DEVELOPMENT OF POLYMER COMPOSITE FOR FRICTION UNITS IN THE MECHANISMS OF AUTOMOTIVE AND PROCESS EQUIPMENT

Anton PANDA - Kostiantyn DYADYURA - Mark BALYNSKYI

Abstract: Based on the established and generalized patterns of influence of various fillers on the structure, physicomechanical and tribological properties of polytetrafluoroethylene composites, a technique for designing sealing devices was developed. The proposed approaches provide an increase in the efficiency of application of these polytetrafluoroethylene composites for various types of sealing elements of sealing devices.
Key words: Polytetrafluoroethylene, Polymer composite materials, Modification, Supramolecular structure, Mechanical Activation, Filling

Introduction

Polymer composite materials (PCM) are widely used to transmit motion or change its relative speed due to the friction force between the drive and a driven members in friction clutches and gears, in disk, tape and brakes, as well as dampers [1, 2]. This allows the material to be reduced in design without losing the required strength and rigidity characteristics. To date, a large amount of research has been conducted in the field of materials science and the use of polymers and PCM in tribosystems. As a result of the conducted research, the efficiency of using polytetrafluoroethylene (PTFE) composites in tribo-conjugations, including in sealed units (SU) of movable joints, is shown, and a number of regularities of the formation of the structure and properties of composites using different fillers, production methods and modification. PTFE compaction are used in situations where conditions for temperature, chemical resistance, or friction or wear requirements do not allow the choice of products from many other materials [3, 4, 5, 6, 7].

Of great importance is the class of materials science tasks, which are aimed at developing and improving the technology of manufacturing new wear-resistant PCM. Their rational choice for specific friction units increase the reliability. In the process of designing structures on the basis of PCM, a preliminary calculation of deformation, strength and other structural characteristics is made. The analysis of these calculations in the future makes it possible to correct structural features by changing the mechanical properties of the composite and the design parameters (size, shape, etc.). The design process of PCM structures provides additional possibilities for controlling the mechanical properties of the composite by varying the matrix and fiber material brands, the size of the fibers, the reinforcing characteristics (direction, frequency, layout scheme), etc. For a rational choice of the above parameters, it is necessary to identify as precisely as possible the components of the stress-strain state of structures in real conditions of operation [2, 3, 4, 8, 9].

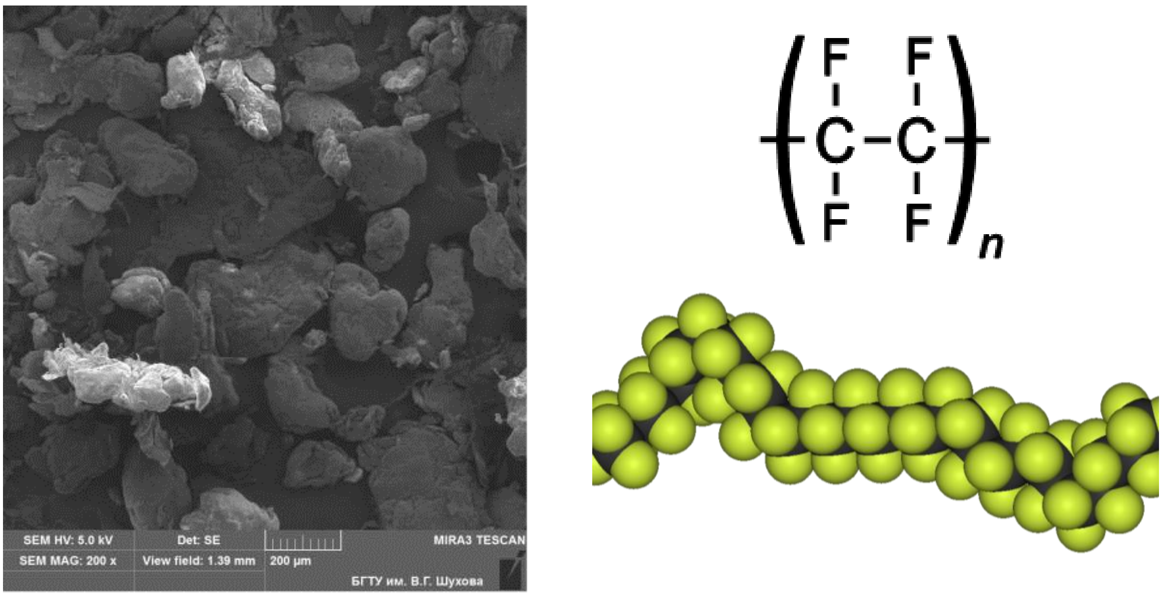
There is a significant number of mechanical aspects that need to be taken into account in the study of PCM. In particular, one of the main problems in solving problems of composite mechanics is an adequate determination of the elastic properties of composite material. In this task, the most common trend is to take into account the specific properties of the matrix and fiber (anisotropy, plasticity, visco-elasticity, etc.) in determining the properties of the composite, as well as taking into account the features of their joint deformation (the presence of a transition layer, adhesion, etc.). The process of calculating the stress-strain state of structures from composites without taking into account the anisotropic properties of the fiber and the matrix does not always give adequate results [2, 10].

A number of constructions from composite materials in real conditions of exploitation show a geometrically nonlinear nature of the relationship between stresses and deformations. The specified nature of deformation requires the development of conceptually new ways of its consideration [5, 6, 11, 12].

The paper proposes an integrated approach to solving this problem, which consists in the development of wear-resistant PCM, the methodological principles of their choice and effective application in sealing devices of mobile joints of engineering products.

Materials and Methods

The object of research - composites of tribotechnical purposes on the basis of PTFE with fillers of different chemical nature. In fig. 1, a shows the characteristic morphology of PTFE. The structure of the PTFE molecule is a linear chain of carbon atoms (Fig. 1, b), completely surrounded by fluorine atoms. Fluorocarbon bonds CF_2 are among the strongest among organic compounds.



a) b)

Fig. 1. The structure of the PTFE:
a) microstructure of industrial PTFE;
b) Molecular structure of PTFE

Consider the characteristics of physico-mechanical properties [10, 12, 14]. The basic properties are shown in Table. 1.

Table 1 The basic properties of PTFE

Properties	**Value**
Physical properties	
Density, g/cm^3	2.14 – 2.26
Thermal capacity, J/K	0.25
Thermal conductivity, W/(m·K	0.2

Mechanical properties	
Tensile strength (Moulding direction), MPa	200 – 300
Elongation at fracture, %	300 – 350
Modulus of elasticity, MPa	700

The seal consists of a polymer shell, which is tightened by a metal spring after installation in the seat groove (Fig. 2).

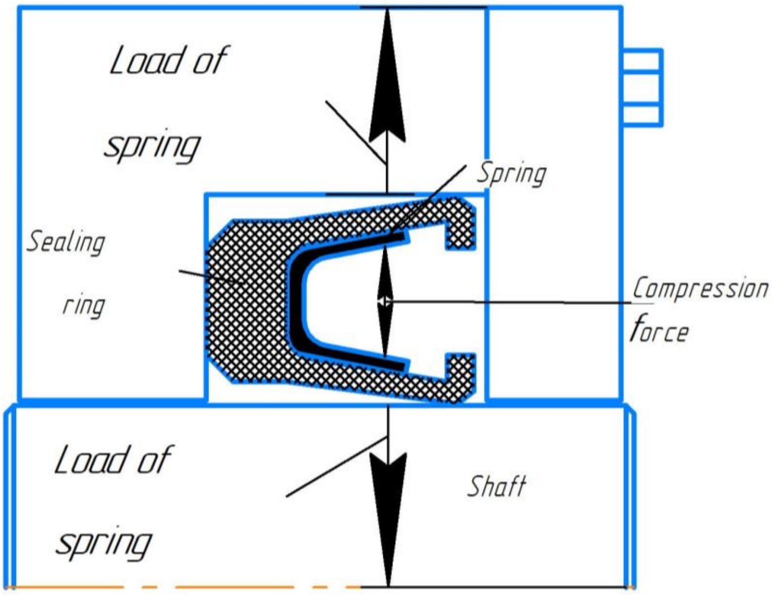


Fig. 2. The principle of operation of the sealing

The elastic spring element creates a constant force that pushes the sealing edges for sealing along the mating surfaces of the groove.
When modeling the stress-strain state of a rubber ring, finite elements were used for which the Mooney-Rivlin model was implemented [13, 15]:

$$W = C_{10} \cdot (I_1^* - 3) + C_{01} \cdot (I_2^* - 3) + \frac{1}{D_1} \cdot k(I_e^* - 1)^2 \quad (1)$$

where C_{10}, C_{01} and D_1 are material constants, I_1^*, I_2^*, I_e^* are reduced strain invariants

Constants of material can be used to calculate the initial shear modulus as follows:

$$\mu_0 = 2 \cdot (C_{10} + C_{01}) \quad (2)$$

The initial modulus of elasticity for a material is calculated as follows:

$$K_0 = \frac{1}{D_1} \quad (3)$$

Use for analysis

$$D_1 = \frac{1}{500 \cdot G} \quad (4)$$

where G is shear modulus.
To take into account the stress relaxation of the sealing element made of elastomer in the model (1), the Mooney – Rivlin constants were recalculated based on the value of the relative

residual strain of 0.6; the following values were obtained [11, 15, 16]: C_{10} = 781178.6 Pa; C_{01} = 154173.9 Pa .
Deformations of PTFE protective rings were considered elastic, the surfaces of the cylinders and the floating piston were determined to be absolutely rigid. Used friction model [9]:

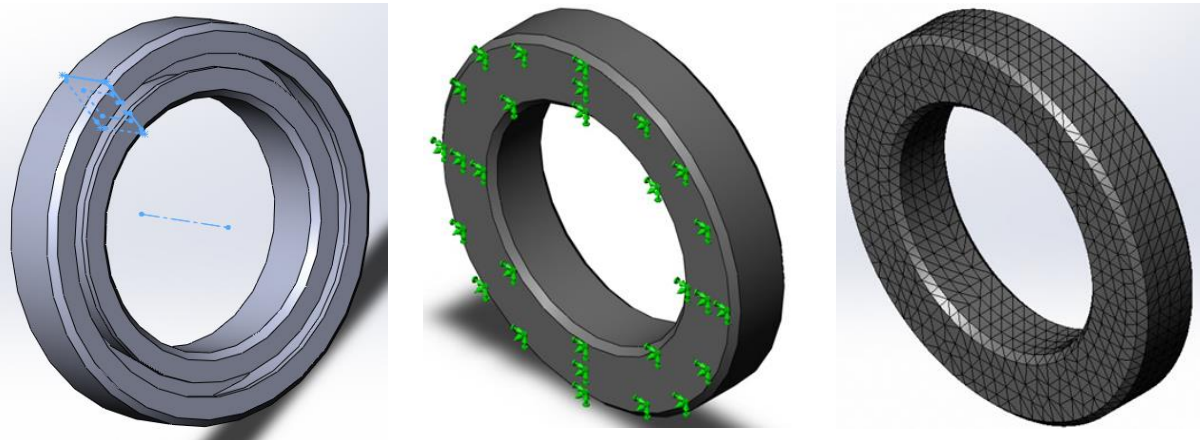
$$\tau = \mu \cdot N \tag{5}$$

where τ is the shear stress; μ is friction coefficient; N is contact normal pressure.

Results

Conducted simulation in the software package SimulationXpress Study. The following data were taken as input parameters for the simulation model:

- a geometric model of the sealing device (Fig. 3);
- characteristics of physical and mechanical properties of materials;
- pressure (20 MPa).



a) **b)** **c)**

Fig. 3. The research in SimulationXpress Study Stress

a) 3D CAD model;
b) Fixed geometry;
c) Finite elements.

The obtained diagrams of equivalent voltages for the sealing element of the device under consideration are shown in Fig. 4. As can be seen from Fig. 4, in the sealing element in a static state, the maximum equivalent voltage is 2199 Pa, which cannot lead to the destruction of the sealing element. After relaxation of the stresses in the power element, the equivalent stresses in the sealing ring decrease, as well as the decrease of the contact pressure on the sealing surface.
The diagram of equivalent stresses, shown in Fig. 4, corresponds to the development of adhesive bonds at the point of contact during a long stop of the mechanism. According to the literature data, the initial (starting) value of the friction coefficient can reach values of 0.2 and more [7].

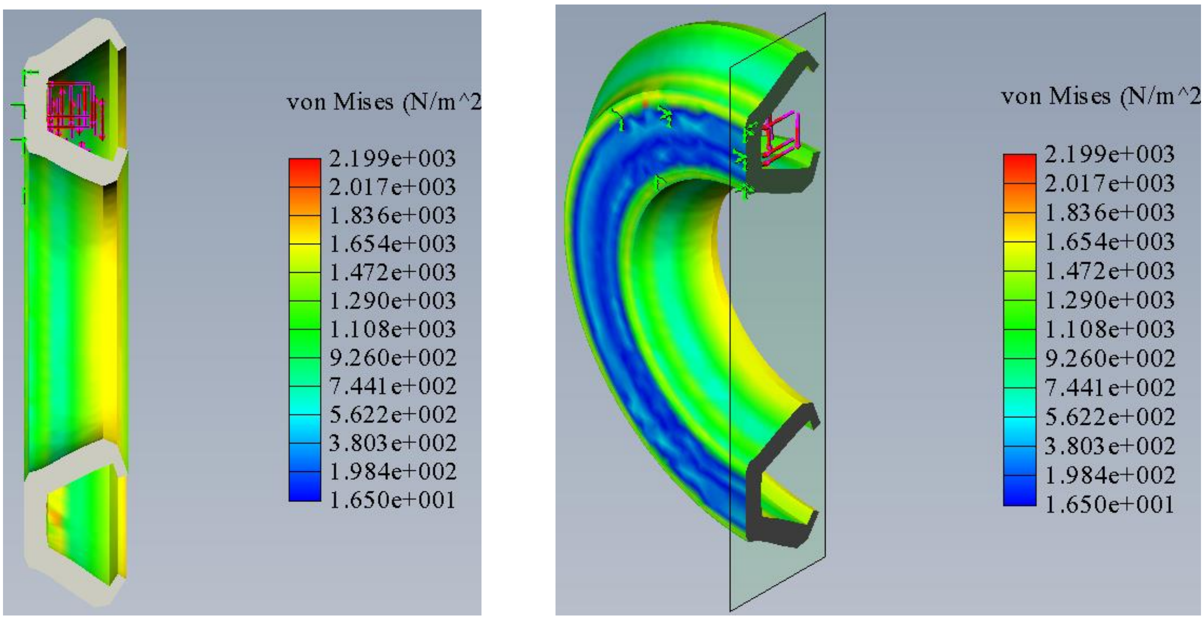


Fig. 4. Diagrams of equivalent stresses in a section of a sealing ring in a static state

At high values of the friction coefficient, the equivalent stresses locally increase, which exceeds the tensile strength for the applied group of polymers. The initial friction at the time of launch, as well as high values of the friction force in the process of movement or rotation of the shaft can lead not only to damage the surface of the sealing ring, but also to its twisting.

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.

From the standpoint of the modern understanding of the problem of creating highly effective tribotechnical materials for the specified and especially extreme operating conditions (high loads and slip speeds, deep vacuum, interchangeable temperatures, large work life and reliability, short working time, etc.), the process of their development and design includes the following approaches:

– the basis of the material, which is usually composite, is selected taking into account the compliance of the complex of its physico-mechanical and tribotechnical properties with the given load-speed and temperature operating modes;

– to reduce frictional losses, a solid lubricant component, which forms shielding films on the tribological surfaces, is introduced as a basis without interacting with the base of the composite material;

- in hard conditions of work, solid refractory inclusions are introduced into the matrix, which perceive the main load during friction;

– to increase the strength of the bond between the matrix and the refractory inclusions, the adhesive-active components are added to the composition of the composition, which improves the wetting of the latter [2-4, 5-9].

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