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).

Keywords: Wear, friction, composite, polyphenylene sulphide

1. INTRODUCTION

Polyphenylene sulphide (PPS) is a semi-crystalline high performance thermoplastic matrix. The tribological behaviour of PPS composites have been study earlier [1, 2]. Fibres reinforced composites are well known to improved the friction and wear performances of the composites [3]. By 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). 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= 0.8μm). Both the pin (Ф6 mm x 20 mm) and the disc (Ф40 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, 0.5 and 0.75 m/s, respectively, the average calculated pressure on the contact pin-disc: 0.25, 0.5, 0.75 MPa, respectively. Here are presented the results for two composites with PPS matrix: 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.

In this work, we 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 shows an increase of the value of friction coefficient with increasing average pressure applied (Fig. 1a). At p= 0.25MPa, the friction coefficient increases on the distance of 1000 m, which present a plateau up to the distance of 2500 m and, finally, increases suddenly 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 pressure. The friction coefficient is stable at the value of 0.12 between 9000-10000 m.

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At $p=0.75$ MPa the value of friction coefficient are sudden increase from 0.16 to 0.24 on the distance of 1000 m. Between 1000-5000 m the evolution is slightly decreased due to developing a graphite and PTFE films formed on sliding surface. Towards the end of the test is observed sudden increase in friction coefficient attributed to discontinuities appeared in graphite film formed on the sliding surface, and because it impoverishes the graphite layer and increases the concentration of carbon fibers on sliding surface [7].

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

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

For polymers and polymer composites the transfer film plays an important role in determining the tribological properties. The friction coefficient decreases with formation of graphite film by reducing the contact between the composite disk and the pin.

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

Wear particles are formed between the two surfaces, which compacts entering again into contact, leading to lower friction coefficient up to a steady state. The friction coefficient shows a unique trend depending on the conditions of pressure, speed and temperature generated in the contact, while the wear rate has different regimes depending on the load.

At the pressure of 0.25MPa is observed the slightest variations in the value of friction coefficient and is assumed that at this speed, adhesion wear are dominated. For v= 0.25 m/s the friction coefficient reached to stabilize at the value of pressure p= 0.25MPa to 0.31 and p= 0.5MPa to 0.38 value. At p = 0.75MPa the friction coefficient is not stable because the composite worn much faster and the glass fiber remain on the surface, for all speeds test. The friction coefficient is not stable; it presents oscillations at irregular intervals.

The presence of variation on the friction coefficient indicates that on the contact surface appeared wear particles or fiber which produced on the disc and pin micro scratches, highlighting the abrasive wear.

In Figure 3a the sliding distance can be divided into four parts: the first contained in a short period, 0-300 m, where the coefficient of friction increases suddenly reaching the maximum value in the second stage between 300-1500 m for each test depending on the decreasing pressure applied. In the third stage, between 1500-6000 m, there is a smooth decrease of the value of friction coefficient, for p= 0.25MPa recorded a value of ~0.33. For p = 0.75MPa the variation of friction coefficient start to appear at greater intervals of time, from 0.33 to 0.37.

Last stage is the steady state of friction coefficient and is maintained at ~0.32 for p=0.25MPa and the value of ~0.38 for p=0.5MPa. At p=0.75MPa

**Fig. 3.** The variation of the friction coefficient of steel pin on PPS GF 40 disc, at v= constant
the value of the friction coefficient are not stable, but its variation value is between 0.32 and 0.36. This dynamic behavior (as a result of regular wear processes) to decrease and increase of the coefficient can be attributed to the formation of wear particles and their trend to eliminate them from the contact [7].

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

The friction coefficient for \( p = 0.75 \) MPa and \( v = 0.5 \) m/s varies between 0.33 up to 0.38, but without having a constant period. Is observed that with increasing pressure and speed, at the contact surface overlap several wear processes.

At the lowest and highest speed, the composite with 40% glass fiber has the lowest value of the friction coefficient.

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

Glass fibers prevent the matrix transfer, and the wear debris already formed, remain “locked” between fibers (Fig. 4). Most dominant wear is the abrasive wear evidenced by the micro cutting appeared on the conjugate surface, the appearance and drag the wear debris remaining therefore uncovered glass fibers into contact.

The presence in the composite of the glass fibers shows an orientation to the direction of sliding direction. A high friction coefficient by the remaining worn fibers is induced on the surface, out of the matrix may result punctually fiber concentrations, leading to a strong abrasive wear mechanism.

### 4. CONCLUSION

The sets of chosen parameters test, (\( p = 0.25 \div 0.75 \) MPa and \( v = 0.25 \div 0.75 \) m/s), revealed the characteristic processes with specific features for the two types of material filler. It showed a strong abrasive character at high sliding speed (\( v = 0.75 \) m/s).

For the composite reinforced with 40% glass fibers, presents at sliding surface a high concentration of fiber, with a high coefficient friction and pronounced pin wear, characterized by micro scratches on the surface. These are due to the uncovered glass fiber remains on the surface.

In case of the composite PPS + 10% carbon fiber + 10% graphite + 10% PTFE (PPS PVX), compared with PPS GF 40, the friction coefficient were lower, revealing in particular the adhesion process of polymer composite particle on the worn surface of the disc, and of the pin.

### REFERENCES
