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Paper

PAPER

CONSTRUCTIVE ANALYSIS OF THE PROCESS OF SEPARATING COTTON FROM LARGE AND SMALL TRASH IMPURITIES

S.Kh.Fayziev [1,*], O.O.Ibodullaev [1], Kh.K.Rakhimov [1], Sh.N.Muxiddinova[1], O.B.Razoqova[1]

[1]Bukhara State Technical University, Bukhara, Uzbekistan

* fayziyev1991@list.ru

Abstract

This study analyzes the scientific basis of mechanical and aerodynamic approaches aimed at increasing the efficiency of separating raw cotton from large and small trash. It was established that in the traditional BCH-2M, CHX-3M2, CHX-5, and APT-12 cleaners, due to insufficient optimization of impact energy, inertial differentiation, grate geometry, and loosening dynamics, there is a technological imbalance between cleaning efficiency and fiber damage. In the study, a design model of a new generation UXK unit was developed that eliminates this problem; it combines multi-stage mechanical selection, an optimized grate profile, the impact-displacement mechanism of the saw drum-grate pair, and aerodynamic separation zones. Experimental analysis shows that the cleaning efficiency of the UXK machine has increased, cotton losses have decreased, and fiber damage has significantly decreased. The research results propose constructive solutions for achieving high quality, energy efficiency, and technological stability in the cotton ginning industry.

Key words: raw cotton, separation technology, saw drum, grate, aerodynamic separation, loosening dynamics, impact energy, inertial differentiation, UXK cleaner, structural optimization, reduction of cotton losses, fiber damage, multi-stage cleaning, energy-saving technologies.

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Today, in the world cotton industry, the application of techniques and technologies for the effective separation of small and large impurities, which directly affect the quality of fiber, in the process of processing fiber, cotton seeds and products obtained on their basis, is one of the priority areas. In world practice, the cleaning of raw cotton using advanced technological means while maintaining its quality, the use of high-performance machines, and ensuring the continuous operation of the

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technological process are of great importance.

World scientific research schools are conducting consistent research on increasing efficiency at all stages of cotton processing, in particular in systems for separating large and small impurities, reducing clogging, and minimizing the negative impact of impurities on the technological process. In particular, ensuring high quality during the primary processing of raw cotton, increasing the degree of cleaning, increasing the productivity of machines and mechanisms, and scientifically substantiating their parameters have become one of the most pressing issues today.

Therefore, the creation of a new generation of cleaning equipment, improvement of existing designs, optimization of operating modes, and ensuring stable operation of the technological process on a scientific basis are at the center of scientific and practical research. Trash impurities (organic, mineral, large, and small impurities) in raw cotton are one of the most important factors in cleaning technology, directly affecting the efficiency of cleaning machines and the smooth operation of the technological line. Contaminants in cotton differ in their origin, size, and adhesion strength.

Until raw cotton reaches processing plants from the field, it mixes with various impurities. The origin, mass, size, and composition of impurities are one of the main indicators determining the technological value of raw cotton. In scientific sources, the composition of pollutants is divided into organic, mineral, small, and large groups.

Organic impurities include leaves, cotton stalks, boll fragments, dry branches, and stem fragments. Due to their elasticity, they have a strong mechanical bond with the cotton fiber and are difficult to separate. Particularly, the boll and stem fragments cause fiber breakage in the saw drum. Mineral impurities: Mixtures such as stones, soil, clods, and sand. These are very dangerous impurities, damaging the saws and grates of gin machines. Fine mineral impurities with sizes of 0.5-5 mm are separated by a mesh mesh, and those larger than 10 mm are required to be separated in special saw-drum cleaners [1]. According to the binding strength of impurities, they were divided into 2 groups. These are active impurities - tightly bound to the fiber from the inner or outer surface. Type 2 - passive impurities - easily adhering to cotton, easily separated by mechanical action or airflow. It is the force of impact in the drum-grate system, the angle of displacement, the speed of rotation, and the geometry of the pile that are decisive factors in the separation of active impurities. The impact of pollutants on the technological flow is divided into the following groups:

-In the ginning machine, fiber breakage increases to 12-1

-The risk of clogging increases in LX/UXK cleaners;

-Energy consumption increases by 1.8-3.2 times;

-Fiber quality (classes M-5, M-4) decreases;

-A loss of 3-5% occurs on the production line.

As a result of these factors, the process of cleaning large trash impurities is the determining stage of the cotton ginning industry, which directly affects the stability of subsequent technological operations and fiber quality [2]. In Uzbekistan, systems for cleaning large pollutants historically developed starting with the BCH-2M machine, and later complex cleaning units such as CHX-3M2, CHX-5, and UXK were formed. In foreign countries, high-performance Lummus, Impact Cleaner, and Super III machines have been developed using the same technology. The first widely used equipment for mechanical separation of large trash impurities in the cotton ginning industry is the BCH-2M saw gin (Fig. 1). Introduced into practice from the 1950s-1970s, this machine laid the foundation for the automation of the technological process, replaced manual separation by a mechanical system, and served as the basis for the design solutions of the next generation of cleaning machines [3].

Structurally, the BCH-2M machine consists of the following main elements: a spiked drum, a saw drum, a stamped mesh surface, brush drums, a grate, and a two-stage regeneration drum. This structure mechanically separates large impurities through the processes of separating cotton based on inertia in sequential stages: loosening → displacement → knife impact → separation. The operating principle of the machine is based on physical mechanisms such as impact force, centrifugal force, drag, and friction difference [4]. However, the use of only one saw drum in the BCH-2M machine, the absence of an additional aerodynamic separation system, the static state of

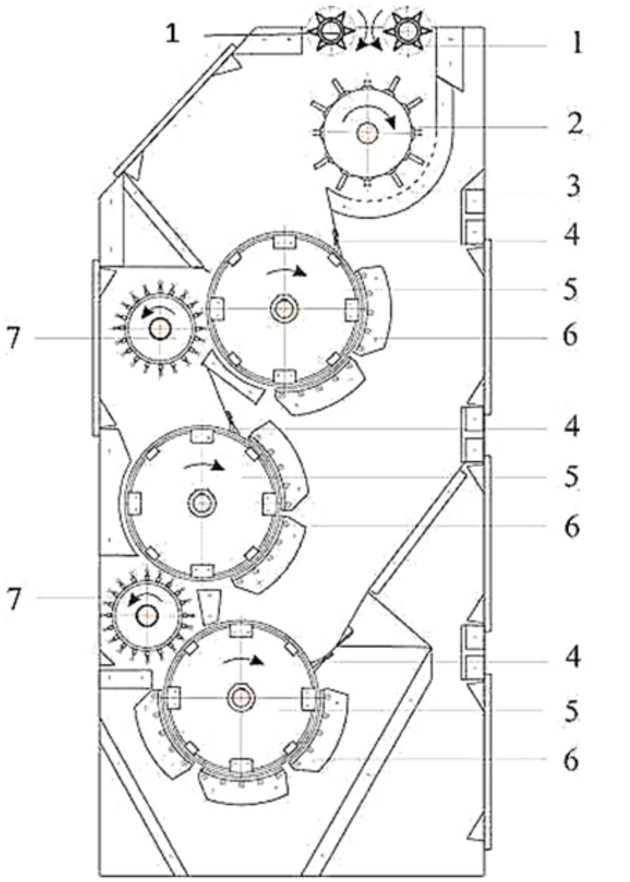

Рис. 1. Figure 1. Diagram of the BCH-2M saw blade cleaner: 1-hopper, 2-feed roller, 3-spiked drum, 4-grid surface, 5-dust chute, 6-sliding brush drum, 7,11,15-saw drum, 8-screw, 9,14-knife, 10-outlet, 12,16-sliding brush, 13-separating brush drum, 17-screw.

the grate bars, and the low regeneration efficiency limit its overall cleaning performance. As a result, the cleaning efficiency of this machine in practical conditions is 30-40%, and it cannot sufficiently separate active impurities. The removal of part of the cotton with large impurities is also noted as a significant disadvantage of BCH-2M [5].

Nevertheless, the BCH-2M machine formed the basic design principles for the further evolution of cotton ginning technologies. Based on this machine, high-performance machines such as CHX-3M2, CHX-5, UXK, and modern Lummus, Super III, and Impact Cleaner were created. The simplicity of BCH-2M, ease of maintenance, and the possibility of modification kept it in cotton-processing enterprises for many years. Although BCH-2M has low efficiency compared to existing modern technologies, its scientific and practical significance lies in the fact that it is evaluated as a machine that for the first time comprehensively used all the main mechanisms of mechanical separation of cotton (impact, friction, centrifugal force, regeneration). This places it in an important place in the history of technological development. At cotton cleaner enterprises, the technological process of separating large trash impurities at the initial stage was previously carried out using the BCH-2M machine, and to eliminate its shortcomings, a CHX-3M2 machine was created (Fig. 2). This machine, with its efficiency and level of design improvement, served as the basis for subsequent new generation machines, such as CHX-5 and UXK [6].

Various organic and mineral impurities accumulate in the composition of raw cotton from the field to the plant. Impurities larger than 10 mm negatively affect the technological line. These are: stones, fragments of branches, fragments of stems, fragments of shells, clods of earth, etc. Such trash blocks the ginning process, causes accidents, and increases energy consumption. Therefore, the separation of large impurities is the most important stage of cotton processing. CHX-3M2 is a modernized version of BCH-2M, characterized by a two-stage saw removal and regeneration system.

The working parts of the CHX-3M2 machine consist of: a hopper, a feed roller, a spiked drum, a stamped mesh surface, a brush drum, two saw drums, and a regeneration drum. This combination ensures high efficiency of the machine.

The spiked drum loosens the cotton, the stamped mesh surface separates small impurities, and the saw drums effectively separate large impurities in two stages. The regeneration drum reduces losses by 2-3 times by re-separating cotton that has been removed with impurities [7]. The effectiveness of the CHX-3M2 machine is due to the two-saw drum system, segmented saw tape, optimized grate angles, and an enhanced regeneration system. It increases the cleaning efficiency from 30-40% to 55-70% compared to BCH-2M. Cotton losses decrease from 3-4% to 1.2-1.6%. The CHX-3M2 machine is an effective technological solution in the cotton industry with a two-stage saw cleaner system, a powerful regeneration mechanism, and optimized structural elements. It provides high results in separating large impurities and serves as a foundation for subsequent modernized machines.

Cleaning raw cotton from large impurities is one of the most important stages of the technological process, the effectiveness of which is crucial for subsequent stages of fine cleaning, optical

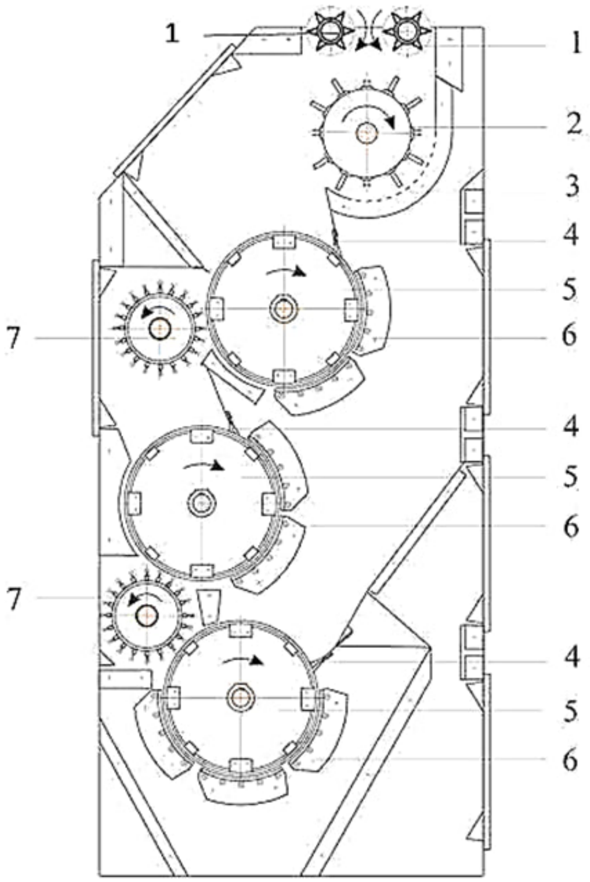

Рис. 2. Figure 2. CHX-3M2 saw cleaner 1-feeding rollers, 2-spiked drum, 3-grid, 4-mounting brush, 5-saw drum, 6-grate, 7-brush separating drum.

and qualitative indicators, and the quality of the final fiber. Modern scientific research interprets the process of separating large impurities as a multifactorial dynamic system based on mechanical selection, inertial forces, impact energy, and aerodynamic differences. Machines for cleaning large trash impurities of the CHX brand are one of the main devices widely used in the cotton industry, consisting of sequentially modernized models such as CHX-3M, CHX-3M2, and CHX-5. These modernizations are aimed at optimizing physical and mechanical processes, stabilizing selection zones, and increasing cleaning efficiency. Practical analyses conducted on the CHX-3M2 and CHX-5 cleaners also confirm the real effectiveness of these design changes [8].

Based on the foregoing, the analysis was carried out according to the following basic physical and mechanical principles: Differentiation of friction forces - selective separation based on the difference in elasticity and trash hardness of cotton.

Inertia and centrifugal forces - an increase in the rate of separation from the drum due to the large mass of large impurities. Impact energy effect - the release of trash from the fiber as a result of the impact of raw cotton on the grate surface under the influence of saw drums. The traction process is the attraction of impurities to the slits during the movement of cotton along the saw on the grate surface [9].

Aerodynamic separation - the lowering of heavy objects in an airflow based on a density difference. These principles were compared with the real design solutions of the CHX-3M, CHX-3M2, and CHX-5 machines, and their influence on the efficiency of the cleaning process was studied. Due to the elasticity of the cotton fiber, it adheres better to the saws of the saw drum, and large impurities have a hard, inert mass and a low coefficient of friction. During the movement process, large impurities fall into the grate slots, and the cotton continues to move along the drum saws. In world practice, this mechanism accounts for 27-34% of the effectiveness of selection.

In the CHX model, the geometry of the grate system is designed to maximize the application of this principle. In experiments, it was noted that the efficiency of the CHX-3M2 and CHX-5 cleaners increased due to the optimization of the size and location of the gaps.

Industrial tests, energy analyses, and technological observations of the CHX-3M2 cleaner showed that the existing design had a number of limitations on the intensity of raw cotton loosening and the process of separating large trash impurities. In particular, the elasticity of the stamped mesh surface was low, and the impact energy was not fully transferred; the distance between the spiked drum and the saw drum was not sufficiently optimized, and the regeneration process in some varieties did not work at all. As a result of in-depth study of these factors, the CHX-3M2 cleaner was modernized and an improved CHX-5 cleaner was created (Fig. 3).

In CHX-5, a grate consisting of triangular knives was used instead of a stamped mesh surface. This has several scientifically based advantages: Triangular knives increase the impact effect by 18-25% on a wavy or stamped surface, increase the possibility of separating bound large impurities by 11-13% and effectively break down the

$$L = \sum_{i=1}^{n} p_i \times l_i$$

Рис. 3. Figure 3. CHX-5 saw cleaner 1-feeding rollers, 2-spiked drum, 3-knife grate, 4-hooking brush, 5-saw drum, 6-grate, 7-brush separating drum, 8-aspiration groove, 9-barrier.

$$H(X) \leq L < H(X) + 1$$

Рис. 4. Figure 4. Diagram of the APT-12 saw cleaner: 1 - feed rollers; 2 - spiked drum; 3, 5, 6, 8-saw cylinders; 4,7-separating blade drums; 9, 12, 15, 18-grate bars; trays 11, 14, 17, 20; rolling grates 10, 13, 16, 19.

mechanical connection between the cotton mass and the impurities. In CHX-3M2, the loosening is mainly carried out by repeated impacts of the saw drums, while in CHX-5, the blade grille creates a "intersecting"path with the piles, the deformation of the cotton increases during the movement process, and the adhered trash and impurities loosely separate between the fibers [10]. As a result, an increase in loosening intensity by 14-17% was noted during industrial tests. The CHX-5 cleaner is a direct modernization of the CHX-3M2 design, which significantly improved the quality of separation of large impurities by increasing the energy of loosening, optimizing the distance between the drums, increasing the impact effect through the blade grating, and redesigning the spatial distribution of the grate bars. From the point of view of modern scientific principles, the CHX-5 design is based on an integrated system of mechanical selection, inertial forces, impact energy, and aerodynamic cleaning, and its technological efficiency meets world standards.

Although the CHX series of cleaners for separating raw cotton from large trash has been used for many years as the main unit in industry, their low productivity and limited opening energy have necessitated the modernization of this technology. Based on these factors, the design of the APT-12 type cleaner was developed, which operates at a higher capacity and has more saw-toothed working parts compared to the CHX series. The main goal of creating APT-12 was to increase cleaning efficiency and enhance the process of separating large impurities through multi-stage mechanical selection. The technological scheme of the APT-12 cleaner (Fig. 4) is represented by the following main working bodies:

In this scheme, unlike the saw drums used in the CHX-3M2 or CHX-5 cleaners, a large number of saw cylinders are arranged sequentially, and each cylinder performs a separate selection stage. As a new constructive approach, a saw drum with a diameter of 250 mm was used, which was designed to: increase the loosening force, enhance the inertial effect, and bring the separation process to a multi-stage form.The advantage of PT-12 over the CHX series is the increase in the number of saw cylinders to increase productivity. As a result, the use of 4 main saw cylinders in the APT-12 created the following possibilities from a purely technological point of view: the cotton flow is subjected to additional loosening at each stage, the probability of separating large trash increases sequentially, and due to the large number of working bodies, the cleaning process is "under continuous energy control".

To achieve dynamic stability, the optimization of the drum mass and diameter was carried out by the designers of a saw cylinder with a diameter of 250 mm, which allows: a small diameter a high rotational speed, as a result of which at high speeds increased separation of large impurities due to inertia. This idea was theoretically correct. Nevertheless, when the APT-12 cleaner was put into operation, a number of serious operational problems arose. The biggest disadvantage of APT-12 was the rapid disruption of the dynamic balance of the saw drum. The APT-12 has many mechanisms, such as 4 saw cylinders, 2 bladed drums, 4 grate bars, and 4 trays. This led to the following negative factors: mechanical operation became more complicated, the adjustment (regulation) process took a lot of time, a large number of working bodies reduced the cotton flow rate, a stable energy exchange was not formed, and the overall productivity of the cleaner remained low.

This situation reduced the advantage of APT-12 over compact cleaners such as CHX-5. Although the design of the APT-12 cleaner was based on the idea of multi-stage mechanical separation, its complex dynamic system did not meet production requirements due to the balance problem of the saw cylinders and the creation of excessive resistance to the technological flow. Also, the large number of operated working bodies and their rapid wear reduced the actual productivity of the cleaner. Therefore, the APT-12 cleaner was not widely used in industry and did not allow for the widespread use of the next generation of large-contamination cleaners in industrial enterprises.

Although the technology of cleaning raw cotton from large trash has been constantly improved over the past 40-50 years, practice shows that all cleaners from small and large trash, such as CHX, CHX-3M2, CHX-5, APT-12, have various design, technological, and operational limitations. The insufficient productivity of these machines, damage to the fiber during the cleaning process, increased vibration and energy losses created the need for a new generation of cleaners that comprehensively clean cotton from large and small impurities [11].

Studies show that in machines of the CHX series:

-Due to the small number of saw drums, the loosening energy is not formed sufficiently;

-Due to the low elasticity of the stamped mesh surface, the impact energy is not fully transferred;

-the distance between the spiked drum and the saw drum is not optimal, which reduces the inertia forces;

-high cotton losses in the regeneration drum;

-an increase in the vibration norm (especially in APT-12) negatively affects the technological flow;

-although the cleaning efficiency from large trash is in the range of 70-82%, fiber and seed damage can reach 3-10%.

In the APT-12 type cleaner, due to the large number of saw cylinders and a complex mechanical structure: dynamic equilibrium is quickly disturbed, as a result of which operation becomes more complicated, as a result of which productivity decreases due to an excessive number of working parts, additional energy consumption increases to increase productivity, and maintenance becomes more difficult. Therefore, APT-12 was not widely used in production.

This situation indicates the existence of a universal problem in cotton cleaning technology - the simultaneous provision of efficiency, quality, and productivity. Based on the above limitations and industrial needs, a new generation of cleaning units the UXK machine for cleaning small and large trash impurities has been created in recent years. Factors that served as the basis for the development of the UXK unit:

-Productivity deficiency of the CHC and APT series;

-the need to reduce fiber damage during the cleaning process;

-the need for complex separation of large and small impurities in one system;

-cotton losses and inefficiency of regeneration on existing machines;

-the requirement for maintaining a continuous flow in modern cotton technologies;

-the need for a stable supply of cleaned cotton to the gin. Fig. 5 shows the schematic diagram and sequence of operation of the UXK unit.

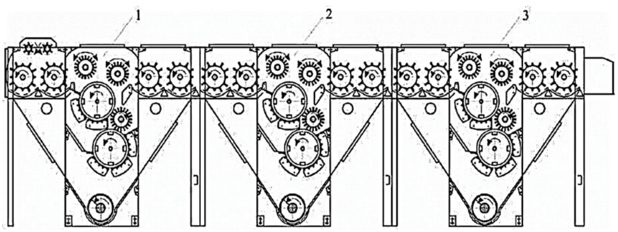

Рис. 5. Figure 5. Diagram of the UXK type unit: 1 - UXK. 01. as a primary supplier; 2 - UXK. 02. intermediate section; 3 - UXK. 03. final section.

These sections are based on the principles of cascade cleaning from large trash, separation of small trash, cotton loosening, dynamic selection, and aerodynamic separation.

The UXK cotton cleaning unit from small and large trash impurities works as follows: when the raw cotton reaches the cleaning section, it passes through the separator and enters the shaft of the UXK unit and uniformly feeds the cotton from the shaft to the spiked drum using feed rollers, under the spiked drums there is a mesh surface mesh, through the holes of which small trash impurities fall under the action of the spiked drum, moreover, the cotton is scraped and the next process is transferred to the saw drum [12]. Raw cotton is evenly attached to the teeth of the saw drum using a stationary locking brush and is dragged through a grate located at the same distance from the saw drum, and in this process, large impurities in the cotton fall between the grate bars into the trash hopper, and the cleaned cotton is separated from the saw teeth using a brush drum and then directed to the next section of UXK 02. This process continues, passing through the sections of the UHK unit, which are located sequentially depending on the amount of cotton contamination [13].

Continuous analysis shows that, although the existing CHC series and APT-12 large-contamination cleaners have certain advantages, their inability to ensure a technological balance between cleaning-damage-performance necessitates the creation of a new generation of units. The UXK unit is a comprehensive solution to these problems, aimed at achieving high efficiency by combining the mechanical, inertial, impact, and aerodynamic principles of separating small and large impurities in one system. The UXK unit increases the quality of cleaning with minimal damage to the mechanical structure of cotton and has been formed as an innovative device that meets the requirements of industry for high productivity [14].

In-depth study of the designs and technological processes of the BCH-2M, 1XK, CHX, CHX-3M2, CHX-5, UXK and other cleaners created to date shows that the most optimal, physically and mechanically justified method of cleaning cotton from large trash impurities is the principle of dragging raw cotton by the teeth of the saw drum with impact force on the surface of the grate. The impact energy generated during the movement of the saw drum loosens the bonds between the impurities and the fibers, and the inertia force allows the separation of heavy and medium-sized impurities through the grate holes. Consequently, the cleaning efficiency directly depends not only on the drum speed or the shape of the saw tooth, but also on the material of the grates, geometric parameters (diameter, shape, edge), surface plane, and angle of arrangement. According to the scientific literature, when the grate profile is chosen incorrectly, there are cases of non-exit of trash through the gap, the appearance of clogs between the grate bars, or damage to the cotton [15]. Studies have shown that although the cleaning efficiency of some machines is relatively high, the mechanical damage to the fiber and seeds also increases significantly. For example, in the old model CHX-3M, equipped with saw drums, fiber damage reaches 1.8-2.3%. In other machines, the opposite occurs: fiber damage is minimal, but cleaning efficiency is low, and 25-40% of large impurities remain undisturbed. These processes are explained by insufficient aerodynamic loosening, inadequate distance between the saw-spike drums, and malfunction of the grate holes.

In some machines, although these two shortcomings fiber damage and low cleaning have been partially eliminated, their productivity remains low, and the problem of stable and even supply of cleaned cotton to the most important link the gin machine persists.

This disrupts the rhythm of operation of the entire technological line, increases waste and energy consumption.Therefore, as one of the main directions of scientific research, such measures as optimization of structural elements, improvement of the grate shape, recalculation of the distance between drums, use of knife grids, and the introduction of three-stage UXK units were put forward. Studies conducted in recent years have confirmed that the main factors for increasing the efficiency of cleaning machines are the optimization of impact energy, increasing the differentiation of inertia, processing the geometry of the grate bars, and increasing the number of cleaning stages. As a result, based on design solutions that allow optimizing the cleaning process from a dynamic, aerodynamic, and mechanical point of view, the development of a new generation of units for cleaning cotton from large and small trash impurities with high efficiency is required.

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