SCIENTIFIC BASIS FOR THE CREATION OF ANTIFRICTION COMPOSITE MATERIAL FOR USE IN CONDITIONS OF INTENSE WEAR

Anton Panda - Kristina Berladir - Konstantin Dyadyura

Abstract:
The increasing use as new structural materials, including special purpose currently, are composites based on amorphous-crystalline linear polymers such as polytetrafluoroethylene (PTFE). This material has unique antifriction properties, high chemical inertness, thermal and cold resistance. The advantage of these materials is in the higher values of their mechanical properties compared to amorphous polymers. However, low wear resistance and insufficient mechanical properties preclude its use in unfilled form. For PTFE there is a possibility of effective purposeful regulation of operational characteristics by filling and structural modifying by means of mechanical activation.
Key words:
Polytetrafluoroethylene, Polymer composite materials, Modification, Supramolecular structure, Mechanical Activation, Filling

Introduction

Design and creation of a new generation of machines with high technical and economic indicators, characterized by high reliability and durability, are closely connected with the use of new structural materials, including polymer. Modern polymer composite materials (PCM) have a high level of physical, mechanical and operational properties under intense operating conditions [1].

Compressor machines belong to the most common technical devices in all industries. Compressors of the piston type are widely used in many fields of technology. Their power is measured in thousands of kilowatts, the pressure reaches significant values. Piston compressors are irreplaceable in the chemical, petrochemical, gas and oil industries, energy, metallurgy and a number of other areas.

Specially designed (or upgraded) compressors are widely demanded that make compression without oil lubrication and are resistant to solvents, providing the required quality of the final product and the safety of compressing many aggressive and explosive gases. Obviously, in providing reliable and durable operation of compressors, the materials of piston and guide rings, as well as sealing seals, play a key role [1].

Seals of the piston and piston rods of such compressors are carried out using wear-resistant composites based on polytetrafluoroethylene (PTFE) and carbon fibers (CF) as the main filler. The efficiency of the use of piston rings and sealing seals from modern PTFE-composites in piston compressors consists in complete refusal to lubricate the friction units; reduction of friction coefficient and, as a result, electric power consumption; reduction of technological expenses for drying, clearing of the transported gas; enhancing the purity of the final product; possibility of using compressor technology in the medical and food industry, special industries.

Materials and Methods

Modification of polymers is a directional change of physical-chemical, mechanical or chemical properties of polymers (fig. 1) [4].

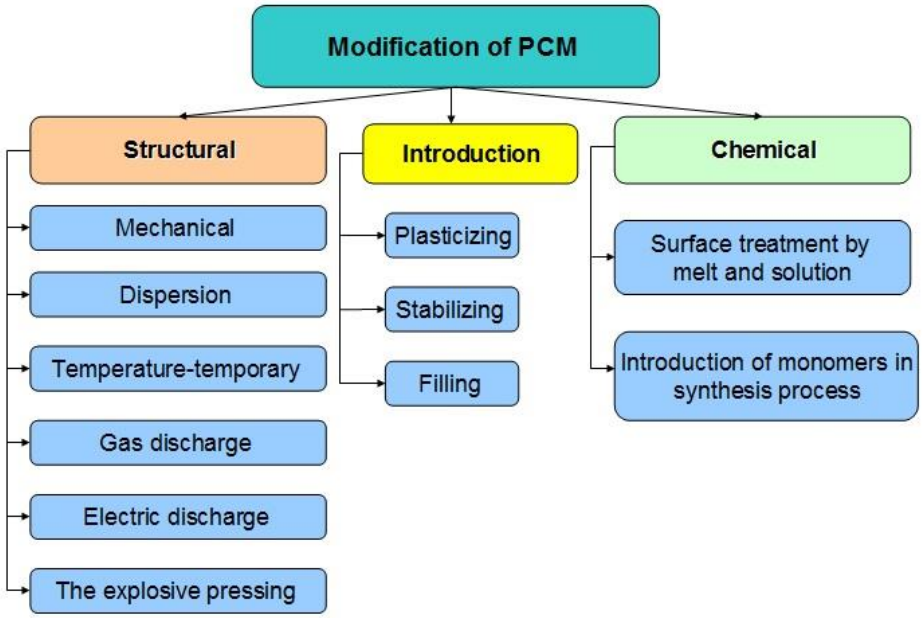

Fig. 1 Scheme of the main methods of modification PCM

1. Structural – modification of physical and mechanical properties without changing the chemical composition of the polymer and its molecular weight – changing SMS of polymer. For example, mechanical activation, shock and wave processing, radiation exposure, using magnetic and electromagnetic fields [5, 6].
2. Introduction to polymer substances that can interact with it, including high-molecular (plasticizing, stabilizing, filling). For example, introduction to PTFE various solid components [7]; matrix modifying by additions of activators of different size, shape and properties [8]; formation of nanopfase matrices with significantly different characteristics [9].
3. Chemical – influence on polymer of chemical or physical agents, is followed by change of the chemical composition of polymer and (or) its molecular weight, and also introduction at a stage of synthesis of a small amount of substance which enters with the main monomer in copolymerization or a sopolikondensation. In particular, the synthesis of polymer matrices of different composition and structure [10]; composition of polymer and oligomer mixture with different levels of interaction [11] etc.

It should be noted that the industrial implementation of these technologies is associated with significant energy, material and labor expenses and requires the managerial study of the price – quality relationship.

In such conditions, PTFE-composites very often determine the lifetime and durability of the compressor. Therefore, the development and selection of materials for details of friction units is the most responsible task of modern compressor construction [2].

The main criteria laid down in the development of antifriction composite materials with high physical and mechanical properties for use in conditions of intense wear, is:

- possibility to work without lubrication,

- reduced wear of the detail and connected surface,
- resistance to the chemical impact of aggressive environment,
- reliable operation at low temperatures.

As the polymer matrix, which most fully satisfies the above criteria, PTFE has been selected due to its unique properties (fig., a). It is an indispensable material in compressors that must provide high purity of compressed gases and are used in the chemical, food, pharmaceutical and other industries [3].

The choice of fillers for adding to the matrix is justified by the following considerations.

Uniqueness of PTFE properties, insufficient study of its physical structure and properties, insufficient informational content of researches of the interphase phenomena and structure-forming processes in case of mechanochemical activation and in the presence of fillers, insufficient study of influence of structure, structure and properties and manufacturing techniques on tribotechnical characteristics of materials on the basis of PTFE do them urgent about objects of further researches.

Results

The results of research in the field of PCM creation based on PTFE convincingly proved the effectiveness of the use of CF (fig. 1, b) [4, 5]. It is established that its optimum content in PTFE-composite varies in a wide range (5-20) mass. % depending on the grade of the filler [6]. The prospect of modifying the BB surface by mechanical activation is shown [7]. The development of various industries requires the creation of high-performance composite materials, at the same time, modern economic conditions require the receipt of composites not only with a high complex of characteristics, but also with a fairly low cost.

At present, the use of CF due to the high cost of complicates their mass application in the industry. Interest in the use of basalt fibers (BF), which is obtained from low-cost and cheap raw materials, has grown rapidly (fig. 1, c). [8]. The work [9] shows the promising use of BF as a reinforcing PTFE filler, including mechanically activated [10].

Solid lubricants are promising for the dispersed filling of fluoropolymers [11]. These include graphite and coke (fig., d). Introduction 15 wt. % graphite or 20 wt % of coke significantly increases the wear resistance of pure PTFE (in 100 and 600 times, respectively) [12]. This circumstance, as well as the availability and relative cheapness of the latter, determine their choice as dispersed PTFE fillers.

Kaolin is a natural substance and belongs to a group of geosilicates, which form the basis of the earth's crust and have a virtually unlimited raw material base (fig., e). The advantage of using this filler is significant industrial reserves in Ukraine and relative ease of extraction and affordable price making it competitive [13]. In addition, its influence on the structure and properties of PTFE has not been studied at all, although other mineral fillers, including mechanically activated, are quite widely used in antifriction PCM.

The particular interest is the study of the influence of the alloying admixture of ultradispersed PTFE (UPTFE) on the structure and properties of PTFE-composites (fig., f). Substantially differing in properties from industrial PTFE, UPTFE has a high thermodynamic compatibility with it, resulting in an effective interaction between them [14]. The noted features make it promising filler for composites based on PTFE.

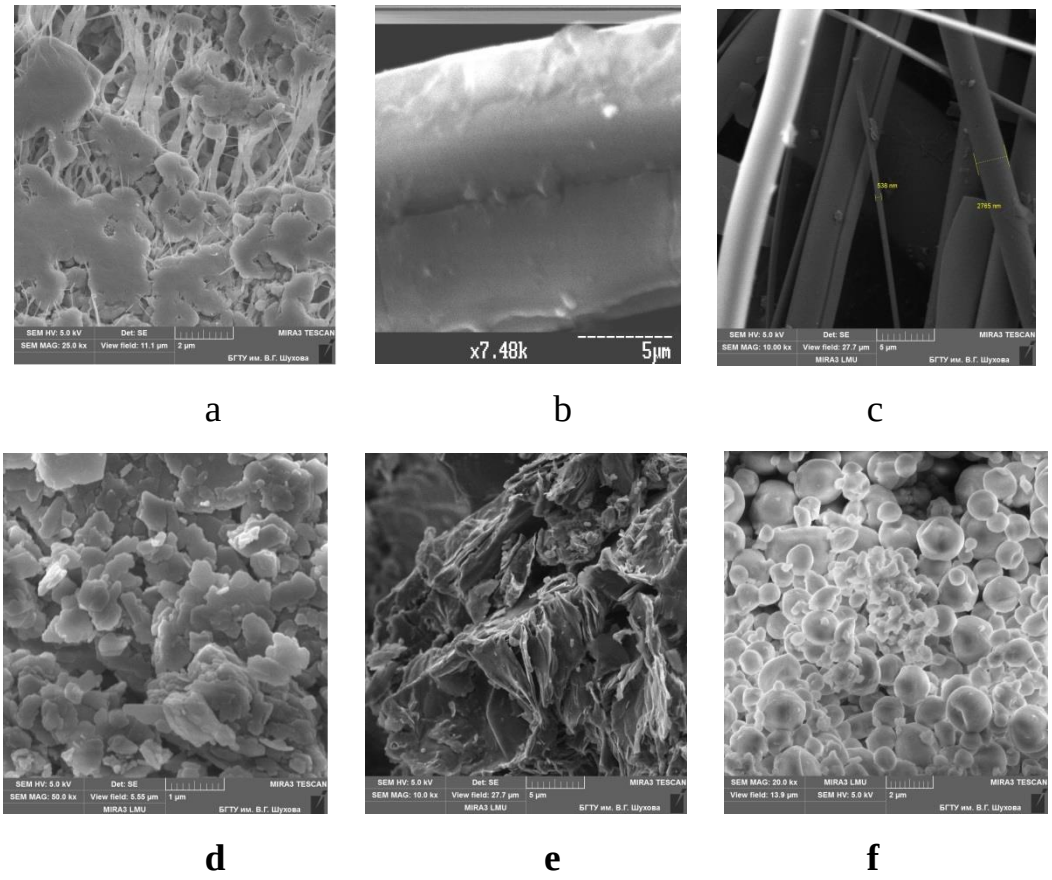

Fig. 1 Microstructure of: a) industrial PTFE brand F-4, b) fragment of CF, c) basalt ultrathin fiber, d) kaolin brand KS-1, e) graphite C-1, f) UPTFE brand "Forum"

Thus, the tendency to realize the tribological properties of polymers, naturally inherent to them, is determined by modifying their supramolecular structure. A convenient means of solving this problem are both traditional fibrous, dispersed and ultrafine fillers.

Conclusion

Uniqueness of PTFE properties, insufficient study of its physical structure and properties, insufficient informational content of researches of the interphase phenomena and structure-forming processes in case of mechanochemical activation and in the presence of fillers, insufficient study of influence of structure, structure and properties and manufacturing techniques on tribotechnical characteristics of materials on the basis of PTFE do them urgent about objects of further researches.

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