


RESEARCH ARTICLE | JUNE 17 2025

## On the mechanism of physical and chemical interactions of components of composite polymer materials filled with inorganic and organic ingredients

Nodira Abed ; Soyibjon Negmatov; Komila Negmatova; Olim Eshkobilov; Malokhat Tukhtasheva; Murodillo Rakhimov; Burkhon Khaminov; Nurillo Ikromov

*AIP Conf. Proc.* 3286, 020005 (2025)

<https://doi.org/10.1063/5.0280151>



View  
Online



Export  
Citation

### Articles You May Be Interested In

Research of internal stresses of polymer and paint coatings by console and force methods formed by amine and isocyanate hardeners

*AIP Conf. Proc.* (June 2025)

Elastomeric materials based on new ingredients

*AIP Conf. Proc.* (June 2022)

Determination of optimum geometrical parameters of the working bodies of cotton processing machines and mechanisms

*AIP Conf. Proc.* (June 2025)

# On the Mechanism of Physical and Chemical Interactions of Components of Composite Polymer Materials Filled With Inorganic and Organic Ingredients

Nodira Abed<sup>1, a)</sup>, Soyibjon Negmatov<sup>1</sup>, Komila Negmatova<sup>1</sup>, Olim Eshkobilov<sup>2</sup>, Malokhat Tukhtasheva<sup>3</sup>, Murodillo Rakhimov<sup>3</sup>, Burkhon Khaminov<sup>1</sup>, and Nurillo Ikromov<sup>4</sup>

<sup>1</sup>Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan

<sup>2</sup>Karshi Engineering Economic Institute, 180100, Karshi, Uzbekistan

<sup>3</sup>Tashkent institute of Chemical technology, Tashkent, Uzbekistan

<sup>4</sup>Andijan Mechanical Engineering Institute, Andijan, Uzbekistan

<sup>a)</sup> Corresponding author: [abed.n.s@inbox.ru](mailto:abed.n.s@inbox.ru)

**Abstract.** This paper examines the mechanism of physical and chemical interactions of components of composite polymer materials filled with inorganic and organic ingredients. Fillers significantly improve the properties of polymers due to structural changes that occur during the filling of polymers, caused by various types of physical-chemical interactions between polymer macromolecules and surface functional groups of the filler. A chemical interaction occurs between the filler and the polymer. As a result, a dense adsorption layer and adhesive bonds are formed between the polymer macromolecules and the structural groups of the filler particles. In this case, along with hydrogen-oxygen or hydrogen-carbon bonds, the formation of adhesive bonds also occurs due to weak Van der Waals attractive forces with a bond energy  $E=0.1-1.0$  kcal/mol, and due to molecular interaction, arising between polyolefin macromolecules and structural groups of filler particles. In this case, the intermolecular bonds between polymer macromolecules are strengthened, improving the properties of composite polymer materials.

**Keywords.** Composite polymer materials, organic and inorganic ingredients, adsorption, polyolefin macromolecules, polydispersity, mechanic activation.

## INTRODUCTION

As is known, in recent years, composite polymer materials (CPM) have been widely used as materials for structural purposes in various sectors of the economy. In Uzbekistan, research is also being widely conducted in the field of developing effective CPM as substitutes for metal parts of the working bodies of cotton processing machines and mechanisms [1, 2]. CPM intended for use in interaction with raw cotton must meet specific requirements and have: high thermal and electrical conductivity, low coefficient of friction, antifriction and wear-resistant properties, sound and vibration-absorbing properties, good rheological properties [3,4].

The development and implementation of innovative technologies in the field of composite materials science, which ensures the improvement of technological equipment for processing raw cotton, is an important task [5,6].

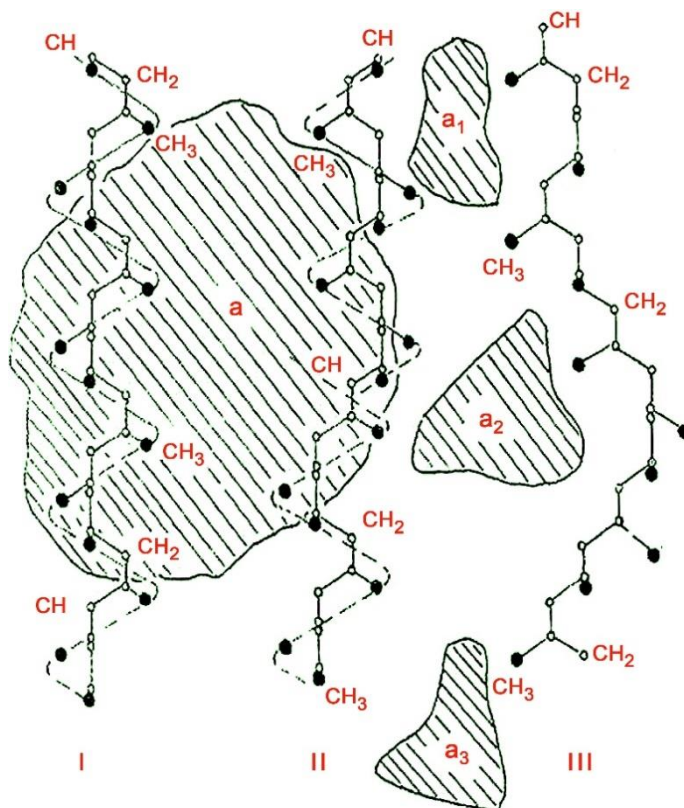
Molecular-mechanical-electrical theory [7,8], which explains the processes occurring during contact interaction of a material with a fibrous mass, is considered one of the fundamental ones for modern materials science and tribology. Based on this theory, a comprehensive study of the processes occurring in the “polymer-filler” and “composite-cotton” systems [9,10] allows us to identify patterns of formation of interphase interaction in polymer compositions depending on the type of polymer binders, the nature, content and structure of fillers and raw cotton, to develop effective anti-friction, anti-friction and wear-resistant composite [11,12] polymer materials that increase the performance and efficiency of the working parts of cotton ginning and cotton processing machines and mechanisms [13,14].

## METHOD

The study of adsorption and adhesion interactions of polymer molecules with the surface of fillers is one of the most important factors determining the properties of filled and reinforced polymer systems, especially at the surface of activated fillers [15]. Considering filled systems from the standpoint of physical chemistry, one can notice an increase in density in filled polymers due to the adsorption of polyolefin macromolecules on the surface of the fillers, leading to a change in packing density. In the presence of fillers, there is some limitation in the mobility of polymer macromolecules in the surface layer and at the interface, due to the interaction of polymer molecules with the filler surface [16]. Moreover, the larger the surface of the filler, the more the mobility of polymer chains is limited during the formation of the surface layer and the looser the packing of molecules in these systems becomes. In this case, a change in the distribution of intermolecular forces occurs and all this is reflected in the packing density of macromolecules [17].

For a more complete understanding of these interactions, let us consider the structural features of the structure of polymers and used fillers such as kaolin and carbon-graphite filler such as soot.

Figure 1 shows the spatial structure of the linear polypropylene chain: chain I has a left-handed rotation of the helix, chain II has two sections of the chain that differ in the spatial arrangement of methyl groups - the lower section has left-handed rotation, and the upper section has right-handed rotation. Chain III is one of the possible forms of the chain having an atactic structure. Chain I is called isotactic, chain III is called atactic, chain II is a stereoisomer.



**FIGURE 1.** Spatial structure of sections of the chain of linear polypropylene with fillers: - a spiral along which the polymer chain is located; a, a<sub>1</sub>, a<sub>2</sub>, a<sub>3</sub> - filler particles (particle sizes are relative).

The mechanical properties of polypropylene (PP) depend on the average molecular weight of the polymer, polydispersity and the content of the atactic phase. A decrease in molecular weight, an increase in the content of the atactic phase and all other changes leading to a weakening of stereoregularity occur when tensile loads on the polymer are applied with a force of 200-300 MPa. Moreover, the destruction of the structure is irreversible. A similar tendency is observed when PP is heated to a temperature exceeding its melting point, equal to 433-448 K. Above this temperature, for example, at 513 K, PP easily melts, forming a viscous-flowing mass. In this state, the PP is irreversibly destroyed. When cooled, its crystal structure is not fully restored and the content of the atactic phase increases

significantly. This explains the leveling of the effect of the presence of fillers in CPM, for example, in antifriction-wear resistant polypropylene composition [18].

As is known, fillers are introduced into a polymer in order to improve its certain properties. However, this is not enough if the technology for the synthesis of composite polymer materials is not optimal and destroys the crystalline structure of the polymer. In an amorphized polymer, the content of isotactic and stereoregular phases is significantly reduced and, accordingly, the content of the atactic phase is increased. Another significant factor that determines the properties of filled compositions is the strength of the bond between the filler particles and the polymer, the conformation and packing density of polymer macromolecules in the adsorption layer, as well as the quality of the polymer layer between the particles, i.e. saturation of this layer with isotactic phase. The chemical interaction of fillers with PP described above with a binding energy  $E = 8-20$  kcal/mol ensures the formation of a dense adsorption layer on filler particles. However, the effectiveness of this mechanism on changing the physical and mechanical properties of the polymer depends on the dispersion of the fillers [19].

One can easily imagine a situation where, for example, in the interval between macromolecules I and II of PP (Fig. 1) single large filler particles (a) are localized, and a situation where these lonely large particles are replaced by many small particles ( $a_1, a_2, a_3$ ) (in the figure between macromolecules II and III) obtained mechanical activation (grinding) of such a large particle (a).

Let's consider the physical-chemical interaction of fillers with PP. Under the technological conditions of CPM synthesis, filler particles are wetted by the fused polymer. Adhesive bonds are formed due to weak Van der Waals attractive forces with bond energy  $E = 0.1-1.0$  kcal/mol and due to physicochemical interaction forces that arise between PP macromolecules and structural groups of filler particles. From the available information it is clear that in the PP macromolecule, among the hydrogen atoms, the most mobile and positively charged, i.e. active are the hydrogen atoms located in the  $\alpha$ -position to the methyl groups. Therefore, most likely, it is these hydrogen atoms that are most involved in the chemical interactions of PP macromolecules [20].

One of the important methods for quantitative assessment of changes in the structure of a polymer in the presence of a filler is the specific surface area and pore volume, which provide valuable information about the packing density of macromolecules, the size of supramolecular formations, the nature of the occurrence and development of defects, and the stress distribution in the system as a whole.

## RESULTS AND DISCUSSION

In accordance with the above, it was of interest to study the influence of both non-activated and mechanically activated fillers on the nature of changes in the structure of polyolefins [21]. It has been established that during mechanical processing of an aluminosilicate filler such as kaolin and a carbon-graphite filler such as soot under the influence of impact-splitting-abrasion deformation, they undergo significant structural changes, in particular, an increase in specific surface area, adsorption capacity and the manifestation of active centers depending on the conditions of mechanical activation (Table 1).

**TABLE 1.** Adsorption characteristics of fillers.

Index	Name of fillers			
	kaolin		soot	
	original	activated	original	activated
Specific adsorption surface, $m^2/g$	24	35	152	184
Adsorption of dibutyl phthalate, $sm^3/100$ g	31	43	90	110

As can be seen from the data in Table 1, mechanical activation helps to increase the specific surface area and improve the adsorption characteristics of fillers.

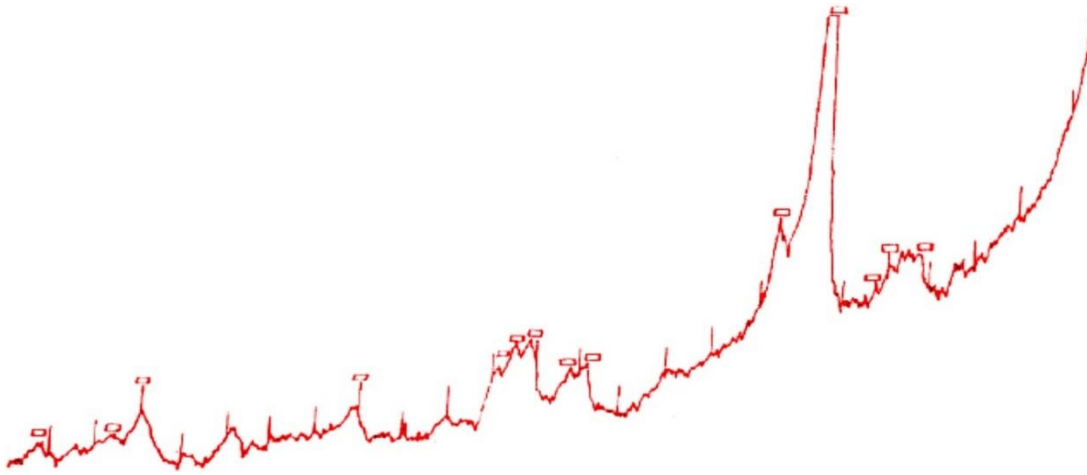
An X-ray diffraction pattern of the original secondary enriched kaolin from the Angren deposit is shown in Fig. 2, from which it can be seen that Angren kaolin consists mainly of kaolinite with a refractive index  $N_g = 1.561$ ; single grains of iron, mica, etc. are found as impurities [22].

Interplanar spacing of kaolinite  $d/n = 0.436; 0.384; 0.356; 0.255; 0.248; 0.237; 0.233$  nm. Kaolinite contains quartz with  $d/n = 0.424$  as impurities;  $0.417; 0.334; 0.245; 0.228$  nm, hydromicas with  $d/n = 0.445; 0.245; 0.255; 0.212$  nm.

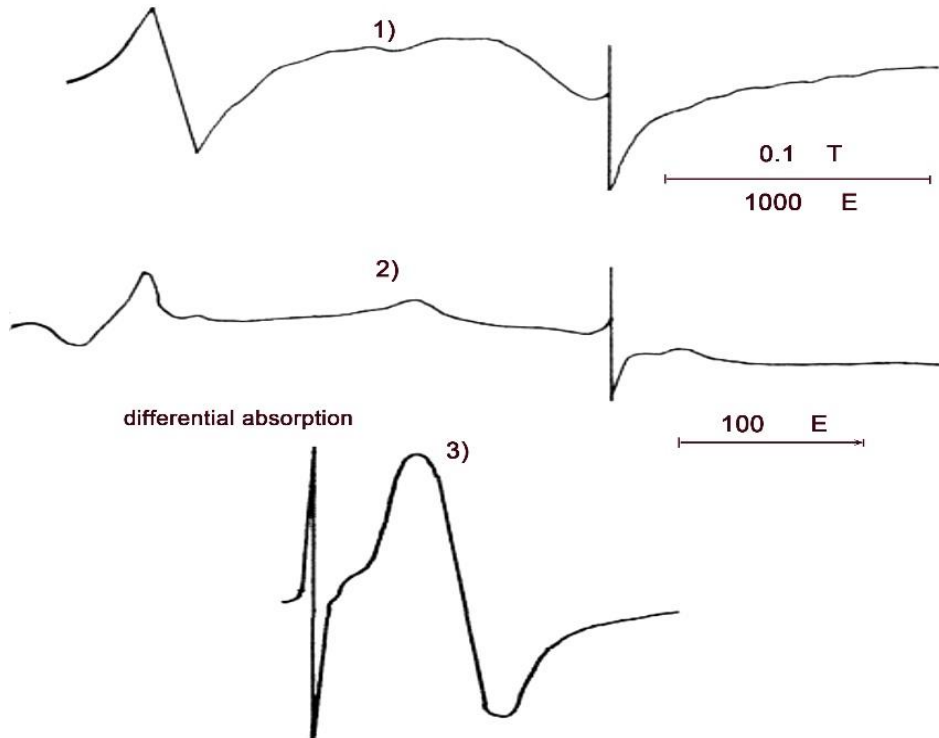
The results of studying the properties and structure of secondary enriched kaolin are of great interest for studying the possibility of its use as an inorganic filler in the production of polymer composite materials.

Kaolin is used as an inorganic filler due to its high plasticity, binding ability, high dispersibility and sufficient mechanical strength of dried samples [23].

A study of the EPR spectra of mechanically activated kaolin from the Angren deposit indicates an increase in the intensity of a single signal in the regions of  $g$  - factor 2.0036 ( $\Delta H = 740$  Oe) and  $g$  - 4.0002, close to the  $g$  - factor of diphenylpicrylhydrazine, characteristic of a stable radical (Fig. 3). The data obtained indicate the radically active nature of mechanically activated fillers. Due to the radical activity of mechanically activated fillers under the conditions of CPM processing, radical processes can occur with the formation of chemical bonds with the active centers of polyolefins, leading to structural changes on the surface layer of the filler compared to traditionally filled polymer materials.



**FIGURE 2.** X-ray diffraction pattern of secondary enriched kaolin from the Angren deposit.

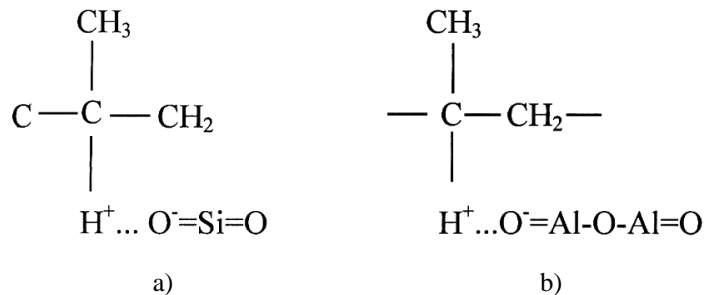


1 – mechanically activated kaolin; 2 – initial kaolin; 3 – mechanically activated soot

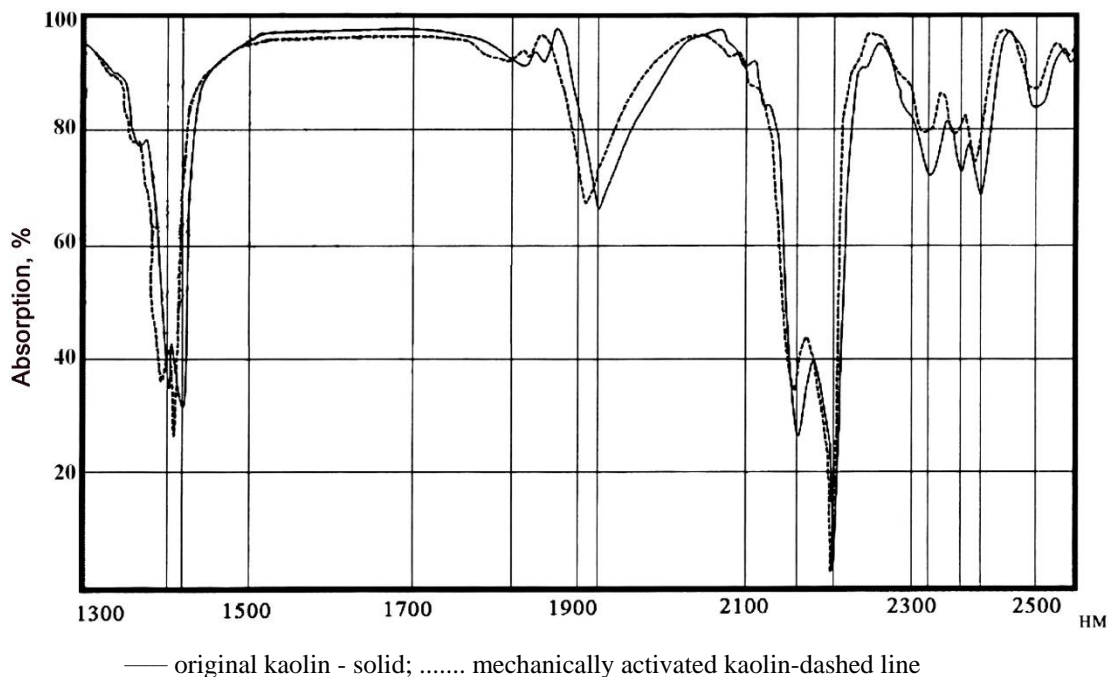
**FIGURE 3.** EPR spectra.

*PP + kaolin system.* Kaolin consists mainly of the mineral kaolinite - aluminum hydrosilicate -  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ . When using kaolin as a filler with PP, the main metal oxides of the kaolinite components ( $\text{Al}_2\text{O}_3$ ,

SiO<sub>2</sub>, H<sub>2</sub>O) interact with the hydrogen atoms of PP, located in the α-position to the methyl groups, with the formation of hydrogen bonds according to the scheme:



In this regard, the IR spectra of unactivated and activated kaolin were studied, which are shown in Fig. 4. As can be seen from the presented IR spectra (Fig. 4), the presence of absorption bands of OH groups in the regions of 1398-1416 and 1389-1416 nm is characteristic of both the original and mechanically activated kaolin samples from the Angren deposit.

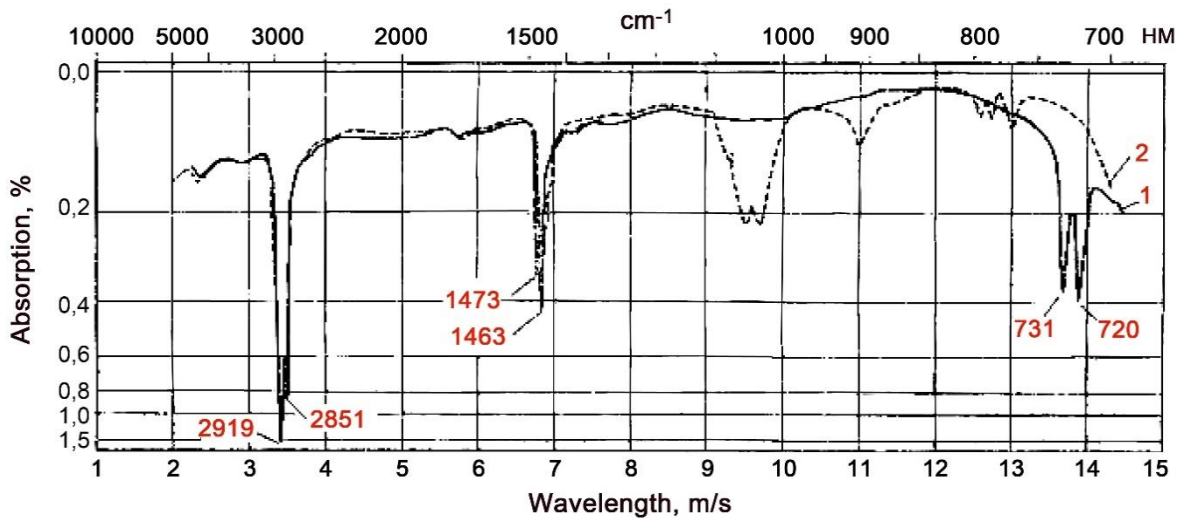


**FIGURE 4.** IR spectra of original and mechanically activated kaolin.

The intensity of stretching vibrations of Si-O bonds is observed in the regions of 2208-2162 and 2208-2162 nm. The triplet maxima in the regions 2381-3218-2356 and 2380-2356-2318 nm indicate slight deformation of the silicon-oxygen tetrahedra. The results of IR spectroscopic studies indicate some structural changes in the process of mechanical activation [24].

Of particular interest is the study of interaction processes occurring in the polyethylene + kaolin system using IR spectroscopy (Fig. 5).

As is known, in the IR spectrum of the original high-density polyethylene, characteristic absorption bands are observed: stretching vibrations of CH<sub>2</sub> - groups in the region of 2900 cm<sup>-1</sup>, a doublet of bending vibrations of CH<sub>2</sub> - groups in the region of 1470 cm<sup>-1</sup> and a doublet of pendulum vibrations of CH<sub>2</sub> - groups in the region of 720 cm<sup>-1</sup>.



1- unfilled polyethylene; 2 - filled polyethylene

**FIGURE 5.** IR spectra of unfilled and filled polyethylene.

From the analysis of the presented IR spectra (Fig. 5) it is clear that the introduction of activated kaolin into the composition of polyethylene leads to a slight change in the spectrum of the polymer with the appearance of characteristic absorption bands in the region of 700 – 1150  $\text{cm}^{-1}$ , related to the bond of metal oxide. Similar changes in the IR spectra are also observed in polyethylene filled with talc and wollastonite [25].

*System PP + carbon black, PP + graphite.* It is important to note that the viscoelastic properties of filled polyolefins are primarily determined by the nature of the filler surface chemistry, the network structure of the filler, the degree of interaction between the polymers and fillers, and the molecular mobility of the chains.

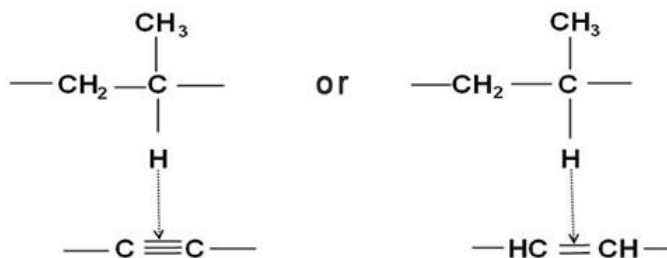
In this regard, of particular interest are CPM consisting of polypropylene + carbon black, which are a microheterogeneous system of polyolefin macromolecules adsorbed on the surface of the carbon black.

In the PP + carbon black system, carbon black particles with PP form an enhanced microheterogeneous structure due to the adsorption and orientation of macromolecular sections, leading to a noticeable increase in the strength characteristics of PP [26].

It would be reasonable to assume that, due to the specific chemistry of the surface of dispersed carbon, the presence of polar functional groups: carboxyl, phenolic, hydroxyl, aldehyde, cationic and others is of significant interest in creating CPM with high strength and wear resistance.

The structural formula of soot can be conventionally represented as  $(-\text{C} \equiv \text{C}-)_{n_1}$  or even  $(=\text{C}=\text{C}=\text{C})_{n_2}$ , where in both cases  $\pi$  - bonds are present in the soot molecules.

The presence of unpaired  $\pi$  - electrons in the structure of acetylene soot, giving narrow single signals, is characteristic of free radicals with a PMF concentration of  $1 \cdot 10^{14}$  spin/g (Fig. 2), which indicates the possibility of forming complexes with PP hydrogens according to the scheme:



This bond, due to the mobility of its constituent electron pair, easily interacts with the  $\alpha$ -hydrogens of PP with the formation of not very strong, so-called  $\pi$ -complexes.

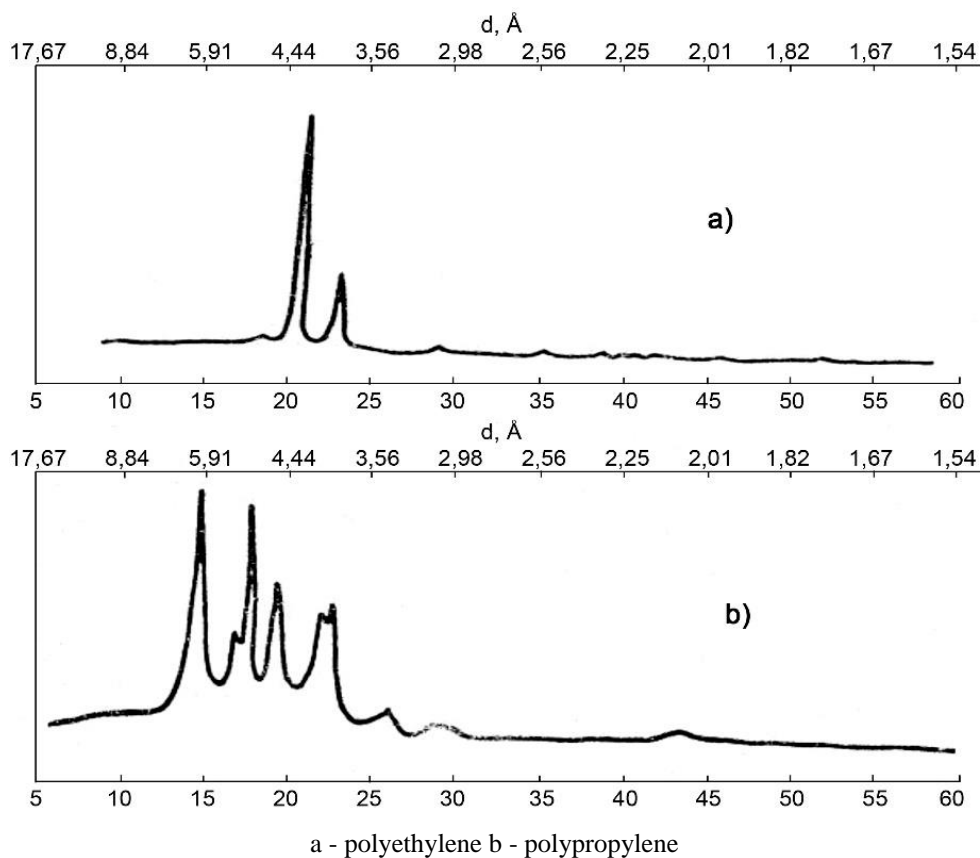
Under the conditions of processing a soot-filled polypropylene composition by injection molding at elevated temperatures, it is possible that  $\alpha$  - hydrogen interacts with active centers in the soot structure, leading to cross-linking of PP macromolecules.

Similar patterns of molecular interaction formation were observed when mechanically activated graphite was used as a filler in polymer composite materials. In this case, each carbon atom is connected to the neighboring three  $\sigma$  - bonds, and the fourth electron actually remains unpaired. Because of this, the elementary unit of graphite is significantly reactive and very prone to forming hydrogen bonds, in particular, with the  $\alpha$  - hydrogen of PP macromolecules.

In addition, during the formation of composite materials under the influence of elevated temperature,  $\alpha$  - hydrogen can be detached from PP macromolecules. As a result of this, obviously, cross-linking of PP macromolecules can occur through graphite [27].

Summarizing the above, we can come to the conclusion that all functional groups on the surface of dispersed carbon are characterized by different degrees of activity and affect the molecular composition of the adsorption layers. It is noted that with an increase in the oxygen content to 5-6% in the functional groups of carbon black, the intensity of its interaction with polymers increases, creating favorable conditions for enhancing interfacial interaction, leading to an increase in the physical and mechanical properties of the CPM.

Figure 6 shows X-ray diffraction patterns of polyethylene and polypropylene.



**FIGURE 6.** X-ray patterns of polyethylene and polypropylene.

Analyzing the X-ray diffraction patterns (Fig. 6), it can be said that fine fillers mainly accumulate in less ordered regions of polyethylene and polypropylene, creating an increased concentration. This explains the increase in the strength characteristics of composite polymer materials.

The results of studies of mechanically activated fillers, both inorganic and organic in nature, using microscopy, X-ray diffraction analysis, EPR and IR spectroscopy allow us to consider the noticeable influence of mechanical activation not only on the degree of dispersion, but also on the structure of fillers, which play a significant role in the formation of adhesive bonds, and, consequently, on the energy of interfacial interaction at the polymer-filler interface, which leads to enhanced properties of filled polymer composite materials [28].

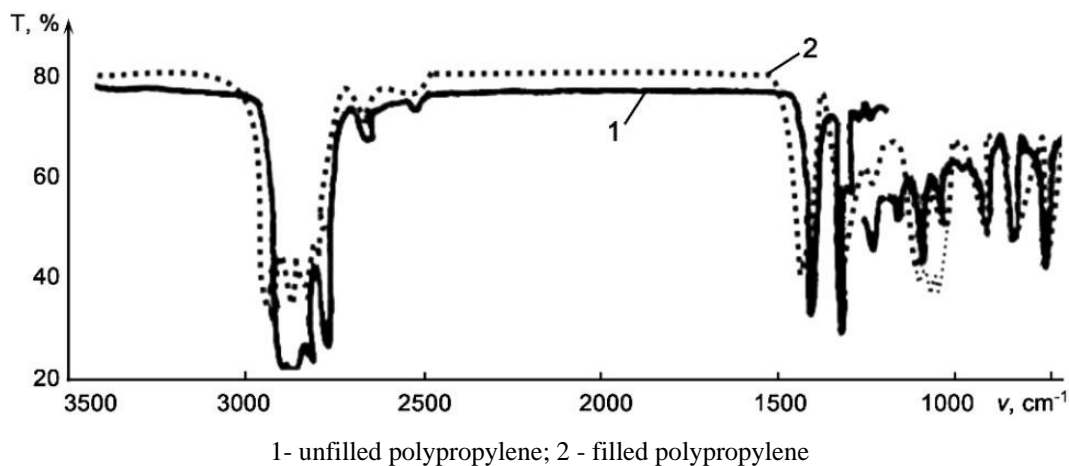
*PP system + fiber fillers (fiberglass, cotton lint).* Fiberglass - an artificial fiber obtained by stretching or dismembering molten glass composition, weight. %: SiO<sub>2</sub> - 56; Al<sub>2</sub>O<sub>3</sub> - 5; CaO - 22; Na<sub>2</sub>O - 11; MgO - 6. It has high mechanical strength, chemical resistance and heat resistance.

The main components are the oxide components of glass fiber, capable of forming hydrogen bonds between the  $\alpha$ -hydrogens of PP and the oxygen atoms present in metal oxides.

Filling polyolefins with glass fibers opens up broad prospects for creating CPM with improved performance properties and increases the elastic modulus and corrosion resistance of parts of rubbing pairs of working bodies of cotton processing machines. The previous section showed an improvement in the physical and mechanical properties of PP containing glass fiber as a filler, due to the occurrence of physical and chemical interactions between mobile hydrogen atoms in the  $\alpha$  position and active centers on the surface of the glass fiber [29].

It should be noted that in the IR spectrum of the original polypropylene there are stretching vibrations of  $\text{CH}_2$  groups in the region of  $2920\text{--}2875\text{ cm}^{-1}$ , bending vibrations of  $\text{CH}_2$  groups at  $1435\text{ cm}^{-1}$ , asymmetric bending vibrations of  $\text{CH}_2$  groups in the region of  $1460$  and  $1454\text{ cm}^{-1}$ , symmetrical bending vibrations of  $\text{CH}_3$  – groups appear in the region of  $1378\text{ cm}^{-1}$ . In the region of  $1200\text{--}1370\text{ cm}^{-1}$  there are torsional vibrations of  $\text{CH}_2$  groups and bending vibrations of  $\text{CH}$  groups. Absorption bands in the region of  $700\text{--}1200\text{ cm}^{-1}$  are caused by pendulum vibrations of the  $\text{CH}_3$  and  $\text{CH}_2$  groups.

In the IR spectrum of filled polypropylene, a rather intense absorption is observed in the region of  $500\text{--}1200\text{ cm}^{-1}$ , which is due to the absorption of silicon oxide (Fig. 7). It is also necessary to note a significant broadening of the band and its shift to the region  $1150\text{ cm}^{-1}$ , which can probably be explained by the interaction of the polymer binder with  $\text{SiO}_2$ . In this case, the strongest absorption lines in the IR spectra are the lines of  $\text{SiO}_2$  in the composition of the filler-glass fiber.

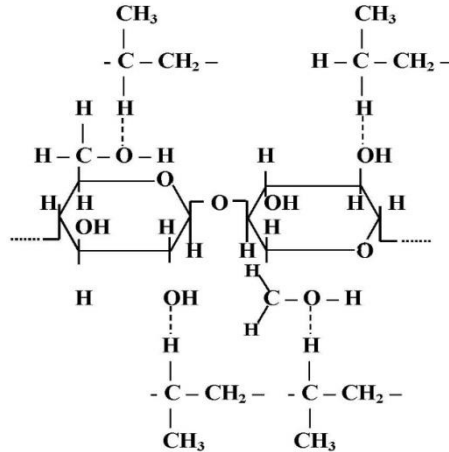


1- unfilled polypropylene; 2 - filled polypropylene  
**FIGURE 7.** IR spectra of unfilled and filled polypropylene.

Changes in the IR spectrum of the polymer binder are probably explained by the fact that molecular interactions occur in the polymer-filler system between active centers on the surface of the filler and polymer molecules. It is known that on the surface of quartz and other aluminosilicate fillers (kaolin, wollastonite) there are ion-exchange and chemically active areas. In this case, adsorption of polyolefins occurs on their surface. In the IR spectra of filled polyethylene and polypropylene, changes in the shape and position of the bands responsible for the stretching vibrations of bonds in polymers were recorded.

*Lint*- a waste product from the processing of cotton cellulose, is a polysaccharide built from elementary units of anhydro-D-glucose, which is saturated with hydroxyl groups. The latter interact with  $\alpha$  - hydrogen of PP, creating strong oxygen-hydrogen bonds [30].

As is known, cellulose, including lint, has strong interactions between macromolecules due to the presence of numerous hydrogen bonds, mainly between the oxygen atoms of hydroxyl groups and the hydrogen atoms of elementary units. Moreover, the oxygen atoms of the hydroxyl groups of lint can also interact with other hydrogen-containing reagents, including PP-type polymers due to the presence of more active  $\alpha$  - hydrogen atoms in its macromolecules according to the scheme:



Based on the results of IR and ESR spectroscopic studies and modern advances in the field of physical chemistry of filled polymer systems, the mechanism of interaction of polymers with inorganic and organic fillers in composite polymer materials can be presented as follows [31].

Under the technological conditions for the synthesis of CPM, filler particles are mixed with the fused polymer. In this case, the formation of adhesive bonds occurs due to weak van der Waals attractive forces with a bond energy  $E = 0.1-1.0$  kcal/mol, and due to the molecular interaction that occurs between polyolefin (PP) macromolecules and structural groups of filler particles. As is known, of the hydrogen atoms present in the PP macromolecule, they are the most mobile and positively infected, i.e. active are the hydrogen atoms located in the  $\alpha$  position to the methyl groups. Due to the nature of their electronic structure, these hydrogen atoms are probably more prone to participate in molecular interactions.

In the case of using mechanically activated aluminosilicate fillers, due to an increase in the specific surface area, in all likelihood, additional hydrogen bonds are formed and polymer chemisorption occurs on the developed surface of the filler due to interaction with active centers [32].

The data obtained indicate an increase in the surface contact area, and, consequently, the concentration of boundary layers, which ultimately leads to a change not only in the structure, but also in the properties of the composites.

It should be noted that fillers are also characterized by particle geometry, i.e. shape and size of particles and size distribution - polydispersity.

Mechanical activation increases the number of particles, the specific surface of particles and promotes the activation of the surface that occurs during the grinding of particles.

It is obvious that during the processing process, molecular interaction occurs between the active centers of filler particles and PP macromolecules. For large particles these connections are single in nature, and for small particles they are multiple in nature. In the latter case, strengthening of intermolecular bonds between PP macromolecules is observed, even if some of these macromolecules have an atactic structure. A peculiar cross-linking of PP macromolecules takes place. The observed picture can be represented as point reinforcement of the polymer, as a result of which a qualitatively new material is formed - CPM. This material, due to its perfect structure, will have improved physical and mechanical characteristics. At the same time, carbon black and graphite will reduce the coefficient of friction, wollastonite, lint, fiberglass will give composite materials greater wear resistance, chalk and kaolin will increase their hardness, wollastonite, lint and fiberglass will increase impact strength, bending strength, and in general, fillers will increase the elastic modulus and strength properties CPM [33].

In this regard, when producing composite polymer materials filled, especially with mechanically activated, mineral, carbon-graphite and fibrous fillers, a chemical interaction may take place between the filler and the polymer, resulting in the formation of strong bonds between the filler particles and the polymers, ensuring the formation of a dense adsorption layer and adhesive bonds that arise between polymer macromolecules and structural groups of filler particles. In this case, along with hydrogen-oxygen or hydrogen-carbon bonds, bonds also arise due to the action of van der Waals forces, and intermolecular bonds between polymer macromolecules are strengthened, improving the properties of composite polymer materials.

## CONCLUSION

It has been revealed that the physicochemical interaction of fillers with the polymer leads to the formation of strong bonds between the filler particles and the polymer, ensuring the formation of a dense adsorption layer and adhesive bonds that arise between the polymer macromolecules and the structural groups of the filler particles. In this case, along with hydrogen-oxygen or hydrogen-carbon bonds, bonds also arise due to the action of Van der Waals forces, and intermolecular bonds between polymer macromolecules are strengthened, improving the properties of composite polymer materials. In addition, it has been established that the structure of the composite polymer material is a highly crystalline polymer structure with an elastically rigid integral extended chain of particles of dispersed fillers associated with it.

Thus, the targeted use of combinations of organic-mineral fillers, due to the specific structure, creates favorable conditions for the processing of composite polymer materials with reduced shrinkage, sufficient density and improved mechanical and tribological characteristics, which are very important in the manufacture of parts from CPM of complex design.

## ACKNOWLEDGMENTS

I would like to thank all colleagues who worked closely on this paper.

## REFERENCES

1. S.S. Negmatov, A.N. Shernaev, G. Gulyamov, N.S. Abed-Negmatova, M.M. Saidov, D.H. Musabekov, Sh. S. Negmatov, M.I. Negmatova. Wear-resistant polymer composite filled with finely dispersed wood and carbon/graphite powders. *AIP Conf. Proc.* 11 July 2012; 1459(1):329–331 .<https://doi.org/10.1063/1.4738486>.
2. Musabekov, D., Abed-Negmatova, N., Gulyamov, G., Shernaev, A., Khodjimuradov, D., & Negmatov, S. (2011). Effective Composite Materials for Friction Pairs of Working Bodies of Cotton Machines. In *Advanced Materials Research* (Vol. 413, pp. 548–550). Trans Tech Publications, Ltd.
3. Negmatov Sh.S., Karimov N.N., Gulyamov G. Possibilities of ignition of raw cotton during its interaction with the working bodies of cotton machines // *Composite materials*. - Tashkent, 2007.- No. 1. – P.85-86.
4. N.S. Abed-Negmatova, G. Gulyamov, S.S. Negmatov, D.M. Hodzhikariev, J.N. Negmatov, Sh. Sh. Eminov, Sh. Bozorbaev, A. Aripova, M.I. Negmatova. Durability of composite polymer materials working in contact with pulp. *AIP Conf. Proc.* 11 July 2012; 1459(1):283–285. <https://doi.org/10.1063/1.4738470>.
5. Abed-Negmatova, N., Negmatov, J., Gulyamov, G., Yuldashev, A., Eminov, S., Bozorboev, S., Aripova, A., Negmatov, S., & Xojimuradov, D. (2011). Composite Polymer Materials and the Details Made of them for Cotton Machines and Mechanisms. *Advanced Materials Research*, 413, 535–538. <https://doi.org/10.4028/www.scientific.net/amr.413.535>.
6. Abed Negmatova, N. S., Negmatov, S. S., Gulyamov, G., & Negmatov, J. N. (2012). Antifriction Wear-Resistant Composite Materials and Details Made from them for Working Bodies of Cotton Machines and Mechanisms. *Advanced Materials Research*, 616–618, 2005–2008.
7. Negmatov S.S., Abed N.S., Gulyamov G., Eshkobilov O.Kh. Features of contact interaction of composite polymer materials with raw cotton in the process of friction. *IOP Conference Series: Materials Science and Engineering*, 1030, (2020). doi: 10.1051/e3sconf/202126405053.
8. Abed N.S., Gulyamov G., Tuhtasheva M.N., Eshkobilov O.Kh. Engineering composite materials for the cotton processing industry. *E3S Web of Conferences* 264, 05053, (2021). doi: 10.1051/e3sconf/202126405053.
9. Abed N.S., Eshkobilov O.Kh., Negmatov S.S., Gulyamov G., Investigation of the Process of Electrification of Composite Polymer Coatings in the Case of Frictional Interaction with the Fibrous Mass. *AIP Conference Proceeding* s2432, 050009, (2021). Doi: 10.1063/5.0089709.
10. Negmatov S.S., Abed N.S., Gulyamov G., Tuhtasheva M.N., Eshkobilov O.Kh., Karshieva Sh.Kh. Study of strength and coefficient of friction of composite materials in the process of contact interaction with raw cotton. *E3S Web of Conferences: Construction Mechanics, Hydraulics and Water Resources Engineering – CONMECHYDRO 2023*.
11. Eshkobilov O.Kh. Investigation of the contact interaction of the working bodies of machines with raw cotton. *E3S Web of Conferences* 365, 04001, (2023). doi:10.1051/e3sconf/202336504001.
12. Gulyamov G., Eshkobilov O.Kh. Composite polypropylene polymer materials that work in contact with raw cotton. In *E3S Web of Conferences* 264, 05055 (2021). doi: 10.1051/e3sconf/202126405055.

13. Tukhtasheva M.N., Eshqobilov O.Kh. Development of a disc tribometer and determination of its optimal parameters and modes of contact interaction of composites with raw cotton. *International Journal of Mechatronics and Applied Mechanics*, 2021, Issue 10. pp. 214–221. doi: 10.17683/IJOMAM/ISSUE10/V1.28.
14. Tukhtasheva M.N., Eshqobilov O.Kh. Investigation of antifriction properties of composite epoxy material in interaction with raw cotton. *International Journal of Mechatronics and Applied Mechanics*, 2022, Issue 12. pp. 134–139. doi:10.17683/ijomam/issue12.20.
15. Kholikulovich E.O. Prevention of the flammability of raw cotton with the use of composite polymer coatings in friction units. *International Journal of Mechatronics and Applied Mechanics*, 2023, Issue 13. –P. 243–252.
16. Alikulov, S., Eshqobilov O. Influence of the process of reserving filled containers of the cotton picker on the completeness of the cotton harvest. *E3S Web of Conferences*, 2023, 390, 06043. doi: 10.1051/e3sconf/202339006043.
17. Eshqobilov O. Improved installation for determining antifriction properties of materials. *E3S Web of Conferences*, 2023, 401, 04024. doi: 10.1051/e3sconf/202340104024.
18. Soyibjon Negmatov, Nodira Abed, Tulkin Ulmasov and Burkxon Khaminov. Thermodynamic compatibility and structural characteristics of interpenetrating polymer vibration damping systems for engineering purposes. *E3S Web of Conf.*, 401 (2023) 05095. DOI:https://doi.org/10.1051/e3sconf/202340105095.
19. Sergienko, VP, Bukharov, SN.N., Anisovich, A.G., N.S. Abed, A.Ya. Grigoriev. The Effect of a High-Frequency Electromagnetic Field on Dynamic Mechanical and Tribotechnical Characteristics of Frictional Composites with a Thermosetting Polymer Matrix. *J. Frict. Wear* 42, 401–407 (2021). https://doi.org/10.3103/S106836662106009X.
20. Bukharov, S.N., Tuleiko, A.S., Sergienko, V.P., Abed, N.S., Alexiev, A.R. Advanced Sound Absorbing Materials to Reduce Noise and Improve the Environmental Situation in Production Facilities and Transportation. In: Karabegović, I. (eds) *New Technologies, Development and Application IV. NT 2021. Lecture Notes in Networks and Systems*, vol 233. Springer, Cham. (2021).
21. A. Kh. Yuldashev, S.S. Negmatov, N.S. Abed-Negmatova, A.G. Abdurakhmanov, Sh. A. Bozorov, Sh. Sh. Eminov, A. Aripova, D. M. Khodjkariev. Melt index of low-density polyethylene and its effect on rotational molding. *AIP Conf. Proc.* 11 July 2012; 1459(1): 344–346. https://doi.org/10.1063/1.4738491.
22. Negmatov S.S. Fundamentals of the processes of contact interaction of composite polymer materials with fibrous mass. -Tashkent: Fan. 1984. – 296 p.
23. Simonov-Emelyanov N.D. and others. Structuring, compositions and properties of dispersed-filled polymer nanocomposites//Plastic masses. -Moscow, 2012. -No.6. -P. 7-13.
24. Lipatov Yu.S. Physical-chemical basis of polymer filling. –M.: Chemistry, 1991. -260 p.
25. Solomko V.P. Filled crystallizing polymers. –Kiev: Naukova Dumka, 1980. -264 p.
26. Trepinnik V.B., Lyubomov B.V. and others. Physical-chemical and technological foundations of mechanical activation of raw materials in the technology of building ceramics // *Ceramics*. -Moscow, 1988. -No. 4. –P.26.
27. Negmatov S.S., Gulyamov G. Mechanical activation of compositions based on thermoplastic polymers // *Scientific. conf. on modern problems of high-molecular polymers: Report - Bukhara, 1998.* –pp.72-73.
28. Negmatov S.S., Gulyamov G. Mechanical activation of filled polymer compositions / *Composite materials and their application: Coll. scientific tr.* -Tashkent: Fan vatarakkiyot, 1998. –P.7-10.
29. S.S.Negmatov, N.S.Abed, S.U.Sultanov, U.K.Kochkarov. Machine-building anti-corrosion composite polymeric materials and coatings based on local raw materials and production waste. *E3S Web of Conf.*, 401 (2023) 05042. DOI: https://doi.org/10.1051/e3sconf/202340105042.
30. Sanjar Sultanov, Komila Negmatova, Soyibjon Negmatov, Nodira Abed, Madina Babakhanova, Muxabat Matsharipova, Gulshan Valiyeva, Olloberdi Madraximov, Nilufar Umirova, Muxiba Babakhanova, Azizbek Nasriddinov; Anti-corrosion coating for engineering purposes. *AIP Conf. Proc.* 16 June 2022; 2432 (1): 050016. https://doi.org/10.1063/5.0090796.
31. Negmatov S.S. Operating conditions of the main working parts of machines and mechanisms for harvesting and processing raw cotton. - Tashkent: Uzbekistan, 1980.- 62 p.
32. Negmatov S.S., Gulyamov G. Mechanical activation of compositions based on thermoplastic polymers // *Scientific. conf. on modern problems of high-molecular polymers: Report - Bukhara, 1998.* –72-73 pp.