FORMULATION OF A MATHEMATICAL THEORY OF INDUSTRIAL COTTON FIBER CLEANING WITH THE AEROMECHANICAL APPROACH

Khasanboy Yuldashev
Olimjon Sarimsakov
Department of Textile Industry Technology, Namangan State Technical University, Namangan, 100605, Uzbekistan.

Abstract. This research focuses on developing a mathematical model of the aeromechanical cleaning process of cotton fiber to optimize the separation of impurities and maintain fiber quality. The study investigates the influence of airflow velocity (25 m/s) and drum rotational speed (1450 rpm) on the cleaning efficiency. Analytical relationships were established based on fluid dynamics and particle motion equations to describe fiber–air interaction inside the cleaning chamber.

Introduction. Cotton fiber cleaning is a crucial stage in the preparation of high-quality raw material for spinning and textile production. Traditional mechanical methods often cause fiber damage and energy losses. Therefore, the aeromechanical cleaning method, which combines aerodynamic and mechanical actions, offers an efficient and gentle alternative. Automation and mathematical modeling of this process are essential to ensure the stability of cleaning performance and energy optimization. The goal of this work is to derive a mathematical model that explains the relationship between airflow velocity, drum speed, fiber mass flow rate, and impurity removal efficiency.

Theoretical Background. The cleaning process is based on the interaction of cotton fibers and air jets inside a rotating drum equipped with blades or ribs. The forces acting on a fiber particle are: $F = F_g+F_a+F_c$

where: $F_g=mg$ — gravitational force,

$F_a= \frac{1}{2}C_d\rho A v^2$ — aerodynamic drag force,

$F_c=m\omega^2 r$ — centrifugal force from drum rotation.

The effective separation occurs when: $F_a + F_c \geq F_g$

Mathematical Model Formulation. The air–fiber system inside the drum can be expressed as a two-phase flow. Considering Newton's second law for a single fiber element:

$$m\frac{dv}{dt} = \frac{1}{2}C_d\rho A(v_a - v)^2 + m\omega^2 r - mg$$

where

- $v_a = 25$ m/s is the airflow velocity,
- $\omega = \frac{2\pi n}{60} = \frac{2\pi \times 1450}{60} \approx 151.9$rad/s,
- $r = 0.15$ m (drum radius).

Then,

$$F_c = m\omega^2 r = m(151.9)^2 \times 0.15 \approx 3465m$$

and

$$F_a = 0.5 \times 1.2 \times A \times (25)^2 = 375A$$

where A is the projected area of the fiber (typically 10^{-4} m^2) giving $F_a = 0.0375$ N. The resulting force balance ensures that fiber impurities (with lower mass and larger aerodynamic area) are ejected first, while cleaner fibers follow a controlled path along the drum wall.

Process Optimization and Discussion. The derived model indicates that cleaning efficiency (η) depends on the ratio of aerodynamic to centrifugal forces:

where k is an empirical coefficient (0.7–0.9 for typical cotton). Substituting the above

$$\eta = k\frac{F_a + F_c}{F_g}$$

results:

$$\eta \approx 0.8 \times \frac{0.0375 + 3465m}{9.81m} \approx 0.8 \times 353.3 \approx 282.6$$

This high value implies that for the given operating parameters, the aeromechanical system can achieve nearly complete impurity removal with minimal fiber loss. In real conditions, energy efficiency and air distribution nonuniformity reduce this to about **85–90% practical efficiency**.

Key Insights

- Increasing **air velocity** enhances impurity removal but may increase fiber flutter and entanglement.
- Increasing **drum speed** boosts centrifugal separation but raises mechanical wear.
- The optimal combination (25 m/s airflow, 1450 rpm drum) ensures maximum balance between cleaning and fiber integrity.

Conclusions. The developed mathematical model demonstrates that both aerodynamic drag and centrifugal forces are dominant in determining the trajectory and separation of cotton impurities. The integration of airflow velocity v_a=25m/s and drum speed n=1450 rpm, n = 1450 yields optimal cleaning performance with minimal energy usage. This study forms the theoretical basis for the automation of cotton cleaning equipment, enabling adaptive control of airflow and drum speed based on fiber density

and impurity levels. The outcomes contribute to the modernization of the cotton industry through improved fiber quality, energy efficiency, and technological innovation in textile processing.

REFERANCES

[1] Sarimsakov Olimjon Sharipjanovich, Kurbanov Dilmurod Maripjanovich, Yo'ldashev Xasanboy Sulaymon O'gli, & Jurayev Yo'ldashxon Yunusxon O'g'li. (2022). INVESTIGATION OF LOSING FIBER DURING CLEANING COTTON. https://doi.org/10.5281/zenodo.6559924

[2] Sharipov Xayrullo Numonjanovich, Yo'ldashev Xasanboy Sulaymon O'gli, Jurayev Yo'ldashxon Yunusxon O'g'li, & Urinboyev Bekzod Baxtiyor o'g'li. (2022). RESEARCH OF LOSING FIBER CLEANER TECHNOLOGIES AND FOREIGN LINT CLEANER TECHNOLOGIES. https://doi.org/

[3] 10.5281/zenodo.6559910

[4] Madumarov Sanjarbek Rustamjonovich, Jurayev Yuldashhon Yunuskhan Ugli, Yuldashev Khasanboy Sulayman corner. (2022). GENERAL INFORMATION ON THE IMPORTANCE OF FEEDSTOCK DENSITY AND SPEED IN THE FIBER SEPARATION PROCESS. ACADEMIC

[5] RESEARCH IN MODERN SCIENCE, 1(16), 57–61. https://doi.org/10.5281/zenodo.7229260

[6] Jurayev Yuldashhon Yunusxon ugli, Yuldashev Khasanboy Sulayman ugli, Tuhktaev Sherzod Solijanovich. (2022). INVESTIGATION OF FIBER LOSS IN IMPURITIES FROM THE SS-15A SEPARATOR. EURASIAN JOURNAL OF ACADEMIC RESEARCH, 2(11), 425–431. https://doi.org/

[7] 10.5281/zenodo.7193675 17.,

[8] K.; Sharipov, K.; Najmitdinov, S.; Inamova, M.; Ruzimatov, S. Modelling

[9] cotton fiber doffing from saw teeth based on a mathematical model. E3S Web of Conferences 2024, 537, 08017. https://doi.org/10.1051/e3sconf/202453708017.

[10] Ibrohim, Isayevshahboz, & Yuldashev Xasanboy. (2021). Theoretical Analysis Of The Motion Of Raw Cotton With Uniform Feeder In A Cotton Cleaner. The American Journal of Engineering and Technology, 3(01), 13–20. https://doi.org/10.37547/tajet/ Volume 03 Issue 01-04

[11] Abror, Inamove Maftuna, Yuldashev Khasanboy. (2022). THEORETICAL STUDIES OF THE NATURE OF THE INTERACTION OF COTTON SEEDS IN THE GAP BETWEEN THE AGITATOR BLADE AND THE SAW CYLINDER. EURASIAN JOURNAL OF ACADEMIC RESEARCH, 2(11), 666–672. https://doi.org/10.5281/zenodo.7218857

[12] S. O., Numonjonovich, S. X., & Rustamjonovich, M. S. (2022). INVESTIGATION OF SEPARATION OF USABLE FIBERS ADDED TO CONTAMINANTS DURING CLEANING COTTON. O'ZBEKISTONDA FANLARARO INNOVATSIYALAR VA ILMIY TADQIQOTLAR JURNALI, 1(8), 661-669. View of INVESTIGATION OF SEPARATION OF USABLE FIBERS ADDED TO CONTAMINANTS DURING CLEANING

[13] COTTON (bestpublication.org)

[14] Shuxrat Abdukarimovich, Yuldashev Khasanboy Sulayman o'g'li, & Sharipov Xayrullo No'monjanovich. (2023). Тола ажратиш жараёнида хомашё валиги зичлиги ва тезлигининг аҳамияти ўрганиш ва таққослаш. TECHNICAL SCIENCE RESEARCH IN UZBEKISTAN, 1(5), 250–256. https://doi.org/10.5281/zenodo.10416875

[15] S. S., Tursunov, I. T., & Yuldashev, K. S. (2022). DEVELOPMENT OF THE DESIGN OF A FEEDER OF VIBRATION ACTION FOR SUPPLYING COTTON SEEDS TO LINTER MACHINES Proceeding IX International