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METHODOLOGY FOR DETERMINING THE TRIBOTECHNICAL PROPERTIES OF STRUCTURAL MATERIALS INTERACTING WITH RAW COTTON

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Abstract: This paper presents a methodology for determining the tribotechnical properties of structural materials interacting with raw cotton under frictional conditions. The main objective of the study is to evaluate the frictional characteristics of materials used for the working elements of cotton-processing machinery in order to reduce mechanical damage to cotton fibers. The experiments were carried out using a disk-type tribometer under a nominal pressure of 0.04 MPa, a sliding speed of 6 m/s, and a test duration of 1 hour. Steel, aluminum, and polymer-coated samples based on ED-16 were subjected to comparative testing. The results showed that polymer coatings cause 1.5–2 times less damage to raw cotton compared to steel and aluminum surfaces. This effect is explained by the lower hardness and higher elasticity of polymer materials. The obtained results confirm that the tribotechnical properties of structural materials play a significant role in preserving the quality of raw cotton and can be effectively applied in the development of working elements for cotton-cleaning, cotton-harvesting, and textile machinery.

Keywords: raw cotton, tribotechnical properties, friction, polymer coatings, mechanical damage, cotton-processing machinery.

Introduction. The efficiency and quality of cotton processing largely depend on the interaction between raw cotton and the working elements of technological machines. During transportation, cleaning, and processing operations, cotton fibers are repeatedly subjected to mechanical contact with various structural materials, which can lead to fiber breakage, surface damage, and a decrease in overall product quality. Therefore, reducing mechanical damage during processing remains one of the key challenges in the cotton industry.

In recent years, increasing attention has been paid to the selection of structural materials with improved tribotechnical properties for use in cotton-processing machinery. The frictional interaction between raw cotton and machine components significantly influences not only the durability of the equipment but also the preservation of the physical and mechanical properties of cotton fibers. Consequently, an in-depth study of friction, wear, and surface interaction mechanisms is essential for improving machine performance and product quality.

Despite numerous studies conducted in this field, there is still a lack of unified and standardized methods for evaluating the tribotechnical characteristics of materials interacting with raw cotton. This complicates the objective comparison of different materials and limits the ability to optimize the design of machine components. The development of reliable experimental methodologies and evaluation criteria is therefore of great practical importance.

In this context, the present study aims to develop and apply a methodology for assessing the tribotechnical properties of structural materials under conditions suitable for cotton-processing equipment. The research focuses on analyzing frictional behavior and material performance to identify optimal solutions for reducing fiber damage and improving the operational efficiency of cotton-processing machinery.

Results. Repeated frictional interaction between machine working elements and raw cotton leads to mechanical damage of the fiber. Based on conducted studies, various methods and structural materials have been recommended to reduce mechanical damage to raw cotton. A considerable amount of scientific research has been devoted to this issue.

Before the development of a standardized method, there was no unified methodology or testing equipment for determining the coefficient of friction between structural materials and raw cotton. This situation made it difficult to compare experimental results and select the most effective materials for the working elements of cotton-processing machinery. Therefore, the need arose to develop a unified (standardized) method.

The creation of such a standard method became possible with the development of new composite polymer materials and coatings intended for use in cotton-processing machines and mechanisms.

The main advantages of the proposed method are as follows:

- relative simplicity for application in cotton-cleaning equipment;
- satisfactory repeatability of test results, allowing evaluation of the effectiveness of newly developed materials based on their friction coefficients with raw cotton;
- the possibility of predicting the degree of mechanical damage to raw cotton depending on the material type and operating conditions of the machinery.

For selecting structural materials for specific working elements of machines operating under frictional interaction with cotton, comparative testing of specimens made from different materials is required. In this process, the surface roughness parameters of the samples, even within the same class, must be as close as possible.

If the surface is mechanically machined, surface roughness with peak rounding radii of less than 100 μm is typically formed. For metallic surfaces, when the peak radius is less than 100 μm, and for hard polymer materials and composites when it is less than 50 μm, intensive mechanical damage to cotton fibers occurs in the contact zone. As a result, the surface roughness of the tested material, particularly the peak rounding radius, changes significantly.

Therefore, it is necessary to ensure that the peak rounding radii of all samples are identical. Studies have shown that polymer coatings applied to steel surfaces exhibit surface roughness corresponding to grades 7–9. Depending on the coating technology, the peak rounding radius ranges from 150 to 350 μm. Taking this into account, during the experiments the surfaces were finished using abrasive papers with appropriate grit numbers.

During tests conducted on a disk-type tribometer at a nominal pressure of 0.04 MPa and a sliding speed of 6 m/s for 1 hour, the relative damage to cotton (mass loss before and after testing) was investigated. The results demonstrated that the ED-16 polymer coating causes 1.5–2 times less damage to cotton compared to conventional structural materials such as steel and aluminum. This effect is explained by the lower hardness and higher elasticity of the polymer material. The zone of intensive damage was also significantly smaller.

In addition, the nominal profile deviation increased by 0.23 μm, and the surface roughness height increased by 1.0 μm. For aluminum and steel surfaces, these values were 0.06 and 0.17 μm, and 0.03 and 0.14 μm, respectively. This indicates that a running-in (adaptation) process of the surfaces is taking place.

Microscopic and electron microscopic analysis of the fibers showed that interaction with steel surfaces leads to distinct cuts and tears in the fibers, whereas interaction with polymer-coated surfaces mainly results in fiber rupture without severe surface damage.

Thus, the developed standard methodology enables the evaluation and control of the tribotechnical properties of structural materials interacting with fibrous masses under operating conditions. This approach contributes to the development of high-performance and wear-resistant materials for cotton-processing, cotton-harvesting, and textile machinery, ultimately reducing mechanical damage to raw cotton and preserving its natural properties, which directly affects the technological and consumer qualities of textile products.

Conclusion. The conducted study demonstrates that the tribotechnical properties of structural materials play a decisive role in minimizing mechanical damage to raw cotton during processing. Comparative experiments revealed that polymer-coated materials based on ED-16 outperform traditional metallic materials such as steel and aluminum, reducing fiber damage by 1.5–2 times under identical testing conditions.

The improved performance of polymer coatings is attributed to their lower hardness and higher elasticity, which reduce stress concentrations at the contact interface and provide a gentler interaction with cotton fibers. Surface analysis and microscopic examination confirmed that polymer-coated surfaces result in less fiber cutting, tearing, and structural damage compared to metallic surfaces.

The developed standardized methodology allows for reliable assessment, control, and prediction of the tribotechnical behavior of structural materials under conditions similar to actual machine operation. Its application enables the design and implementation of high-performance, wear-resistant working elements for cotton-processing, cotton-harvesting, and textile machinery. Consequently, the mechanical integrity and natural properties of raw cotton are preserved, positively influencing the technological and consumer quality of textile products.

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