Effect of adding graphite powder to a UP polymer on friction and wear for different loads and rubbing speeds

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Abstract. The aim of the present work is the investigation of the influence of graphite powder addition to an unsaturated polyester type polymer (32% styrene content in mass) on the mechanical and tribological properties. For this purpose, we conducted bending tests and wear tests with a combination of four loads and three speeds for three different compositions (0, 1 and 2% graphite). The wear tests were carried out on a dry type pin on disk tribometer. The disk is made of quenched and annealed C48 steel (540 Hv hardness). Before the rubbing process, the discs were subjected to polishing in order to obtain approximately the same initial surface roughness. The results show that the addition of graphite powder improves the tribological properties; a noticeable decrease of the coefficient of friction, the mass loss and the wear rate are achieved with the increase of the graphite powder percentage for all sliding speeds and loads. A 2% graphite content causes a drop of the friction coefficient from 0.4 to 0.2. The results of bending tests showed a significant decrease of the stress and strain at failure and a slight increase in Young's modulus. In addition, for the three compositions, the results show a clear preponderance of the influence of the load on the tribological properties.

Introduction.

Industrial demand for improved abrasion resistance and wear of mechanical parts is constantly growing for over 20 years. It is justified by the desire to reduce the losses associated with the phenomena of friction and wear. It is generally accepted that they represent 6 to 10% of GNP in industrialized countries [1]. Polymers are already integrated in many industrial applications because of their advantageous properties (low density, good corrosion resistance, low cost and simplicity of implementation. Numerous studies were performed on polyamide 66 (PA66), polyether ether ketone (PEEK), poly butylene terephthalate [2-4]. In these last years, fiber reinforced polymer, micro or nano particles are increasingly used in tribological applications. A significant number of researches are devoted to their study [5-7]. In the same way, we present in this paper the experimental results on the effect of the addition of graphite micro particles on the mechanical and tribological properties of a thermoset polymer.

Experimental technics.

Two types of experiments were conducted in this study:
1) The three-point bending tests.
2) The wear tests.

1) The three-point bending tests were carried out on a 5KN capacity Z 20 type bending machine, electrically controlled and provided with software for acquisition and processing of data.
We performed three-point bending tests at 2mm/min speed and 25 ° C room temperature. Relations (1) and (2) are used to obtain the stress-strain curve.

$$\sigma = \frac{3Fl}{2bh^2} \; ; \; \epsilon = \frac{6hw}{l^2} \qquad (1)$$

2) The wear tests were performed on a pin / disc type tribometer with dry condition at room temperature for three sliding speeds (Vg = 0.08, 0.32 and 0.63 m/s) and four normal loads (Fn = 11;16 ;22 and 28 N).

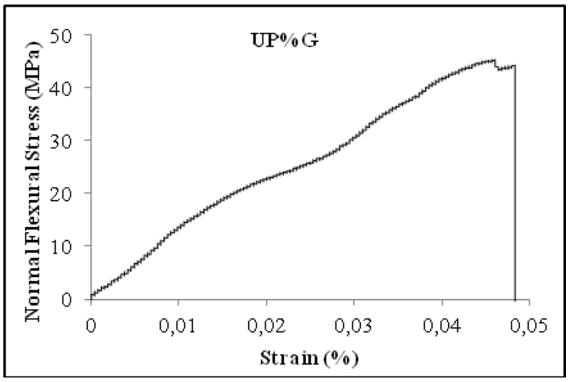
Materials and specimen geometry.

The materials used for the production of the pins and the flexural test specimens are:
-An unsaturated isophthalic and pre-accelerated polyester resin matrix containing unsaturated monomer (32% by weight of styrene), cross-linked at ambient temperature by the addition of an organic peroxide catalyst and an accelerator. It changes successively from the initial viscous liquid state to the gel state than to the state of non melting solid.
- A hardener type (MECP 50), Methyl-ethyl-ketone peroxide, in an amount of 3% by mass which is the most commonly used for the production of laminates at room temperature.
We have used commercial graphite powder which has not undergone any chemical treatment.
Three different compositions were prepared (matrix with no graphite added UP0% G, matrix with addition of 1 and 2% graphite (UP1% G and UP2 % G).
The parallelepiped shaped pins with a square section (S = 36 mm^2), length l = 17 mm and the flexural test specimens of dimensions (L = 100, b = 10 and h = 4 mm) were cut from molded plates. They are then milled to the dimensions required by the standards.
The fabrication of the plates begins with the preparation of the different mixtures (resin + hardener) for the UP0% G plate and (resin + hardener + charge) for the plates UP1% G and UP2% G graphite powder. The mixtures were then homogenized one after the other. They are then poured into the prepared molds . After curing and demolding, the plates are cut to size with a diamond saw cooled with water.
C48 steel disks are machined to 60 mm diameter, 10 mm thickness with a central hole of 8 mm diameter. They are then quenched and tempered. The quenching temperature is 850 ° C with a holding time of one hour thirty minutes in the oven followed by water cooling. The quenching is carried out at a temperature of 250 ° C with forty minutes holding time and a slow cooling to room temperature inside the oven. The hardness after treatment was 540 Hv. After machining the disks were polished for a better homogenization of the initial surface conditions. For the three compositions, three tests were conducted for each parameter. This gives a total of 144 samples.

Results and discussions.

Bending tests. For the three compositions studied (UP0% G, UP1%G and UP2% G), the stress-strain curves (Fig. 1) show a brittle behavior. The dispersion of the results obtained for the same composition (stress and strain at failure, Young's modulus) remains very low. It is mainly due to the conditions in which the plates were prepared. The stress and strain at failure (σ_r ε_r) (Fig. 2 and 3) decreases with the increasing of the graphite percentage. Young's modulus in bending (Fig. 4) showed an opposite behavior. Graphite powder has probably limited the movement of the molecular chains of polyester resin.

Wear test. Fig. 5 shows the behavior of the friction coefficient as a function of the sliding speed Vg and the normal force Fn for the three compositions. We can see a notabale increase in the coefficient of friction as a function of Vg and Fn, this behavior is in accordance with results obtained by other authors [7-9]. At dry sliding conditions, increasing the normal force causes an increase in the contact surface which causes the elevation of the friction coefficient. The same is true for the sliding speed which is generally a source of temperature rise resulting in an increase of the friction coefficient.



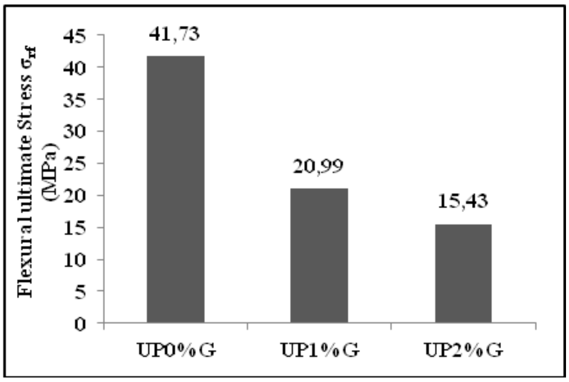
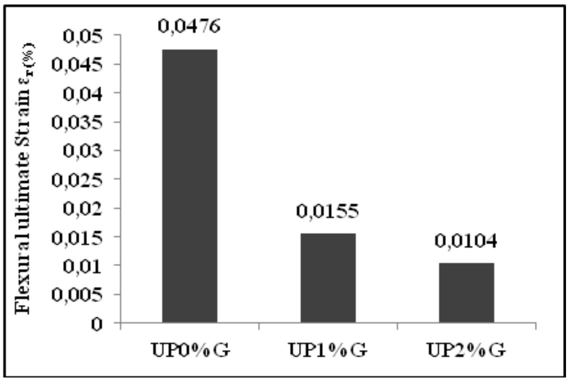


Fig. 1: Normal Flexural Stress versus Strain for UP0%G.

Fig. 2: Stress at failure versus the graphite percentage.



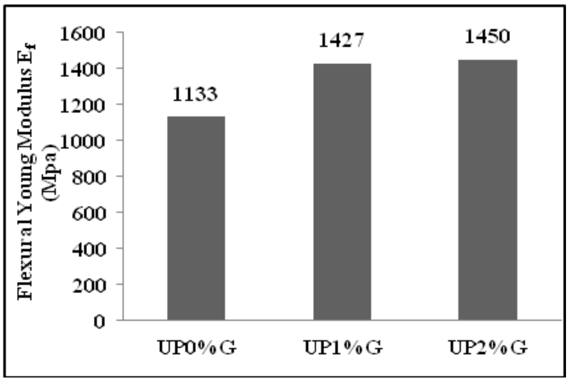
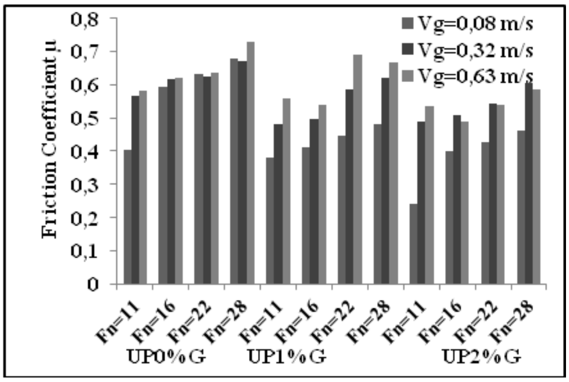


Fig. 3 : Strain at failure versus graphite percentage.

Fig. 4 : Young's Modulus versus graphite percentage.



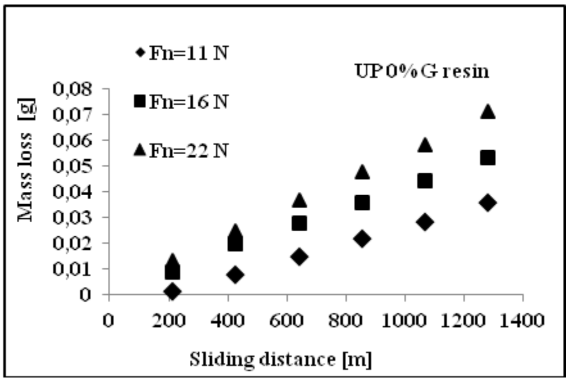


Fig. 5 : Coefficient of friction versus the Normal load Fn and the sliding speed Vg for the three studied compositions.

Fig. 6 : Mass loss as a function of the sliding distance for the UP0%G resin at V=0.32m/s.

However, for the same speed and load conditions, the addition of 2% of graphite reduces the coefficient of friction from 0.4 to 0.2. A significant decrease in tensile strength and strain at failure is observed.

According to these results, there is a possibility of developing a composition with better compromise between these properties.

For the three compositions studied, the mass loss increases linearly with the sliding distance and the normal force Fn. The slope of the curve seems to increase for higher normal force which is a sign of higher abrasion (fig. 6).

Samples with graphite powder show lower mass loss and wear rate for all the normal force (Fig. 7 and 8). Graphite is known for its structure consisting of a pile of hexagonal plates at the top of which atoms present weak bonds with their neighbors. It is brittle, soft and is therefore a good solid lubricant; this explains the contribution to the reduction of the friction coefficient, the mass loss and the wear rate. The same behavior has already been observed in the case of a composite (fiber-reinforced PEEK carbon [5].

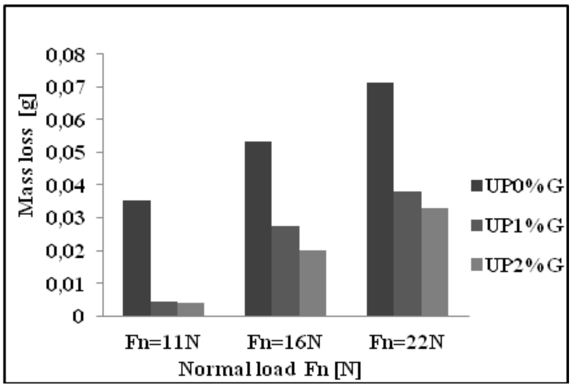


Fig.7 : Mass loss versus normal load for the three compositions at Vg= 0.32m/s.

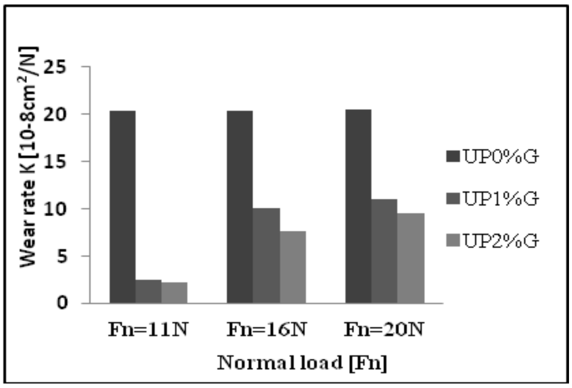


Fig.8 : Wear rate as a function of the Sliding distance for the three compositions at Vg=0.32m/s.

Conclusion.

In this study, an experimental program was conducted in order to determine the tribomechanical properties of a polymer loaded with graphite powder.

The effect of the graphite powder percentage, the normal force and the sliding speed on the tribological properties was investigated. The following conclusions can be drawn:

The addition of graphite powder polyester keeps its fragility and leads to a drastic reduction of the stress and strain at failure. Young's modulus increases with the content of graphite powder.

Increasing the graphite powder content leads to a substantial drop in the coefficient of friction, the mass loss and the wear rate. A 2% graphite powder content leads to a decrease of the friction coefficient from 0.4 to 0.2. A compromise between the mechanical and tribological properties depending on the conditions of use can already be obtained by expanding the experimental study.

The results for the variation of tribological properties as a function of sliding speed and normal force for the three compositions studied show a great similarity with those of the literature [5] and [7-9].

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