Analysis of the Interaction of Fibrous Material with a Multifaceted Grid of the Cleaner

Juraev Anvar, Rajabov Ozod

Abstract: The article cited the development of technology for cleaning raw cotton from small waste using a multifaceted grid bar on an elastic basis. A constructive scheme and principle of operation of the multifaceted grid bar of the cleaner of fibrous material from small waste is given. Analytical methods are obtained expressions for determining the movement of fibrous material on the grid bar. A numerical solution of the problem of impact interaction of a fibrous material with a multifaceted grid built graphical dependencies of the parameters of the zone of purification of fibrous material. The results of comparative tests of the recommended zone for the purification of a fibrous material from fine waste substantiate the necessary technological parameters.

Index Terms: Keywords: fibrous material, small waste, cleaning, impact, impulse, multifaceted grid, elastic support, rebound, flight angle, dragging speed.

I.INTRODUCTION

The main disadvantages of the existing technology and designs of cleaning fibrous materials are low cleaning effect, low productivity, as well as high damage to fibrous material [1,2]. To eliminate these drawbacks, a number of designs and technologies for cleaning fibrous material have been developed [3]. At the same time, the effect on the cleaning effect of the construction of grid is important.

II. LITERATURE REVIEW

A. Analysis Of The Structures Of The Grid Surfaces Of Fiber Materials Cleaners

The grid surfaces of the cleaners of fibrous materials from small waste are known. They contain stamped steel sheets with cells of various shapes (through holes across the entire surface of the steel sheet) curved along an arc of a circle and fixed firmly in the cotton cleaner case [4]. The main disadvantage of this design is the low cleaning effect of the fibrous material due to the passive interaction of the fibrous material with the fixed surface of the grid.

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A different design of the debris screen of a fiber material cleaner is known, the openings of which are provided with fiber in the shaking visors (elastic plates) at an angle to the trap.

In addition, the visors are located in the direction of rotation of the cylinder, made a width smaller than the width of the holes of the grid. The grid also has an actuate shape with a certain radius and is fixed rigidly in the cleaner body [5].

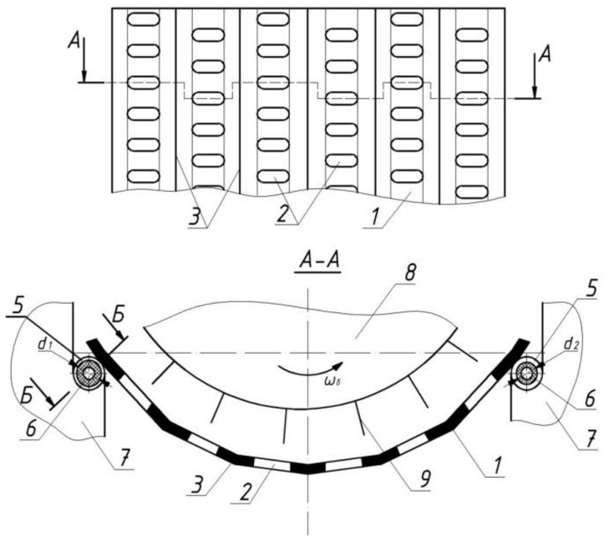
The disadvantage of this design of the grid surface is the low cleaning effect of the fibrous material due to the small cross-section of the holes, their quick clogging, as well as the rigid connection of the grid with the cleaner body, which limits the expansion of the grid activation during the process of pulling cotton along it. In the well-known construction of the drainage grid, the visors are shortened and installed in a recess in the grid holes [6]. The disadvantage of this construction of the drainage grid is also the rigid connection of the grid with the cleaner body, which limits the expanded activation of the grid during the process of pulling cotton along it. To increase the effect of shaking cotton particles on a grid surface due to their vibrations, a grid design of a fibrous material cleaner has been proposed [7]. In this construction, the grid installed rigidly in arcuate sidewalls is made with rows of holes; some of the jumpers of each row of holes are made protruding with either spherical or broken curve. In this case, the grid with the recommended bridges form a kind of wavy (there are protrusions and depressions) surface. A disadvantage of the known design is a significant inhibition of cotton particles on the surface of the net due to the cyclically varying heights of the bridges between the holes. This significantly increases the damage to the fibers of cotton, as well as decreases the productivity of the machine. In the device for drying and cleaning cotton - raw [8], containing vertical on the measure with feeding nodes, located in height on the measures in a checkerboard manner perforated (with holes) and solid surfaces, each solid surface of the walls combined with the wall of the corresponding branch pipe heat agent supply and is made of two mutually different mutually perpendicular sections, the smaller of which is located in a plane adjacent to the perforated surface, while the nozzles of the nozzles are located on a smaller section. In addition, the angle of inclination of the perforated surfaces to the horizon is 50^0-55^0, with large areas of solid surfaces of the walls connected with subsequent perforated surfaces with vertical shields to form a zigzag channel for the fiber. The disadvantage of this design is the low effect of cleaning cotton due to the lack of forced mechanical dragging on zigzag grid surfaces. This design is mainly intended for drying cotton.

In the construction, the grid surface made of stamped from sheet steel with holes, curved along an arc of a circle along four corners (edges) have steel bushes welded to it, the holes of which include fingers rigidly connected to the cleaner body, and elastic (rubber) parts are installed between the fingers and bushings. As a result, when the fibrous material interacts with the surface of the grid, oscillations (vibrations) of the grid occur due to the deformation of the elastic sleeves. In this case, the first two elastic bushes installed in the left corners of the grid have a greater thickness relative to the thickness of two elastic bushings installed in the right corners of the grid. This provides the greatest amplitude oscillations of the grid at the beginning of the interaction of the pulled-in fibers with a caustic cylinder of the cleaner [9]. The disadvantage of this design is insufficient contact and monotonous movements of the pulled cotton blotters across the surfaces of bridges between the grid holes, as well as insufficient impulsive interaction of the cotton blots with the grid surface and insufficient braking when dragging along the inner cylindrical grid of the grid does not allow obtaining a significant effect of cleaning cotton.

B. Development Of An Effective Technology For The Purification Of Fibrous Material From The Used Multifaceted Grid

A significant increase in the cleaning effect of the fibrous material (cotton) from the fine waste of the drainage grid of the fibrous material cleaner is accomplished by improving the design of the grid surface by providing the trajectory of movement of cotton particles in the zone of dragging along the broken line along the planes (edges) that make up the grid surface. In this case, the directions of the interaction of the cotton buds with the planes of a multifaceted grid surface change cyclically. This leads to the effective isolation of small waste from cotton bales [10, 11].

The grid surface of the fibrous material cleaner consists of a debris removal grid 1, with holes 2 (Figure 1). The grid surface 1 is made as a part of a multifaceted prism with ribs 3. Holes 2 are made in rows in each face (planes), and between adjacent faces of the hole 2 are arranged in a checkerboard pattern.



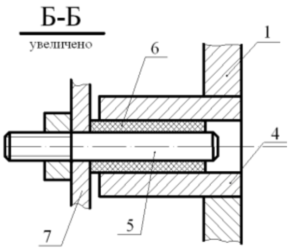


Figure 1. Grid surface of fiber material cleaner

The strain net 1 at the edges in the four corners have bushings 4 rigidly connected to it, which include fingers 5 which are rigidly connected to the cleaner body 7. Elastic (rubber) sleeves 6 are installed between the sleeve 4 and the fingers 5. A cylinder with spike 8 is installed above the grid 1 in the housing 7. In the process, raw cotton is picked up by the spike 9 of the cylinder 8 and dragged along the grid surface 1. At the same time, the cotton buckets will move along the edges of the grid surface 1, changing the trajectory of movement, undergoing cyclic interactions with a multifaceted grid surface 1. This leads to the effective release of waste. The weed impurities released during this process fall out through the openings 2. At the same time, due to the change in the total weight of cotton on the surface of the grid 1, some deformations of the elastic sleeves 6 occur. Considering that the mass of raw cotton dragged varies with time, the deformations of the sleeves 6 also change. This leads to oscillations of the grid 1 with a certain frequency and amplitude. In this case, at the beginning of the zone of pulling cotton – fiber, the oscillations of grid 1 will occur with the greatest amplitude due to the larger diameter ($d_1 > d_2$, thickness) of elastic sleeves 6 in this zone, and at the end of the zone of pulling of raw cotton will be the smallest. The frequency and amplitude of oscillation of the grid 1 depends on the stiffness of the elastic sleeves 6, the mass of the grid 1 and the change in the mass of the pulled cotton. The fluctuations of the grid 1 significantly intensify the release of weed impurities, which leads to an increase in the cleaning effect up to 10%.

III. RESEARCH METHODS

Methods and theoretical principles for calculating the shock interaction of a fibrous material with a multifaceted grid surface

In the process of cleaning the fibrous material from small waste, the shells striking to the grid surface excrete waste particles from it. In this case, the cotton fly flying from the surface of the cleaving with a certain centrifugal force. Given the relatively small gap between the spike and the grid surface in the first approximation, the speed at the moment of impact of the voltages with the grid surface will determine:

$$V_p \leq \omega_c \cdot R_c \tag{1}$$

where, ω_c - is the angular velocity of the spike cylinder, R_c - is the radius of the tops of the cylinder heads.

At the same time, as D.S.Tashpulatovloss of speed in the flight zone of the bat reaches 10% [12] (Fig. 2).

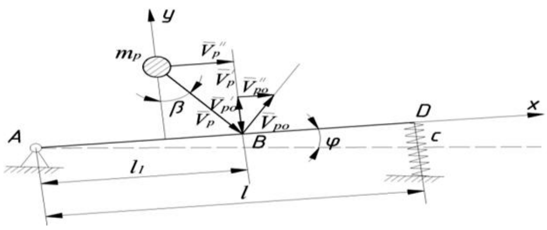


Figure 2.Calculation scheme for determining the interaction of bat with a grid surface

According to the design scheme, taking into account the angle of inclination of the speed of the cotton buds β, the vertical component of which determines the actual impact pulse, and the horizontal component determines the speed of the advancement of the cotton on the grid surface of the cleaner.

$$\overline{V}_p = \overline{V'}_p + \overline{V''}_p \, ; \overline{V}_{p_0} = \overline{V'}_{p_0} + \overline{V''}_{p_0} \quad (2)$$

$$V_p' = V_p \cos\beta \, ; V_p'' = V_p \sin\beta \, ; V_{p_0}' = V_{p_0} \cos\beta \, ; V_{p_0}'' = V_{p_0} \sin\beta$$

At the same time, the interaction of cotton leaflets with a grid surface is considered elastic, and therefore the reflection coal will also be β. According to the design scheme in figure 1 system calculation, i.e. the determination of the post-impact velocities of the cotton and grid net flyers was made by Lagrange methods [13]. In this case, the generalized coordinates were taken y - by a datum and φ- by a net surface.

The kinematic energy of the system will be:

$$T = \frac{1}{2} m_p \dot{y}^2 + \frac{1}{2} \frac{m_p l^2}{3} \dot{\varphi}_s^2 \quad (3)$$

Derivatives from kinetic energy will be:

$$\frac{\partial T}{\partial \dot{y}} = m_p \dot{y} \, ; \quad \frac{\partial}{\partial t}\left(\frac{\partial T}{\partial \dot{y}}\right) = m_p \ddot{y} \, ; \quad (4)$$

$$\frac{\partial T}{\partial \dot{y}} = \frac{m_p l^2}{3} \dot{\varphi} \, ; \quad \frac{\partial}{\partial t}\left(\frac{\partial T}{\partial \dot{\varphi}_s}\right) = \frac{m_p l^2}{3} \ddot{\varphi}_s \, ;$$

It should be noted that the speed of the cotton buds at the beginning of striking the grid surface is equal $\overline{V_p'}$, and its projection on the y-axis is negative according to (2) $\overline{V_p'}$. At the beginning of the strike, the grid surface on an elastic basis is in static rest, i.e. the initial angular velocity of the grid is zero. At the end of the strike, the speed of the cotton bumps along the y axis will be $\overline{V'}_{p_0}$, and the speed of the net after the impact $\dot{\varphi}_p'$.

Based on these considerations, the increments of the partial derivatives (4) of the kinetic energy of the system at the generalized velocities are equal to:

$$\Delta\left(\frac{\partial T}{\partial \dot{y}}\right) = m_p (\dot{y}' + \dot{y}); \quad (5)$$

$$\Delta\left(\frac{\partial T}{\partial \dot{\varphi}_s}\right) = \frac{m_p l^2}{3} \dot{\varphi}_s' \, ;$$

According to the design scheme, the generalized pulses are defined as follows:

$$P_{pu} = \left.\frac{\delta A}{\delta y}\right|_{\delta\varphi_c = 0} = \frac{S \delta y}{\delta y} = S \quad (6)$$

$$P_{su} = \left.\frac{\delta A}{\delta \varphi_c}\right|_{\delta y = 0} = \frac{S l_1 \delta \varphi_s}{\delta \varphi_s} = S l_1$$

It is known [14] that the Lagrange equations at impact are linear equations with respect to the speeds of the cotton flaps and the grid after the impact. For the system in question, they are written as follows:

$$m_p(\dot{y}' + \dot{y}) = S \quad (7)$$

$$\frac{m_p l^2}{3} \dot{\varphi}_s = S \cdot l_1$$

In the cotton cleaner from small waste, the blow of cotton particles occurs when it interacts with the surface of the net. Its speed determines the subsequent oscillations of the grid. The relationship between the speeds is the recovery coefficient at impact. This coefficient is taken into account by the relative velocities of the interacting elements projected on the y axis. At the same time we have:

$$k = -\frac{(\dot{y}' + \dot{\varphi}_s' l_1)}{-\dot{y}} \quad (8)$$

From the obtained (8) we obtain the dependences of the speeds before and after the impact.

$$k\dot{y} = (\dot{y}' + \dot{\varphi}_s' l_1) \quad (9)$$

Then the system of linear equations will be:

$$(\dot{y}' + \dot{\varphi}_s' l_1) = k\dot{y}$$

$$\dot{y}' - \frac{m_s l^2 - \dot{\varphi}_s'}{3 m_p l_1} = -\dot{y} \quad (10)$$

Resolving the received (10) we have:

$\dot{y}' = \left(\frac{k m_s l^2 - 3 m_p l_1^2}{m_p l^2 + 3 m_p l_1^2}\right)\dot{y}$ - cotton speed after hitting the net surface:

$\dot{\varphi}_s' = \left(\frac{3 m_p l_1 (k+1)}{m_s l^2 + 3 m_p l_1^2}\right)\dot{y}$ - the angular velocity of the net after impact.

In view of (2) we have:

Y-speed in y

$$V_p' = \left(\frac{\left(\cos\beta + \frac{\dot{\varphi}_s'}{V_p} l_1\right) m_p l^2 - 3 m_p l_1^2}{m_s l^2 + 3 m_p l_1^2}\right) V_p \cos\beta \, ; \quad (11)$$

On the x axis we have: $V_p'' = V_p \sin\beta$

In this case, the size of the rebound of cotton particles after impact with a grid surface is important:

$$h_p = \left[\frac{\left(\cos\beta + \frac{\dot{\varphi}_S'}{V_p} l_1\right) m_p l^2 - 3 m_p l_1^2}{m_s l^2 + 3 m_p l_1^2}\right] t_n \, ; \quad (12)$$

IV. RESULTS AND DISCUSSION

Problem solving and analysis of results

Based on the numerical solution of expressions (11) and (12), graphical dependences of the change in the velocity and magnitude of the rebound of cotton particles after hitting the grid surface are plotted depending on the system parameters. In figure 3 shows the graphical dependences of the change in the speed of movement of cotton particles on a multifaceted grid surface on the change in the angle of flight of the particles in the cleaning zone. Thus, with an increase in the angle β with a mass of m_p= *0.25 g*, the speed V_p'' increases from 1.2 m / s to 3.49 m / s, and with a mass of pulled cotton equal to 0.85 g, the speed increases only to 1.83 m / s. Therefore, to increase the rapid movement of cotton particles in the cleaning zone, it is advisable to sufficiently loosen the cotton so that the mass of the lump of raw cotton being pulled through does not exceed (0.5 ÷ 0.7) g, at which the speed of cotton pulling is within (3.0 ÷ 3.5) m / s.

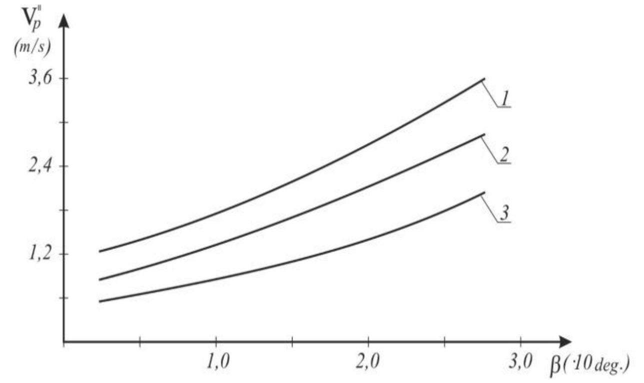


Figure 3. Graphic dependences of the change in the speed of movement of cotton particles on a multifaceted grid surface on the change in the angle of flight of the particles in the cleaning zone

Where, *1 –* m_p*=0.25 g; 2 –* m_p*=0.5 g; 3–* m_p*=0.85 g*

In figure 4 shows the graphical dependences of the change in the speed of movement of cotton particles along a multifaceted grid surface on the change in the length of the faces and the length of the flight of particles in the cleaning zone. From the computational scheme it can be seen (see Figure 2) that the speed at which the cotton flyers move along the grid surface depends on the length *l* of the grid faces and on the length l_1 of the flight of the fly in the cleaning zone. Analysis of the graphs show that with increasing *l* and l_1, the speed of advance of the voltages increases according to a nonlinear pattern.

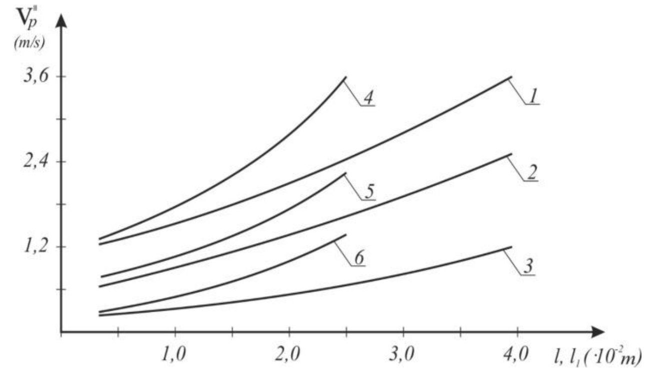


Figure 4. Graphic dependences of the change in the speed of movement of cotton particles on a multifaceted grid surface on the change in the length of faces and the length of flight of particles in the cleaning zone

where, 1,2,3 – $V_p'' = f(l)$; 4,5,6 – $V_p'' = f(l_1)$

1,4 – with m_p*=0.25g;* 2,5– at m_p*=0.5 g*; 3,6 – at m_p*=0.85g*;

At the same time, an increase in the length of the grid faces to $4.0 \cdot 10^{-2}$ m leads to an increase of up V_p'' to 3.5 m / s with m_p = 0.25 g, and with a mass of cotton clump of more than 0.85 g, the speed at which cotton moves along the grid the surface reaches (0.95 ÷ 1.2) m / s. Therefore, to ensure the speed of advance of the cotton sheaves on the grid surface up to (3.0 ÷ 3.5) m / s, the recommended values of the length of the grid face are *l = (3.2 ÷ 4.5)* 10^{-2}*m*.From curves 4,5,6 in figure 4 it can be seen that the speed of pulling through the multifaceted grid surface reaches up to (3.0 ÷ 3.5) m / s with a mass of volatile (0.25 ÷ 0.30) g with l_1 *= (2.0 ÷ 2.5)* 10^{-2} *m*. It is important to study the magnitude of the rebound$h_p$of cotton hops after interacting with the surface of a multifaceted grid.

In Figure 5 shows the graphical dependences of the change in the magnitude of the rebound of cotton buds on the change in the angle of inclination of its flight in the cleaning zone. The analysis of the technology of cleaning cotton from small waste shows that the value of the angle of flight of the volley depends mainly on its mass, as well as on the angular velocity of the peg barrel of the cleaner.An increase in the angle of flight of the flaps of cotton from 4.4^0 to 32^0 leads to a decrease in the magnitude of the rebound of the flaps of cotton from $1.5 \cdot 10^{-3}$ m to $0.46 \cdot 10^{-3}$ m with a pulse time t_p = 0.4 s, and at t_p = 0.08 s, the value of the rebound of the bat decreases from $0.75 \cdot 10^{-3}$ m to $0.21 \cdot 10^{-3}$m.

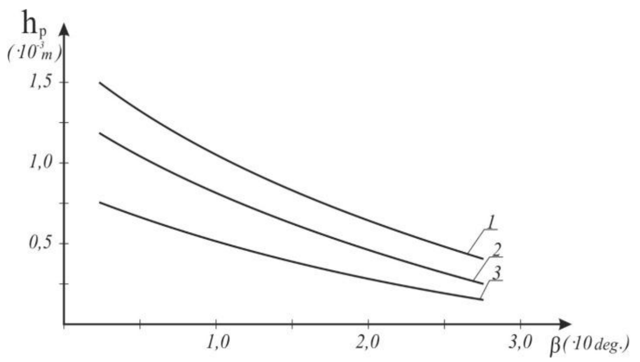


Figure 5. Graphic dependences of the change in the magnitude of the rebound of cotton particles from the change

in the angle of inclination of its flight in the cleaning zone where, *1 – t_p=0.4 c; 2 – t_p =0.2 c; 3– t_p =0.08 c;*

This is explained by the fact that at smaller values of the angle β, the impact of the volley will be significant, and thus the magnitude of the rebound will be large. In this case, the allocation of waste will be effective. But then the speed of pulling the cotton flyers is significantly reduced. In addition, damage to cotton fibers and seeds may increase. Therefore, the recommended values are $\beta \leq 25^0 \div 35^0$; In figure 6 shows the graphic dependences of the change in the magnitude of the rebound of cotton buds on the change in the zone of interaction between the length of the grid. Analysis of the graphs in figure 6 shows that an increase in the speed of flight of the bat when it leaves the surface of the spike leads to an increase in the length of the flight, while the magnitude of the rebound of the bat after hitting the grid polyhedral surface is significantly reduced. It should be noted that with an increase in the flight length l_1, the impact interaction of the cotton sheaves with a multi-faceted net surface decreases.

With increasing l_1 from $0.2 \cdot 10^{-4}$ m to $1.76 \cdot 10^{-4}$ m, the magnitude of the rebound of cotton sticks from the multifaceted grid surface along the *y* axis decreases from $1.46 \cdot 10^{-3}$ m to $0.47 \cdot 10^{-3}$ m at $m_p = 0.25\ g$, and at $m_p = 0.85 g$, the rebound value decreases from $0.52 \cdot 10^{-3}$ m to $0.19 \cdot 10^{-3}$ m by nonlinear regularity.

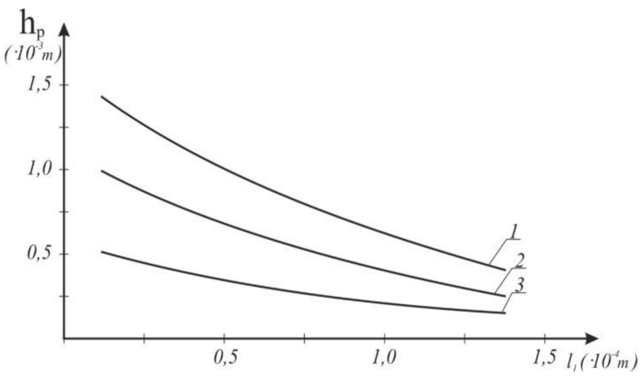


Figure 6. Graphic dependencies of the change in the magnitude of the rebound of cotton particles on the change in the zone of interaction between the length of the grid
Where, *1 – m_p=0.25 g; 2 – m_p=0.5 g; 3– m_p=0.85 g*

At the same time, the greater the hl, the greater the likelihood of waste and the possibility of advancing the cotton by reducing its contact with the grid, therefore the recommended flight lengths (projection along the x axis of a multifaceted grid surface) are $l_1 = (2.0 \div 2.5)\ 10^{-2}$ *m.*

V. EXPERIMENT AND RESULT

Based on the recommended parameters of the cotton cleaning zone using a multifaceted grid surface, a prototype of the cleaner was manufactured. There were comparative tests in a ginning factory. In figure 7 shows the recommended multifaceted grid (still image)

Figure 7.A prototype of a multifaceted grid surface mounted on the UGC cotton ginning unit

When testing, the recommended design of the upgraded section of the UGC cleaning unit showed high reliability. The test results showed that the cleaning effect in comparison with the existing option in the recommended design of the cleaner increases by an average of 7.3%, mechanical damage to seeds decreases by 0.04%, free fiber in the cotton raw material decreases by 0.07%. Due to the additional vibrations, the grid ensures effective isolation of weed impurities and eliminates the process of inhibition of cotton. The results of comparative technological tests on production lines of cleaning with serial and experienced designs of sections of cleaning units UGC are shown in table 1.

Table1

Indicators	**After the serial unit in the 1st line UGC**	**After the upgraded section of the unit in the 2nd line UGC**
Original raw cotton		
humidity	8.5 %	8.5 %
Mass fraction of weed impurities	3.0 %	3.0 %
After cleaning the cotton		
humidity	8.5 %	8.5 %
Mass fraction of weed impurities	0.57	0.45
Cleaning effect of the machine	81%	88.3%
Mechanical damage to seeds	1.35 %	1.31 %
Loose fiber	0.195	0.124

VI. CONCLUSIONS

An effective design of the multifaceted grid surface of the cotton cleaner from small waste has been developed. The problem of the shock interaction of cotton particles with a grid surface is solved. Based on the numerical solution of the problem, a graphic zone of cotton cleaning has been built.

The recommended values of the system parameters are recommended.

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