value is reduced to 2.89 Nm at $m_{нс}$=5.0 kg and up to 3.21 Nm at $m_{нс}$=7.0 kg. the Reduction in the required power of the scraper shaft in the recommended version comes up to (10÷12)% as compared to the existing separator option. The separator designs were improved and their parameters were justified [8,9,10,11,12].



1,3-for existing variant; 2,4- for recommended variant,
1,3-at $v_в$=20 m/s, 2,4-at $v_в$=15 m/s

Fig. 7. Dependences of change of the moment on a shaft of the scraper lever of the separator on total shifted weight of cotton



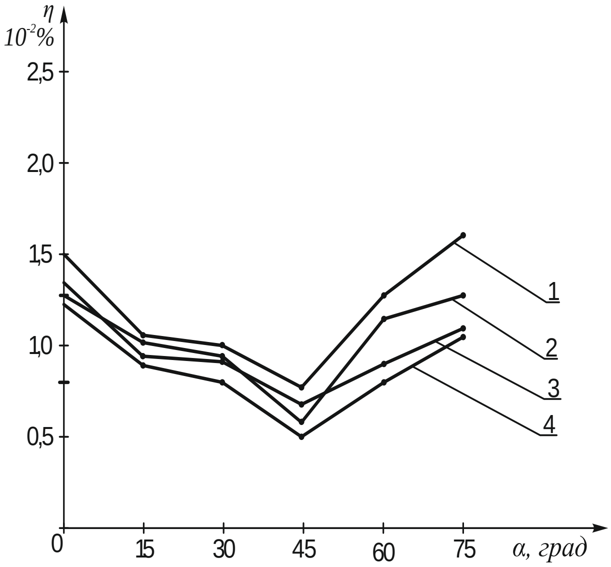
1-at $m_{лс}$=7,0 kg; 1-at $m_{лс}$=5,0 kg;

Fig.8. The variation of moment along the shaft of the scraper arm of the separator of changing the angle of the axis of the mesh openings of the separator

V. METHODS AND RESULTS OF EXPERIMENTAL STUDIES

In order to justify the angle of inclination of the axis of the conical holes of the separator grid, appropriate experiments were carried out. The experiments are compared with the existing version of the separator. The experiments of five variants of grids with cylindrical and conical holes at the angle of inclination of the axes of the holes were given: 00, 15^0, 30^0, 45^0, 60^0. Experiments were conducted at three moisture content of cotton, W=12.5 per cent, 10.5 per cent, 9.5 per cent, respectively, in the debris of 4.8%, 5,5%, 6,5%.

According to the results of the experiments, the dependences of the change in the amount of free fiber on the change in the angle of inclination of the cylindrical and conical holes of the separator mesh were obtained. Analysis of the graphs shows that at the angle of inclination of the axes of the holes of the grids 450, for both cylindrical and conical holes, the free fibers are the smallest. But, with conical holes at α=450, humidity 12.5% freer fiber will be smaller (0,3÷0,4)·10-2% compared to the serial version of the grid. With a cotton moisture content of 9.5%, this difference reaches (0.35÷0.45)·10-2%.



1,2-at –W=12,5%; 3,4- at –W=9,5%;
1,3- with cylindrical holes.; 2,4- with conical holes.

Fig.9. The amount of free fiber depends on the change in the angle of inclination of the cylindrical and conical holes of the separator mesh

Therefore, in the recommended variant α=45^0 free fiber is significantly reduced. It should be noted that in the recommended version of the grid with conical holes with an axis inclination of 45 degrees, the damage of seeds is reduced by (20÷30)% relative to the serial version.

VI. CONCLUSION

On the basis of the analysis of work of grids and scrapers of the separator of fibrous material the grid with conic apertures with an angle of inclination of the axis 450 is developed. On the basis of theoretical studies, the basic parameters of the zone of removal of raw cotton bats by scrapers are justified. Experimental studies have identified options that allow a significant reduction in damage to seeds and cotton fibers, as well as a decrease in free fiber.

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