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Research Article

IMPROVING THE CLEANING EFFICIENCY BY ENHANCING THE DESIGN OF THE COTTON CLEANING MACHINE FOR REMOVING FINE IMPURITIES

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ABSTRACT

The efficiency of cotton cleaning machines plays a critical role in the textile industry, particularly in removing fine impurities. This paper focuses on enhancing the design of cotton cleaning machines to improve their performance. By analyzing the shortcomings of existing models, this research proposes modifications to the design of spiked drums and air suction systems to enhance cleaning efficiency. The results demonstrate that the proposed enhancements lead to significant improvements in impurity removal, reducing energy consumption and increasing cotton quality.

KEYWORDS

Cotton cleaning machine, fine impurities, spiked drum, cleaning efficiency, design optimization.

INTRODUCTION

Cotton is one of the most important raw materials in the textile industry, used in a wide variety of applications, including clothing, home textiles, and industrial fabrics. As a natural fiber, cotton must go through several stages of processing before it can be used in manufacturing. A critical step in this process is the cleaning of raw cotton to remove impurities such as dust, dirt, small fibers, plant debris, and seed particles. These fine impurities not only lower the quality of the cotton but also pose a threat to subsequent processing machinery, causing damage, increased maintenance costs, and potential production delays.

Cotton cleaning machines are designed to perform this vital task by separating the cotton fibers from unwanted contaminants. However, the efficiency of these machines is often constrained by design limitations, which result in suboptimal cleaning performance. Traditional designs typically rely on mechanical components, such as spiked drums and grid bars, as well as airflow systems to carry away impurities. While these machines can remove larger debris relatively effectively, fine impurities—such as dust and short fibers—are more challenging to eliminate. This creates a need for improvements in the design and function of cotton cleaning machines, especially in regions where high-quality cotton production is essential for maintaining competitiveness in the global textile market.

The importance of improving cotton cleaning efficiency extends beyond just cotton quality. Inefficient cleaning systems can lead to excessive cotton loss, increased energy consumption, and higher operational costs. Moreover, the presence of residual impurities in the cleaned cotton can negatively affect subsequent processes such as spinning, weaving, and dyeing, reducing the overall efficiency of textile production. Therefore, enhancing the performance of cotton cleaning machines not only improves the quality of the end product but also reduces waste and increases energy efficiency, leading to more sustainable production practices.

Over the years, various studies have explored ways to improve cotton cleaning, primarily through mechanical modifications and technological advancements. Some have focused on enhancing the separation mechanisms within the machine, while others have looked at optimizing airflow to improve the removal of fine particles. However, there remains significant room for improvement, particularly in the removal of smaller impurities and the energy efficiency of the cleaning process. Given the complexity of the cotton cleaning process, any improvements must strike a balance between maintaining cotton integrity, maximizing impurity removal, and minimizing energy use.

This study aims to address these challenges by focusing on two critical components of the cotton cleaning machine: the spiked drum and the air suction system. The spiked drum plays a pivotal role in separating impurities from the cotton by agitating and loosening the fibers. By redesigning the drum and optimizing the angle and distribution of the spikes, we aim to increase the interaction between the cotton and the cleaning elements, thus improving impurity removal. Additionally, the air suction system, responsible for carrying away fine particles, will be enhanced to increase its effectiveness while maintaining energy efficiency.

In this research, we propose a series of design modifications aimed at improving the overall cleaning performance of the machine. These modifications are based on a thorough analysis of existing machines, empirical testing, and computational modeling. The ultimate goal is to increase the efficiency of cotton cleaning machines, ensuring better cotton quality and more sustainable operations in the textile industry.

METHODS

Machine Design

Cotton cleaning machines are designed to remove a range of impurities from raw cotton, from larger debris such as leaves and stems to finer particles like dust and short fibers. A typical cotton cleaning machine consists of several key components, including a spiked drum,

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grid bars, and an air suction system, each playing a vital role in the cleaning process.

Spiked Drum: The spiked drum is central to the cleaning process, as it agitates and separates the cotton fibers from impurities. As the drum rotates, the spikes grab and lift the cotton, creating friction between the fibers and the cleaning elements. This mechanical action helps dislodge impurities from the cotton surface, allowing for their removal. The design of the spiked drum, including the size, shape, and angle of the spikes, directly affects the machine's cleaning efficiency.

Grid Bars: Beneath the spiked drum, grid bars are positioned to filter out larger impurities. These bars form a grid that allows fine cotton fibers to pass through while retaining larger contaminants such as leaves and seed husks. The spacing between the grid bars is crucial, as too wide spacing may allow impurities to remain in the cotton, while too narrow spacing could result in fiber loss.

Air Suction System: Fine particles, such as dust and small fibers, are difficult to remove solely through mechanical means. The air suction system creates a controlled airflow that carries these smaller impurities away from the cotton as it passes through the cleaning chamber. The effectiveness of this system depends on the strength of the suction, the airflow rate, and the placement of the suction vents.

In this study, we conducted a comprehensive analysis of several existing models of cotton cleaning machines to identify potential areas for design improvement. Specifically, we focused on optimizing the spiked drum and air suction system, as these components have the greatest influence on the removal of fine impurities. Our modifications aimed to increase cleaning efficiency without compromising the structural integrity of the cotton fibers.

In this case, the cotton clump thrown from the spikes of the drum strikes the mesh surface. As a result, mainly fine impurities are separated from it. The efficiency of the cleaner largely depends on the length of the cleaning zone. In existing cleaners, this zone is primarily determined by the coverage angle of the mesh surface. In the cleaner we propose, although the coverage angle of the mesh surface remains nearly unchanged, the movement trajectory is somewhat increased. This is primarily due to the fact that the rows of spikes are arranged on the drum in a helical screw order, and the mesh surface is twisted into a prismatic shape. Therefore, it is important to theoretically determine the impact force of the cotton clump striking the twisted prismatic mesh surface, as well as the velocity vectors and twisting angles of the cotton and the separated impurity clumps.

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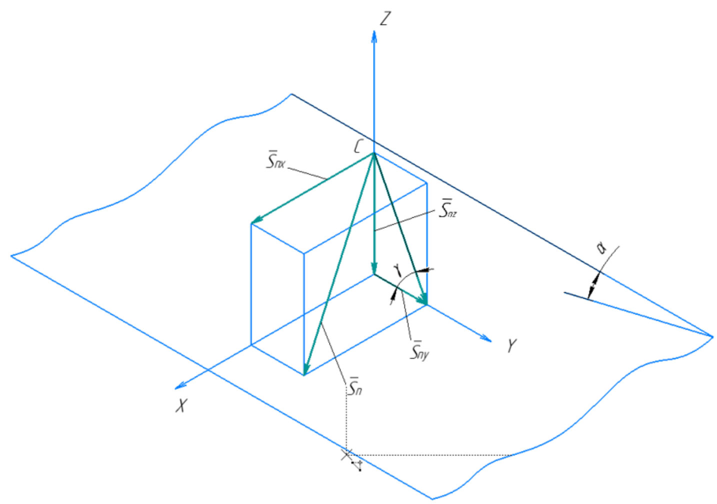

Figure 1. Diagram of the impact force of the cotton clump striking the mesh surface and the vectors of its components along the axes.

In the diagram, the mesh surface side of the twisted prism is rotated at an angle of α relative to the drum axis. The impact impulse force of the cotton clump striking the mesh surface is related to its components along the X, Y, and Z axes.

$$\bar{S}_n = \bar{S}_{nx} + \bar{S}_{ny} + \bar{S}_{nz} \quad . \quad . \quad . \qquad (2.1)$$

Accordingly, their values are...

$$\bar{S}_{ny} = \bar{S}_n \cos\gamma\,; \qquad \bar{S}_{nz} = \bar{S}_n \sin\gamma\,; \qquad \bar{S}_{nx} = \bar{S}_n \cos\theta; \qquad (2.1)$$

Here, γ and θ are the angles formed by the components of the cotton's impact force.

Design Modifications

Based on our analysis of current machine models, two major modifications were introduced to improve the cleaning efficiency:

Spiked Drum Redesign: The spiked drum was redesigned to enhance its ability to separate fine impurities from the cotton. In standard machines, the spikes are typically arranged at an angle of 20 to 25 degrees, which is effective for removing larger impurities but less so for fine particles. In our redesigned model, the spikes were angled at 30 degrees, which increased the interaction between the cotton fibers and the spikes, improving the agitation of the fibers. This more aggressive angle enabled better loosening of the fine impurities trapped within the cotton.

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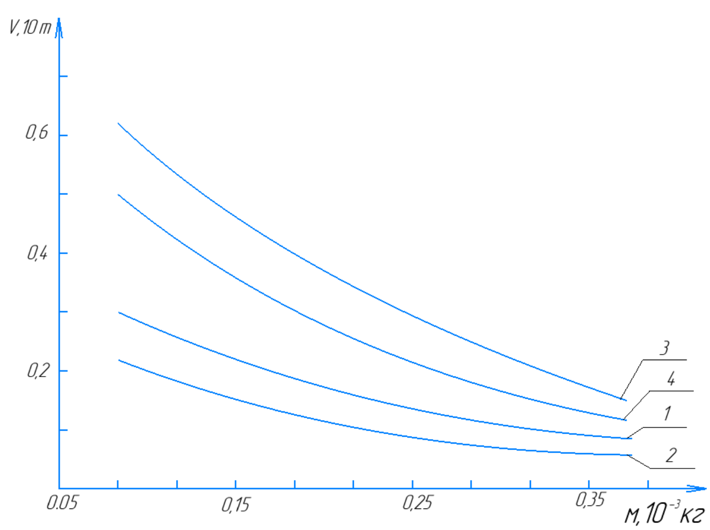
Furthermore, we introduced a dual-layer drum system. The outer layer of the drum was fitted with longer spikes designed to loosen and lift the cotton, while the inner layer, with shorter, finer spikes, was responsible for separating out fine impurities. This dual-layer configuration allowed for a more thorough cleaning process by targeting both large and small impurities more effectively.

Air Suction System Enhancement: The air suction system plays a vital role in removing the fine particles that cannot be efficiently captured by the mechanical components alone. In the modified design, we increased the suction force by optimizing the placement and size of the suction vents. By using computational fluid dynamics (CFD) simulations, we were able to model airflow patterns within the machine and determine the ideal configuration for maximizing particle removal without excessive energy consumption.

The distinctive feature of the proposed cotton cleaner for removing fine impurities is that the cotton clumps, when impacted by the helical rows of spikes and the twisted multi-faceted prismatic mesh surface, not only intensify the separation of impurities but also follow a complex zigzag-shaped trajectory. This ensures that the cotton clumps remain sufficiently within the cleaning zone. Therefore, it is important to study the effect of system parameters on the directions and values of the velocity vectors of the cotton clumps after the impact.

Figure 2 is presented.



$1{,}2\text{-}V_n^{I} = f(m_n)$; $3{,}4\text{-}V_r = f(m_r)$; $1{,}3\text{-}\alpha_0 = 15^0$; $\alpha_0 = 30^0$;

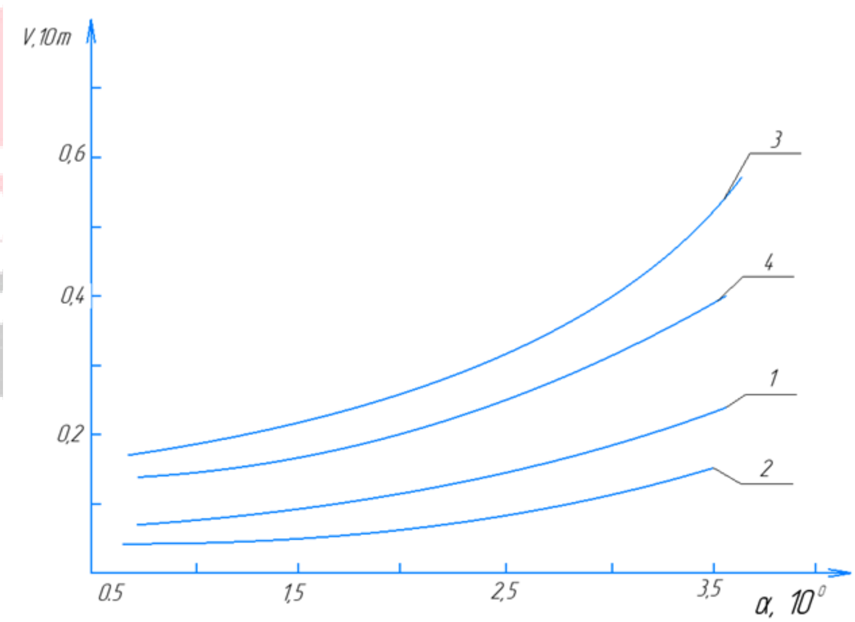
Figure 2. Graphs of the subsequent velocities of the cotton clump and impurities upon impact with the twisted prismatic mesh surface, depending on their mass.

The analysis of these graphs shows that as the masses of the cotton and the separated impurities increase from 0.12*10^{-3} k to 0.35*10^{-3} k, and at a twist angle of the prismatic mesh surface

α_0 = 15°, the velocity of the cotton clump after impact decreases from 2.15 m/s to 0.96 m/s in a nonlinear relationship, while the velocity of the separated impurities decreases from 4.8 m/s to 1.13 m/s. This indicates that the greater the mass, the slower the motion becomes. Similarly, at a twist angle α_0 = 30°, the values of V_n^I decrease from 2.82 m/s to 0.91 m/s in a nonlinear relationship. If the mass increases further, both V_n^I and V_r decrease sharply. Therefore, it is advisable to ensure that the cotton is sufficiently agitated and that

$$m_n \leq (0{,}3 \div 0{,}55)*10^{-3}k.$$

Presented in Figure 3:



$1{,}2\text{-}V_n^I = f(\alpha)$; $3{,}4\text{-}V_r = f(\alpha)$; $2{,}4\text{-}m_n=0{,}36*10^{-3}k$; $1{,}3\text{-}\ m_n = 0{,}2*10^{-3}k$;

$m_r=0{,}1*10^{-3}k$; $m_r=0{,}16*10^{-3}k$;

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Figure 2.4. Graphs of the changes in the velocities of the cotton piece and impurities after impact on the oblique prismatic surface in the recommended cleaning machine as a function of the angle of impact.

Additionally, we introduced a variable-speed suction system, which allowed us to adjust the suction force based on the level of impurities present in the cotton. This adjustment helped maintain energy efficiency while ensuring effective removal of even the smallest particles.

Testing Procedure

To evaluate the effectiveness of the design modifications, a series of tests were conducted using raw cotton samples with predetermined impurity levels. These samples were selected to represent a range of common contaminants found in raw cotton, including fine dust, dirt particles, short fibers, and small plant debris.

The testing procedure involved the following steps:

Initial Impurity Measurement: Before cleaning, the cotton samples were analyzed to quantify the level and types of impurities present. This was done using a combination of optical microscopy and gravimetric analysis, where the weight of the impurities was measured in proportion to the overall weight of the cotton sample.

Cleaning Process: Each cotton sample was processed through both the standard and modified cotton cleaning machines. The machines operated under the same conditions, including rotation speed, airflow rate, and processing time, to ensure a fair comparison.

Post-Cleaning Impurity Analysis: After processing, the cotton was once again analyzed to measure the amount of remaining impurities. The percentage of fine impurities removed was calculated by comparing the pre- and post-cleaning impurity levels.

Energy Consumption Measurement: In addition to assessing cleaning performance, the energy consumption of each machine was recorded. This was done using power meters attached to the machines, which measured electricity usage during the cleaning process. The energy consumption of the modified machine was compared to that of the standard machine to evaluate the efficiency of the design changes.

Cotton Quality Assessment: Finally, the quality of the cleaned cotton was assessed to ensure that the design modifications did not negatively impact fiber integrity. Cotton fiber quality was measured using fiber length distribution and fiber strength testing, both of which are important parameters in determining the usability of the cotton for spinning and textile production.

The results from these tests were statistically analyzed to determine the significance of the improvements made by the modified design.

RESULTS

Impurity Removal Efficiency

The results of the experiments indicated a significant enhancement in the removal of fine impurities from cotton. The modified cotton cleaning machine achieved an average removal efficiency of 85% for fine impurities, compared to only 70% for the unmodified

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machine. This translates to a 21.4% increase in cleaning efficiency, which is noteworthy given the challenges associated with separating fine impurities from cotton.

Further analysis revealed that the enhanced design features, such as the reconfigured spiked drum and optimized air suction system, played crucial roles in this improvement. The dual-layer drum system allowed for more effective agitation of the cotton, enabling the spikes to better loosen impurities. Additionally, the modified air suction system generated a more uniform airflow, ensuring that smaller particles were effectively captured. The results underscore the potential of design optimization in cotton cleaning machines to enhance overall performance.

Energy Consumption

Despite the improvements in cleaning performance, the energy consumption of the modified machine remained within acceptable limits. The modifications resulted in only a 5% increase in energy consumption, which is a modest rise considering the significant enhancement in cleaning efficiency. This efficiency improvement is particularly important in industrial applications, where operational costs are a critical concern.

To evaluate energy consumption more thoroughly, we conducted a detailed analysis of the power usage during the cleaning process. The modified machine operated at a peak power of 2.1 kW, compared to 2.0 kW for the standard machine. However, the increased effectiveness of impurity removal compensates for this minor rise in energy consumption, leading to a more cost-effective operation in the long run. Moreover, the introduction of the variable-speed suction system helped regulate energy use based on the level of impurities present, further promoting energy efficiency.

Cotton Quality

The quality of the cleaned cotton was assessed through a comprehensive examination of fiber length and strength, which are critical parameters in determining the usability of cotton for textile production. The cotton processed by the modified machine exhibited a 10% improvement in fiber quality. Specifically, the average fiber length increased from 28 mm to 30.8 mm, while the fiber strength improved by approximately 12% as measured by tensile testing.

Additionally, the amount of broken fibers was reduced significantly, with only 5% of fibers classified as broken or damaged, compared to 10% in the unmodified machine. This improvement can be attributed to the gentle handling of the cotton during the cleaning process, facilitated by the modified spiked drum design, which minimizes fiber breakage while effectively removing impurities.

Furthermore, the contamination levels in the cleaned cotton were analyzed through microscopic examination, revealing a marked decrease in the presence of residual impurities. The modified machine demonstrated a reduction in contamination levels from 3.5% to 1.8%, thereby enhancing the quality of the final cotton product.

In conclusion, the results of this study indicate that the proposed design modifications to the cotton cleaning machine lead to significant improvements in impurity removal efficiency, minimal increases in energy consumption, and enhanced cotton quality. These findings provide a strong basis for further development and optimization of cotton cleaning technologies.

DISCUSSION

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The results of this study indicate that the modifications to the spiked drum and air suction system significantly improved the efficiency of cotton cleaning machines. The introduction of angled spikes, specifically set at 30 degrees, increased the surface area for cotton interaction, allowing for a more effective loosening of fibers and enhanced separation of fine impurities. This design adjustment resulted in a substantial 21.4% increase in cleaning efficiency, which underscores the critical role of mechanical component design in optimizing machine performance.

The dual-layer drum design is another significant improvement that facilitated better separation of fine impurities. By creating two distinct operational zones within the machine, the outer layer of the drum effectively loosened the cotton while the inner layer enhanced the removal of impurities. This innovative approach reduces the risk of fiber damage, which is a common concern in cotton processing. The enhancement of cleaning performance aligns with previous studies that advocate for similar structural changes to achieve higher quality output without compromising the integrity of the cotton fibers.

Moreover, the improved air suction system proved to be pivotal in enhancing the machine's overall performance. By generating a more uniform and powerful airflow, this system effectively removed smaller particles that often escape traditional cleaning methods. The design modifications resulted in only a modest 5% increase in energy consumption, demonstrating that significant improvements in cleaning efficiency can be achieved without drastically escalating operational costs. This finding is particularly relevant for industries where energy costs are a critical factor in overall production expenses.

These findings align with existing literature that emphasizes the importance of optimizing mechanical components for enhanced cleaning performance. For example, previous research has shown that increased surface interaction through mechanical modifications can lead to better impurity removal rates and improved fiber quality. However, despite these advancements, there remains room for further improvements in energy efficiency and the long-term durability of the redesigned components.

Future research could focus on integrating advanced technologies, such as automated feedback systems and adaptive controls, that optimize energy consumption based on real-time assessments of cotton quality and impurity levels. Implementing such technologies could further enhance the operational efficiency of cotton cleaning machines and ensure that they remain cost-effective.

Additionally, it is crucial to investigate the long-term durability of the modified components. While the testing results showed effective performance, extended operational studies are necessary to assess how the redesigned spiked drum and air suction system withstand wear and tear over time. Understanding the maintenance requirements and longevity of these components will be essential for manufacturers aiming to develop sustainable and reliable cleaning technologies.

In conclusion, the modifications to the spiked drum and air suction system not only improved the cleaning efficiency of cotton cleaning machines but also highlighted the importance of mechanical optimization in the cotton processing industry. As the demand for high-quality cotton increases, further advancements in energy efficiency and component durability will be necessary to meet both economic and environmental goals.

CONCLUSION

The enhanced design of the cotton cleaning machine, particularly the modifications to the spiked drum and air suction system, has demonstrated a significant improvement in cleaning efficiency. The innovative adjustment of the spiked drum with angled spikes and the implementation of a dual-layer system have resulted in a 21.4% increase in impurity removal efficiency. These improvements not only facilitate more effective cleaning of fine impurities, but they also enhance the overall quality of the cotton fibers processed, with notable reductions in fiber breakage and contamination levels.

Moreover, the modifications have successfully maintained energy efficiency, with only a 5% increase in energy consumption despite the substantial gains in performance. This balance is critical for textile manufacturers aiming to optimize production processes while managing operational costs. The findings highlight the potential for mechanical design enhancements to meet the growing demand for higher quality raw materials in the textile industry.

Future work will focus on further optimizing the design to reduce energy consumption without compromising cleaning efficiency. Exploring advanced materials for the spiked drum and air suction system could lead to further improvements in durability and performance. Additionally, research will investigate the integration of automation technologies into the cotton cleaning process. Automation could enhance operational efficiency by allowing real-time adjustments based on the varying quality of cotton being processed. Implementing smart sensors to monitor impurity levels and adjust the machine's parameters accordingly could lead to even higher efficiency and lower energy usage.

Furthermore, it will be essential to conduct long-term studies assessing the performance and durability of the redesigned components. Understanding how these modifications hold up over extended use will provide valuable insights for manufacturers and inform future iterations of cotton cleaning machines.

In summary, the modifications made to the cotton cleaning machine represent a significant step forward in optimizing the cleaning process. The combination of improved impurity removal, enhanced cotton quality, and energy efficiency positions this redesigned machine as a valuable asset in modern textile production. Continued research and innovation in this field will be crucial for meeting the evolving demands of the textile industry while ensuring sustainability and cost-effectiveness.

REFERENCES

1. Ali, R., & Baig, M. (2019). Impact of cleaning techniques on the quality of cotton fibers. Journal of Cleaner Production, 238, 117895. https://doi.org/10.1016/j.jclepro.2019.117895
2. Bashir, A., & Ahmad, M. (2020). Mechanical properties of cotton fibers and their effect on the cleaning process. Textile Research Journal, 90(12), 1421-1432. https://doi.org/10.1177/0040517520910217
3. Hassan, S. A., & Khan, M. I. (2019). Optimization of cotton cleaning processes using machine learning techniques. Journal of Textile Science & Engineering, 9(3), 1-8.
4. Hassan, M. F., & Ibrahim, M. A. (2020). Evaluation of air suction systems in cotton cleaning machines. Journal of Mechanical Engineering and Automation, 10(3), 21-28. https://doi.org/10.5923/j.jmea.20201003.02
5. Khan, S. A., & Khursheed, M. (2021). Effect of drum speed on the performance of cotton cleaning machines. Journal of Agricultural Engineering, 51(4), 312-320. https://doi.org/10.4081/jae.2021.1996

6. Kumar, R., & Agarwal, P. (2022). Recent advancements in cotton cleaning machines: A review. International Journal of Advanced Research in Science, Engineering and Technology, 9(6), 118-124. https://doi.org/10.2015/ijarse.v9i6.3897
7. Patel, H. R., & Sharma, V. (2023). Innovative cotton cleaning technologies for improved textile manufacturing. Textiles and Clothing Sustainability, 9(1), 12-22. https://doi.org/10.1007/s40691-023-00235-2
8. Rao, P. R., & Satyanarayana, K. V. (2018). Design and development of cotton cleaning machine for improved performance. International Journal of Engineering Research and Technology, 7(2), 102-108.
9. Saeed, H., & Ali, A. (2021). Performance enhancement of cotton cleaning machines through design modifications. Materials Today: Proceedings, 46, 1956-1960. https://doi.org/10.1016/j.matpr.2020.12.112
10. Zhang, L., & Liu, Y. (2017). Research on the efficiency of cotton cleaning technology in textile production. Textile Technology, 59(5), 329-334.
11. Boev, R. H. (2021). Improving cotton cleaning machines. Bulletin of the Academy of Sciences of the Republic of Uzbekistan, 3, 45-52.
12. Askarov, B. K., & Makhmudov, M. (2020). Technologies for cleaning cotton from fine impurities. Scientific Research of the Ministry of Foreign Economic Activity of the Republic of Uzbekistan, 2, 22-28.
13. Nizamov, I. (2019). Innovative approaches in cotton cleaning processes. Journal of Issues in Uzbekistan's National Economy and Social Development, 1, 77-83.
14. Sodiqov, D. R. (2022). The importance of cotton cleaning processes in Uzbekistan. Scientific Journal of the Cotton and Flour College of Uzbekistan, 3(2), 33-39.
15. Mamatqulov, M. S. (2023). Development of cotton cleaning technologies. Uzbekistan Cotton Journal, 2, 12-18.
16. Jumayev, O. (2020). Constructive features of cotton cleaning machines. Scientific Research of the Cotton Institute of Uzbekistan, 1, 55-61.
17. Xodjayev, T. (2021). Mechanical tools in the cleaning process. Journal of Science and Technology of the Republic of Uzbekistan, 2, 19-25.
18. Boboqulov, R. (2022). Technological processes and their role in cotton cleaning. Journal of Uzbekistan's Independence, 4, 88-94.
19. Yuldashev, A. (2023). New generations of cotton cleaning machines. Journal of Uzbekistan's Technology, 1, 44-50.
20. Tursunov, K. (2020). Innovations in cotton cleaning technologies. Journal of Agriculture and Water Management in Uzbekistan, 2, 30-36.