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DEVELOPMENT OF SELF-LUBRICATING MATERIALS BASED ON POLYTETRAFLUOROETHYLENE [1]

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Abstract. *In the given work of researches on development of wearproof polymeric composite materials based on polytetrafluoroethylene are resulted. Tribotechnical properties of polymeric materials containing liquid lubricant were investigated. Perspective self-lubricating polymeric composites for improvement of reliability, safety and working effectiveness of transport and technological equipment for oil and gas mining industry are developed.*

Keywords: *polytetrafluoroethylene (PTFE), polymeric composite materials (PCM), filler, supramolecular structure, friction factor, surface of friction.*

Introduction

Effective economic development of northern territories of the Russian Federation is focused, first of all, on an intensification of productivity of an oil and gas complex that means large-scale use of the various technological, mining equipment and huge park of career technics. The operational durability of applied technics in many respects is defined by quality of used materials**.**

In this connection, creation and application of tribotechnical polymeric materials gets an actual meaning for improvement of quality, reliability and durability of knots of a friction of the mechanics working in extreme conditions.

The problem of improvement of quality, reliability and durability of mechanisms is one of the primary goals of modern mechanical engineering and has not only scientific and technical, but also the important economic value.

For creation of reliable modern technics development of highly effective wearproof materials to provide of reliable and durable work of knots of a friction of the mechanisms exploiting in a wide range of loadings, speeds, temperatures and which capable functioning in aggressive environments, at transitive modes and in vacuum is required. Using of polymers as constructional materials of tribotechnical application is caused by many factors, including possibility to form composites with the set properties [1]. Expansion of sphere of use of polymers is conducted basically in two directions.

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One of them – updating of properties of known kinds of polymers. The most accessible and comprehensible method of updating is use of possibility of introduction in polymers of the liquid and solid components joint action of which can change initial properties of polymers and therefore materials with the set properties can be obtained [2].

The purpose of the given work is development of new self-lubricating tribotechnical polymeric composite materials (PCM) based on polytetrafluoroethylene (PTFE).

Methods and objects of research

Objects of research are polytetrafluoroethylene (GOST 10007-80), natural zeolite of the Kempendjajsky deposit and engine oil of M-8B trademark. To provide of introduction of liquid lubricant into the polymeric sample technology of engine oil impregnation is developed. For increase of structural activity of filler preliminary mechanical activation in planetary mill AGO-2 was conducted for 2 minutes, then engine oil impregnation for 24 hours at a room temperature was carried out. Composites were received by dry mixing of components in high-speed mill. Samples of composites for mechanical, tribological and structural researches were received on technology of cold pressing with the subsequent sintering. Liquid-phase filling of filler and a composite by engine oil was equal to 28.3 wt. % and 0.6-1.6 wt. %, accordingly. Mechanical properties of PCM were defined on standard samples (GOST 11262-80). Tests were conducted on test machine "UTS-2" (Germany) at speed of moving captures of 100 mm/minutes. Tribotechnical characteristics (friction factor, mass wear rate) were defined by the friction test machine SMT-1 (the scheme of a friction "shaft-plug", loading – 0,45-1 MPa, speed of sliding – 0,39 km/s). In the role of counterpart a steel shaft made from steel 45 with hardness 45-50 HRC and roughness 0.06-0.07 microns was used. Wear rate was defined on weight loss of samples in unit of time. The friction moment was registered with the device of Thermodate 17E3 and friction factor was calculated from friction moment data. Structure researches of the composites before and after friction carried out with Scanning Probe microscope NTEGRA and optical microscope Olympus BX-41.

Discussion of results

In Table 1 comparative characteristics of mechanical and tribotechnical characteristics of composites based on PTFE and natural zeolites are presented. It is shown, that filling PTFE by the natural zeolites activated for 2 minutes leads to increase of mechanical characteristics up to 10-20 %, wear rate in this case in 130 times lower in comparison with wear rate of initial PTFE.

Filling of PTFE by zeolite which preliminary was impregnated by engine oil M-8B results in decrease of wear rate in 615 times with some increase to 10 % in relative lengthening at rupture and some decrease to 20 % in tensile strength in comparison with unfilled PTFE.

Table 1. Mechanical and tribotechnical characteristics
of composites based on PTFE and natural zeolite

Composite	$\varepsilon_{p,}$ %	σ_p, MPa	*I*, mg/h	*f*	*T*, ºC
PTFE	300	20	75-80	0,3	45
PTFE+2 wt. % zeolites (act.)	340	22	2,15	0,2	45
PTFE+5 wt. % zeolites (act.)	310	20	0,6	0,32	48
PTFE+2 wt. % zeolites, filling of oil	305	15	2,1	0,02-0,15	34-39
PTFE+5 wt. % zeolites, filling of oil	324	16	0,13	0,02-0,05	38-40
PTFE+5 wt. % $MgAl_2O_4$	260	16	0,6	0,1-0,2	45-48
PTFE+5 wt. % Al_2O_3	280	17	0,4	0,02-0,04	42-45

The note: ε_p – relative lengthening at rupture, %; σ_p – tensile strength, Mpa;
I – wear rate at loading 0,45 MPa, mg/h; *f* – friction factor; *T* - temperature in a friction area, ºC.

Possibly, it is connected with Rehbinder's effect, that is with fall of durability of solids, simplification of deformation and destruction of solids owing to reversible physical and chemical influence of environment that is engine oil [3].

Also it is shown that decrease of wear rate to 4.6 and friction factor in 10 times in comparison with composites based on PTFE modified by:

– zeolite activated for 2 minutes;

– nanospinel of magnesium;

– nanopowder of aluminium oxide.

It is known that in case of oil-containing PCM during processing reactions of oxidation and dehydration occur, owing to that oxygen-containing substances with double bonds are formed. At composite formation these components, participate in process of structurization of polymer that gives qualitatively new properties of matrix. Formation of polar groups in volume and polymer surfaces promotes increase in adhesive interaction of polymer and metal that leads, first, to formation of a stable and strong transferred film on counterpart surface; in second, products of oxidation of oils play a role of wear processes inhibitors (break a chain of radical reactions of oxidation of a polymeric material), thereby protect a composite from wear process; in third, participate in processes of structurization of polymer with formation of wearproof structure [4].

Further in Table 2 results of researches on tribotechnical characteristics of composites at 1 and 2 MPa are resulted.

Table 2. Tribotechnical characteristics of PCM at 1 and 2 MPa

Structure	1 MPa			2 MPa		
	I, mg/h	*f*	*T*, ºC	*I*, mg/h	*f*	*T*,ºC
PTFE	106.45	0.043	60-65	312.30	0.043	75-80
PTFE+2 wt. % zeolites, filling of oil	2.3	0.023-0.030	40-46	29.5	0.016-0.024	55-60
PTFE+5 wt. % zeolites, filling of oil	1.67	0.016-0.020	50-55	4.8	0.018-0.022	65-70

Analyzing of results of tribotecnical tests shows positive influence of fillers on the tribotechnical characteristics of PCM. It is visible that wear resistance of PCM raises up to 55-65 times, in friction factor and temperature in a zone of contact decrease to 2 times in comparison with unfilled PTFE. It is possibly connected with lubricating of friction pair by oil containing in pores of filler. Due to high sorption abilities of natural zeolites to hydrocarbons they are capable to keep a cover of adsorbed molecules of lubricant components and to deliver them in a friction zone when content of them will decrease owing to desorption from metal surface at temperature rising. Thus, there is a prevention of adhesive wear process of sliding metal surfaces.

Also the reason of decrease in wear rate of composites, probably, increase of mobility of molecular chains of a polymeric matrix in a thin surface layer and more favorable redistribution of pressure on frictional contact is. Increase in wear rate of composites when using of liquid lubricant possibly connected with realization of internal effect of Rebinder.

As result of decrease in temperature in a friction zone keeping in initial range of physical, chemical and mechanical characteristics of both the lubricant environment and surfaces of a friction is. Thus, the auto regulation mode of tribotechnical as well as anticorrosive properties of a composite material is provided.

Decrease in friction factor can be caused also by heating of a material and formation of a mobile layer of the carrying over which is carrying out function of lubricant. It is established that transferred film formation occurs in local areas of maximum contact interaction of surfaces.

To estimate of efficiency of tribotechnical materials PV factor is used. Increasing of PV factor values testify about improvement of materials efficiency and these materials can be used at higher loads and velocities of friction. In connection of this with purpose to determine of maximum functioning load of PCM based on PTFE loading abilities of developed composites are investigated. On the basis of these data PV factors of materials were calculated.

Loading ability of PCM is ability to stand the load providing normal functioning of friction knot. Loading ability of composites determines by load which lead to maximum state of the construction. At such load leads to local or total destruction, cracking and deformation [5].

On Fig. 1 dependence of loading ability of the material on applied load demonstrated.

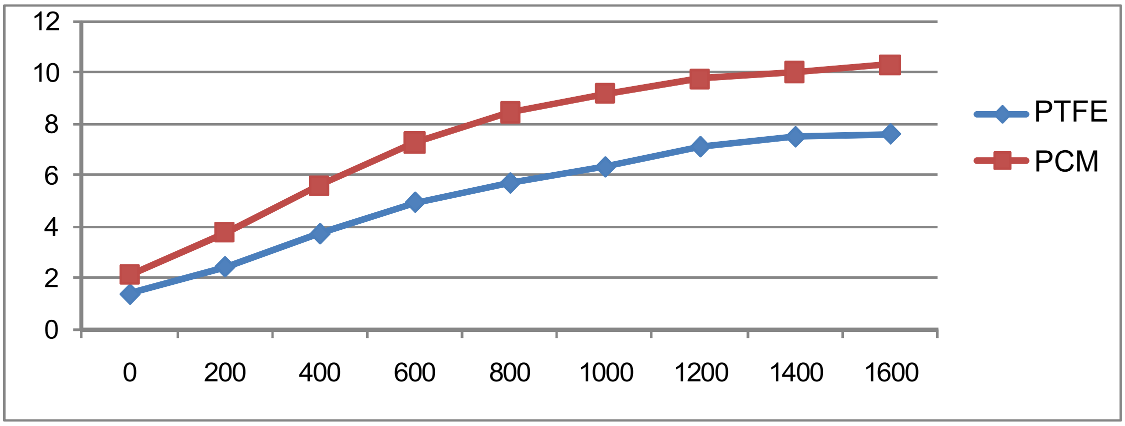

Fig.1. Dependence of loading ability of the material on applied load

It is established that modification of PTFE values of permissible pressure increase up to ~10 MPa. Probably, it can be explained by fact that particles of zeolite under influence of temperature, load and sliding velocity during friction transferred on surface of friction and form stable cluster structure with matrix which protect materials from wear.

Thus, it is established that complex modification of PTFE by liquid and solid fillers leads to increase of PV factor values up to 4 MPa*m/s at sliding velocity 0.39 m/s while values of PV factor of unfilled PTFE equal to 2.5 MPa*m/s.

The microrelief and morphology of surfaces of a friction have been studied with scanning probe microscopy (Fig. 2).

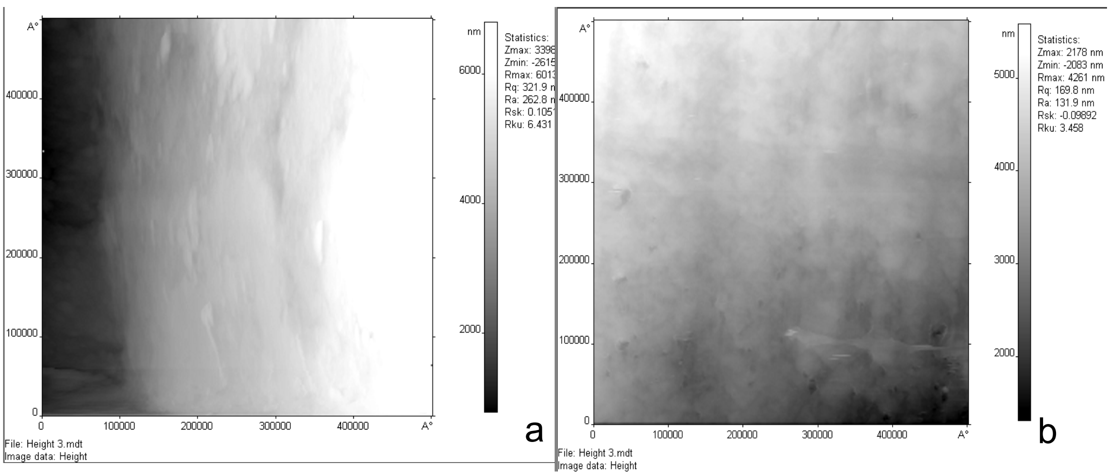

Fig. 2. The Relief of surface of PCM:
a) before friction; b) after friction

It is established, that decrease in friction factor of composite is caused by reduction of the area of contact to a metal surface due to particles of zeolite come over from a polymeric matrix. Average-square and average roughness of the PCM surface after friction decreases in 2-3 times. It, probably, one of the important contributions to the general decrease in friction factor since at roughness reduction specific pressure in contact areas is decreases. Reduction of a roughness of a composite testifies also to a friction on transferred film.

Thus, perspective self-greased polymeric composites are developed for increase of reliability, safety and efficiency of operation of transport technics of the North.

Developed materials characterized by stable and low values of friction factor and wear intense, increased mechanical properties promoting toughness of knots and high loading ability. Using such materials allows to make longer functioning time of friction knots, improve reliability, safety and efficiency of transport and technological equipment of oil and gas mining industry.

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