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Characteristic of polymer sliding materials using to work at elevated temperature

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ABSTRACT

Purpose: The purpose of this project was to estimate the possibility of using glass carbon particleste as a reinforced component of polymer matrix in composites. Application as a basic components modified properties of phenolic resin glass carbon give a sliding composites characterized profitable tribological properties. Microscopy examination of the sliding surface together with the results of tribological investigations made it possible to conclude about friction and wear processes of the investigated composites.

Design/methodology/approach: Composites on the phenolic resin as a matrix have been investigated. Apart from traditional fillers, such as graphite or brass, glassy carbon was used for the modification of the properties. Based on studies of the friction coefficient and the wear, usefulness of glassy carbon as a material reinforcing and modifying the tribological properties of sliding materials was determined. Studies of the surface structures of friction couple materials allowed the identification of the processes taking place in the upper surface after friction and wear tests, as well as the determination of wear mechanisms. Analysis of composite surface after friction give estimation of wear mechanism and forming of surface layer during friction.

Findings: The results of research into mechanical and tribological properties of materials with a polymer matrix intended for work in friction couples under heavy load conditions.

Practical implications: The results of that investigation confirm that glass carbon is main component deciding on the tribological properties of composites. Glassy carbon particles limited wear and thermal destruction of matrix. Modification using glassy carbon let to obtain sliding composites working at elevated temperature in extremely work condition then non modified polymer materials.

Originality/value: Glassy carbon particles limited wear and thermal destruction of matrix. Modification using glassy carbon let to obtain sliding composites working at elevated temperature in extremely work condition then non modified polymer materials.

Keywords: Tribological properties polymer composites; Sliding composite; Glass carbon; Mechanical properties

PROPERTIES

1. Introduction

The principal advantages of plastics as sliding materials are connected with their high resistance to the action of corrosive environments, a low specific weight, easiness of formation, relatively good mechanical strength, low friction and wear coefficients values, silent running, capacity for damping vibrations and easiness of introducing fillers or grease. For their numerous virtues, plastic materials have a few significant disadvantages. The most important of them are connected with low thermal conductivity, a low operational temperature, high thermal expansion, lack of dimensional stability under load and viscoelasticity [1, 2]. A reduction of the drawbacks mentioned is carried out mostly through modification of pure polymers with fillers [3, 4]. Those most often applied, usually in a powder form, include: metallic fillers (copper, tin, bronzes, brass or metal oxides), non-metallic fillers (polyethylene, poly (tetrafluoroethylene), MoS_2, black carbon or graphite), or mineral fillers (e.g. chalk or mica). Their role is to change the properties of a material, which in this case refers to sliding properties and resistance to wear. Fillers also allow reducing the production costs through minimized utilization of the matrix material. To enhance mechanical properties, reinforcing materials are introduced in a fibrous form. The fibres used for reinforcing polymers are first of all [5]: glassy, carbon, aramid or polyethylene fibres. Knowledge of the properties of different modifying and reinforcing materials enables the creation of such a composition which will prolong the operational period for bearings and minimize the energy losses resulting from friction. Most often, it is graphite that has been used as a carbon component in the composites with specific sliding properties, whereas glassy carbon particles (an amorphous carbon structure obtained as a result of high-temperature decomposition of organic precursors) have not been used as a modifier so far. The main advantage of carbon materials or carbon composites used for modifying properties is their structural stability at high temperatures. Those materials do not melt and their resistance to oxidation is very high. Some of them can work in friction systems to a temperature as high as 2000°C [6, 7]. An example of such application are the materials of brakes in high-speed TGV trains [3], where as one of the components enhancing thermal resistance, is the ”carbonized component” [5]. Another example are composites of a carbon-carbon type in airplane brakes [3, 6, 8].

Glassy carbon is characterized by high hardness, high thermal resistance, high thermal conductivity, a very low thermal expansion coefficient and resistance to thermal shock [9, 10]. A supposition can be therefore made, that by introducing an additional carbonized components in a friction material, the material’s thermal properties can be improved (thermal resistance, conductivity), which will allow increasing the temperature of friction systems operation [11, 12]. This would constitute a basis for obtaining new, in terms of quality, materials, possessing good tribological properties and not leading to the friction partner’s wear [12, 13].

The subject of this study is an evaluation of glassy carbon usefulness as a component modelling the properties of sliding materials with a polymer matrix. The technological conditions of obtaining a polymer matrix composite which contains particles of carbon of an amorphous structure as well as its basic tribological properties, i.e. the friction coefficient and frictional wear, have been determined.

2. Experimental part

The matrix of the sliding material was phenol-formaldehyde resin. As the main component, glassy carbon was incorporated in the resin in an amount equal 50% of the mass fraction. The composite material containing glassy carbon (WS) was additionally modified with a 5% graphite addition (Gr), a 5% flake graphite addition (Gp), and an addition of flake graphite (5% and 5% of brass Mo). The materials compositions and their denotation are presented in Table 1.

Compression moulding was applied to produce samples. Glassy carbon and other components were introduced directly into the liquid matrix through mechanical stirring. After drying the composition at a temperature of 60°C, profiles were formed through compression moulding for subsequent studies. Standard pressure of ca. 20 MPa and a temperature of ca. 140-160°C were applied. Tests of mechanical properties as well as bending and impact resistance tests were carried out for the produced materials, whose results are provided in Table 1.

Table 1.
Mechanical properties of the investigated materials

Composite	Signify	Flexular strenght,Rg, MPa	Impact strenght U, kJ/m^2
FF-50%WS	FF-WS	47.8	2.2
FF-50% WS + graphite	FF-WSGr	37.0	1.98
FF-50% WS + + flake graphite	FF-WSGp	58.4	3.6
FF-50% WS+flake graphite + brass	FF-WSGpMo	70.9	2.6

The results of mechanical properties tests have shown that the bending and impact strength depend on the fillers applied. Composites containing only glassy carbon exhibited satisfactory bending strength, with simultaneously low impact resistance. After their modification with granular graphite, the bending strength and impact resistance decreased. Improvement of the mechanical properties was achieved by introducing a flake form of graphite and modifying the composite’s composition with a brass powder.

Study of the coefficients of friction and wear served as a verification of glassy carbon’s usefulness as a modifier of composites tribologiacal properties. Measurements were made the friction coefficient, pin and disc’s weight loss and of the temperature near the friction zone (by contact method). The results are presented in Tables 2, 3 and 4, depending on the type of pin applied as a counter specimen. In the study, cast iron pins (cast iron EN-GJL-300), steel pins (steel X4CrNi 18 8) and brass pins (B100) were used. The working surfaces of specimens and counter specimens were ground on an abrasive paper of 500 granularity for the pins and of 320 granularity for the composite materials containing glassy carbon (WS).

The tests were performed on a T01 tester in the following conditions: speed disc v = 0.5 m/s, load on pin Q = 25 N, friction distance s =2500 m.

3. Analysis of the results

The study of the coefficients of friction and wear in a couple with the EN-GJL-300 cast iron has shown that the friction coefficient value depends on the glassy carbon fraction. The friction coefficient value for materials containing glassy carbon ranges between 0.15 and 0.25 (Table 2). The composite specimen’s wear was very low and only when brass was used as a filler, the wear increased several times, amount to ca. 30 mg. The weight loss of the cast iron pin varied between 0.1 and 0.5mg.

From among the fillers applied, it is flake graphite that causes a reduction of the friction coefficient (specimen FF-WSGp). A slight reduction of the friction coefficient was noticed in the initial period of cooperation, after admixing a brass powder in the FF-WSGpMo composite, but in the final period of cooperation, the coefficient reached its highest value of ca. 0.25.

Similar results were obtained for composites cooperating with steel. The friction coefficient in a composite containing only glassy carbon achieved the value of 0.13 and was stable throughout the test, however, in the initial period of wearing-in, it was relatively high at 0.25. The composite mass loss was even lower than for couples with cast iron. At the same time, the pin's mass loss increased, which was probably connected with increased abrasion wear in the steel material characterized by lower hardness than cast iron (Table 3). A reduced wear of the cast iron counter specimen was also caused by graphite precipitates' presence in the cast iron, which precipitates minimized the friction coefficient and wear as a result of deposition of the wear products coming from graphite on the composite and the pin's material.

The composites cooperating with bronze were also characterized by a small mass loss, testifying to insignificant wear of the sliding material in the friction couple. The reason for changes in the tribological characteristics may lie in the occurrence of wear products on the surface of the cooperating elements in the friction couple. On the composites sliding surfaces, the bronze pin's material was deposited in the form of a red, shiny strip of a width close to the pin's diameter. On the pin itself, there are some clear traces of friction wear and presence of small amounts of the composite wear products transferred to the counter specimen in the form of spots and bands on the cast iron pin's surface.

The transfer of material, in particular bronze, from both the pin and the composite material (FF-WSGrMo) caused that in such couple, the friction coefficient grows and the wear decreases, since in the upper layer of the cooperating materials, an inter-action takes place between the corresponding materials containing copper deposited on both the pin and the composite.

Table 2.
Tribological properties of the investigated materials in a couple with cast iron

Signify	Composite mass decrement, mg	Pin mass decrement, mg	Coefficient of friction
FF-WS	0.2	4.0	0.18-0.13
FF-WSGr	1.1	2.2	0.18-0.13
FF-WSGp	0.5	-0.1	0.17-0.16
FF-WSGpMo	0.0	1.4	0.18-0.15

Table 3.
Tribological properties of the investigated materials in a couple with steel

Signify	Composite mass decrement, mg	Pin mass decrement, mg	Coefficient of friction
FF-WS	0.05	3.4	0.25-0.13
FF-WSGr	0.2	8.6	0.12-0.16
FF-WSGp	0.1	2.5	0.08-0.14
FF-WSGpMo	0.0	2.1	0.11-0.15

Table 4.
Tribological properties of the investigated materials in a couple with bronze

Signify	Composite mass d decrement, mg	Pin mass decrement, mg	Coefficient of friction
FF-WS	5.9	0.1	0.13-0.17
FF-WSGr	1.1	0.3	0.16-0.14
FF-WSGp	3.5	0.2	0.12-0.18
FF-WSGpMo	31.2	0.2	0.13-0.25

In the composites couple with a pin made of bronze, an increased friction coefficient was observed (Table 4). The friction coefficient level was by almost half higher than for composites cooperating with steel or cast iron. The lowest friction coefficient as obtained for a composite containing only glassy carbon as well as for composites containing graphite.

The results of tribological research of polymer matrix composites working at elevated temperature in Fig. 1 have been shown. Research of tribological properties at 20, 100, 180 and 260°C temperature shown, that coefficient of friction is amount 0.12-0.18.

Application as a basic components modified properties of phenolic resin glass carbon give a sliding composites characterized profitable tribological properties. Microscopy examination of the sliding surface together with the results of tribological investigations made it possible to conclude about friction and wear processes of the investigated composites.

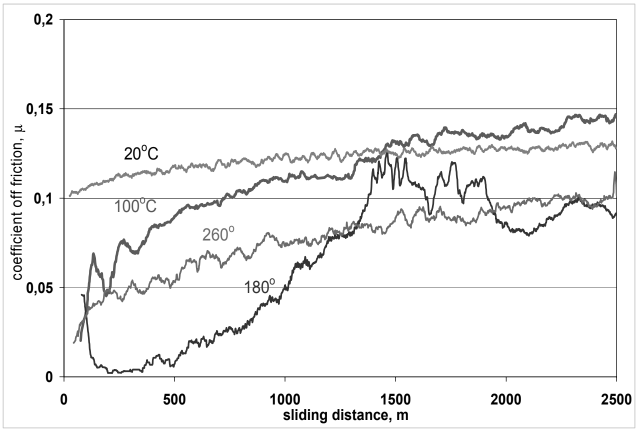

Fig. 1. Results of investigation coefficient of friction of composite FF-WSGM containing glassy carbon, brass and graphite in elevated temperature

In the case of a cooperation with steel or cast iron, such a large amount of products was noticed on neither the composite surfaces nor the pin surface (Fig. 1). A corroboration of the above findings can be a qualitative X-ray analysis of the surface of a composite specimen containing graphite and brass (Fig. 1) after cooperation with a steel sample.

Presence of brass was found on the specimen surface in the form of both grain (Fig. 2 p.2 and 3) and the deposited wear products (Fig 2. p.5). In addition, presence of wear products coming from the steel pin was found on the analyzed specimen surface (Fig.2 p.6 and p.4).

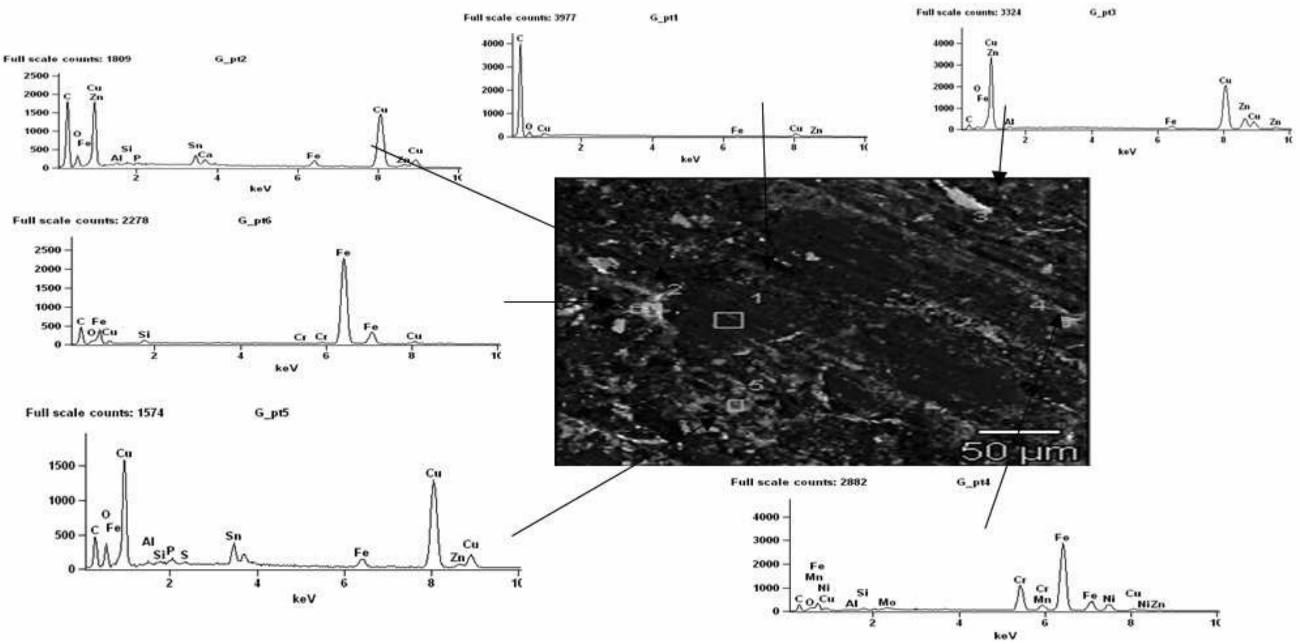

Fig. 2. Results of an X-ray analysis of a composite containing glassy carbon, graphite and brass, and of the wear products after cooperation with brass

Analysis of composite surface after friction give estimation of wear mechanism and forming of surface layer during friction. The results of that investigation confirm that glass carbon is main component deciding on the tribological properties of composites. Glassy carbon particles limited wear and thermal destruction of matrix. Modification using glassy carbon let to obtain sliding composites working at elevated temperature in extremely work condition then non modified polymer materials.

4. Conclusions

A composite containing particles of carbon of an amorphous structure as reinforcement, is characterized by good tribological properties, i.e. a low value of the friction coefficient and high wear resistance. The friction coefficient level is also determined by the presence of fillers which reduce friction (graphite, brass). A certain content of modifying fillers leads to enhanced mechanical properties and influences, to an insignificant degree, the friction coefficient value, contributing at the same time to a reduction of wear processes. High hardness and high abrasion resistance of glassy carbon reduce the intensity of destruction and wear processes of materials cooperating with it. This results first of all from differences in the wear mechanism which occurs in the case of a glassy carbon reinforced composite. After addiction of glassy carbon particles, wear mechanism comes down to destruction of largely glassy carbon particles, without destroying the polymer matrix material.

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