THE ROLE OF OPTICAL SENSORS IN OPTIMIZING THE TECHNOLOGICAL PARAMETERS OF COTTON CLEANING MACHINES

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Annotatsiya: ushbu maqolada paxta xomashyosini tozalash jarayonida optik sensorlardan foydalanish samaradorligi tahlil qilinadi. An'anaviy paxta tozalash texnologiyalarida iflosliklarni ajratish jarayoni mexanik usullar orqali amalga oshiriladi, bu esa mahsulot yo'qotishlariga va sifatsizlikka olib keladi. Innovatsion texnologiyalar, jumladan optik va spektral analiz sensorlari, tozalash jarayonini avtomatlashtirish va optimallashtirish orqali mahsulot sifatini sezilarli darajada oshirish imkonini beradi.

Kalit so'zlar: paxta xomashyosi, optik sensorlar, tozalash samaradorligi, avtomatlashtirish, innovatsion texnologiyalar, ifloslik miqdori, chigit, tola, namlik, mahsulot sifati, sensor, agregat.

Аннотация: В данной статье анализируется эффективность использования оптических сенсоров в процессе очистки хлопкового сырья. В традиционных технологиях очистки хлопка процесс отделения загрязнений осуществляется механическими методами, что приводит к потерям продукции и снижению качества. Инновационные технологии, включая оптические и спектральные анализаторы, позволяют автоматизировать и оптимизировать процесс очистки, значительно повышая качество продукции.

Ключевые слова: хлопковое сырье, оптические сенсоры, эффективность очистки, автоматизация, инновационные технологии, количество загрязнений, семена, волокно, влажность, качество продукции, сенсор, агрегат.

Annotation: This article analyzes the efficiency of using optical sensors in the process of cleaning cotton raw materials. In traditional cotton cleaning technologies, the process of separating impurities is carried out by mechanical methods, which leads to product losses and reduced quality. Innovative

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technologies, including optical and spectral analyzers, enable the automation and optimization of the cleaning process, significantly improving product quality.

Keywords: cotton raw material, optical sensors, cleaning efficiency, automation, innovative technologies, impurity amount, seeds, fiber, moisture, product quality, sensor, aggregate.

Introduction

In our country, special attention is being paid to the development of the production of high value-added finished textile and light industry products based on deep processing of raw cotton, as well as to improving the quality and quantity indicators of cotton products intended for both domestic and foreign markets through the modernization of the cotton cleaning industry, thereby ensuring their competitiveness.

The Republic of Uzbekistan holds a leading position in the world in cotton production and export. Producing high-quality fiber that meets international standards sets an important task for specialists and scientists in the field of cotton processing: to improve existing equipment and technologies.

In order to create favorable conditions for the implementation of artificial intelligence technologies in the social and economic sectors, to ensure Uzbekistan's inclusion among the world's leading countries utilizing AI technologies, and to fulfill the goals and objectives set out in the "Digital Uzbekistan – 2030" Strategy, it is crucial to implement the tasks outlined in the Presidential Decree No. PQ-358 dated October 14, 2024, "On the Approval of the Strategy for the Development of Artificial Intelligence Technologies Until 2030." One of the key priorities of this strategy includes the development of new technologies for the primary processing of seed cotton and the improvement of equipment and methods for removing fine and coarse impurities, which are considered important issues in the cotton industry.

This, in turn, has placed new responsibilities on the workers and researchers of the cotton cleaning industry. Specifically, it is necessary to identify the causes of declining cotton quality and the damage to fibers and seeds, and to carry out scientific research aimed at eliminating these issues.

A number of foreign researchers such as Hangxu Zhou, V. Baker, Jimmy R. Stove, Donald William Van Doorn, William S. Anthony, Philip J. Leduc, Leslie G. Hill, David H. Kelly, Mark A. Stratton, Marvis N. Gillum, Sidney E. Hughs, and others have been involved in the development and improvement of new equipment and technologies in the technological processes of cotton raw material cleaning.

Among the scientists of our country, G.I. Miroshnichenko, T.I. Boldinskiy,

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R.G. Maxkamov, Ye.F. Budin, R.V. Korabelnikov, I.T. Maksudov, R.Z. Burnashev, G.D. Djabbarov, A.D. Djuraev, Kh. Akhmadkhodjaev, R. Murodov, O.I. Rajabov, O.J. Murodov, S.O. Sayitqulov and others have conducted research and developed methods and machinery for cleaning cotton raw materials. They have carried out theoretical and experimental studies of the cleaning process and proposed various design modifications, optimal technological parameters, and operating modes for machine mechanisms.

Many scientific studies have shown that it is possible to improve fiber quality by reducing the mechanical impact during cotton processing [1].

Although a large body of theoretical and practical research has been carried out in the field of cotton cleaning, there is still a lack of equipment and technologies that fully meet the requirements of modern times. No cleaning device has yet been developed that prevents damage during transportation, completely removes all impurities, and ensures the gentle cleaning of passive fine impurities without affecting their natural properties.

Therefore, it is appropriate to carry out scientific research aimed at improving the technology and machinery used for cotton cleaning, ensuring efficient and high-quality output of both fiber and seed [2-4].

At present, cotton processing enterprises utilize “flow-directed” (continuous flow line) equipment complexes in the drying and cleaning sections, which are considered the most convenient and modern technology for removing impurities from cotton raw materials (Figure 1).

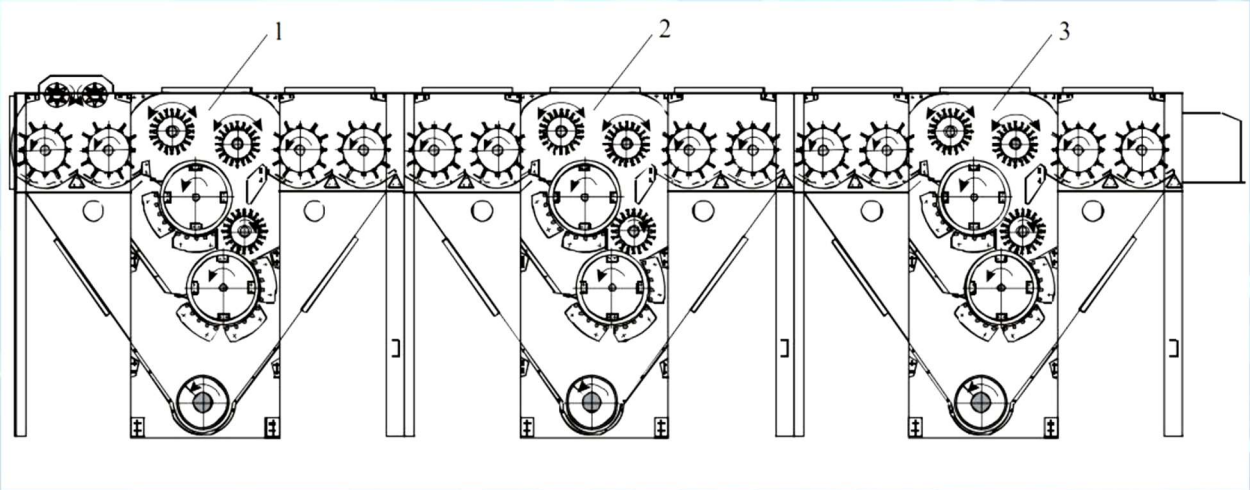


Figure 1. Diagram of the UXK brand combined cotton cleaning aggregate.

1 – UXK 01 initial cleaning section; 2 – UXK 02 intermediate cleaning section; 3 – UXK 03 final cleaning section.

Cleaning cotton raw material from impurities is a critical step in producing high-quality end products. While traditional methods rely on manual labor and mechanical equipment, modern technologies allow this process to be automated

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using robotic systems.

Figure 2 illustrates the technological sensor scheme installed on the UXK brand combined cotton cleaning aggregate, which operates as follows: 1 – The cotton raw material is delivered to the technological line via a feed chute. 2 – All measurement sensors and analysis modules are connected to a central unit. 3 – An infrared (IR) optical sensor determines the moisture level of the cotton raw material. 4 – A spectral detection sensor identifies coarse and fine impurities in the cotton and controls their separation. 5 – The final output control unit evaluates the quality of the cleaned cotton and detects any remaining impurities.

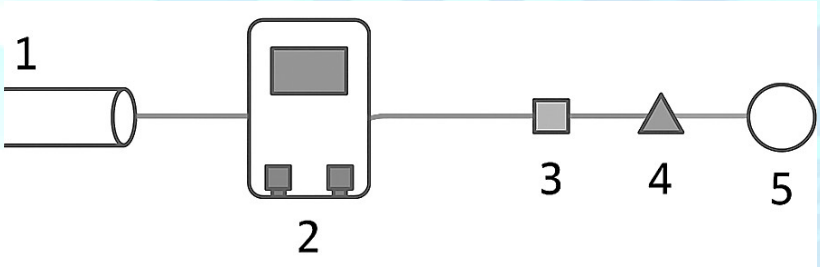


Figure 2. Technological sensor scheme

Based on this, various sensors are used to ensure high-quality cleaning and automation of the cotton raw material processing. These sensors are employed to detect impurities, optimize the cleaning process, and maintain quality control.

To mathematically evaluate cleaning quality and efficiency, the following key parameters were analyzed:

The results obtained at the input of the cotton cleaning aggregate are as follows: The moisture content of the cotton raw material was W_{in}=8.1 %, and the impurity mass fraction was M_{in}=3.0%. After installing sensors for cleaning fine and coarse impurities, the following results were obtained from the cleaned cotton raw material: The moisture content was W_{out}=8.0% and the impurity mass fraction was M_{out}=0.3%. The cleaning efficiency of the UXK combined cotton cleaning aggregate was found to be η=90.0% the mechanical damage to the seed was D=1.35% and the amount of free fiber was T=0.205%, as determined through laboratory analysis [5-7].

The cleaning efficiency of the UXK combined cotton cleaning aggregate is determined using the following formula:

$$\eta = \frac{M_{in} - M_{out}}{M_{in}} \cdot 100\% = \frac{3.0 - 0.3}{3.0} \cdot 100\% = \frac{2.7}{3.0} \cdot 100\% = 90\%$$

Figure 3 demonstrates that the cleaning efficiency of the cotton raw material significantly increased after optimizing the UXK cotton cleaning aggregate with integrated sensors.

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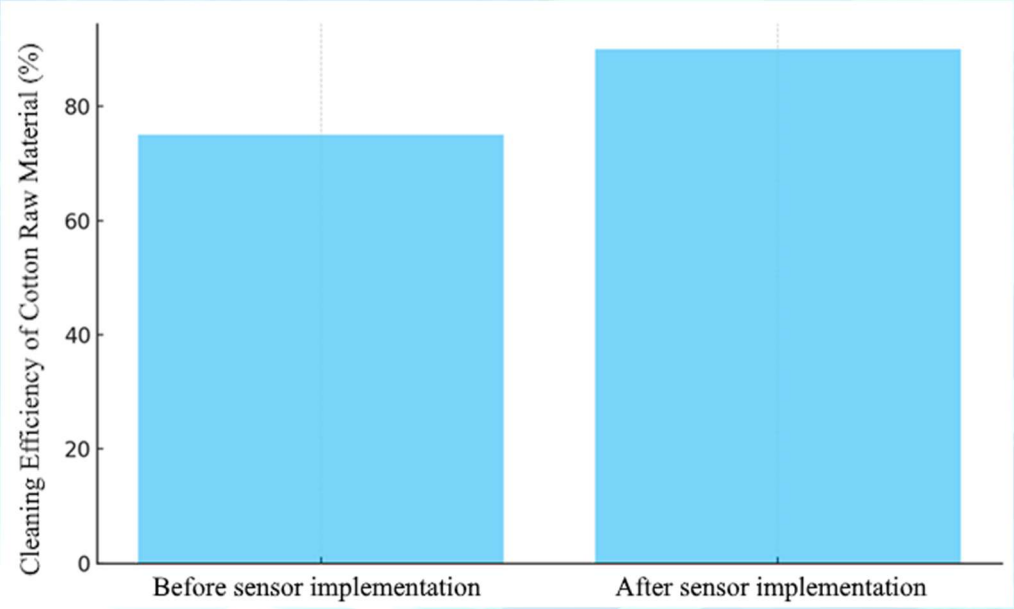


Figure 3. Cleaning efficiency of cotton raw material from impurities using innovative sensor systems.

This graph illustrates a significant increase in the cleaning efficiency of cotton raw material as a result of implementing sensor systems. Before the use of innovative sensors, the cleaning efficiency was around 75%. With the introduction of sensor technologies, this indicator was increased to 90%. These sensor systems reduce mechanical impact during the cleaning process, enabling effective detection and removal of impurities, thereby proving their effectiveness.

Figure 4 compares the moisture and impurity levels of the cotton raw material at the input and output stages of the cleaning aggregate. In the UXK cotton cleaning aggregate, the moisture content at the input was 8.1%, while at the output it was 8.0%, indicating minimal change that does not affect fiber quality or structure. However, the impurity level dropped significantly from 3.0% at the input to 0.3% at the output, confirming the effectiveness of the sensor systems and highlighting the importance of this technology in improving cotton quality indicators.

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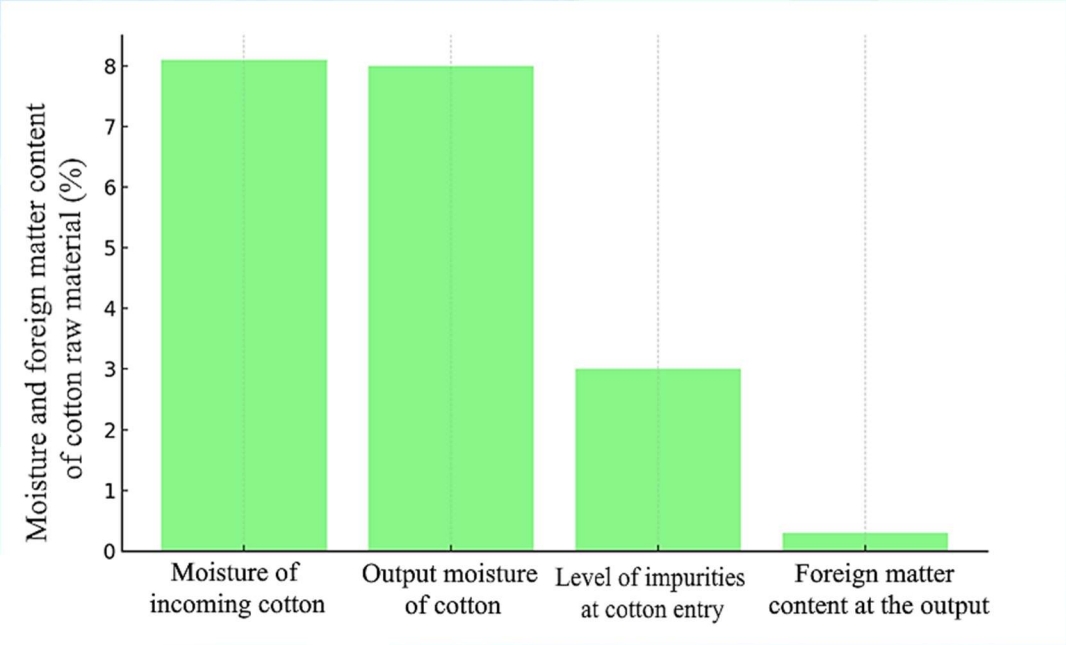


Figure 4. Comparative graph of moisture and impurity levels at the input and output of the UXK cotton cleaning aggregate.

Figures 5 and 6 present the results of the analysis of seed damage and the percentage of impurity removal from cotton raw material [8-10].

The increase or decrease in mechanical damage to the seed depends on the cleaning method and the impact of the equipment. The effect of damage can be evaluated using the following ratio:

$$D_{nor} = \frac{D}{\mathrm{M}_{in} - \mathrm{M}_{out}} = \frac{1.35}{3.0 - 0.3} = \frac{1.35}{2.7} \approx 0.5$$

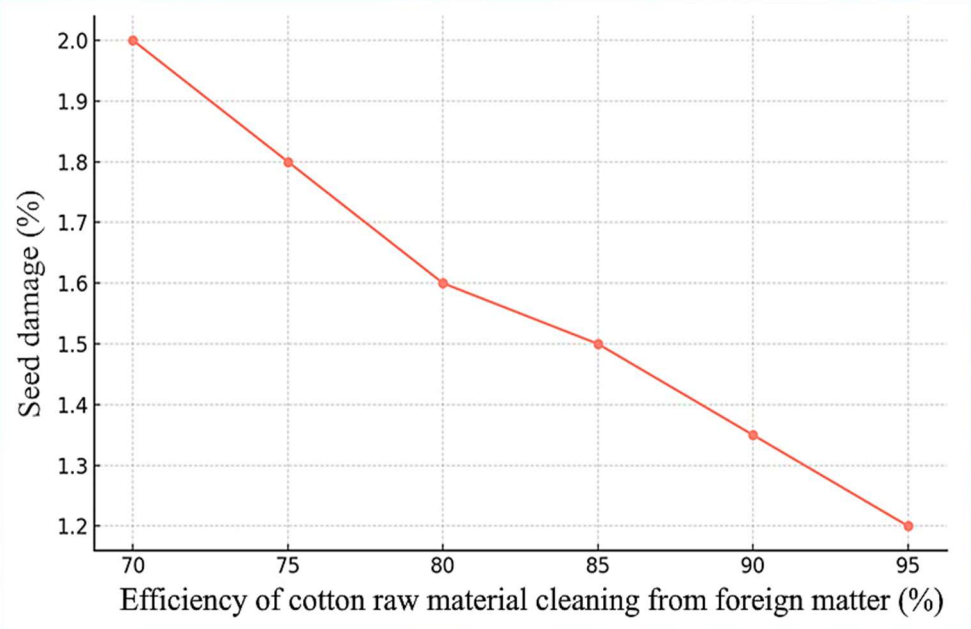


Figure 5. Correlation between seed damage and cleaning efficiency of cotton raw material

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This graph shows the correlation between the degree of mechanical damage to seeds and the cleaning efficiency of cotton raw material. As observed from the graph, the higher the efficiency, the lower the level of seed damage. This indicates that innovative technologies and optimized operating modes make it possible to reduce mechanical impact on the cotton raw material. In the cotton industry, this indicator plays a crucial role in preserving the quality of both fiber and seed.

The increase in cleaning efficiency is directly associated with a reduction in mechanical damage to the seeds. Based on the calculations above and the experimental results, the following empirical-statistical regression model was developed to describe the efficiency (η) of removing fine and coarse impurities from cotton raw material:

$$\eta = 5.12 + 28.34 \cdot W_{in} - 12.43 \cdot M_{in}$$

Where:

W_{in}- Moisture content of incoming cotton raw material (%),

M_{in}- Mass fraction of impurities in incoming cotton raw material (%).

Regression model for seed damage (D):

$$D = 0.85 + 0.23 \cdot M_{in} - 0.14 \cdot \eta$$

Where:

η– efficiency of cleaning cotton raw materials from small and large impurities (%).

The models were subjected to statistical verification, and the obtained coefficients of determination (R^2) were 0.93 and 0.89, respectively. These values indicate that the models describe the process with a high degree of accuracy and reliability.

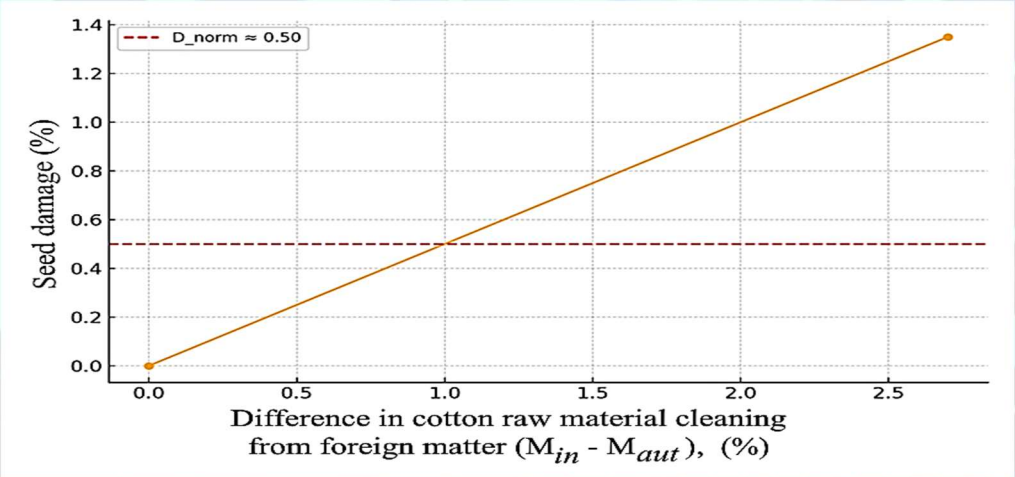


Figure 6. Relationship between mechanical seed damage and the level of impurities in processed cotton raw material

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This graph illustrates how the degree of mechanical seed damage varies in relation to the amount of impurities removed from the cotton raw ($M_{kir} - M_{chiq}$). The red dashed line on the graph represents the value of D_{norm}, indicating that for every 2.7% of impurities removed from the cotton raw material, there is an average of 0.5% seed damage [11-15].

This indicator serves as an important technical criterion for evaluating the effectiveness of fine and coarse impurity removal technologies in cotton processing. Moreover, this approach plays a significant role in optimizing the design of cotton cleaning machines.

In conclusion, it can be stated that after the implementation of sensors in the UXK brand combined cotton cleaning aggregate, the impurity content of the cotton raw material was reduced from 3.0% to 0.3%, while the moisture content remained nearly unchanged-decreasing only from 8.1% to 8.0%. With the help of sensors, the cleaning efficiency of the aggregate increased to 90%. Moreover, mechanical seed damage decreased from 1.5% to 1.35%, and the amount of free fiber was reduced from 0.25% to 0.205%, indicating a substantial improvement in cleaning quality.

The application of optical sensors and advanced technologies in cotton cleaning plants significantly enhances the efficiency of the cleaning process. As a result, the quality of cleaned cotton improves, fiber loss is minimized, production speed and efficiency increase, and resources are used more effectively, ultimately boosting the competitiveness of cotton fiber.

Thus, the widespread integration of modern sensor systems provides an important foundation for advancing the cotton industry and enabling the production of high-quality products for the global market.

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