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DEVELOPMENT OF HETEROCOMPOSITE POLYMER MATERIAL COMPOSITIONS TO INCREASE THE SERVICE LIFE OF COTTON GINNING EQUIPMENT PARTS

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Abstract: Today in mechanical engineering, due to the high demand for large-scale technological equipment made from composite materials for various operational conditions, special attention is being paid to its modernization by improving production techniques and technologies, as well as to the application of energy- and resource-saving methods for obtaining high-quality cotton fiber.

This article provides an analysis of modern materials used in the production of loosening drum pegs during the cleaning of cotton fibers from fine impurities in the cotton industry, as well as the work carried out to date on measures to improve the designs of these parts. Also, in order to reduce the friction of the loosening drum peg with cotton fibers and prevent damage to cotton fibers, it is proposed to coat the surface of the drum with new composite multifunctional polymer materials based on reactoplast, as well as pegs with cast parts.

Keywords: wear-resistant thermoset material, coating, fiber, drum peg, mechanical strength, tribological properties, morphological analysis, filler, reinforcing agent, part.

Introduction.

In mechanical engineering, there is a high demand for large-scale technological equipment made from composite materials suitable for various operational conditions. Consequently, modernizing this equipment by improving its production techniques and technologies, and using energy- and resource-efficient methods to obtain high-quality cotton fiber, are among the leading priorities. This, in turn, makes ensuring the necessary operational reliability and efficiency of machines and mechanisms, including technological equipment used in the cotton industry, one of today's most critical factors [1]. Currently, various technological and design methods exist to protect cotton from mechanical damage. One of the most effective methods is the application of wear-resistant composite polymer materials to the working surfaces and parts of equipment that come into frictional contact with cotton.

An analysis of scientific research on improving the peg drum for cleaning fine impurities from cotton reveals that studies have been conducted on the use of composite materials and the optimization of the working surface designs of technological equipment. These studies aimed to enhance their properties, structure, composition, as well as their physical, chemical, mechanical, and operational characteristics. As a result, it has been possible to preserve the natural properties of cotton to a certain extent by protecting it from mechanical damage. However, insufficient research has been conducted on improving the material of the peg itself—the main technological working part of the drum for loosening fibrous materials—or on increasing its productivity [2].

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The raw cotton opening and cleaning drum enables the cleaning of fibers from fine impurities, their separation, and the acquisition of high-quality cotton fiber. The opening drum consists of longitudinal rows fixed to a cylindrical rim, with pegs fastened in each row, the tips of which form a sinusoid. These pegs are positioned at an angle in the radial plane corresponding to each row, which helps to improve and accelerate the process of cleaning fine impurities from the cotton. In this process, the seed cotton entering the drum is caught by pegs with curved surfaces and dragged along the mesh surface. The heads of the pegs, due to their curved profile and the curved surface of the drum, effectively capture the cotton fibers. The pegs, which constitute the working surface of the drum, are made of a multifunctional heterocomposite material resistant to impact and wear. Therefore, due to low friction between the cotton fiber and the peg, less fiber is retained on the peg's surface. This ensures the cotton moves in the desired direction along the mesh surface. This makes it possible to reduce the stagnation of cotton tufts in the cleaning zone, which in turn minimizes damage, especially to high-grade cotton [3-5].



Figure 1. General view of the equipment for cleaning fine impurities from 1XK variety seed cotton, made of ST4 Steel.

Figure 1 provides an analysis of modernizing the saw-toothed drum pegs of a fiber material cleaner made from ST4 steel. This modernization involves coating them with a wear-resistant polymer material to create cast pegs, which reduces the crushing of cotton fiber and seed, and extends the operational life of the equipment's working surfaces [6].

The cotton industry is a strategic sector of Uzbekistan's economy, and the reliable and long-term operation of primary cotton processing equipment is a crucial factor in determining production efficiency. The working components of cotton cleaning machines undergo intensive wear due to the effects of abrasive dust, mineral impurities, moisture, and continuous dynamic loads. As a result, the service life of the parts is shortened, the stability of the technological process is disrupted, and the quality indicators of the cotton fiber decline. Therefore, developing heterocomposite polymer material compositions with high wear resistance, corrosion resistance, and strength is a pressing scientific priority in modern materials science.

Research on the selection and scientific substantiation of binders and fillers for polyfunctional heterocomposite polymer materials used in mechanical engineering was conducted by Ziyamukhamedova, Bakirov, and Nurdinov [1]. The authors determined that the compatibility between the polymer binder matrix, mineral fillers, and modifiers defines the physical-mechanical and operational properties of the composition. They demonstrated that using natural mineral fillers

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enhances the material's hardness, wear resistance, and cost-effectiveness. These studies serve as a crucial scientific foundation for creating a new generation of heterocomposite materials for cotton ginning machines.

The development of the cotton and textile industry and the improvement of export-oriented production were investigated by Kholikov [2]. The author emphasizes that a key factor in increasing production efficiency within cotton and textile clusters is the use of modern technologies and high-reliability equipment. This further underscores the economic and practical importance of developing innovative materials that extend the service life of cotton ginning machine parts.

The physical and mechanical properties of machine parts made from polymer composite materials were investigated by Ziyamukhamedova, Bakirov, and Jalolova [3]. The research results revealed that the composition of the composite, the dispersity of the filler, and the degree of inter-component bonding directly affect the material's strength, hardness, elasticity, and wear resistance. The authors demonstrated that compositions with an optimal formulation can be successfully used as replacements for metal parts or as their protective coatings.

Begatov et al. studied the changes in the physical and mechanical properties of high-speed steel resulting from chemical-thermal treatment [4]. The research findings indicate that controlling the microstructure and hardness of the material's surface is a crucial factor in reducing wear intensity and extending service life. This approach also holds methodological significance for improving the technology of protecting the working surfaces of cotton ginning equipment parts with polymer composite coatings.

In studies conducted by Dalioev and Jo'rayev on optimizing the structural parameters of cotton cleaning equipment, the influence of a peg drum with elastic elements on the efficiency of cleaning cotton from fine trash was experimentally determined [5]. The authors demonstrated that the geometric parameters and material properties of the working components are among the primary factors determining the efficiency of the technological process. These results confirm the necessity of creating highly wear-resistant composite materials for these working components.

Daliev, Jo'rayev, and Bobomatov conducted full-factorial experimental studies on the design of elastic-supported cotton cleaners with mesh surfaces [6]. The research findings established that the surface condition and structural parameters of the working components significantly affect the quality of cotton cleaning and the operational reliability of the equipment. Therefore, it was substantiated that increasing the wear resistance of the working surfaces is intrinsically linked to material selection.

The structure formation processes in mixed matrices with natural reinforcing fillers have been thoroughly investigated by Ziyamukhamedova et al. [7]. The research established that the effective bonding of natural fillers with the polymer matrix leads to the formation of a dense spatial structure, increased mechanical strength, and improved wear resistance. These scientific findings are crucial for selecting the optimal composition of heterocomposite materials developed for cotton ginning machines.

Methods for the mechanical and chemical modification of epoxy binders using natural minerals were developed by Ziyamukhamedova and Shaymardanov [8]. The authors found that mechanochemical activation increases the dispersion of mineral fillers and strengthens the adhesive bond with the polymer matrix. Consequently, the physicochemical, tribological, and operational properties of the composite materials were significantly improved.

The mechanical properties of hybrid-structured heterocomposite polymer materials and coatings utilizing local raw and energy resources were studied by Jalolova and Ziyamukhamedova [9]. According to their research, using local mineral components not only increases the material's hardness,

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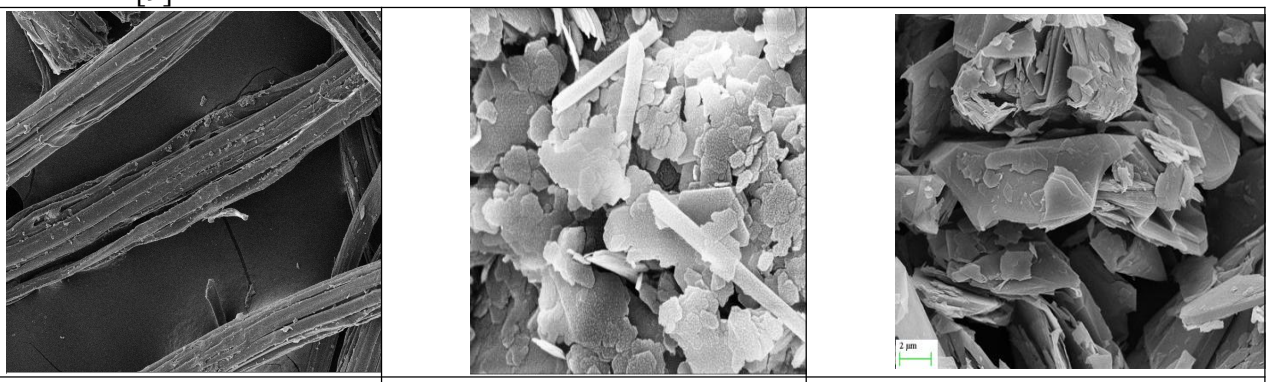
impact resistance, and wear resistance but also reduces production costs. This enables the creation of economically efficient compositions for the cotton ginning industry.

The technical specifications and grades of kaolin, a common component in composite materials, are defined in the O'zDSt 1056:2014 standard [10]. This standard regulates the granulometric composition, purity level, and application areas of kaolin, serving as a normative basis for its selection as a mineral filler in polymer compositions.

A methodology for determining the hardness of protective-decorative coatings by the scratch method is provided in GOST 27326–87 [11]. This standard is one of the main testing methods used to evaluate the surface strength and performance properties of composite coatings. This methodology allows for an objective assessment of the quality indicators of the heterocomposite polymer materials being developed.

For coating the actual contact surfaces of cotton cleaning drum pegs with wear-resistant materials and for the application of cast parts, ED-20 epoxy reactoplast was selected as a binder. The hardening component, polyethylene polyamine (PEPA), along with kaolin, technical carbon, and silk processing industry waste (SPIW), were chosen from local raw materials. These materials were selected for their advantages, which include high density, moisture/water resistance, resistance to highly aggressive liquid and gaseous chemical environments, mechanical strength, high corrosion resistance, thermal resistance, ability to operate at low temperatures, good adhesion to metal surfaces, ease of use, and environmental safety, among others [7-8].

The properties of composite materials are improved by incorporating various types of dispersed and fibrous fillers. The purpose of using dispersed fillers in polymer composite materials is to enhance the material's physical and mechanical properties, increase its operational performance, and reduce its cost. Fibrous fillers improve the deformational properties of polymer materials. Additionally, these fibers are superior to other types because they effectively absorb the binder and do not form brittle structures on the fiber surface or at the binder interface. Morphological analysis (Fig. 2, a) showed that the unevenness of the fiber surfaces and the absorbency of the binder ensure the strength of the composite material. This, in turn, can extend the service life of parts operating under conditions of frictional wear. [9].



a b c

Figure 2. Microstructure of materials obtained with a Gemini 500 (FE-SEM) scanning electron microscope: (a) Short-fiber silk processing waste, (b) AKF-78 grade kaolin, (c) Technical carbon

The hardness of wear-resistant composite polymer materials was determined based on the GOST 27326-87 standard, which is designed for determining the hardness of decorative coatings. The essence of the method involves measuring the width of the scratch left on the material's surface by a

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diamond needle, which has a tip angle of (45±10) °, under the influence of a load from a sclerometer [10].

Structural Analysis. A Gemini 500 (FE-SEM) field-emission scanning electron microscope was used to conduct structural studies on fillers obtained through the mechanical activation method. The Gemini 500 (FE-SEM) is a high-precision device that enables the research of nanoscale particles. Such devices provide excellent resolution and image quality at both high and low accelerating voltages.

Conclusion.

Conducted studies show that adding self-lubricating dispersed fillers, such as graphite, to the composition of heterocomposite polymer materials ensures the material's wear resistance. However, the mechanical activation of these particles facilitates their absorption into the structure of other fillers, thereby ensuring uniform mechanical properties of the composite material throughout the volume of the part. The metal oxides in the kaolin, added as a dispersed filler, increase the hardness of the composite material and ensure its long-term performance. The fact that the coefficient of friction in the metal-polymer pair decreases in direct proportion to the applied load and inversely to time leads to the conclusion that this composition will behave similarly when in contact with cotton.

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