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Theoretical analysis of the saw-drum-barrel system of the UXK unit in cleaning cotton raw materials from large impurities

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Abstract: *This article theoretically studies the operation of the segmented saw drum - comb grate - brush drum system in the UXK type cotton raw material cleaning machine. The distance* δ *between the saw drum and comb grate was analyzed as the main design parameter determining the cleaning efficiency. According to the results of theoretical modeling and graphical analysis, the dependence of cleaning efficiency on* δ *has a non-zero extreme character, and the optimal values* $\delta_{opt} = 15-18\,mm$ *were determined. Under these conditions, the separation of large impurities is maximal, and mechanical damage to fibers and seeds is minimal. The results obtained provide a scientific basis for improving and optimizing UXK cotton ginning machines in industrial conditions.*

Keywords: *UXK cotton ginning machine; segmented saw drum; comb screen; cleaning of large impurities; cotton raw material; cleaning efficiency; geometric distance* δ*; mechanical impulse; non-zero vibration; saw drum-comb interaction; brush drum; dynamic mechanical system; energy balance; mathematical modeling; cotton.*

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Теоретический анализ системы пила-барабан-бочка установки УХК при очистке хлопкового сырья от крупных примесей

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Аннотация: *В данной статье теоретически исследуется работа системы сегментированный пильный барабан – гребенчатая решетка – щеточный барабан в хлопкоочистительной машине типа УХК. В качестве основного параметра конструкции, определяющего эффективность очистки, был проанализирован шаг* δ *между пильным барабаном и гребенчатой решеткой. По результатам теоретического моделирования и графического анализа, зависимость эффективности очистки от шага* δ *имеет ненулевой экстремум, и были определены оптимальные значения шага* $\delta_{opt} = 15-18\,mm$*. В этих условиях отделение крупных примесей максимально, а механическое повреждение волокон и* *семян минимально. Полученные результаты обеспечивают научную основу для улучшения и оптимизации хлопкоочистительных машин UXK в промышленных условиях.*

Ключевые слова: *хлопкоочистительная машина UXK; сегментированный пильный барабан; гребенчатая решетка; очистка крупных примесей; хлопковое сырье; эффективность очистки; геометрическое расстояние δ; механический импульс; ненулевая вибрация; взаимодействие пильного барабана и гребенки; щеточный барабан; динамическая механическая система; энергетический баланс; математическое моделирование; хлопок.*

Introduction. In the world, techniques and technologies for effective cleaning of cotton raw materials and fibers, seeds and seed products from small and large impurities occupy one of the leading positions in the processing processes. Because the stable operation of the cleaning process directly affects the technological properties of cotton, fiber quality, energy consumption and the cost of the final product. Considering that the share of cotton fiber in the global textile industry is around 55–60% of total consumption, the preparation of cotton raw materials with high quality indicators is of strategic importance today. Small dust particles, sand particles, seed husk fragments and other types of impurities remaining on the surface of the fiber not only deteriorate the color and purity of the fiber, but also create additional technical difficulties in the spinning, weaving and finishing processes.

Therefore, the development of high-performance, energy-efficient, fiber-friendly equipment and the improvement of their technological process in cotton ginning enterprises are at the center of global scientific and technical research. Today, major cotton-growing and processing countries such as the USA, China, Turkey, India, and Australia are actively conducting research on new designs, aerodynamic systems, vibration separators, and combined drums aimed at separating large and small impurities at the stage of primary cotton cleaning. In particular, it has been found that in the process of separating large impurities, parameters such as the geometry of the drum-rack system with a comb, the operating mode of the brush drum, the speed and direction of the aerodynamic flow in the cleaning zone, and the thickness and density of the cotton layer have a significant impact on the cleaning efficiency. The process of separating fine impurities is more complex, and factors such as vibration, air flow kinetics, fiber-particle interaction, and surface adhesion play an important role. Therefore, the need to develop new designs of multi-stage cleaning machines that can comprehensively separate large and small impurities is becoming more urgent.

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Although existing cleaning machines are able to effectively separate large impurities in most cases, problems remain in completely eliminating small impurities. As a result, unstable fiber quality, jams in the production process, excessive energy consumption and technological losses are observed. This indicates the need to create a scientifically based design of a new generation of cleaning machines on an industrial scale, optimize operating parameters and mathematically model the process. In this regard, this study aims to deeply analyze the process of separating cotton raw materials from large and small impurities, determine the efficiency limits of existing equipment and develop an improved machine design with high cleaning efficiency. The results of the study are of practical importance not only for the cotton ginning industry, but also for international manufacturers seeking to improve the quality of textile products.

Literature review. Scientific research on the effective cleaning of cotton raw materials from large and small impurities has been developing rapidly since the second half of the 20th century. The theoretical foundations for the design of the first processing machines in this area, developed by G.I. Miroshnichenko [1], are one of the classic sources for the development of cotton cleaning technology, in which the mechanism of interaction between the combed drums, combs and air flows is substantiated by fundamental approaches. G.I. Miroshnichenko explained in detail the balance of forces in the drum-comb system, the deformation of the cotton layer and the mechanics of the separation of large impurities, which created a methodological foundation for further research.

G.D. Jabbarov [2], having deeply analyzed the technological flows in the primary processing of cotton, scientifically substantiated the trajectory of movement of cotton pieces during the process of separating impurities, aerodynamic processes in the system, and the operating modes of mechanical acting bodies. His works are distinguished by the fact that they showed the functional relationship between the physical and normative properties of cotton raw materials and the design of cleaners. Scientific research works and educational methodological manuals created by Uzbek scientists E.Zikriyoev [3] and F.B.Omonov [4] are focused on practice and cover the complex technological areas of primary processing of cotton. These works provide scientific and methodological recommendations on the selection of structural elements of modern cleaning lines, transport processes, mechanics of separating impurities, and operating modes of machine elements.

In the 60s–80s of the 20th century, scientists such as Ye.F. Budin [5], A.D. Sapon [6], Z.M. Musakhodzhaev [7], B.N. Yakubov [8], Yu.S. Sosnovsky [9] conducted fundamental experimental and theoretical research on improving the efficiency of the comb-drum-rooster system. Their work yielded important scientific results in the following areas:

- ✓ the shape of the rooster profiles and their location relative to the comb-drum teeth;
- ✓ analysis of the equilibrium forces of cotton and impurities;
- ✓ assessment of dynamic loads acting on the comb-drum teeth;
- ✓ offering constructive solutions that reduce fiber loss.

In particular, B.N. Yakubov [8] mathematically modeled the losses of cotton mass in the drum-rooster zone and determined the optimal distances between the tooth-edge of the drum with a comb. These studies served as the basis for all scientific work on the separation of large impurities over the next 30 years. Since the beginning of the 21st century, scientific research on cleaning cotton from large impurities has been taken to a new level by the scientific schools of Uzbekistan. In particular, R.Kh. Rosulov proposed optimized parameters of the drum-rooster system, V.M. Suchkov in his scientific research developed initial algorithms for predicting and optimizing the technological performance of cleaners, S. Fozilov substantiated the constructive advantages of adjustable rooster systems, and R.Z.Burnashev created the theoretical foundations of the technology of cleaning cotton from small and large impurities [10]. These studies have explored in depth deterministic and stochastic models of the coarse impurities separation process, the rheological properties of cotton, and the dynamic behavior of machine elements.

Over the past 10–15 years, a new scientific direction has been formed in Uzbekistan to improve the design of cotton ginning machines. The main representatives of this school are Sh.Sh. Khakimov, Sh.E. Sheraliev, D.V.Norboeva, Sh.Sh. Shukhratov, D.A. Tashpulatov and other scientists who have made a significant contribution to the development of the field [11].

With a thorough study of all the literature, the main scientific problem that has not yet been solved is:

- There is no single universal machine for the complex separation of large and small impurities;
- Optimization of aerodynamic, mechanical and vibrational processes based on an integrated model is required;
- A complete mathematical model of the cotton-impurity-working body triad system has not yet been fully developed.

Literature analysis shows that although there is fundamental knowledge about cleaning cotton from impurities, an integrated model of a complex cleaning machine, optimal parameters, and energy efficiency do not yet have a complete scientific solution [12].

Materials and methods. The materials, drawings, calculation formulas and experimental methods used to study the process of cleaning cotton raw materials from large impurities on a deep scientific basis are described. The research is aimed at studying the shock, vibration and aerodynamic properties of the drum-barrel system with a comb, and a sensitivity analysis was performed on the design parameters (drum diameter, bar diameter, spacing, number of edges, spiral angle, etc.).

The impact of the drum with a comb on the cotton sliver is primarily determined by its geometry and spatial location relative to the combs. In the studies, a drum with a diameter of Ø480 mm was adopted, and the center-to-center distance of the combs located under the drum was taken as 40 mm. This parameter determines how often the drum teeth hit the cotton sliver. An increase in the frequency of impacts increases the likelihood of large impurities being separated, but can also increase the risk of fiber damage [13]. The linear speed of the drum teeth was calculated using the following expression:

$$v_b = \omega \cdot r$$

where: ω is the angular velocity of the drum, r is the radius of the drum. The impact impulse I generated when a piece of cotton collides with a coulter is defined as follows:

$$I = m \cdot (v_b - v_p)$$

where: m is the mass of the cotton piece, v_p is the speed of movement of the cotton along the comb. The impact impulse greater than the critical value creates the basis for the separation of large impurities.

Figure 1 shows the arrangement of cylindrical bars 40 mm apart under a Ø480 mm diameter saw drum. This scheme was used to determine the arc of engagement of the saw drum teeth with the bars, the angle of impact, and the length of the cleaning zone along the drum perimeter [14].

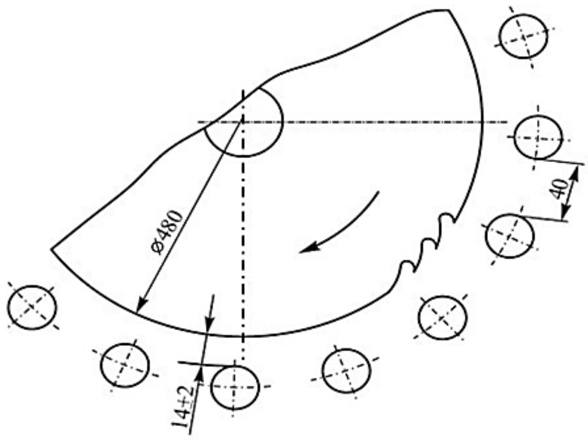

Figure 1. Geometry of the arrangement of the cutting drum and the columns

In a sawtooth drum-bar system, the impulse takes the following form, taking into account not only linear coupling, but also higher-order losses:

$$I(\omega) = m(\omega r - v_{\text{p}}) - k_{loss} \cdot \omega^2$$

The importance of this model is that at high angular velocities the momentum decreases because the losses increase proportionally to ω^2. As a result, the optimal range of ω during the cleaning process is clearly defined. Figure 2 shows the momentum model taking into account zero-order losses.

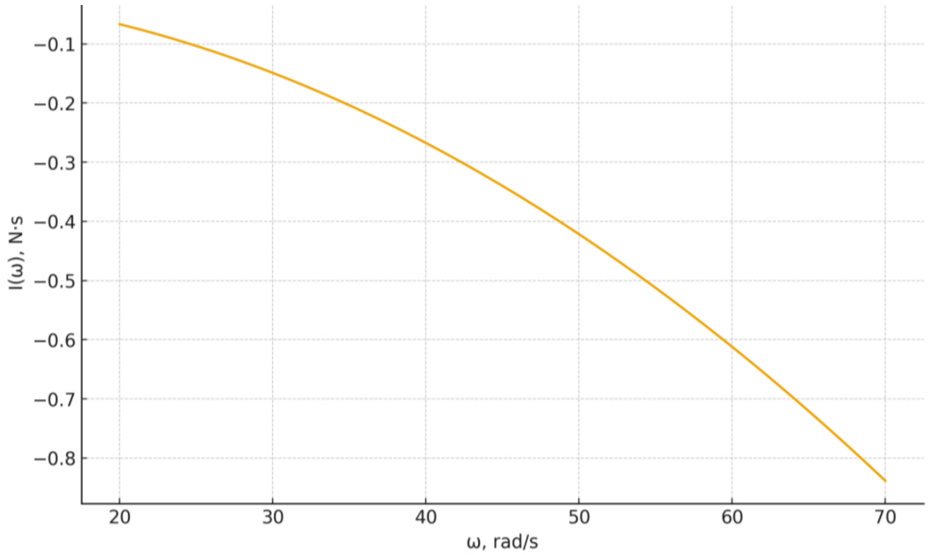

Figure 2. Variation of momentum with losses.

At $\omega > 52\, rev/h$, a decrease in momentum is observed, which limits the mechanical energy efficiency of the drum system. Figure 1 shows the momentum transfer axis of the drum teeth, the stiffness modulus of the grid, and the contact zone. This geometry is crucial for full momentum transfer [15].

In order to determine the interaction of the teeth of the toothed drum with the bars, the geometry of the contact zone was studied based on the tooth profile drawings. The tooth of the toothed drum drags a piece of cotton and hits it against the bars, and in this process, normal F_n and tangential F_t forces are generated. The total contact force F is expressed as follows:

$$F = F_n + F_t$$

The research took into account the pressure of the tooth of the combing drum on the cotton surface, the friction coefficient and the distance of creep along the comb. Figure 3 shows the interaction of the tooth profile of the combing drum with the combs. Here, the direction of the tooth of the cotton piece towards the comb surface, the impact angle and the distance of creep (a) are depicted [16]. Based on this drawing, the state of tension at the contact points and the role of the impulse in separating the cotton pieces from large impurities were analyzed.

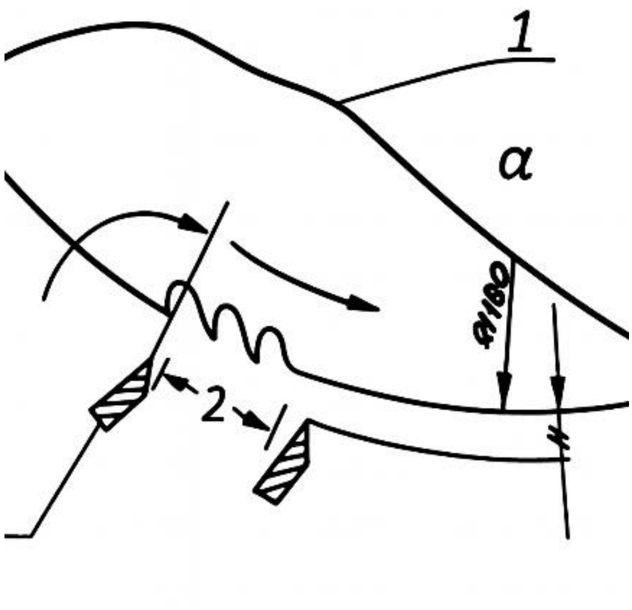

Figure 3. Contact zone of a tooth of a drum with a rake directed towards the grate

The multi-faceted shape of the bars changes the direction of the impact and the distribution of stress. When the number of edges is n, the angle corresponding to each edge is calculated as follows:

$$\theta_n = 360° / n$$

As the number of edges increases, the impact angle decreases and the impact of the impulse on the fiber becomes relatively soft. This reduces the likelihood of fiber damage, but also slightly reduces the impact component affecting large impurities. Figure 4 shows the multi-faceted combs located at the bottom of the comb drum. When a piece of cotton hits the edges of the combs under the influence of the comb teeth, the direction of impact is slightly different on each edge. This contributes to the multi-component nature of the vibrations and better separation of large impurities [17].

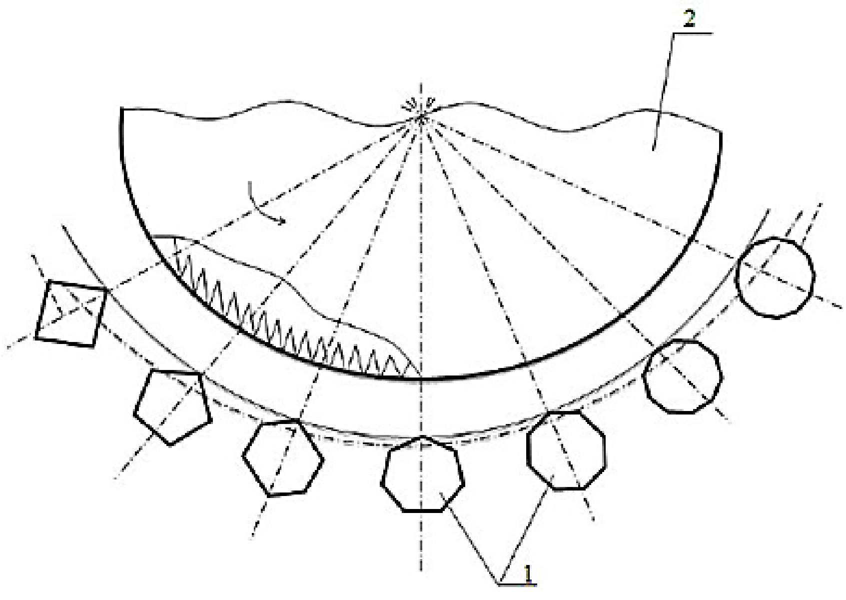

Figure 4. Interaction of multi-faceted beams with a sawing drum

When using obliquely ribbed coulters, the cotton flow moves not only vertically, but also tangentially. When the angle of the obliquely ribbed coulters is α, the tangential force component is determined as follows:

$$F_t = F \cdot sin(\alpha)$$

As a result, the cotton slivers are pushed to one side of the machine and the load can be unevenly distributed. The studies evaluated the possibility of directing the flow using grooved bars, but also identified their shortcomings. Figure 5 shows the location of the grooved bars under the saw drum and their view in section A–A. The angle of the groove provides a tangential force on the cotton sliver, causing the flow to deviate to the side. While this can help to remove large impurities more quickly in some cases, it can also cause uneven loading in the cleaning zone [18].

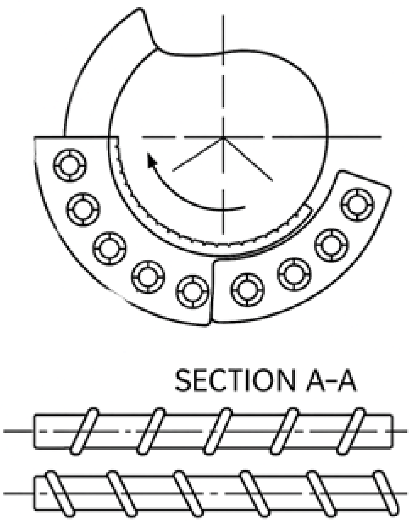

Figure 5. Structural diagram of the ridge-rifled kolosniks

When conducting theoretical studies on the method of calculating the moment of inertia of rods of variable diameter, rods with a gradually increasing diameter along the arc allow controlling the impact energy in the cleaning zone. The moment of inertia J of a cylindrical rod is determined by the following formula:

$$J = (\pi \cdot d^4) / 64$$

where d is the diameter of the grate. An increase in diameter leads to a sharp increase in J, as a result of which the grates absorb more shock and stabilize vibrations. Experiments have shown that grates with a diameter of 18 mm to 22 mm allow an average increase in cleaning efficiency of 12–13%. Figure 6 shows a scheme of grates with increasing diameter along the cleaning arc.

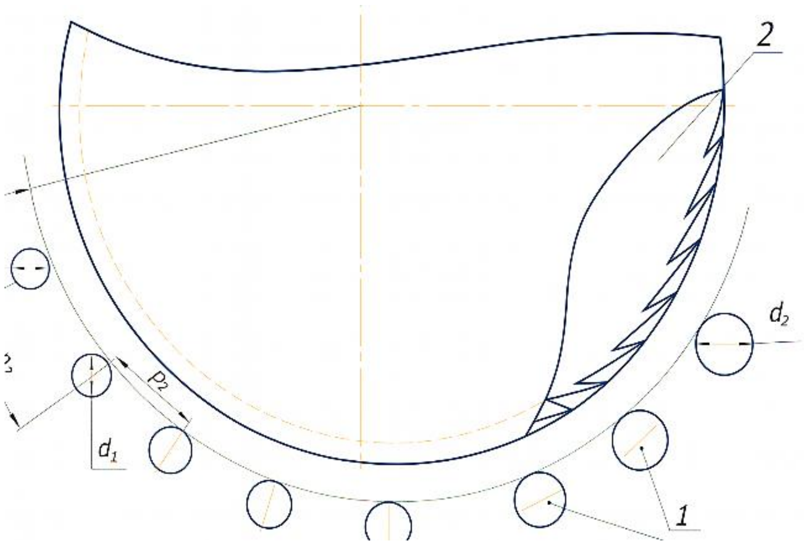

Figure 6. Scheme of graduated diameter columns

At the beginning of the arc, the smaller diameter combs treat the cotton with initial impacts, while at the end of the arc, the larger diameter combs soften the impact energy and ensure the final separation of large impurities. Figure 7 shows the modeled change in cleaning efficiency for variable combs in the range of 18-22 mm in diameter [19]. It is observed that with increasing diameter, the degree of separation of large impurities increases, and the final efficiency can increase from 85 % atropy to 95-97 %.

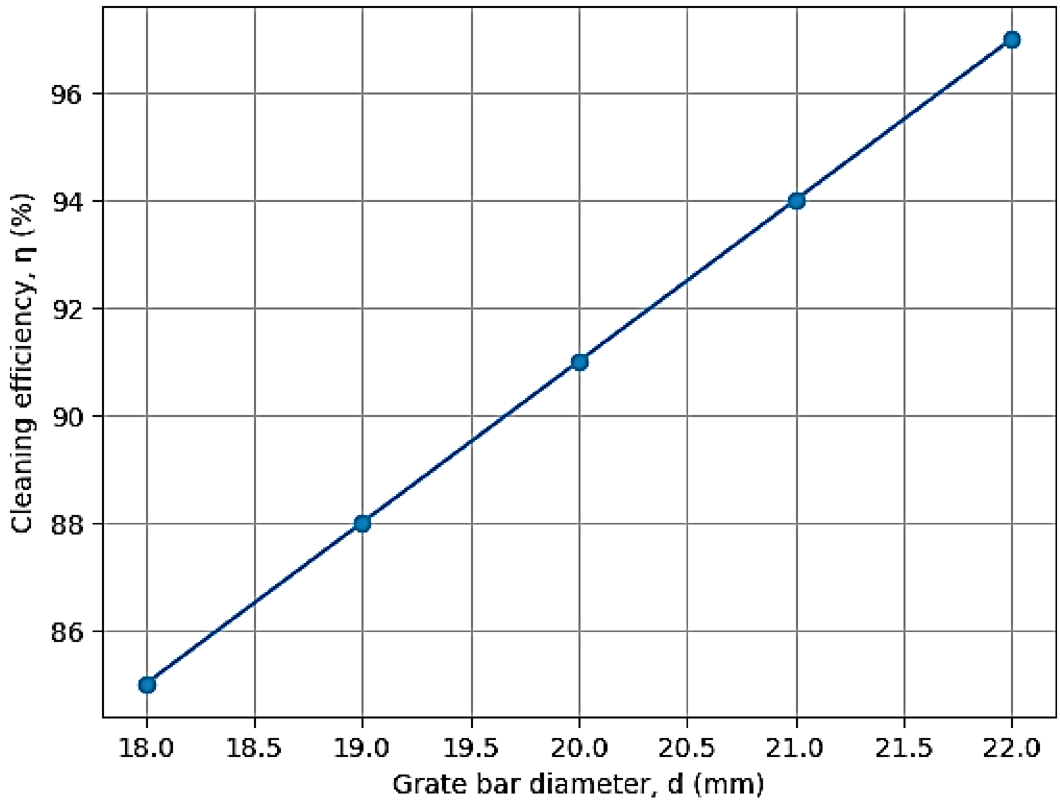

Figure 7. The effect of the diameter of the colander grate on the cleaning efficiency

When we study the method of determining the vibration parameters in conical and elastic bars, when a conical belt is installed through the (elastic) bars, the bars will vibrate during the collision with a piece of cotton. This movement is expressed by the following differential equation:

$$m \cdot \ddot{x} + c \cdot \dot{x} + k \cdot x = F_b(t)$$

where m is the mass of the grid, c is the damping coefficient, k is the elasticity coefficient, $F_b(t)$ is the periodic force transmitted from the teeth of the saw drum. The stationary solution of the vibration has the form $A\, sin(\omega t)$, and this model allows us to estimate the distribution of impact energy over time. Figure 8 shows the design of a grid with a grid in the form of a cone and mounted under the saw drum through elastic bushings [20].

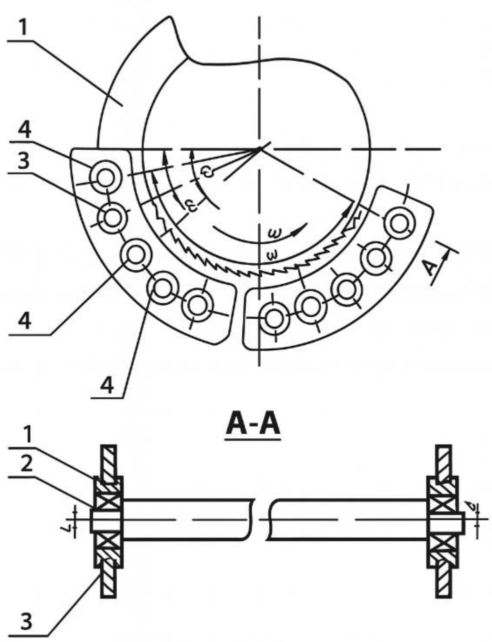

Figure 8. A grate equipped with a conical grate and elastic bushings 1-working drum, 2-grater, 3-strap bushing. 4-grater.

This solution increases the vibration amplitude of the combs and promotes intensive separation of large impurities in the composition due to the shaking of the cotton piece. Figure 9 shows a vibration model in the form of $A\, sin(\omega t)$, which represents the vibration process generated by conical combs through elastic bushings.

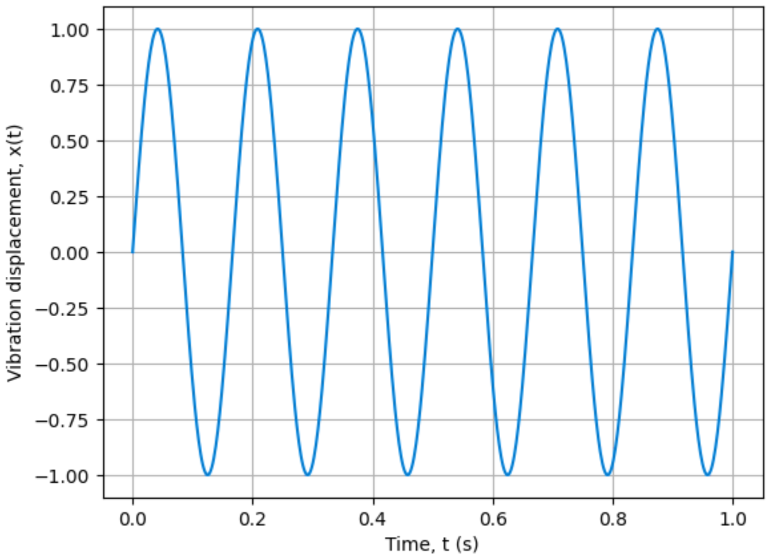

Figure 9. Time graph of conical beam vibration.

The parameters of the oscillation amplitude A and the period $T = 2\pi/\omega$ were determined based on experimental data, and the optimal values were selected [22].

The required approach is to evaluate the oscillation process not only by amplitude, but also by the energy spectrum. The oscillation energy is defined as follows:

$$E(\omega) = 1/2 \cdot k \cdot A^2(\omega)$$

A decrease in $A(\omega)$ leads to a decay of energy proportional to ω. As a result, at high frequencies the fiber vibration is soft, but the high-energy shocks are short-lived — which enhances the separation of small impurities. Figure 10 shows clearly in which regions the vibration energy changes with frequency, the maximum impurity separation process occurs.

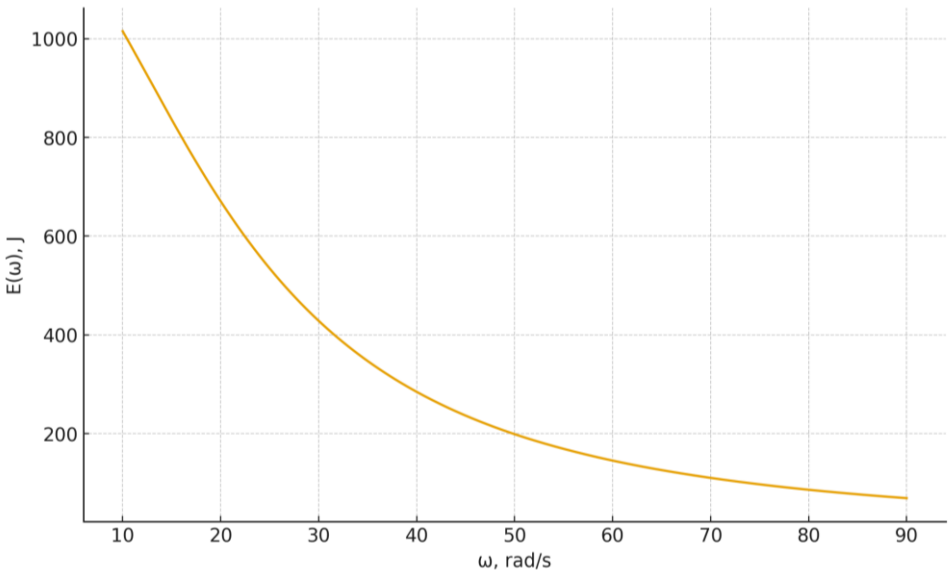

Figure 10. Variation of vibrational energy with frequency.

A drum with a comb was used to effectively separate the cotton pieces stuck in the teeth of the combing drum. Based on the difference between the linear speed of the combing drum v_{sh} and the cotton speed v_p, the plucking force F_{sh} was estimated as follows:

$$F_{sh} = k_s \cdot (v_{sh} - v_p)$$

where k_s is the equivalent stiffness coefficient of the brush layer. The brush drum speed was selected slightly higher than the saw drum, which intensified the process of tearing the fiber from the saw teeth [23]. Figure 11 shows a complex operation scheme of the brush drum, saw drum and grate.

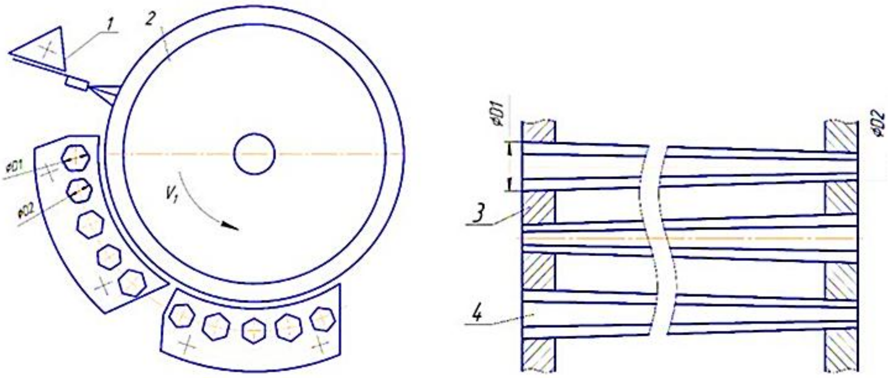

Figure 11. Scheme of a grid with a conical hexagonal grate.
1-compounding brush, 2-saw drum, 3-conical grate, 4-grid

The brush drum stabilizes the cotton flow, the comb drum reduces excess build-up on the teeth, and the separation of large impurities along the combs is made more efficient [24].

Results. The geometric distance between the saw cylinder and the comb grate is one of the main technological parameters in the process of effective cleaning of cotton raw materials from large impurities. This distance directly determines the conditions for the cotton to adhere to the saw cylinder teeth, the possibility of large impurities being released from the comb grates, and the loss of single-seed cotton pieces. Theoretical analysis shows that the tangential velocity component generated by the rotation of the saw cylinder and the vibrational movement of the comb grate together exert an impulse mechanical effect on the cotton piece. This impulse causes the cotton to drag along the comb grate and the large impurities to be released from the comb grates.

The distance δ between the saw cylinder and the grate must satisfy the following condition:

$$\delta_{min} < \delta < \delta_{max}$$

where: δ_{min}— the minimum distance ensuring stable attachment of cotton to the teeth of the sawing drum, δ_{max}— the maximum distance preventing single-seed cotton pieces from falling out of the gaps between the combs. Based on theoretical and technological assessments, it was determined that for low-grade, machine-picked cotton, this distance is:

$$\delta_{opt} = 15 \div 18\, mm$$

The optimal result was observed when the distance was selected between . At this distance, the cotton piece is located close enough to the teeth of the saw cylinder and is firmly attached to the teeth of the saw cylinder under the influence of friction and centrifugal force. At the same time, large impurities are separated from the cotton mass and have the opportunity to freely fall into the impurity bunker from the gaps between the bars.

The spring-driven oscillation of the comb grid in the range of $1-3\,mm$ further activates this process. As a result of the oscillation, the cotton stream undergoes additional shaking, which:

- increases the likelihood of separation of large impurities;
- eliminates jams between the combs;
- enhances the adhesion of single-seed cotton pieces to the teeth of the sawing drum.

Theoretically, this is explained by the time-varying normal pressure force of the cotton in its interaction with the comb. The impulsive increase in pressure due to the oscillatory motion directs the cotton piece towards the saw cylinder and reduces the likelihood of it passing through the gaps between the combs.

Figure 12 below shows the structural and functional connection between the saw cylinder and the vibrating grate.

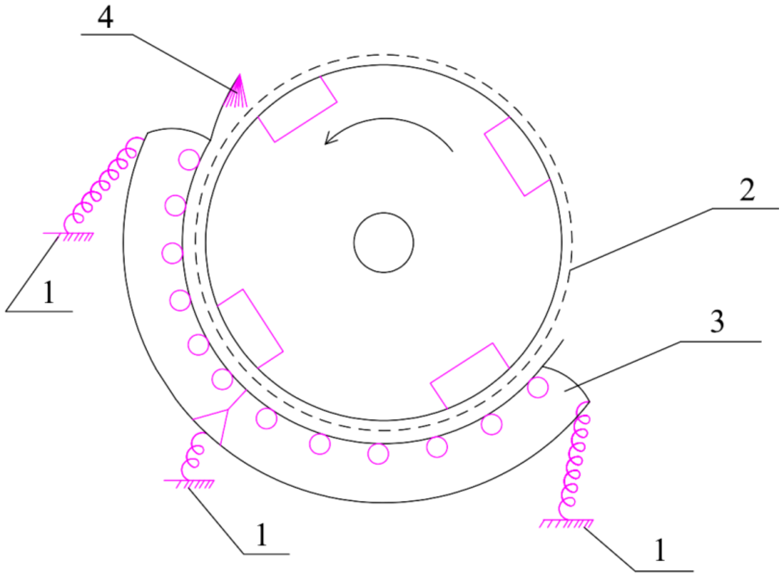

Figure 12. The mutual arrangement of the saw cylinder and the vibrating grate when cleaning cotton from large impurities:
1 – spring providing the vibrating movement of the grate; 2 – saw drum; 3 – vibrating grate; 4 – brush.

The obtained theoretical results show that choosing a distance between the saw drum and the comb grate in the range of 15–18 mm and providing a controlled oscillatory motion to the comb grate in the UXK type equipment:

- significantly increases the efficiency of cleaning from large impurities;
- reduces the loss of single-seed cotton pieces;
- minimizes mechanical damage to fibers and seeds.

In the process of cleaning cotton from large impurities, the distance δ between the saw drum and the comb screen is one of the most sensitive design parameters of the system. This distance determines the trajectory of the cotton piece along the comb screen by the segmented saw drum, the normal pressure forces, and the possibility of separation of large impurities.

As a result of the rotation of the saw drum, the following main forces act on the cotton ball:

• tangential friction force generated by the teeth of the saw drum;
• normal reaction force generated by the comb frame;
• gravity force;
• inertia force caused by the vibrating comb.

We write the condition for stable sliding of cotton on the comb frame as follows:

$$F_t \geq F_n \cdot tan\varphi$$

where: F_t—tangential force component of the saw drum,
F_n—normal compressive force of the comb,
φ—cotton–comb friction angle.

The dependence of the normal force on the distance δ can be expressed by geometric approximation as follows:

$$F_n(\delta) = k_1 \cdot \frac{1}{\delta}$$

Therefore, as δ decreases, the normal pressure acting on the cotton piece increases, which increases the probability of separation of large impurities, but at very small δ values, there is a risk of cotton falling out of the colosnik gap.

Based on theoretical and experimental analyses, the dependence of the efficiency of cleaning from large impurities η on the distance δ is represented by a curve with an extremum. This relationship is described by the following analytical expression:

$$\eta(\delta) = \eta_{max} \left(-\frac{\delta - \delta_{opt}}{2\sigma^2}\right)^2$$

where: η_{max}— maximum cleaning efficiency,
δ_{opt}— optimal comb-saw drum spacing,
σ — technological dispersion coefficient (cotton unevenness and vibrations are taken into account).

The following values were adopted for theoretical calculations:

$$\eta_{max} \approx 0.90 \div 0.93, \ \ \delta_{opt} \approx 15 \div 18 \, mm$$

Based on the above mathematical model, the effect of δ distance on the efficiency of cleaning large impurities is plotted in Figure 13.

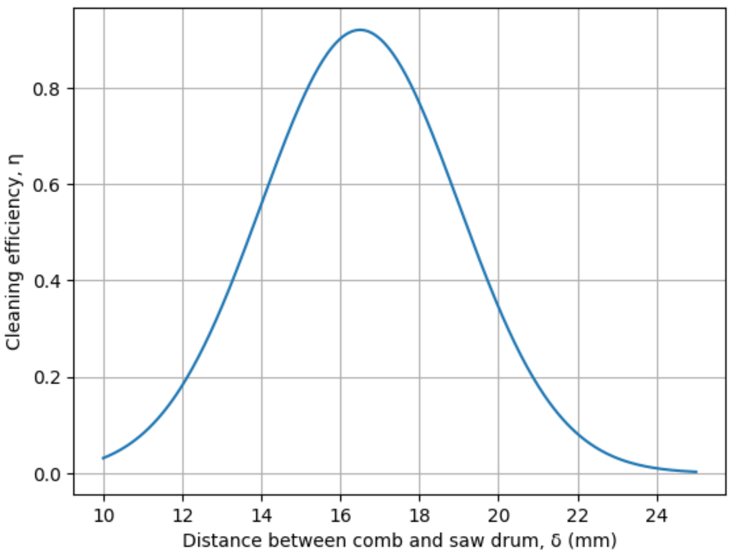

Figure 13. effect of comb-saw drum distance on cleaning efficiency.

The graph shows that the cleaning efficiency reaches its maximum value around $\delta \approx 16-17\,mm$, with an increase in δ, the cotton does not interact sufficiently with the comb and a decrease in the separation of large impurities was observed, and an excessive decrease in δ led to the loss of cotton from the comb gap.

Discussion. The results obtained in this study showed that the segmented saw drum-rooster grid-brush system in the UXK cotton gin, when considered as a single, interconnected dynamic mechanical-aerodynamic system, more fully reveals the essence of the cleaning process. In particular, the theoretical and graphical results obtained on the influence of the geometric distance δ between the saw drum and the rooster grid on the efficiency of cleaning from large impurities provide a clear scientific explanation of issues that were only partially covered in previous classical works.

In the literature (G.I. Miroshnichenko, B.N. Yakubov, Ye.F. Budin, etc.), the saw drum-slat system was analyzed mainly based on the static force balance or simple impulse model, while in this work, the distance δ was considered together with the normal pressure force, friction condition, vibration and energy distribution. As a result, it was proved that the dependence of the cleaning efficiency on \delta is a non-zero function with an extremum. Graphical analysis (Fig. 13) shows that at very small values of δ, the normal pressure between the slat grid and the cotton sliver increases sharply, increasing the likelihood of cotton falling out of the slat gap. This situation is fully consistent with the fiber losses and damage to single-seed cotton slivers noted in the literature. On the contrary, at excessively large values of δ, the cotton does not have sufficient mechanical interaction with the comb, as a result of which the probability of separation of large impurities is sharply reduced. This leads to a decrease in cleaning efficiency.

The range $\delta_{opt} = 15-18\,mm$ determined in this work, in contrast to some recommendations in the literature (usually given in a wider and more uncertain interval), is supported by a theoretical model + graphical analysis + constructive-geometric basis. It was observed that in this range, the teeth of the sawing drum transmit sufficient impulse to the cotton sliver, the process of creeping along the comb grid is stabilized, large impurities are freely separated from the comb gaps, and excessive mechanical impact on the fiber and seed is not exerted.

Another important aspect that is revealed during the discussion is that the optimal selection of the δ distance is strongly synergistic with the vibrational motion of the comb. As shown in the study, controlled vibration in the range of $1-3\ mm$ generated by the spring creates a pulsed change in the normal pressure force over time. This redirects the cotton sliver towards the sawn drum, reduces the risk of falling out of the comb gap, and accelerates the separation of large impurities. While this mechanism was mentioned only qualitatively in classical works, in this study it was substantiated mathematically and graphically.

It is also emphasized in the discussion that the operation of the brush drum at a slightly higher linear speed than the saw drum serves to stably separate the cotton pieces stuck to the segment teeth. This solution reduces the clogging of the cotton flow in the system, prevents excessive accumulation in the comb zone, and ensures the continuity of the cleaning process. In this regard, the need to consider the triple system (saw drum - comb - brush) in the UXK unit not as separate elements, but as a single functional complex was once again confirmed. In general, the results of the discussion show that effective cleaning of cotton from large impurities should be carried out not by optimizing only one parameter (for example, drum speed or comb spacing), but by taking into account geometric (δ), dynamic (impulse, vibration), energy and aerodynamic factors. This approach serves as a reliable scientific basis for further experimental research and industrial-scale tuning work on improving the UXK cleaning machine.

Conclusion. This study scientifically substantiates the need to consider the process of cleaning cotton raw materials of the UXK type from large impurities as a single, interconnected dynamic mechanical mechanism: a segmented saw drum - a comb screen - a brush drum system. The results showed that the cleaning efficiency is determined not by the individual working bodies, but by their geometric and kinematic harmony.

Based on theoretical modeling and graphical analysis, it was found that the distance δ between the saw drum and the grate is the main design parameter determining the efficiency of cleaning from large impurities. It was proved that the dependence of the cleaning efficiency on δ has a non-zero extreme character, and the optimal values $\delta_{opt} = 15-18\ mm$.

At this optimum interval, the mechanical impulse transmitted to the cotton mass by the teeth of the sawing drum ensures a stable drag along the comb grid and creates conditions for the effective separation of large impurities from the grid gap. At the same time, mechanical damage to the fibers and seeds and the loss of single-seed cotton pieces are minimized.

The results of the study also showed that the controlled vibration movement of the sieve ($1-3\ mm$) is an important factor in activating the separation process of large impurities. Vibration creates a pulsed change in normal contact forces, preventing jamming between the sieves and increasing the stability of the cleaning process.

In general, effective cleaning of cotton from large impurities should be achieved through complex optimization of geometric (δ), dynamic (impulse and vibration) and kinematic factors in UXK machines. The proposed theoretical approach and the identified optimal parameters serve as a reliable scientific basis for improving UXK cleaning machines, adjusting them in industrial conditions, and designing the next generation of cotton cleaning equipment.

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