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WEAR BEHAVIOUR OF POLYPHENYLENE SULPHIDE COMPOSITES DURING DRY SLIDING TESTS

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ABSTRACT

Two polyphenylene sulphide matrix-based composites were investigated: PPS GF 40 (PPS -polyphenylene sulphide +40% glass fibers) and PPS PVX (PPS - polyphenylene sulphide +10% PTFE+10% carbon fibers +10% graphite). The tribological properties of these composites were tested on a Universal Tribometer UMT-2 (CETR) apparatus (pin-on-disc test, in dry sliding, with the help of a pin-on-disk tribotester. The tribological behaviour was found to depend on the adding material(s) in the tested composites and better results were obtained for the composite containing solid lubricants (PTFE and graphite).

Keywords: Wear, friction, composite, polyphenylene sulphide, glass fibers, carbon fibers, graphite, pin-on-disk

1. INTRODUCTION

Polyphenylene sulphide (PPS) is a semi-crystalline high performance thermoplastic matrix for composites. The tribological behaviour of PPS composites have been study earlier [1, 2]. The fibres reinforced composites are well known to improved the friction and wear performances of the composites [3]. Adding materials like PTFE, carbon fibres and graphite into the thermoplastic polymers [4, 5, 6] the friction and the wear of the composites is reduced.

2. EXPERIMENTAL DETAILS AND MATERIALS

In this study, the disc was made of polymer composite: PPS GF 40 (PPS + 40% glass fibres) and PPS PVX (PPS + 10% PTFE+ 10% carbon fibres + 10% graphite). The concentrations are given as mass percentage in the composite.

The wear and friction tests were performed on a pin-on-disc machine (Universal Tribometer UMT-2, CETR). The pin is perpendicularly to the surface of the disc that is horizontally positioned. The pin was made of steel (41MoCr11 grade, HRC 55-58, Sa= 0.8 μm). Both the pin (Φ6 mm x 20 mm) and the disc (Φ40 mm x 5 mm) were cleaned before being tested. For each test, a new pair pin-disc was used. The tests were performed in dry sliding regime, at the ambient temperature and for a sliding distance of 10000 m. The test parameters were: the sliding speed: 0.25 m/s, 0.5 m/s and 0.75 m/s, respectively, the average calculated pressure on the contact pin-disc: 0.25 MPa, 0.5 MPa, 0.75 MPa, respectively.

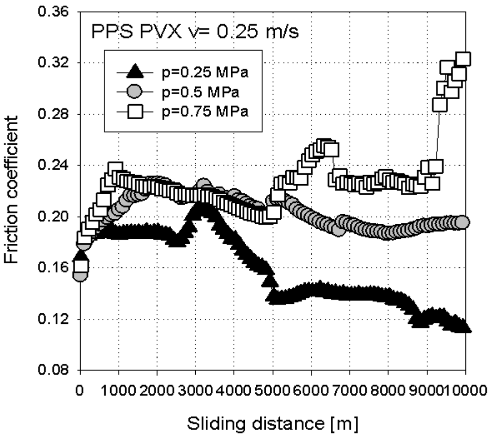
In this work, the authors studied the influence of sliding speed on the tribological behaviour of the two composites: PPS GF 40 and PPS PVX.

3. RESULTS AND DISCUSSION

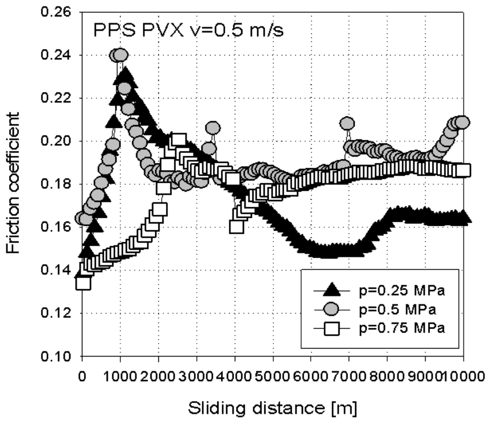
For v= 0.25 m/s, the value of friction coefficient of the composite PPS PVX sliding against steel, evidenced an increase with increasing the average applied pressure (Fig. 1a). At p=0.25 MPa, the friction coefficient increases on the distance of 1000 m, then it presents a plateau up to the distance of 2500 m and, finally, it suddenly increases at a value of 0.20, between 2500-3000 m. After 3000 m, the value of the friction coefficient decreases to 0.14 due to the formation of a layer of graphite on the sliding surface of the disk, caused by the van der Waals bonds break under the influence of the pressure.

The friction coefficient is stable at the value of 0.12 between 9,000-10,000 m.

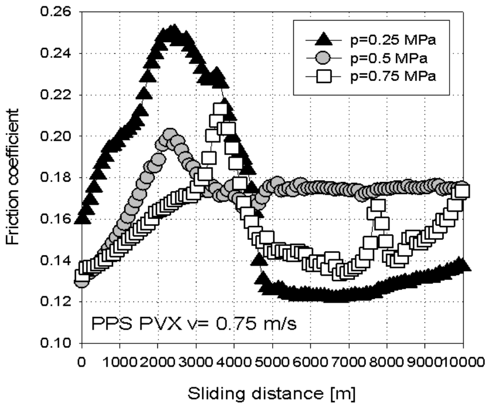
At p= 0.75 MPa, the value of the friction coefficient is suddenly increased from 0.16 to 0.24, on the distance of 1000 m. Between 1,000-5,000 m, the evolution is slightly decreased due to the generation of a transfer film formed on sliding surface, including both solid lubricants (PTFE and graphite). Towards the end of the test, a sudden increase in the friction coefficient was notied, attributed to the discontinuities appeared in transferred film formed on the hard surface and because it impoverishes this



a) v=0.25 m/s



b) v=0.5 m/s



c) v=0.75 m/s

Fig. 1. The variation of the friction coefficient for the friction couple steel pin on PPS PVX disk

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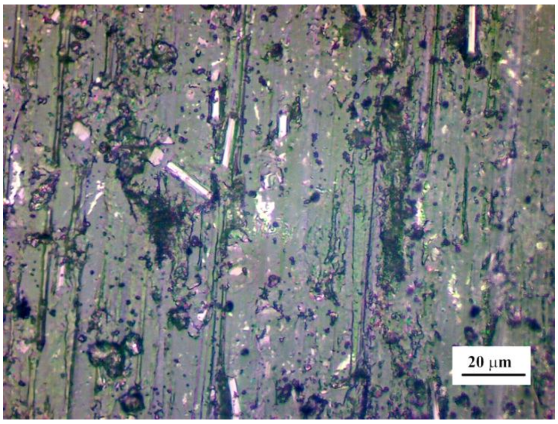
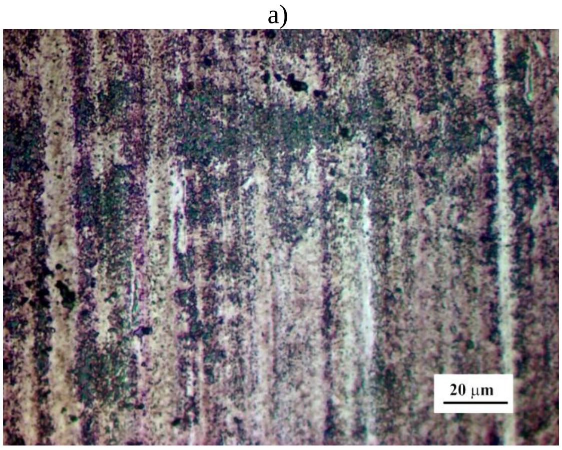
layer and increases the concentration of carbon fibers with the superficial layer of the composite wear track [7].

For v=0.5 m/s and v=0.75 m/s, the lowest values for the friction coefficient were recorded, for the average pressure of 0.25 MPa, not exceeding 0.16, the hard surface being covered with a solid mixt lubricant film (Fig. 2).



a)



b)

Fig. 2. The optical images of the disk made of PPS PVX (a) and steel pin (b) (v= 0.5 m/s, p= 0.25 MPa)

At p= 0.5 MPa and v= 0.75m/s, a decrease of the friction coefficient was noticed, up to a value of 0.18, which is the lowest value recorded for this average pressure. There is a decreasing value of the coefficient with increasing the sliding speed. PTFE can be easily pulled out from the matrix to form a continuous transfer film on the steel counterpart, having an important contribution in reducing the friction.

For the polymers and the polymer composites, the transfer film plays an important role in determining the tribological properties. The friction coefficient decreases when the transfer films is initiated and maintained, reducing the abrasive component of the friction and wear processes in the contact between the composite disk and the pin.

Figure 3 presents the evolution of the friction coefficient for pin (steel) on disk (PPS reinforced with 40% glass fibers) tests, for the sliding distance of 10000 m, under dry sliding regime. With increasing average pressure and sliding speed, the abrasive wear predominates.

The wear particles are formed between the two surfaces and they are compacted when entering again into the contact, leading to a lower friction coefficient up to a steady state value. The friction coefficient shows a unique trend, depending on the test conditions (the average pressure, the speed and the temperature generated in the contact).

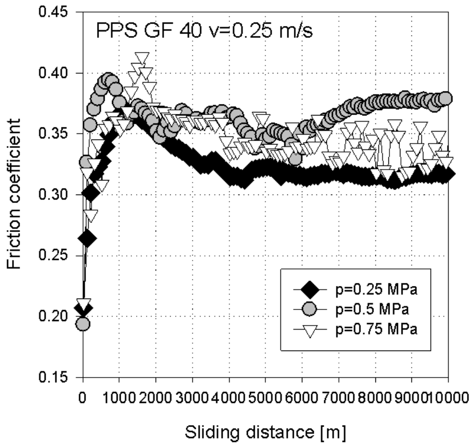
At the pressure of 0.25 MPa, the slightest variations in the value of friction coefficient were observed and it is assumed that at this speed, the adhesion wear are dominated. For v= 0.25 m/s, the friction coefficient becomes stabilized for the value of the average pressure of p= 0.25 MPa to 0.31 and for p= 0.5 MPa to 0.38. At p = 0.75 MPa, the friction coefficient is not stable because the composite worn much faster and the glass fibers remain within the superficial layer in a higher concentration as the bulk material, for all tested speeds. The friction coefficient presents oscillations at irregular intervals.

The presence of these oscillations of the friction coefficient indicates that the wear particles appeared in the contact, the fibers (fragmented or not) from the composites and also those "fixed" into the hard surface topography produces micro-scratches on both surfaces in contact, highlighting the abrasive wear component.

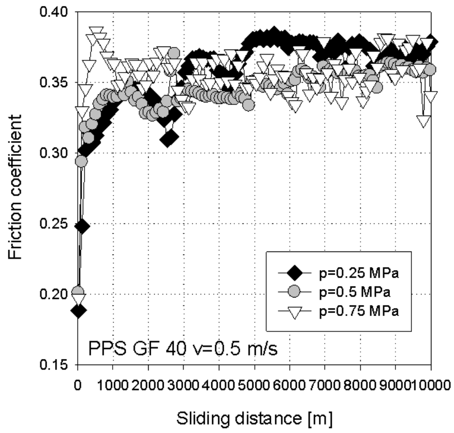
In Figure 3a, the evolution of the friction coefficient on the sliding distance can be divided into four stages: the first is on a short time period, 0-300 m, where the friction coefficient suddenly increases, reaching the maximum value in the second stage,

between 300-1500 m, for each test, depending on the applied pressure.

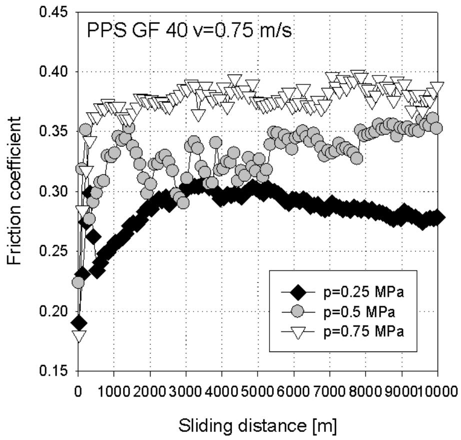
In the third stage, between 1500-6000 m, there is a smooth decrease of the value



a) *v*=0.25 m/s



b) *v*=0.5 m/s



c) *v*=0.75 m/s

Fig. 3. The variation of the friction coefficient for the friction couple steel pin on PPS GF 40 disk

of friction coefficient up to ~0.33, for p= 0.25 MPa. For p= 0.75 MPa, the variation of friction coefficient occurs on greater intervals of time, from 0.33 to 0.37.

The last stage is the steady friction state and is maintained at ~0.32, for p=0.25 MPa and at the value of ~0.38 for p=0.5MPa.

At p=0.75 MPa, for the steel pin on PPS GF 40 disc, at v=constant, the value of the friction coefficient is not stable, but its variation is closer, between 0.32 and 0.36. This dynamic behaviour (as a result of cyclic wear processes) of oscillating the coefficient can be attributed to the formation of the wear particles and the tendency of eliminating them from the contact [7].

At v=0.5 m/s, for all three applied contact pressures, the friction coefficient values are contained in a small range of values, from 0.35 to 0.38. For p=0.25 MPa, the coefficient has an increasing value, by leaps at irregular intervals. These variations are caused by uneven distribution of the glass fibers within the superficial layers and the forming of local agglomerations.

For p = 0.75 MPa and v = 0.5 m/s, the friction coefficient varies between 0.33 up to 0.38, but without having a constant period. Increasing the average pressure and the sliding speed, several wear processes are overlapping.

At the lowest and highest speeds, the composite with 40% glass fibers has the lowest value of the friction coefficient. It seems that for these testing regimes, the presence of a softer polymer (PTFE) and of graphite makes the other tested composite to generate wear particles that are recirculated in the contact and causes larger oscillations of the friction coefficient.

The glass fibers prevent the matrix transfer on the hard surface and the wear debris, already formed, remain "locked" among the fibers (Fig. 4). The most dominant wear process is the abrasive one, evidenced by the micro cutting wear tracks appeared on the conjugate surface, the drag of the wear debris out of the contact and, thus, uncovered glass fibers remain on the surface.

On the wear track, many glass fibers are oriented in the sliding direction. A high friction coefficient is induced by this higher concentration of glass fibers on the surface, leading to a more intense abrasive wear process.

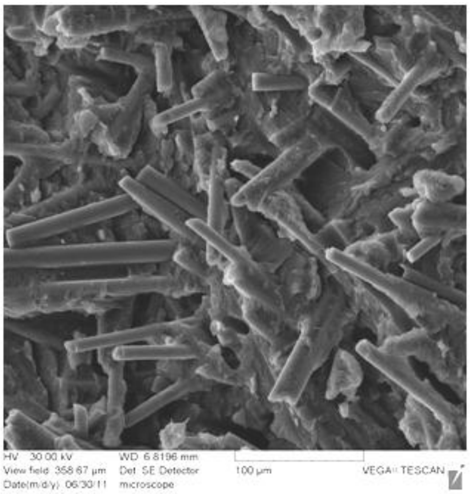


Fig. 4. A SEM image of a worn surface of PPS GF 40 disk (test parameters: *v*=0.75 m/s, *p*=0.75 MPa)

4. CONCLUSION

The sets of the selected test parameters (p = 0.25 ÷ 0.75 MPa and v= 0.25 ÷ 0.75 m/s) revealed the processes with specific features for these two types of material filler, both composites exhibiting a strong abrasive character at the high sliding speed of v= 0.75 m/s.

The composite reinforced with 40% glass fibers presents a high concentration of fibers within the superficial layers, with a high coefficient friction and pronounced pin wear, characterized by micro-scratches on the surfaces. These are due to the uncovered glass fibers remained on the surface.

In case of the composite PPS + 10% carbon fiber + 10% graphite + 10% PTFE (PPS PVX), as compared to PPS GF 40, the friction coefficient was lower, revealing an adhesion process on the hard surface of the disk and even on the pin (re- attachments of the wear debris to the composite surface), due to the presence of a polymer with higher lubricity (PTFE) and to other solid lubricant (the graphite).

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