

Friction induced heating properties of the polyamide/steel type contacts

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Abstract. The endurance and the life time of the mechanical transmissions are highly influenced by the functioning conditions and, not at least, by the materials that they are manufactured from. The increase of the endurance and functioning life time, corroborated with a friendly impact with the environment, is one of the main aims of the worldwide research areas of today. According to this, the development of new materials characterised by low costs and high endurance represents one of the solutions obtained by the specific scientific research. The paper investigates the friction induced heating properties of the polyamide/steel type contacts by considering dry friction conditions. It is studied the contact between a steel made pin and a PA46 and PTFE added PA46 polyamide made disk, under different testing conditions, depending on the rotational speed of the disk and the normal force, at the environmental temperature. The tests are achieved on a tribometer equipped with a pin-on-disc module and, as output, the friction coefficient is measured. Due to the friction is developed a heating of the local contact area. The heat is calculated according to the measured friction coefficient, the normal load and the relative sliding velocity. Finally there are given conclusions regarding the friction induced heating properties of the tested materials.

1. Introduction

The environmental friendly solutions are widely researched themes today in many areas as: energy production systems, automotive industry, aircraft and railway industry, food production and processing systems, chemical industry etc. These solutions are characterised by low energy consumptions and low CO₂ and other pollution gases emissions, during their manufacturing process and their usage. According to this, one research direction is represented by the development of new materials; a class of materials which are characterised by small frictional losses and good endurance in the contacts with steel made parts is represented by the polyamides. These materials, in combination with steel made parts, have applications in automotive industry, aerospace engineering, chemical industry and electronics due to their good tribological properties, corrosion resistance and simple and economic manufacturing process [1, 2, 3, 4].

In the scientific literature the tribological properties of the polyamide type materials are determined by performing two categories of tests on the tribometer: tests performed on the pin-on-disc module and tests performed on the reciprocating module.

In [5] there are performed test on a pin-on-disc module for a composite PA66 polyamide with different values for the contact pressure and for the velocity; as results, there are highlighted the

friction and wear behaviour of the tested material: low friction coefficients in combination with steel materials and stabilised wear.

The paper [6] presents the mechanical properties of a class of PA66 polyamides. The tests are performed on a pin on disk type tribometer under dry and lubricated conditions. In the case of no lubricated conditions, the friction coefficient is increasing with the increasing of the force and has values between 0.15 ... 0.23 for forces between 50 N ... 250 N, the pin diameter $d=10$ mm and the velocity $v=0.025$ m/s; the friction coefficient is decreasing with the increasing of the sliding velocity – below 0.1 for 0.1 m/s.

In [7] the friction is studied using a pin-on-disc module (the pin is made of two types of polyamides and the disk is made of steel) with normal loads of 5, 10, 20 and 30 N and rotational speeds of 1000, 1500 and 2000 rpm for a pin of 12 mm diameter, dry friction conditions and 1 km sliding distance. The friction coefficient is decreasing with the increasing of the force with values between 0.14 ... 0.42 for the pure PA66 and with 0.32 ... 0.42 for the graphite reinforced PA.

The dry sliding tests on reciprocating type motions modules are performed in [8] and [9]. In [8] the tests were performed on an Universal Micro Tribometer (UMT) [10] on the reciprocating module equipped with a ball on block device, at a humidity of 40% with a stroke of 5 mm. The test period is about 1800 s and the friction coefficient of PA66 is equal with 0.22 ... 0.28 increasing with the increasing of the normal load and with the increasing of the frequency. The paper [9] presents the study of the friction coefficient and of the wear in the case of a GCr15 steel ball in contact with a PA66 plate; the tests were performed on a Universal Micro Tribometer (UMT) [10] by using the reciprocating module of it. The normal loads were 1 N, 2 N, 3 N, 4 N for a diameter of 4 mm of the ball; the sliding velocities were 31.42, 62.83, 94.25, 1245.66 mm/s. Under dry conditions, the friction coefficient decreases with the increasing of the normal load with values between 0.15 ... 0.4 and is increasing with the increasing of the translational speed.

Under no lubricated conditions, due to the friction, in the local area of contact, it is produced heat. The paper [11] studies the heat produced by a dry friction of PA6 nanocomposite fabrics and steel; the local temperature increases with the increasing of the normal load and the increasing of the test period.

The paper investigates the friction induced heating properties of the PA46 and PTFE added PA46 polyamide on steel type contacts by considering dry friction conditions and different testing conditions, depending on the rotational speed of the disk and the normal force, at the environmental temperature. The heat is calculated according to the measured friction coefficient, the normal load and the relative sliding velocity. Finally there are given conclusions regarding the friction induced heating properties of the tested materials.

2. The tests

The experimental rig used to perform the tests is an Universal Micro Tribometer (UMT) [10] connected to a computer, as it can be seen in figure 1. On the test rig may be performed wear and friction tests.

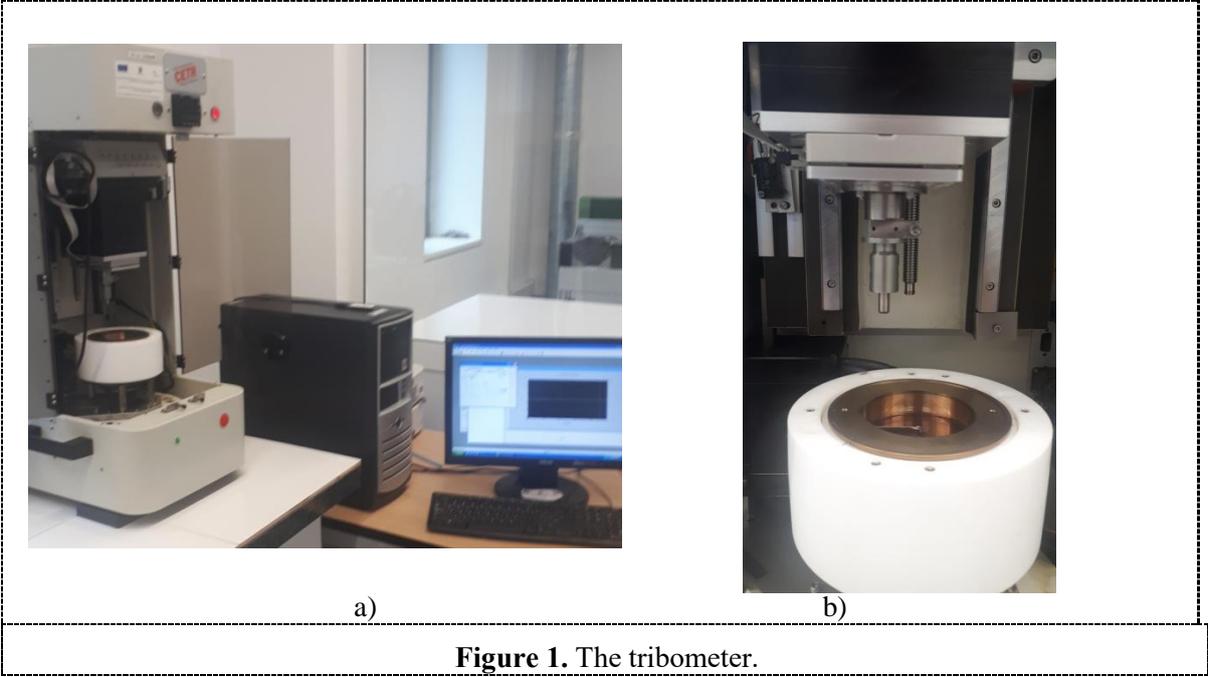
The wear can be measured by using a sensor which allows the vertical stroke for the slider of 150 mm with an accuracy of 50 nm [10]; the lateral stroke is equal with 75 μ m and can be adjusted with an accuracy of 2 μ m [10].

The friction tests are performed in order to find out the friction coefficient between different materials being in contact. The friction coefficient is calculated automatically by the test rig's software as the ratio between the force measured about a horizontal direction, same with the motion's direction and the vertical normal load measured about the vertical direction; these forces can be measured by the sensors in an interval of 0.1 ... 1000 N with the resolution up to 50 mN [10].

A pin-on-disc module is mounted inside the tribometer. The steel made pin has the diameter equal with 6.3 mm. Inside the rotary module are mounted the PA46 and PTFE added PA46 polyamide disks which will be in contact with the steel made pin (figure 2).

The tests are performed after a running-in period of 2 hours at a rotational speed of the disk equal with 1000 rpm and a normal force of 50 N. After that, the tests are accomplished at the room

temperature of 22 °C, with a set of rotational speeds equal with: 500 rpm, 1000 rpm, 2000 rpm and 3000 rpm; the normal forces used for the tests are equal with: 10 N ... 50 N. Each test duration is equal with 10 minutes. The sliding radius is equal with 12 mm.



During the tests there are measured the normal force and the horizontal force oriented opposite to the rotation's direction. The software calculates the friction coefficient as the ratio between the two measured forces. The friction induced heat is calculated with [11]

$$Q = \mu F v t \tag{1}$$

where: μ represents the friction coefficient; F – the normal force; v – the speed; t – the test period.

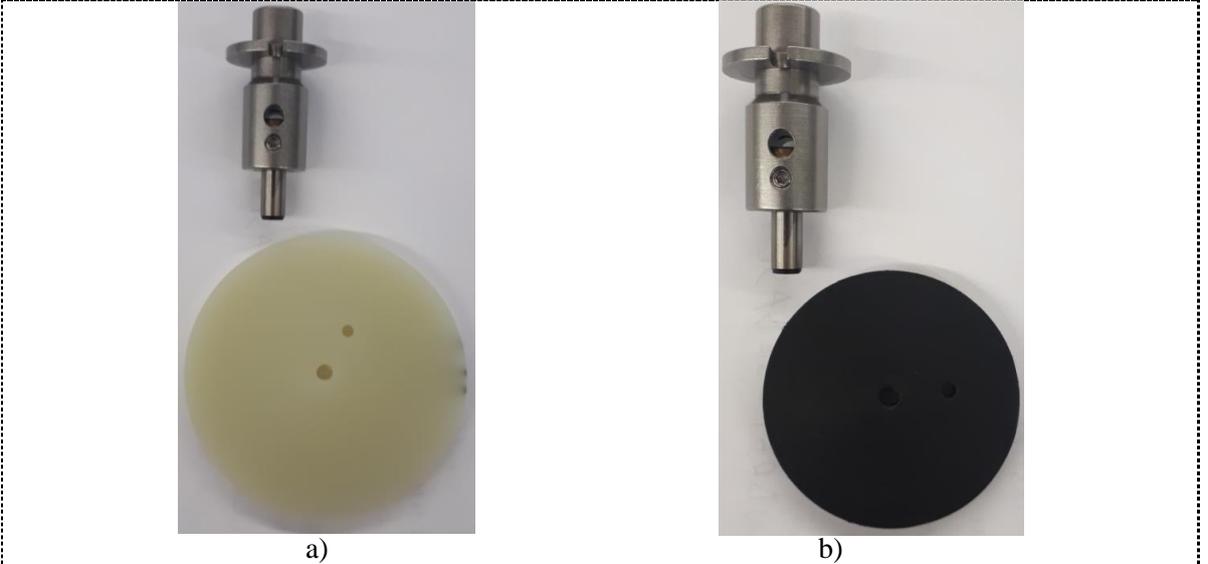


Figure 2. The polyamide disks in contact with the steel made pin.

3. Results and conclusions

The results present the evolution of the wear during the running-in test and variation of the friction induced heat with the rotational speed of the disk and with the normal force.

Figure 3 shows the evolution of the wear during the running-in process. The value of the wear, for the PA46 polyamide is stabilised after approximately 60 minutes at a value around 0.08 mm. The wear for the PTFE added PA46 polyamide is higher (about 0.11 mm) and it is stabilised after 100 minutes.

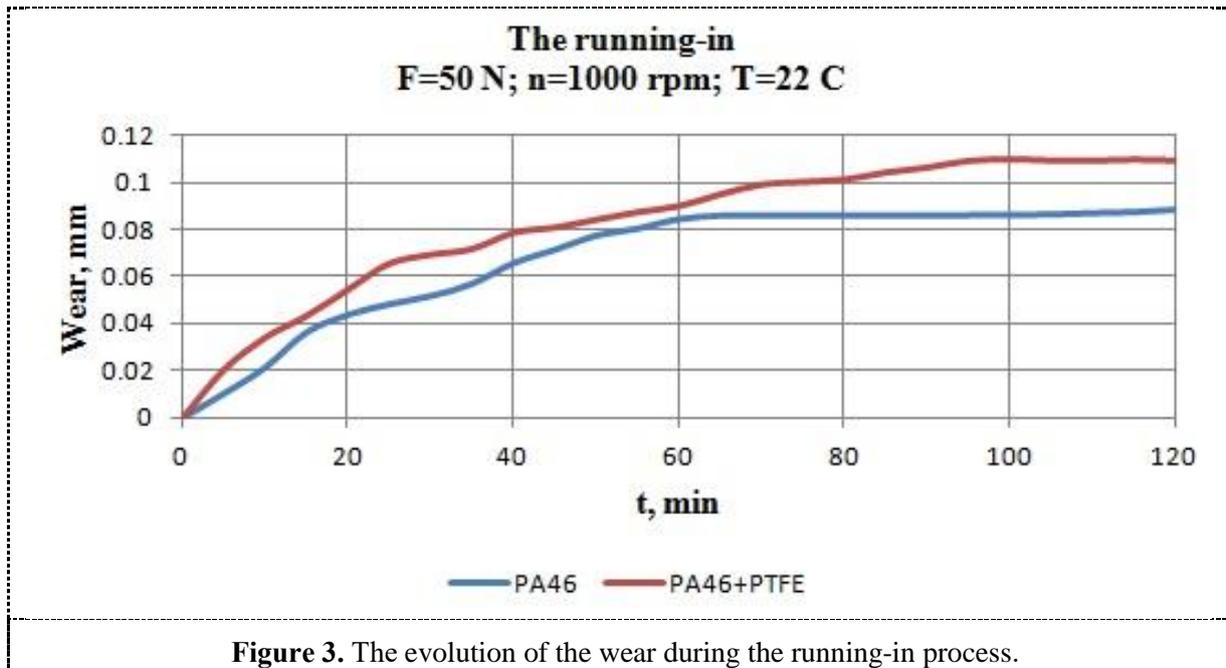


Figure 3. The evolution of the wear during the running-in process.

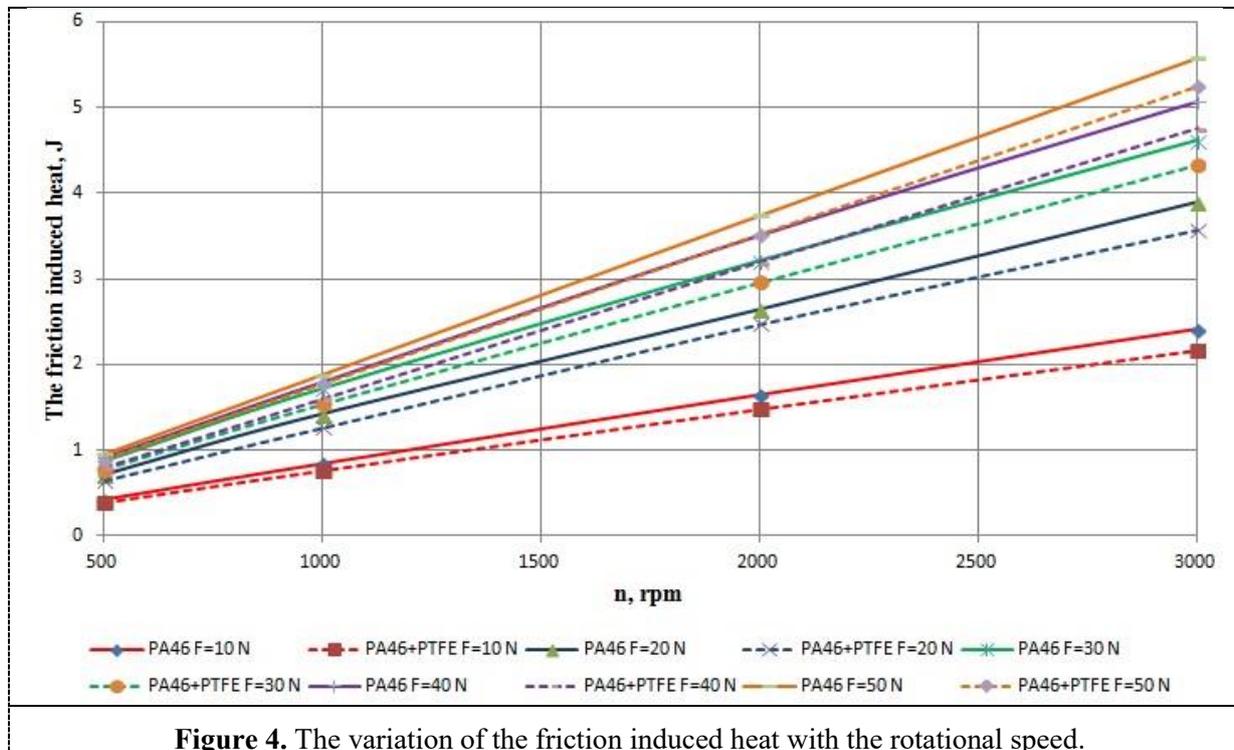


Figure 4. The variation of the friction induced heat with the rotational speed.

The variation of the friction induced heat with the rotational speed and with normal load is presented in figure 4 and in figure 5. Figure 4 highlights that the amount of the friction induced heat increases with the increasing of the normal force and with the increasing of the rotational speed. The PTFE added PA46 polyamide produces smaller amounts of friction induced heat than the PA46 polyamide. According to figure 5, higher differences regarding the evolution of the friction induced heat, between the PA46 and the PTFE added PA46 are noticed at high rotational speeds.

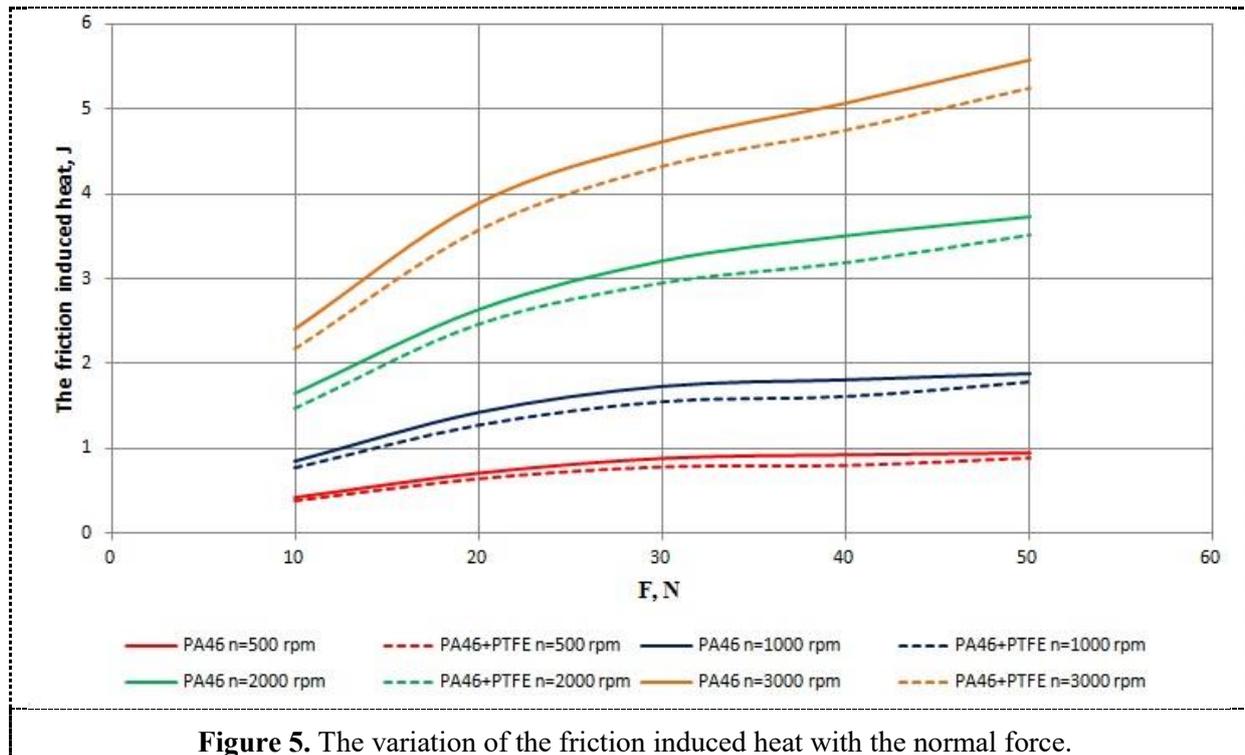


Figure 5. The variation of the friction induced heat with the normal force.

As a general conclusion, the PTFE added PA46 polyamide has a higher wear than the PA46 polyamide and the wear is stabilised at a constant value after a longer period of time, instead of the case of the PA46 polyamide. The friction induced heat increases with the increasing of the speed and of the normal force, for both materials. In all the cases, the PTFE added PA46 has a smaller friction induces heat production. Regarding their applications, the PA46 polyamides are preferable to be used in order to obtain high endurances of the mechanical components. For smaller amounts of produced friction induced heat, the PTFE added polyamide is preferable to be use.

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