

Electrical and tribological properties of gradient epoxy-graphite composites

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Materials

ABSTRACT

Purpose: The goal of this work was to use gravity casting as a method to prepare composite material that is characterized by gradient of electrical and tribological properties. Furthermore electrical and tribological properties of composites filled with two different kinds of graphite were compared.

Design/methodology/approach: In this research the method of preparing polymeric gradient composites was gravity casting. The experimental procedure focused on evaluating the electrical resistivity and coefficient of friction (by the pin-on-disc method) of gradient composites.

Findings: Gravity casting method allowed to obtain materials with different percentage of graphite content in subsequent layers of composite. Moreover it was observed that values of coefficient of friction were higher for composite with SV94 graphite than for composite with PV60/95.

Research limitations/implications: The main problem for this work was to obtain continuous change of properties depending on the distance from surface. The particle's diameter distribution, shape and size of reinforcement were significant in manufacture of composites and influenced gradient of tested properties.

Practical implications: Method applied in this research allowed to obtain materials that are characterized by gradient of electrical and tribological properties. Such composites find applications in electrical industry and in mechanical engineering.

Originality/value: New polymeric gradient materials were developed using gravity casting technique. Electrical and tribological properties of these composites were determined depending on distance from the surface of the test piece.

Keywords: Polymeric Gradient Materials (PGMs); Gravity casting; Electrical and tribological properties

1. Introduction

Composite materials are widely used in many fields of industry. Depending on required properties and predicted practical applications there are known many combinations of polymeric matrixes and reinforcements. Scientists work out new technologies of manufacture of materials that has continuous distribution of composition and properties. This kind of materials, named Functionally Gradient Materials (FGMs), offer a solution for many advanced applications by suitable connection two or more materials that have dissimilar properties [1-7]. Till now correct connection of

dissimilar materials in FGMs was possible by applying variety of methods like [9]: pressing [6,8], centrifugation [7,10], gravity casting [11], UV irradiation [12], selective laser sintering (SLS) [13,14] and compression moulding [15].

Arrangement in properties of composite, along one or more directions, can be achieved for instance by controlling size or quantity of filler. The main problem during the production of the composite, that changes properties continuously, is suitable choice of technological parameters.

The purpose of this work was to produce two types of epoxy composites that differ by the type of graphite. Then electrical and

tribological properties of produced composites were analysed, namely surface electrical resistivity and coefficient of friction were determined respectively.

2. Materials and methods of research

2.1. Materials

Two materials were applied to produce specimens, first one was the matrix of specimens – epoxy resin together with (curing agent) that were purchased from Organika-Nowa Sarzyna (Poland). As a filler two kinds of graphite powders were used, they were obtained from DIMEX (Poland). Materials that were used in research and their characteristics are presented in Table 1 to Table 3.

Table 1.
Characteristic properties of epoxy resin

Trade name	Epidian 6
Density (20°C)	1,17g/cm ³
Viscosity (25°C)	10000÷15000 mPa·s
Boiling point	> 200°C
Melting point	-
Ignition temperature	> 200°C
Autoignition point	> 300°C

Table 2.
Specification of curing agent – triethylenetetramine (TETA)

Trade name	Z-1
Form	colourless liquid
Density (25°C) [g/cm ³]	0,98
Viscosity (25°C) [mPa·s]	20÷30
Amine value [mg KOH/g]	min. 1100

Table 3.
Characteristics of graphite

Type of graphite	PV 60/65	SV 94
Chemical composition		
Carbon	64.8%	94.23%
Ash	35.2%	5.77%
Grain size	125µm – 10%	> 500 µm 0.1% < 160 µm 42% < 100 µm 11%

To produce the specimens gravity casting was chosen, one of the effective methods applied to prepare materials characterized by various properties changing with distance from surface [20]. Previous to casting weights of components were calculated in order to prepare the following compositions that contain (by volume):

- 15% graphite + 85% (Epidian 6+Z1),
- 10% graphite + 90% (Epidian 6+Z1),
- 5% graphite + 95% (Epidian 6+Z1),
- 100% (Epidian 6+Z1).

Three mixtures were made for every gradient material sample. First, in order to prevent adhesion between mould and specimen and facilitate their separation, release agent was applied on the

surface of the mould. Subsequently the first mixture which contained 15% of graphite was poured into mould. Then succeeding layers with lower graphite content were poured into the mould. Before pouring succeeding layers regular breaks equal 33 minutes (gelation time) were made to allow pre-curing of previous layer. The sequence of poured mixtures in ready gradient material sample is presented in Fig 1.



Fig. 1 Scheme of layers

2.2. Electrical and tribological investigation

Investigation of surface resistivity of composites was carried out according to PN-88/E-04405. Figure 2 presents arrangement of electrodes on sample while testing surface resistivity.

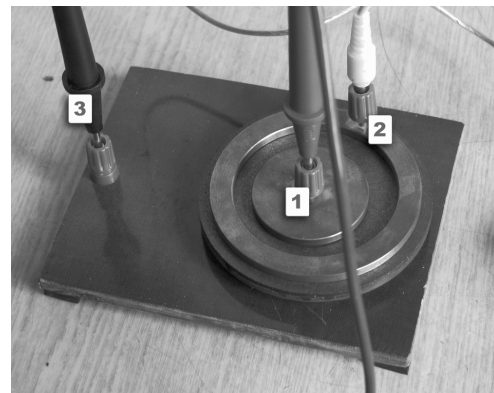


Fig. 2 Arrangement of electrodes: 1 – guarded electrode, 2 – guards electrode, 3 – unguarded electrode

Wear resistance of composites is dependent on velocity, sliding distance, load and test method. In order to determine the tribological properties of epoxy-graphite composites it was used pin-on-disc method (Fig. 3).

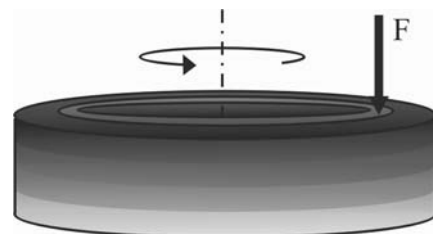


Fig. 3 Pin-on-disc method

The investigation was performed in order to evaluate coefficient of friction, for various quantities and types of graphite. Tests were carried out at the following parameters of wear:

- rotational velocity of disc – 300 rpm,
- load on pin – 10N,
- sliding distance – 500m .

2.3. Results and discussions

Tested electrical property of composite that was reinforced with SV94 graphite is shown in Fig. 4. Average values calculated from five measurements are shown. As can be seen mean values of surface resistivity increased markedly with decreasing quantity of filler in volume of composite. This result is in accordance with expected and planned tendency. Electrical resistivity of graphite is much lower than the same property of epoxy resin. Produced gradient composites may be applied in the industry in all cases where reduced surface resistivity is needed.

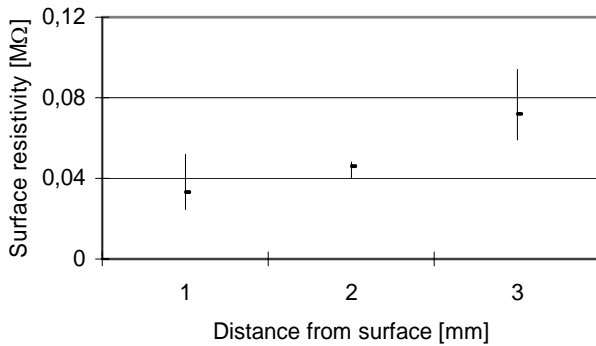


Fig. 4 Arithmetic average for surface resistivity SV94

In Figures 5 to 7 tribological properties for two composites are presented. The dependence of average value of friction coefficient on distance from the surface of the sample is presented in Fig.5. As can be seen for both graphite types coefficient of friction increased together with distance from the surface. It means that the higher is graphite content the higher is friction. It is in opposition to expected and planned results. Normally graphite is used in polymer composites to lower the coefficient of friction. Probably the reason was that pin used in testing device possessed to sharp tip to test this kind of composite. When pin hits filler's particle sudden friction force change is expected. It was observed as pin and pin holding arm vibration and force instability (Fig. 8). To avoid this effect new tribological test are planned using another method. A device with greater sliding surface is planned to be used. Mean values of coefficient of friction for composite with SV94 graphite were higher than for composite that was filled with PV60/65. For this composite also more pronounced dependence on distance from sample's surface was observed.

Observed results of coefficient of friction depending on time of sliding and sliding distance were not so univocal. For first layers of both composites coefficient of friction increased together with time and distance of sliding. It can be explained by higher content of graphite at the bottom of this layer due to sedimentation process (the

bottom became the surface in tribological testing). For the rest of the tested surfaces dependences were various. Probably the results were influenced by the distance from the top of cast layer and by sedimentation process. But also these results were highly determined by pin and pin holder vibrations. Measurements using another method are needed and planned.

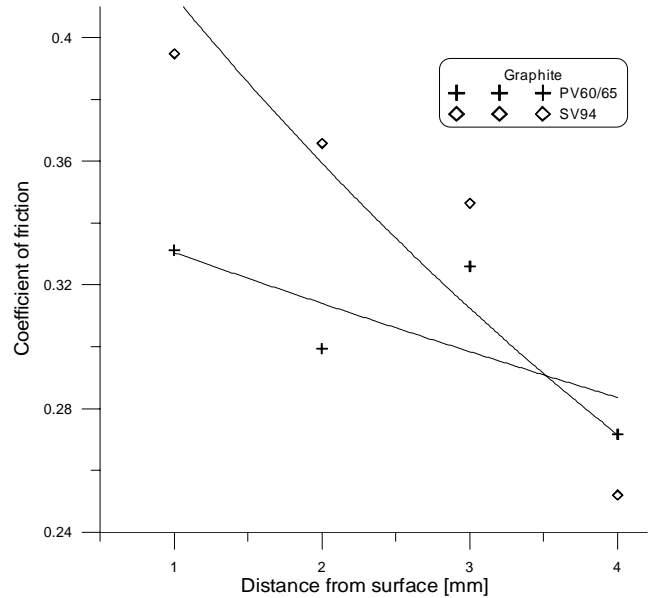


Fig. 5 Comparison average value of fraction factor between two kinds of graphite

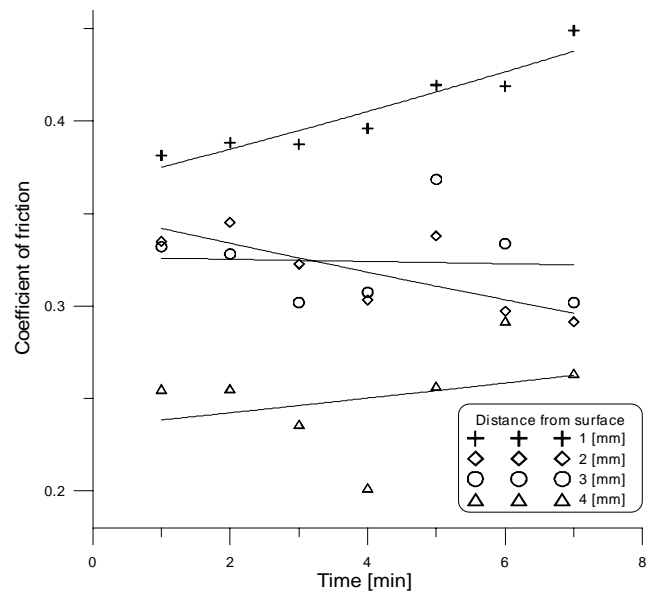


Fig. 6 Average value of fraction factor for graphite PV60/65

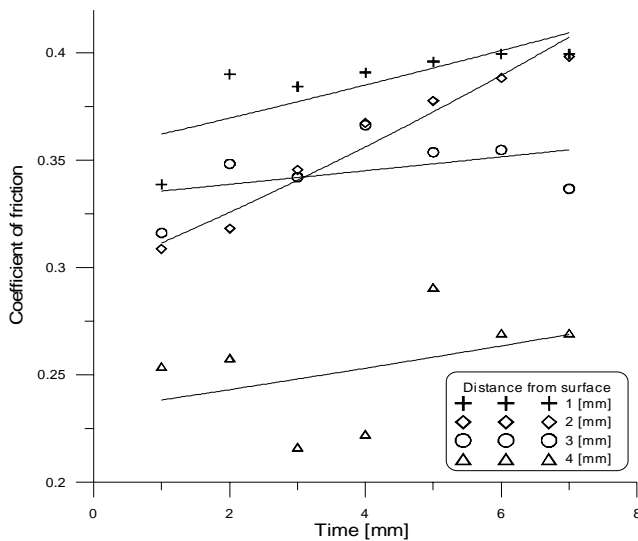


Fig. 7 Average value of fraction factor for graphite SV94

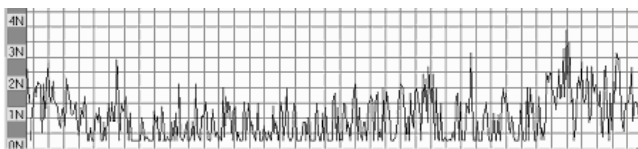


Fig. 8 Dependence of friction force on sliding distance

3. Conclusions

This study was carried out in order to evaluate the electrical and tribological properties of the gradient composites. On the basis of obtained results the following conclusions were drawn:

- gravity casting method allowed to produce composite material with gradient of properties,
- the surface resistivity increased significantly with decreasing content of filler in composite,
- the specimens that contain SV94 graphite exhibited higher coefficient of friction than specimens with PV 60/65,
- the lower was filler content the lower was coefficient of friction, but this dependence have to be verified,
- because of pin and pin holder vibrations observed in tribological tests a new method of friction and wear testing is planned.

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