A global point of view on wear depth for dry linear contact of composite polimers on steel

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ABSTRACT

In this article we present a graphical assessment of the dry linear contact for composite materials reinforced with glass fibers as well as of the influence of the sliding speed, load and friction coefficient. Perpendicular loads, the contact temperature and the wear of the metal surface were recorded .The wear volume was calculated using the Archard relationship. Using the Archard relationship, the width of trace can be calculated in 3 locations. Numerous experimental trials were performed in connection to the wear of the metal surface, the contact temperature and the value of the friction coefficient. A connection between the evolution of the wear process and the dependency on the contact temperature and friction coefficient can be observed.
Keywords: hardness of steel, steel surface wear, plastics with glass fibers, dry friction linear contact, contact temperature

1. INTRODUCTION

One of the most sophisticated tribosystems is the one between a polymer polymer with short fibers (SGF) on steel, where the contact is dry. In this case, the input parameters are permanently modified. Based on comprehensive experimental tests, a study for the evolution of wear for a certain duration, as well as for certain loads and contact temperatures. The materials used were composite thermoplastic materials reinforced with glass fiber. The glass fiber content varied from a material to another. The evolution of wear was highlighted depending on the duration, the load, contact pressure and sliding speed. Starting from an extended study, we have tried to come up with a graphical representation of the wear process for a dry contact between polymers reinforced with glass fibers and C120 steel, respectively Rp3 steel. For experimental tests, Archard's relationship for adhesion wear was used.

Derjaguin-Muller-Toporov [1] (DMT) model. This model is correct for nanometrically sized bodies, with steel characteristics. The main characteristic of short fiber reinforced polymers (SFRP) is their high level of resistance to rapid loads. This occurs at a relatively low price compared to other materials.

Wang, et all, [2] have studied Nylon 1010 composite with MoS_2 filler and short carbon fibers, the study being carried out in a ring-block wear tester, using a dry contact. The following two aspects were observed: by adding the MoS_2 filler, it has led to an increase in wear, while adding the carbon fiber filler has led to a decrease in wear.

Chang and Friedrich [3] have noticed that the particles, respectively the nanoparticles do not entirely contribute to the film transfer, thus reducing the adhesion and, as a consequence, also reducing the friction coefficient.

Cho and Bahadur [4] have carried out a study on nanosized CuO-filled polyphenylene and on polyphenylene sulfide composites (PPS) reinforced with short carbon fibers (CF) and aramid fibers (Kevlar).

Dorin Rus [5][6] have highlighted the behaviour of polyamide and polycarbonate reinforced with glass fibers (SGF) in friction on steel surfaces .

No studies regarding the correlation between friction and use concerning the complex friction-wear phenomenon were shown. In our paper we have studied on Timken type couples (with linear contact), in conditions of dry sliding friction, the behavior of glass fiber reinforced composite materials under controlled loads and speeds. We have studied the influence of the percentage of glass fiber, as well as the influence of load and speed on the wear process.

Kukureka, et all [7] have studied the wear of PA66 in rolling-sliding contact. For the polymer they added glass, carbon or aramid, and both for the glass fibers and for the carbon fibers a drop in the friction coefficient was noticed.

Stachowiak, et all [8] have studied the abrasive effect for the three body abrasion of metal samples, the tests were carried out on two ball-on-flat installations and modified pin-on-disk tribometer. The ball-on-flat teste yielded the most significant results.

Dwyer-Joyce [9] has noticed that during contact the wear due to contamination with solid compounds of lubricants occurs, the phenomenon closely resembling the abrasion with three bodies

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2.MATERIALS AND METHODS

Wear and friction are analysed from several points of view, such as speed relative to load and stress. The two samples are cylindrical liner and flat sample.

2.1 EXPERIMENTAL METHOD

A Timken type couple with linear friction contact was used as experimental equipment. Thus the normal load and the contact temperature can be controlled. The friction couple is built out of a plastic cylinder which revolves at different speeds. The plastic piece rests on the polished surface of a steel plan disk. The cylinder has a diameter of 22.5 mm and a thickness of 10 mm.

The friction couple is built out of a cylindrical liner (1) and a flat disk (2). The liner is fixed by means of a nut (3) on the driving shaft (4). The disk sample is placed in a hole made in the elastic blade (5) (Figure 1)

An electric motor (7), the shaft (4) with rotation movement using trapezoidal belt.

Figure 1 shows the functional scheme (a) friction couple (b) and its installation within the experimental equipment (c). The way in which the liner moves against the plane sample is illustrated in Figure 1c.
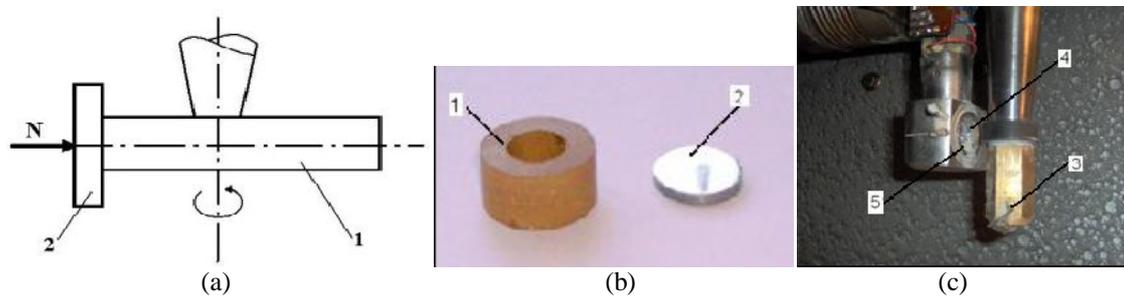

(a)   (b)   (c)

Figure 1. Functional scheme (a) the way how the liner moves against the disk, (b) friction couple, and (c) its installation in the experimental equipment, where 1 - cylindrical liner; 2 – steel flat disk sample; 3 – nut; 4 – hole; 5 - knife-edge.

An electric motor (7), the shaft (4) with rotation movement using trapezoidal belt. The friction couple is built of a cylindrical liner (1) a flat disk (2). The liner is fixed by means of a nut (3) on the driving shaft (4). The disk sample is placed in a hole made in the elastic blade (5). An electric motor (7), the shaft (4) with rotation movement using trapezoidal belt transmission (6). The normal and tangential (friction) stresses are measured by means of resistive tensiometers, mounted on the elastic blade (5). The normal load to the elastic blade (5) is applied, through a calibrated spring system (8). The installation can register the friction force on an *X-Y* recorder. The duration is controlled with a clock and the contact temperature is measured with a miniature thermocouple (9), connected to a millivoltmeter. The installation can also study the wear using other radiometers techniques. For this purpose, the installation has a tank (10) assembled on a base (11) and a tube for collecting the radioactive wear particles (12). (Figure 2)

The unidirectional testing is investigations of metal surface wear. The tests were based on Hooke's law, at normal loads of 10; 20; 30; 40 and 50 N, loads which are adequate to some contact pressures all calculated considering the elastic contact hypothesis, meaning: 16.3; 23.5; 28.2; 32.6 and 36.4 MPa

Experimental tests were carried out on composite thermoplastic materials such as polyamides and polycarbonates reinforced with short glass fibers, whose content varies between 20 and 30%. Metal samples were manufactured from two steel types: C 120 steel hardened 59 HRC and Rp3 steel hardened 62 HRC
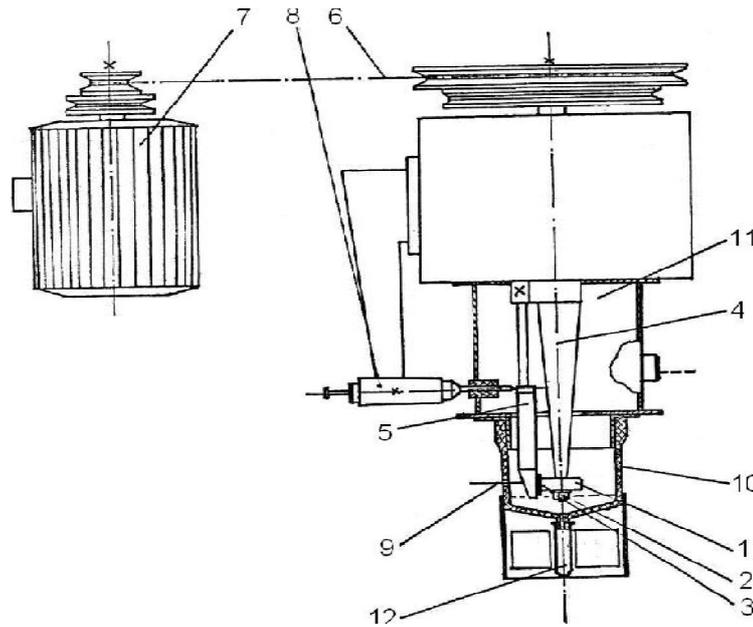
Figure 2. The scheme of experimental equipment with linear contact friction couple, Timken type

3.RESULTS AND DISCUSSION

All the tests were limited to an hour. The volume and wear depth for the wear process were determined.

The curves for depth of the worn metal material (h_u) (Tab.1), as well asa the normal load for each couple were charted.The regression functions and the regression factor were calculated for each couple.

We have charted the characteristic curves for each couple.

Tab. 1. The regression function between the depth of the worn metal material (h_u) and the normal load (N)

| Friction couple	v (cm/s)	Regression function	Correlation factor
Polyamide + 30% SGF/C120 steel	18.56	$V_u = 0.0005\,N^2 + 0.012\,N$	$R^2 = 1$
Polyamide + 30% SGF/C120 steel	27.85	$V_u = 0.0004\,N^2 + 0.0188\,N$	$R^2 = 1$
Polyamide + 30% SGF/C120 steel	37.13	$V_u = 0.0005N^2 + 0.0104N\ 0.1423$	$R^2 = 1$
Polyamide + 30% SGF/C120 steel	46.41	$V_u = 0.0017\,N^2 - 0.0017\,N + 0.47$	$R^2 = 1$
Polyamide + 30% SGF/C120 steel	55.70	$V_u = 0.0034\,N^2 - 0.0922\,N + 0.877$	$R^2 = 1$
Polyamide + 30% SGF/C120 steel	111.4	$V_u = 0.0006\,N^2 - 0.0205\,N + 0.272$	$R^2 = 1$
Polyamide + 30% SGF/ Rp3 steel	153.57	$V_u = 0.0007\,N^2 + 0.1668N + 0.0675$	$R^2 = 1$
Polyamide + 30% SGF/Rp3 steel	18.56	$V_u = 0.0003\,N^2 + 0.018\,N$	$R^2 = 1$
Polyamide + 30% SGF/Rp3 steel	27.85	$V_u = 0.0009\,N^2 + 0.0188\,N$	$R^2 = 1$
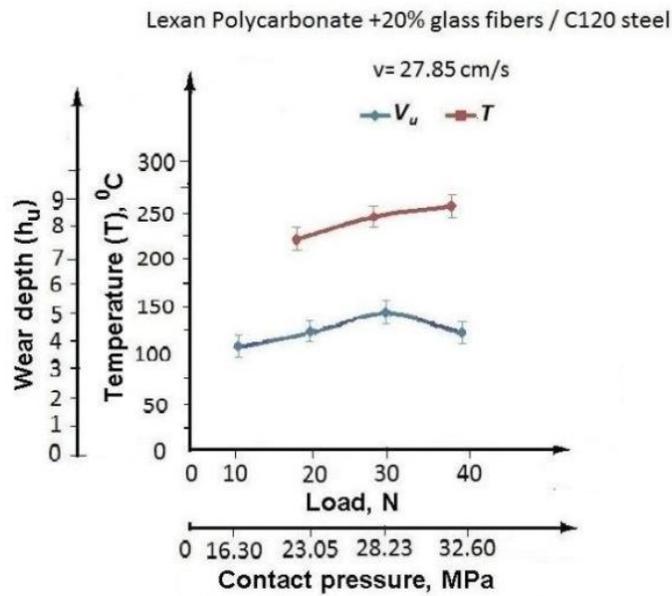
Figure 3 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the speed of 27.85 cm/s, for PC Lexan 3412 + 20% SGF / C120
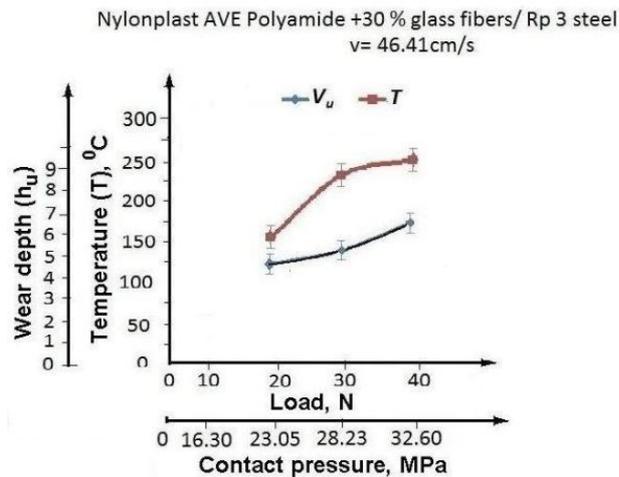

Figure 4 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature of speed of 46.41 cm/s for Nylonplast AVE Polyamide + 30% SGF / Rp3 steel
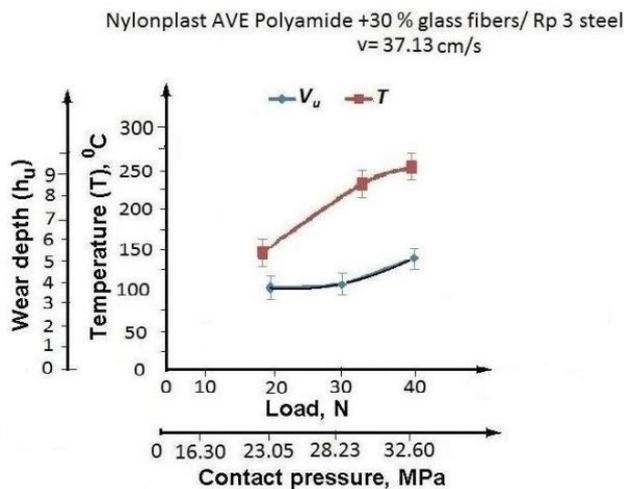
Figure 5 Wear evolution as depth function of the normal load and friction coefficient at the sliding speed of 37.13 cm/s for Nylonplast AVE Polyamide + 30% SGF / Rp3 steel
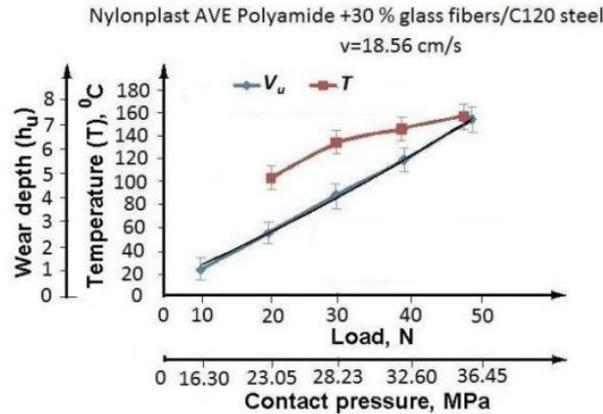

Figure 6 Wear evolution as depth function of the normal load and contact temperature and variation of wear mode, at speed sliding of 18.56 cm/s for Nylonplast AVE Polyamide + 30% SGF / C120 steel
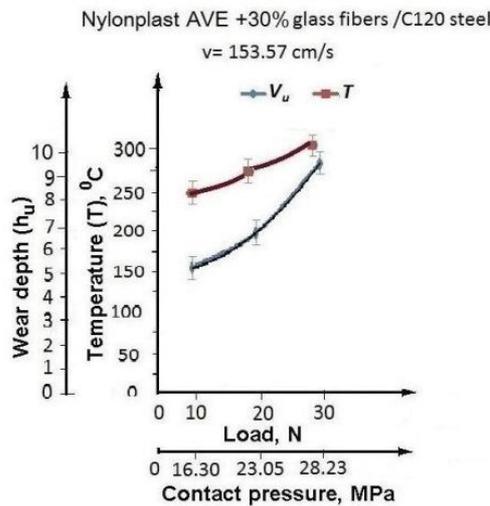

Figure 7 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 153.57 cm/s for Nylonplast AVE Polyamide + 30% SGF / C1
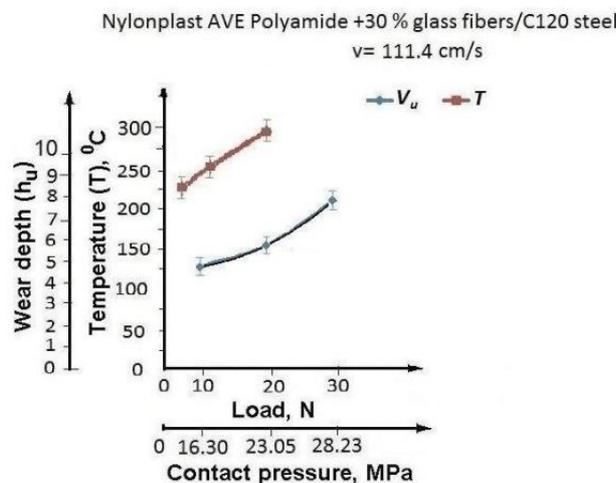

Figure 8 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 111.4 cm/s for Nylonplast AVE Polyamide + 30% SGF / C120 steel
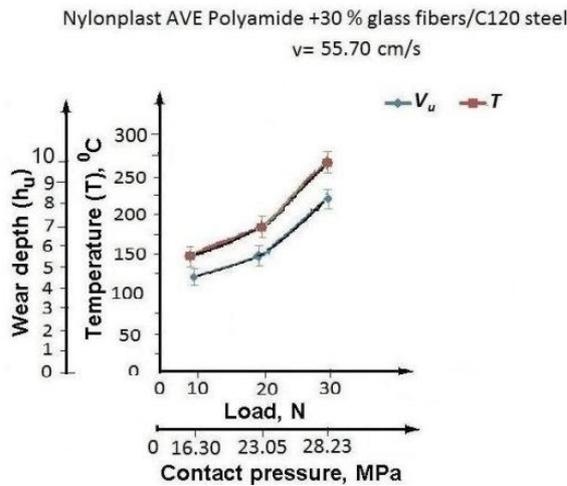
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Figure 9 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 55.70 cm/s for Nylonplast AVE Polyamide + 30% SGF / C120 steel
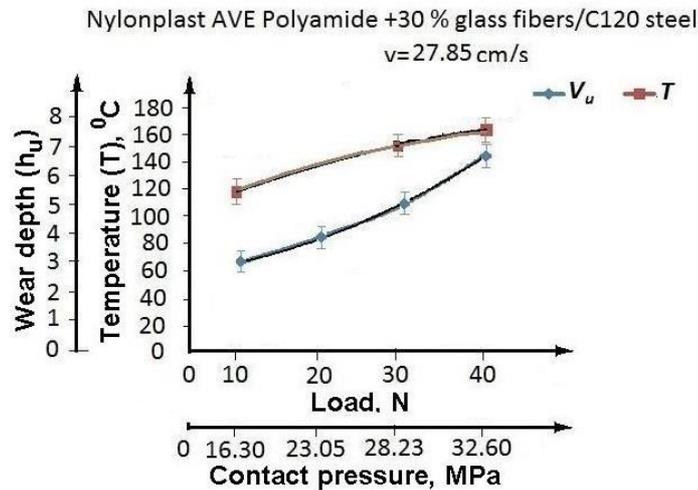

Figure 10 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 37.13 cm/s for Nylonplast AVE Polyamide + 30% SGF / C120 steel
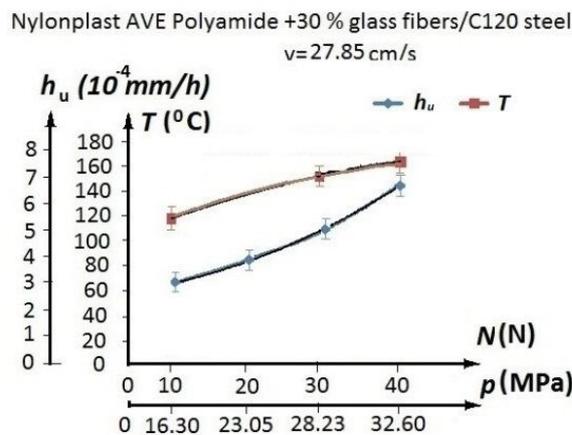

Figure 11 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 27.85 cm/s for Nylonplast AVE Polyamide + 30% SGF / C120 steel
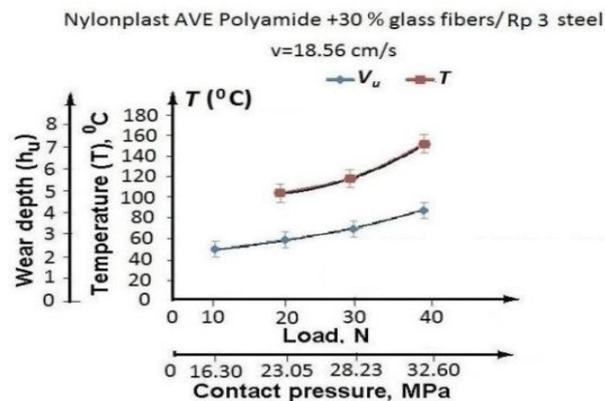
Figure 12 Wear evolution as depth function of the normal load and contact temperature and variation of contact temperature at the sliding speed of 18.56 cm/s for Nylonplast AVE Polyamide + 30% SGF / Rp3 steel

4.CONCLUSION

From the information presented above we can draw some conclusions:

- the wear process of metal surfaces in dry friction contact against plastic materials reinforced with short glass fibers evolves over time, depending on loading, moving from the initial abrasive wear caused by glass fibers, at adhesion wear characterized especially by the transfer of plastic material on the metal surface, but also by corrosion;

It is difficult to establish a mathematical relationship between the input and output parameters. The linear dry contact between the composite material and steel is highly complex. By changing a single input parameter, all output parameters of the systems will change.

This phenomenon is so complex that the system evolves while the action of the loads leads from abrasion to adhesion wear and to corrosion. This phenomenon occurs simultaneously with the transfer of thermoplastic material unto the metal surface.

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