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NEW ANTIFRICTION MATERIALS OF THE FLUVIS GROUP BASED ON MODIFIED CARBON FIBERS

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Physicomechanical properties are given for antifriction materials based on fluoroplast-4: Flubon 20, Fluvis 20, Vako-fluvis, and Superfluvis.

Reliable operation and long working life in compressors and pumps is dependent to a considerable extent on the sealing components and piston rings, particularly if it is impermissible to use lubricants. Self-lubricating antifriction materials are made in the main from composites containing fluoroplast-4 (polytetrafluoroethylene PTFE), of which the following grades are the most familiar: F4K20, F4K15M5, AFGM, AFG-80S, and Flubon. The fillers in these composites are the following: coke, graphite, and carbon fibers (CF).

Composites based on coke satisfy only poor specifications for wear resistance and working life. The coke has an abrasive action on the counterbody in the friction unit and causes wear. Composites based on graphite are viable only in a moist atmosphere and subject to restricted loads. The main filler for fluoroplast-4 to provide antifriction behavior recently has been CF, which are complicated carbon structures having high strength, elastic modulus, and heat and chemical stability, with low coefficient of friction and density [1, 2]. Finely divided CF instead of coke raises the strength by a factor of 1.5 and the wear resistance of the fluoroplastic composite by factors of 6–8.

However, CF have complicated structures, and their properties are dependent to a considerable extent on the production technology and raw material, so not all CF can give a fluoroplast composite, and the CF made by various factories with identical compositions differ considerably in properties. The textures of carbon-fiber materials (specific surface, pore shape and size, and hydrophobic-hydrophilic properties) are determined in the main by the final temperature of heat treatment and the nature of the initial raw material.

The makers of Flubon in Belarus encountered this problem. The composite had unsatisfactory properties. A solution was found by examining the surface properties of the CF and devising a method of modifying them, on research done at the IMMS of the Belarus National Academy of Sciences. This method of additional processing for CF has been used at the Svetlogorsk chemical fiber company on making carbon strip for filling fluoroplast-4. This strip has been used at the Grodno Mechanical Plant in making the composite Fluvis™, one of the best such materials as regards wear resistance and strength [3, 4]. Figure 1 shows wear rate measurements for carbon-fluoroplastic materials. The tests were performed on seals of the same design with a final pressure of 20 MPa and temperature 150°C [5].

We also examined modifications of Fluvis composite of friction units working in dried pure gases or vacuum. The lack of water in the gas prevented the formation of a protective film on the friction surface, so the interaction of the polymer with the metal counterbody approaches that of friction for ideally clean (native) surfaces free from adsorbed com-

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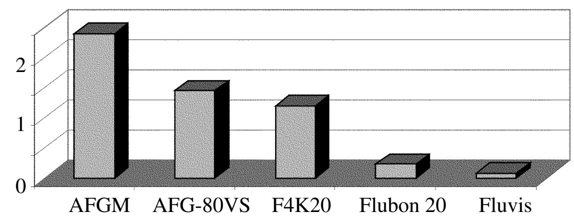

Fig. 1. Wear rate $J \cdot 10^3$ of self-lubricating materials, mm/h.

TABLE 1

Properties of materials based on fluoroplast-4	Flubon-20	Fluvis-20	Vako-fluvis	Superfluvis
Density, kg/m^3	1930–1950	1950–1980	2000–2100	2000–2080
Tensile strength, MPa	17	20–23	24–25	28–33
Yield point in compression (T = 18°C), MPa	8–10	17–18	18–21	22–25
Elastic modulus in compression, MPa:				
T = 18°C	380	460–510	540–710	750–1000
T = 100°C	200	–	250	500
T = 150°C	90	35	130	240
Creep under load of 18.7 MPa in 24 h, %	–	5.0	1.8	1.5
Wear, mm^3/(N·m)	–	$(2.2–4.5) \cdot 10^{-7}$	$(0.5–1.5) \cdot 10^{-7}$	$(1.2–1.5) \cdot 10^{-7}$
Brinell hardness, MPa	–	55	–	65
Thermal conductivity at T = 125–250°C, W/(m·K)	–	0.25–0.44	–	0.30–0.60
Thermal diffusivity at T = 125–250°C, m^3/sec	–	$(0.19–0.22) \cdot 10^6$	–	$(0.22–0.26) \cdot 10^6$
Specific resistivity, Ω·cm	–	10^6	–	$2 \cdot 10^5$
Mass loss on heating to T = 250°C, %	–	2.0	–	0.6
Linear thermal expansion coefficient at T = 20–200°C, 1/°C (along/trans)	$–/6.5 \cdot 10^{-5}$	$(12.5–14.2) \cdot 10^{-5}/2.5 \cdot 10^{-5}$	$(12.5–14.5) \cdot 10^{-5}/–$	$(13.5–16.5) \cdot 10^{-5}/(5.0–6.0) \cdot 10^{-5}$

pounds. The filler particles directly contact the counterbody and increase the force of their molecular interaction, and consequently the wear of the polymer composite. Some materials for friction units in dry gases (AFGM, AFG-80S) do not satisfy all the requirements of current engineering.

We also examined the features of solid lubricants, of which molybdenum disulfide MoS_2 is a unique one. The coefficient of friction for MoS_2 is lowest in a dry atmosphere and increases with humidity by more than a factor of 2, which is due to the formation of hydrogen bridges between the basal planes of the MoS_2 crystal, which hinders their relative displacement [6, 7]. However, it is difficult to use this lubricant in fluoroplast composites made by cold pressing and subsequent sintering at 375°C because of the oxidation of the MoS_2 (on heating above 150°C in air), with the formation of molybdenum oxide and sulfuric acid. We therefore devised an improved technology for making the fluoroplast composite and improved equipment for sintering the blanks without the access of air.

These tests led to the development of a Vako-fluvis™ composite differing from the Fluvis™ composite in composition, manufacturing technology, and areas of use. The new composite (TU BY 400084698.165) is routinely produced by

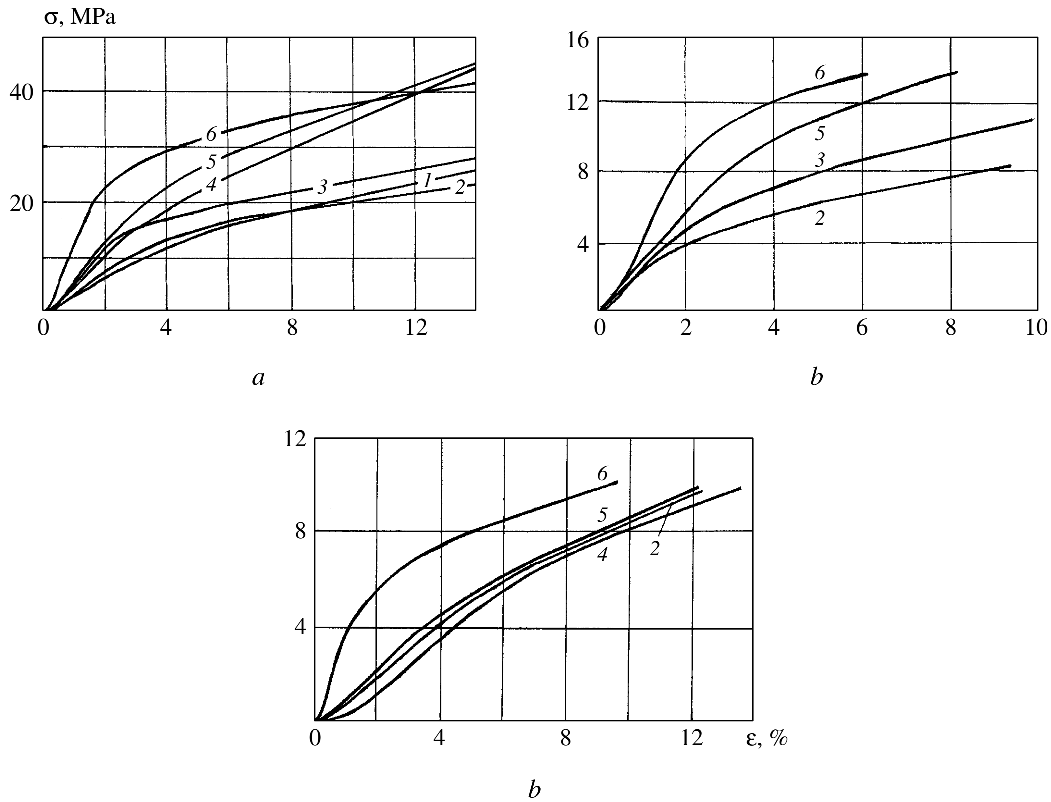

Fig. 2. Compression curves for fluoroplast composites (strain rate 5 mm/min) at various temperatures: *a*) 18°C; *b*) 100°C; *c*) 150°C; *1*) fluoroplast-4; *2*) Flubon; *3*) F4K20; *4*) Fluvis; *5*) Vako-fluvis; *6*) Superfluvis.

the Grodny Mechanical Plant and is intended mainly for friction units working in dry gases or vacuum, as it has elevated wear resistance, and good elastoplastic and thermophysical properties by comparison with other composites (see Table 1). The Vako-fluvis™ composite is used for example in compressors (Barrens company, Russia), and in ball valves at pressures up to 35 MPa (Korbet company, Russia), and so on.

At the IMMS (Belarus National Academy of Sciences), a method has been developed for depositing a thin layer of fluoropolymer on CF in a discharge plasma, which improves the wettability of the CF by molten fluoroplast-4 and heightens the technological compatibility [8, 9]. Then CF with fluoropolymer coating is used to fill fluoroplast-4 with improvement in the structure of the interphase layers, and with the elimination of porosity and defectiveness, together with improved density, elastostrength properties, thermal conductivity, and wear resistance. Tests stably reproduce the strength in tension, which is analogous to that of fluoroplast-4 (28–33 MPa). This leads one to reject the assertion that adding one vol.% of any filler to PTFE substantially reduces the tensile strength by 0.5 MPa, since the particles of filler are nuclei for cracks and represent a foreign body in the fluoroplast matrix.

This plasma modification method has been used to produce BELUM™ carbon material, and this is used as the basis of the upgraded fluoroplast composite Superfluvis™.

Superfluvis is used in particularly important friction units, where the working life and reliability justify the use of a fairly expensive material.

At the Frunze Sumi Company, the Superfluvis composite has been used in place of Flubon in unlubricated friction units, e.g., for piston rings in heavy compressors. At present, Superflubon is undergoing working life tests in the shaft sealing unit of the fourth stage of a 4GM2.5U-2/3-250 compressor for automobile gas-filling stations, which previously have not worked without lubrication. The lubricant feed to the working cylinder and the seal have been withdrawn. The pressure difference across the seal is 20–25 MPa, shaft temperature about 150–160°C. Up to the present, the total working time has been 1000 h.

Comparative tests have been done on the physicomechanical properties of these composites and their analogs, with particular attention given to the strength and elasticity on compression, including at elevated temperatures, since these materials are intended primarily for use under compressive loads, while the temperature in the friction zone is well above the room value even at low sliding speeds.

We recorded the curves for the compressive stress σ in relation to the strain ε under identical conditions on an Instron 5567 tester for various composites (Fig. 2), which showed that the highest performance occurs in the Superfluvis composite, with Vako-fluvis somewhat inferior, and with that relationship persisting at high temperatures.

Superfluvis is thus a new high-grade antifriction fluoroplastic material made by researching and modifying CF.

Unfortunately, the technology for making these materials has been optimized for particular grinding and mixing equipment. Experts on making fluoroplast composites know how important it is in obtaining good quality by the stages of grinding and mixing. The elastic and strength parameters of CF are dependent on the manufacturing technology, surface treatment, and the features of individual stages, which determine the fractional composition of the ground CF, the electrophysical properties, the tendency to clumping, the capacity for uniform mixing with the fluoroplast, and the adsorption interaction.

Joint efforts by scientists and production workers are thus important in the area of fluroplast antifriction materials, and one needs a comprehensive approach to research on the properties of CF and composites based on them, as well as of features of the manufacturing technology. This will provide new grades of these unique materials and improve the quality of existing ones.

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