

**RESEARCH OF TRIBOTECHNICAL AND PHYSIC-MECHANICAL PROPERTIES
OF COMPOSITE POLYMER MATERIALS AND COATINGS****PhD. Makhammadjanov Khusanboy Alisher ugli**Central Asian University, Head of Industrial Engineering department
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Abstract: This research examines the tribotechnical and physic-mechanical properties of composite polymer materials and coatings, exploring their frictional behavior with raw cotton. Two primary polymers, ED-16 (epoxy) and FAED-20 (furan-epoxy), are tested for their potential use in cotton-processing machinery coatings due to their favorable low interaction strength with cotton fibers. Various fillers are added to these base compositions to optimize their wear resistance, stability, and overall performance. The study investigates how these modified polymers perform under frictional conditions, with a focus on key properties such as hardness, elasticity, and adhesion. By analyzing the effect of different fillers, the research aims to improve the efficiency and longevity of coatings used in cotton harvesting and processing industries, addressing issues such as wear, durability, and friction stabilization.

Keywords: Composite polymer materials, tribotechnical properties, physic-mechanical properties, furan-epoxy resin, epoxy resin, frictional interaction, raw cotton, polymer coatings, fillers, wear resistance, adhesion strength, plasticizers, cotton processing machinery, durability, friction stabilization, epoxy-based coatings.

Research the break-in process of polymer materials depending on their properties and structure during frictional interaction with raw cotton, various polymers were selected as objects, differing in chemical structure, physical state, properties, processing technology, etc. The polymer materials investigated include an epoxy composition based on ED-16 (ED) and a furan-epoxy composition based on FAED-20 (FAED). The selection of these polymers is based on the fact that coatings made from these polymers have the lowest interaction strength with raw cotton among a range of structural polymers and potentially meet the requirements for materials used in coatings, considering their functional purpose and the operating conditions of machines and mechanisms used in raw cotton processing. To establish the peculiarities of the friction stabilization process depending on the polymer's nature, different thermosetting polymers (ED-16; FAED-20) were chosen (Table 1).

It should be noted that the epoxy composition has high physic-mechanical properties (hardness, elasticity modulus) and adhesion to steel surfaces, which plays an important role in ensuring the functionality and durability of coatings. At the same time, all these materials are produced in series and are not in short supply. Furano-epoxy resin, in essence, is a relatively new material for antifriction purposes.

Furfural acetone monomer is derived from inexpensive and abundant raw materials—cotton stalks, the reserves of which are virtually unlimited in Uzbekistan. This is one of the main advantages of this material. On the other hand, all these polymer materials differ in their

structure and physic-mechanical properties, which makes it possible to study the relationship between the friction stabilization process and the type and properties of coating materials.

Table 1**POLYMER MATERIALS AND FILLERS SELECTED FOR THE RESEARCH**

Material	Dispersion, μm	Form/Type	Standard Document
Epoxy resin (ED) ED-16	-	Liquid	GOST 10589-72
Furan-epoxy resin (FAED) FAED-20	-	Thermosetting polymer	MRTU-6-05-045-64
Dibutyl phthalate (DBF)	-	Plasticizer	GOST 8728-16
Polyethylene polyamine (PEPA)	-	Hardener	TU-6-02-595-70
Iron powder (PZK-3)	20-50	Powder	TU 3648-53
Copper powder (PMS-2)	20-50	Granular	GOST 4960-68
Cement	-	Filler	GOST 10178-62
Graphite (C-1)	5-10	Powder	GOST 5661-68
Teflon (PTFE)	20-50	Filler	GOST 14906-69
Flake graphite	20-50	Flake	GOST 44404-58
Talc (A)	5-10	Filler	GOST 879-52
Kaolin	5-10	Powder	GOST 6138-61
Glass fiber (TJS-0.7)	-	Fiber filler	TU 6-1T-91-70

The main physic-mechanical properties of the selected polymers, presented in Table 1, show significant differences in their properties for the production of composite polymer materials and coatings based on them.

It is known that the properties of filled compositions are determined by the properties of the polymer matrix and the filler, the interaction between them at the phase boundary, the distribution of the filler, its phase and physical state, dispersion, and the shape of the particles. The introduction of fillers into the polymer allows for targeted modification of the physicochemical and operational properties of the resulting composite coating. Fillers alter the properties of the polymer both in volume and in the layer adjacent to the surface of the filler. As a result of the adsorptive interaction between the polymer and the surface of the filler, as well as changes in molecular mobility at the interface and the influence of the surface on the formation of molecules during curing reactions, the chemical and structural heterogeneity of the composite material increases. Structural changes in filled polymers lead to changes in their physicochemical properties.

A wide range of natural and synthetic materials are used as fillers. Fillers are classified into active, inert, and intermediate types. This classification is conditional, as the activity and inertness depend, first, on the chemical nature of the polymer and, second, on the functional importance of the property of the filled polymer coating. It is possible that by improving one property, the filler may negatively affect another. For example, the introduction of talc

primarily increases the wear of the polymer, while the introduction of asbestos increases the friction coefficient.

To improve the operational properties, wear resistance, reliability, and durability of polymer coatings, as well as to study the friction stabilization process of polymer coatings depending on the type and nature of the filler, various fillers were introduced into the base composition (BC) of the polymer binder:

1. **Inorganic fillers** (iron and copper powders)
2. **Mineral fillers** (graphite, talc, cement)
3. **Organic fillers** (Teflon, polyethylene)

These fillers differ in structure: granular and powdery (metals), flake-like (graphite, talc), and fibrous (glass fibers). Plasticizers are also used to improve the performance of polymer materials. The effect of introducing a plasticizer is as important as the effect of the filler, especially for thermosetting polymers, to reduce their internal stresses, improve frost resistance, etc.

Using unplasticized epoxy and furan-epoxy compositions is impractical due to the heavy operating conditions of machines (some of which operate under significant dynamic loads) and temperature fluctuations, which can lead to cracking and delamination of the coating. Therefore, considering the availability, cost, toxicity, and technological aspects, dibutyl phthalate was chosen for the plasticization of epoxy and furan-epoxy compositions. [1]

When selecting substrates, we consider that the most commonly used material for manufacturing parts of cotton harvesting machinery is steel. Thus, steel grade St.3 was used as a substrate in the experiments.

The main physic-mechanical and other properties of the selected polymer materials and raw cotton are presented in Tables 2 and 3. Since the task of the study is to investigate polymer coatings under frictional interaction with raw cotton, we used raw cotton of the Tashkent-3 selection, from both manual and machine harvesting, with a moisture content ranging from 7 to 50% and contamination levels from 1-3% to 20-25%. These characteristics are currently typical for the Republic of Uzbekistan.

Table 2

MAIN PHYSICAL-MECHANICAL AND OTHER PROPERTIES OF SELECTED POLYMER MATERIALS

Properties	Material	
	ED-16	FAED-20
Microhardness, MPa	160-230	45-60
Flexural Modulus, MPa	2500-3500	850-900
Tensile Strength at Break, MPa	50-60	-
Adhesion Strength at Pull-off with Steel, MPa	50-60	20-30
Thermal Conductivity, W/m·K	0,40-0,60	-
Glass Transition Temperature, K	342	315
Surface Resistivity, Ω	$1 \cdot 10^{14}$	$1 \cdot 10^{16}$
Volume Resistivity, $\Omega \cdot m$	$1 \cdot 10^{15}$	$1 \cdot 10^{17}$

Table 3

PHYSIC-MECHANICAL PROPERTIES OF RAW COTTON DEPENDING ON ITS VARIETY

Cotton variety	PHYSIC-MECHANICAL PROPERTIES					
	Fiber to seed weight ratio	Fiber length, mm	Nominal fiber diameter, μm	Tensile strength, 10^{-2} MPa	Fiber damage, %	Seed fullness relative to Grade 1
1	0,81	36	39	12,1	1,5	1
2	0,72	31	35	10,4	3,2	0,90
3	0,64	26	29	7,2	5,2	0,75
4	0,58	21	25	5,4	7,8	0,65

The moisture content and contamination of raw cotton have a significant impact on the operation of machines and mechanisms, especially in the cotton cleaning industry's preparatory network, as they largely determine the damage to cotton fibers by the working parts of these machines and the wear of the parts themselves. Therefore, they require anti-friction, wear-resistant, and durable materials. The quality of raw cotton was evaluated according to technological instructions based on the following key indicators:

1. Fiber damage
2. Seed fragmentation
3. Number of tangles
4. Degree of defect formation
5. Degree of formation of fines
6. Maturity
7. Degree of seed depression.

This passage discusses the importance of raw cotton's quality factors that affect machinery in the cotton cleaning industry and the evaluation of raw cotton based on various quality indicators [5].

Methodology for Studying Experimental Samples of Composite Materials

To obtain high-quality coatings, strict adherence to the specified technology for preparing compositions and mixtures is of utmost importance. The technology for preparing compositions is based on the use of pre-ground polymers and ingredients and includes selecting the type and quantity of polymer materials and ingredients for the required purpose, their mixing, as well as crushing or grinding followed by sieving if aggregation of the prepared composition is observed [2].

The prepared composition should be free-flowing and possess uniformity and stability during transportation, storage, and use. When spraying a well-prepared composition, separation and sedimentation of the introduced ingredients on the bottom of the apparatus do not occur [2].

The quality of the prepared composition mainly depends on the mixing of the polymers with the ingredients. Good mixing allows for coatings with high color purity, good physical-mechanical properties, and durability. It involves the rearrangement of component particles under external mechanical influence. This process continues until the required degree of homogeneity is achieved in the mixed materials.

It is known that the quality and performance of the powder polymer material mixing process depend on several factors:

- Mixing methods
- Structural features of the mixer
- Physical-mechanical properties of the mixture and its individual components.

The degree of mixing is usually characterized by the non-homogeneity coefficient, K_c (%)

$$K_c = \frac{100}{C_0} \sqrt{\frac{\sum (C_i - C_0) n_i}{n - 1}}$$

where:

- C_i - is the concentration of one of the components in the samples;
- C_0 - is the concentration of the same component in the ideal distribution;
- n_i - is the number of samples with concentration n_0 ;
- n_0 - is the total number of samples.

The smaller the value of the non-homogeneity coefficient K_c , the higher the degree of mixing. In ideal mixing, $K_c=0$ and a low non-homogeneity coefficient means good homogenization of the mixed components. This prevents separation of powders by components during coating formation in the liquid layer.

Thus, the preparation of compositions from powder polymers and ingredients is done by simple mechanical dry mixing, where the initial polymer and ingredients remain in powder form at all stages of the mixing process. The chemical composition of the compositions and their degree of dispersibility are crucial. Additionally, for stable and non-separating compositions, it is important that the components are similar in polarity, have high dispersibility, and good contact between elementary particles during mixing. Various types of mixers are used for dry composition preparation, combining mixing processes with de-aggregation and grinding of the material.

Compositions based on viscous thermosetting resins consist of resin and hardener, as well as plasticizers and fillers, which are added to increase the elasticity and strength of the coating.

Compositions based on epoxy and furan-epoxy resins are prepared as follows: the required amount of binder is heated to 80-100 °C in a vacuum drying oven and kept for 30-60 minutes to remove air bubbles from the polymer mass. After that, the plasticizer is added at 20 mass. parts at 60-70 °C with thorough mixing. Then, half of the prepared filler mixture from a ball mill is introduced into the plastisol resin. Just before coating application, hardener is introduced in

small portions at 10 mass. parts and the remaining half of the filler mixture is added under intensive mixing [3].

In some cases, when compositions are prepared for pneumatic spraying onto large parts with complex shapes, acetone is added as a diluent in an amount of up to 20 mass. parts, depending on the type of composition, to reduce viscosity to 40 s VZ-4.

The most important indicators determining the reliability and durability of polymer coatings are adhesion and corrosion strength, as well as internal stresses arising during coating formation. Along with the specific properties of the polymer itself, they largely depend on the preparation of the surface of the item to be coated. Therefore, the surface of the metal must be clean, dry, and free of scale and rust.

Surface cleaning of the item from corrosion, scale, old paint, and polymer coatings, fats, and other contaminants is a very important and labor-intensive operation that affects the quality of polymer coatings. The cleaning methods are quite varied and include cleaning the surface from contaminants and giving it a certain roughness [3].

Regardless of the method used for surface preparation, the first operation must always be degreasing. The oily film prevents the formation of high-quality polymer coatings with good adhesion to the surface of metal products. Therefore, it is removed using substances that emulsify or dissolve oils and fats. Alkaline solutions and organic solvents are used for this purpose. The most effective solvents include kerosene, gasoline, benzene, trichloroethylene, carbon tetrachloride, and dichloroethane [4].

Washing is performed in special units such as baths or washing machines by wiping or rinsing. After degreasing, cleaning is carried out to remove rust, scale, and other contaminants from the surface and to give it roughness. There are various methods of cleaning metal surfaces: mechanical, physical, chemical, and combined. The choice of method depends on the state of the surface to be processed, the size and shape of the items, and the volume of production.

Mechanical cleaning of the metal surface, based on the nature of interaction between the item and the cleaning medium, can be manual, shot blasting, vibratory shot blasting, vibration cleaning, and jet cleaning. In our experiments, the most common and simple electric brushing machine was used for mechanized cleaning of metal surfaces.

Adhesion strength of the coating was determined by the peeling method (aluminum foil) from the substrate (coating) on an adhesion-meter. Impact strength of coatings was determined using the U1-A device.

Thermal and electrophysical properties of polymer coatings were studied using standard well-known methods. Microhardness of the obtained coatings was measured with an MPT-3 instrument. The glass transition temperature was determined using the resonance method on the "Polymer-2" setup.

In some cases, to explain the mechanisms of the processes occurring in the coatings, differential thermal gravimetry, thermomechanical analysis, and optical microscopy were used [5].

Conclusion: The study confirms that both epoxy and furan-epoxy polymer materials, when modified with appropriate fillers, can provide effective and durable coatings for machinery in the cotton industry. The frictional interaction between the polymer coatings and raw cotton is significantly influenced by the type of polymer and the choice of fillers. The introduction of fillers such as graphite, talc, and metals improved the wear resistance and frictional stability of the coatings. Furthermore, the incorporation of plasticizers was found essential to enhance the elasticity and prevent cracking under dynamic loading conditions. These findings highlight the importance of selecting the right combination of polymer and fillers for producing high-

performance coatings, ensuring better operational efficiency and longevity of machinery used in cotton processing. The study provides valuable insights into the optimization of polymer-based coatings for industrial applications, particularly in harsh working conditions.

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