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Wear Behavior of a Glass Fiber-Reinforced PEI Composite

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ABSTRACT: The wear behavior of a thermoplastic polymer, polyetherimide, and of a composite with this polymer as matrix and a reinforcement of glass fiber fabric has been analyzed. The test was carried out according to the Standard ASTM G99 using a device pin-on-disk. Obviously, the reinforced material has higher wear strength than the nonreinforced material. Also, the evolution of the wear with the temperature has been studied at ambient temperature and at 50, 100, 150, and 200°C. The effect of the temperature is very important because when it was increased the wear was increased, except to 200°C. At 200°C there was an important decrease. The test temperature was measured in the inner of the furnace and when it was 200°C in this zone, the temperature in the contact point was higher and it would be close to glass transition temperature of the polymer (~217°C), this is the reason for an important micro-structural variation in the material.

KEY WORDS: wear, polyetherimide, glass fabric, temperature.

INTRODUCTION

NOWADAYS, STRUCTURAL DESIGNS in which contact exists between metallic and composite elements are becoming more and more commonplace due to the increasing use of the latter type of materials. If there is movement between these pieces, a wear process is created. Usually, the weakest part is that made up of the composite if it has a polymeric matrix.

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The matrix employed in this study was made of polyetherimide (PEI), a thermoplastic used in industrial components because of its good mechanical properties and excellent behavior at high temperatures resulting from its very high glass transition temperature.

Several studies on the sliding wear mechanism with other types of fiber and matrix have been carried out. For example, Schön [1] measured the friction coefficient in the case of aluminium against a composite of epoxy resin and glass fiber. The value obtained was 0.23 at the beginning, with a maximum value of 0.68. On the other hand, Reinicke et al. [2] studied the tribological behavior of several thermoplastic matrices (PA-46, PPA, PPS, and PEI) reinforced with different amounts of glass fibers and PTFE. Experiments were performed at room temperature and also at 150°C. The findings prove that using PTFE as an internal lubricant results in an improvement in the tribological behavior of all polymers tested. Also, the authors think that the tribological behavior close to the glass transition temperature of the polymers is of interest. Viswanath et al. [3] analyzed the effect of the volumetric fraction of fiber and matrix in the wear behavior of two composites of woven roving glass/polyester and glass/phenolic. Glass/phenolic composites generally showed minimum wear and a composition of 30 wt% of matrix in both of the composites gave minimum wear and minimum coefficient of friction. Srinath and Gnanamoorthy [4] studied the effect of fiber reinforcement (glass and carbon) on the friction and wear behavior of nylon 66. Tests were conducted under different normal loads and sliding velocities at ambient temperature. Quintelier et al. [5] carried out wear tests between steel and a PPS composite reinforced with carbon fiber. The frictional behavior of this material pair resulted in a friction coefficient of 0.33, while a carbide film is formed in the wear track. Bijwe et al. [6] reported the influence of the amount of aramid fabric in polyethersulfone (PES) on abrasive wear performance. In the present work, three orientations of PES composites containing Kevlar 29 fabric with three concentrations of 64, 72, and 83% in weight were selected to study the influence on wear. It was observed that 83% fabric composite showed the highest resistance to abrasive wear. Su et al. [7] evaluated the friction and wear behavior of carbon fabric composites. Previously, the carbon fibers were modified with strong HNO₃, etching, plasma bombardment, and anodic oxidation. The composite made of the carbon fabric modified with anodic oxidation showed the best tribological properties and the one made of carbon fabric etched with HNO₃ had the poorest tribological behavior. Also, the variations of friction and wear properties with temperature were analyzed. Namely, the wear rates of the composites at elevated temperature above 180°C were much larger than that below 180°C, which was attributed to the degradation and decomposition of the adhesive resin at excessively

elevated temperature. Finally, Wan et al. [8] investigated the sliding friction and wear characteristics of three-dimensional braided carbon fabric reinforced epoxy resin composites. The test were performed under normal loads of 50, 100, and 150 N and velocities of 0.42 and 0.84 m/s. The main result is that the specific wear rate decreased with the increase in the product of load and velocity.

EXPERIMENTAL PROCEDURE

Material

The material used in this work was a composite with a matrix of PEI reinforced with glass fabric (type of glass fiber weave 8 H Satin). The mass of fabric was 300 gm^{-2} and the resin content 33%. PEI is a high-performance thermoplastic resin whose chemical structure is formed by an aromatic imide, which gives stiffness and a high glass transition temperature, and an ether group which gives flexibility to the polymer chain.

Polyetherimide (PEI), a polymer with high mechanical and thermal performances, was used in this study, without any reinforcement and with glass fiber fabric (8H Satin) reinforcement with a volumetric fraction of 67%.

Wear Test

The test was carried out in accordance with the ASTM G99 Standard [9] employing a pin-on-disk device (Microtest) (Figure 1).

The ball employed was made of steel with $\sim 55\text{HRC}$. During the test, the ball became worn and was consequently rotated every kilometre while the specimen was weighed.

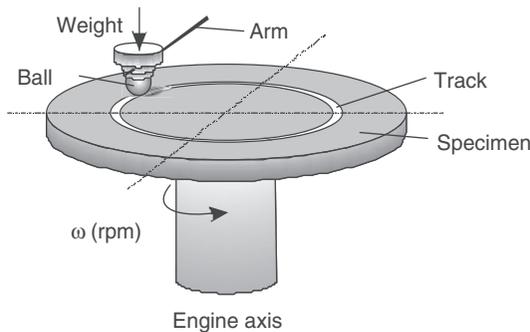


Figure 1. Schematic functioning of a pin-on-disk test.

Table 1. Mean values of the friction coefficients.

PEI	Friction coefficient	
	Temperature (°C)	0.7
PEI + glass fiber	20	0.38
	50	0.42
	100	0.43
	150	0.48
	200	0.39

The turn speed selected was 137 rpm. This speed enabled continuous contact to be maintained between the ball and the specimen. The weave of the material combined with an excessive turn speed caused the arm to jump, resulting in discontinuous wear of the material. The aforementioned turn speed was equivalent to a tangential speed of 0.2 m/s at the ball-specimen point of contact. Furthermore, a normal load of 10 N was chosen, this load is recommended by the Standard [9].

RESULTS

Table 1 shows the friction coefficients between the ball and the specimen in the case of PEI and PEI with glass fiber to different test temperatures.

Figure 2 shows the wear volume of material versus sliding length in a test carried out at ambient temperature. The wear in the case of the resin is much higher than in the resin reinforced with glass fiber.

Figure 3 shows the curves corresponding to the wear suffered by the glass fiber-reinforced material. The tests were carried out at ambient temperature, 50, 100, 150, and 200°C.

The first conclusion to be drawn from the figure is that the loss of material increased with temperature, although with the following characteristics, there was a very substantial increase in losses between ambient temperature and 50°C. At 100 and 150°C, the losses were very similar, though greater than that obtained at 50°C. It is worth noting that at 200°C there was a decrease in loss, the curve being situated between those corresponding to ambient temperature and 50°C. The reason for this behavior is that although the internal temperature of the furnace was 200°C, the real temperature at the contact point between the steel sphere and the composite specimen must be higher owing to friction, and could even be higher than the glass transition temperature of the polymer ($\cong 217^\circ\text{C}$). This situation generates a softening and an increase in the ductility of the polymer,

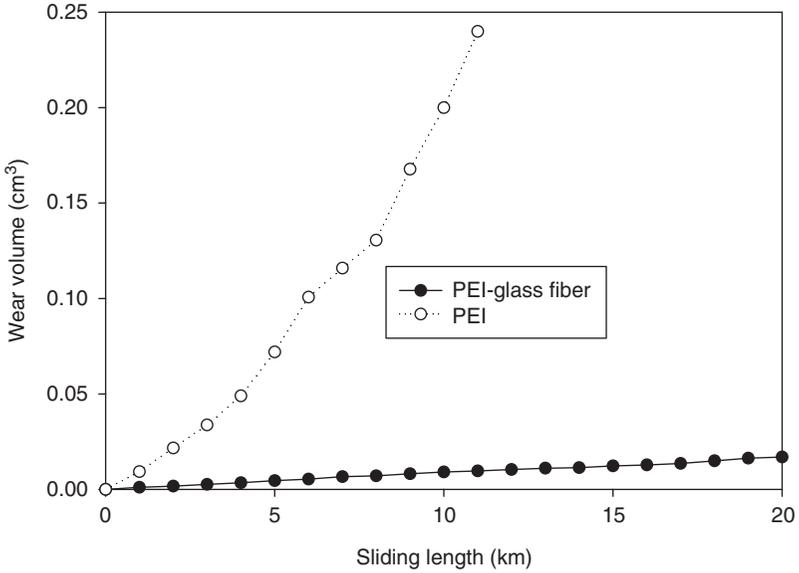


Figure 2. Wear volume versus sliding length at ambient temperature for two materials.

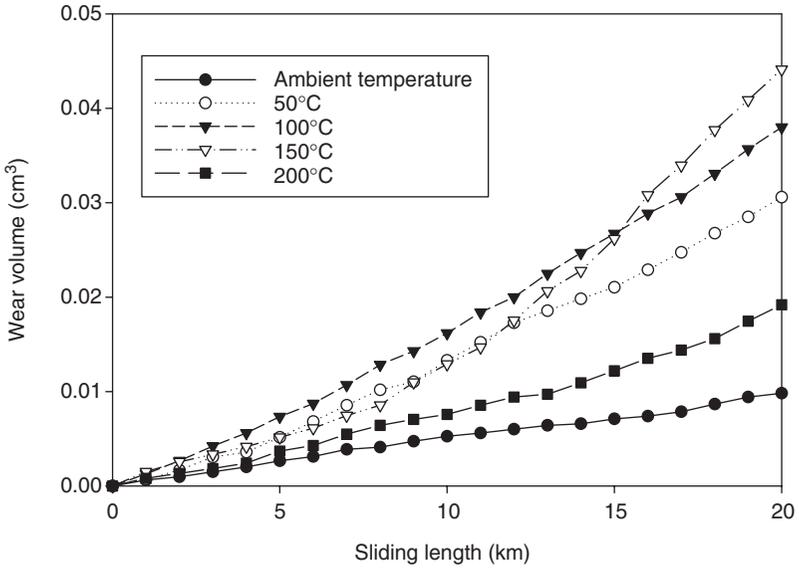


Figure 3. Wear volume versus sliding length of the PEI reinforced with glass fiber for different temperatures.

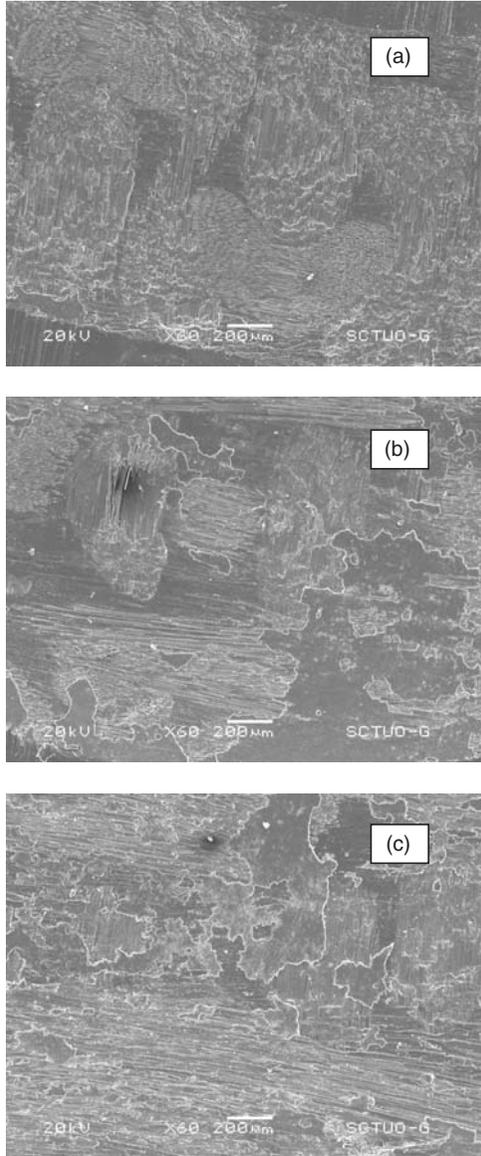


Figure 4. SEM micrographs of the tread track at the end of the test at: (a) ambient temperature, (b) 50°C, (c) 100°C, (d) 150°C, and (e) 200°C.

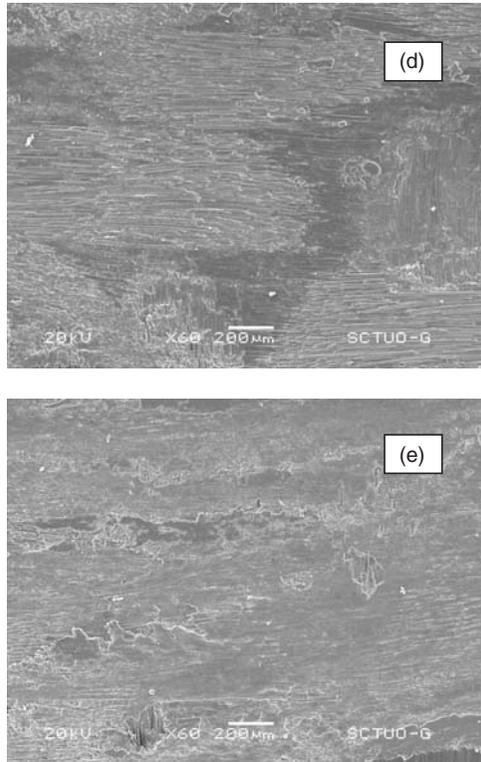


Figure 4. Continued.

which becomes deformed, creating a tread track, although the wear will be minimized.

Figure 4 shows SEM micrographs of the surface of the specimens tested at different temperatures. All of the micrographs are obtained from the center line of the wear track. In Figure 4(a), obtained from the specimen tests at ambient temperature, a homogeneous wear can be observed without important damage zones. In Figure 4(b), corresponding to the test at 50°C, the damage in some zones is more substantial and the wear is less homogeneous than in the previous case. This is because there are substantial zones of fiber and other, likewise important, zones of resin. Figure 4(c) (specimen tested to 100°C) is quite similar to the previous figure, although the percentage of fiber that can be observed is higher. This means that the matrix has suffered more wear and the detached volume has increased. Figure 4(d) shows the surface of the specimen tested at 150°C. This figure is

quite similar to the previous one, although there could perhaps be a greater amount of broken fibers.

Finally, Figure 4(e), corresponding to the tread track of the specimen tested at 200°C, shows mainly a resin layer. However, there are zones which have suffered substantial damage.

CONCLUSIONS

When a polymer is reinforced with fibers, this concept can be applied to its wear strength.

If the test temperature increased, the wear volume increased too, except to temperatures close to the glass transition temperature of the polymer.

If the material is working to temperatures close to T_g of the polymer, the increase of temperature that derives from the friction between the pieces causes that the temperature T_g is surpassed forming a soft resin layer by which the ball slides causing an important decrease in the wear.

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