

Study on the friction in steel/polyamide ball on disk type contacts

M T Lates¹, C C Gavrilă¹ and R Papuc¹

¹Product Design, Mechatronics and Environment Department, “Transilvania” University of Brasov, Brasov, Romania

E-mail: latesmt@unitbv.ro

Abstract. The paper presents the experimental study of the friction in the case of steel/polyamide ball on disk type contacts by considering as testing parameters the temperature, the load and the rotational speed. The tests are performed, for two types of polyamides, on a tribometer which allows rotational motions at small and high speeds, with controlled normal loads and temperatures. The tests begin with a one hour running-in at 500 rpm, at ambient temperature. After the running-in process there are made tests, for two types of polyamides at 90°C and 120°C, at loads of 3 N, 5 N, 7 N and at rotational speeds of 5 rpm, 1500 rpm and 3000 rpm. The results are indicating the polyamides behaviour at high temperatures with different loadings, at small and high rotational speeds. The conclusions of the paper offer recommendations regarding the applications of the tested polyamide materials according to temperature, loading and rotational speeds, in the case of ball on disk type contacts.

1. Introduction

The friction phenomenon in steel/polyamide type contacts is found in the case of mechanical transmissions which should be characterised by high durability, small vibrations; these requirements are achieved due to the properties of the polyamide type materials: small friction and small wear in combination with steel type materials, good behaviour at high loads and high temperatures.

In [1] there are presented the mechanical behaviour characteristics of a polyamide type material reinforced with short fibre glass; the tests, performed at the ambient temperature are concluding that the polyamide materials are used in the automobile industry due to their easy fabrication, their light weight and their economy [1]. The results presented in [1] shows that the polyamide type materials have, up to a certain value of the strain, a linear elastic mechanical behaviour; this is the case that these materials are suitable to be used.

The theory of linear elasticity for orthotropic materials was successfully applied in [2] in order to find out the temperature influence on the polyamide type materials; the tests shows that the polyamides have a small variation of the mechanical properties with the temperature, in the case of small stresses and strains.

The thermo – mechanical properties of polyamides are presented in [3], [4] by using mechanical, thermal and rheological tests; according to the results, the polyamides are suitable to be used in environments with temperatures up to 180°C due to the reason that they are keeping the mechanical and friction properties.



The friction properties of the polyamides which are tested under different loadings and different temperatures are presented in [5]; the results are indicating that the polyamides are suitable to be used at high temperatures in lubricated environments due to their low-friction properties (sliding friction coefficients at about 0.1 and 0.6 for dry conditions [6]).

The polyamide type materials are used for the case of point shape contacts in rolling ball bearings or in ball screws [7, 8]. The paper presents, according to the conclusions from the literature, the results of the tests performed for two type of polyamides machined in disk shapes in contact with steel balls for different loads, temperatures and rotational speeds in sliding conditions. The conclusions of the paper offer recommendations regarding the applications of the tested polyamides.

2. The equipments

The tests are performed on an UMT type tribometer [9] which is equipped with a ball on disk module – figure 1.

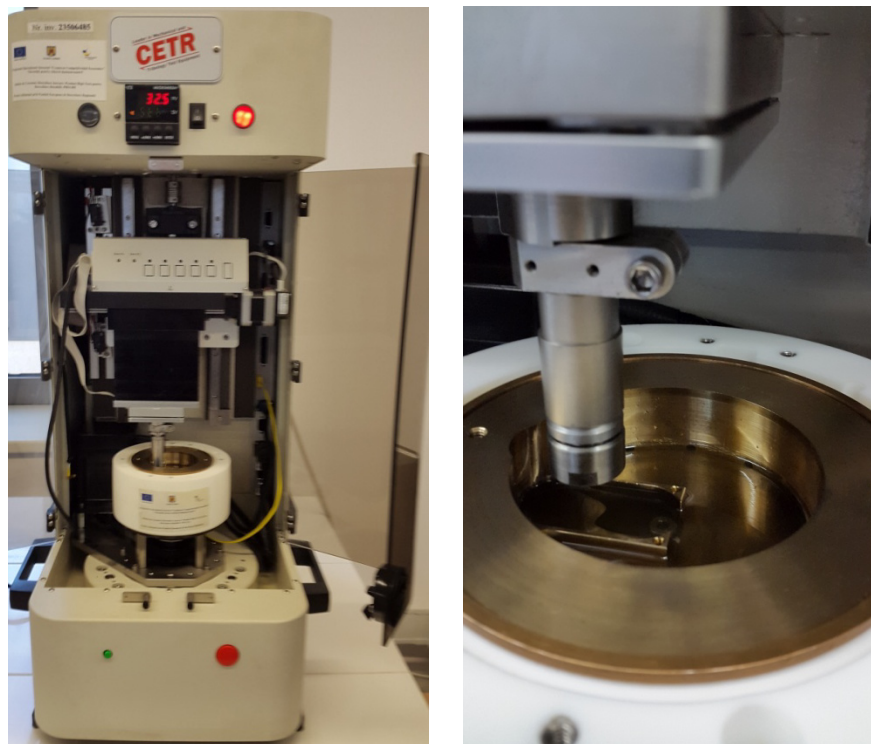


Figure 1. The tribometer equipped with a ball on disk module.

On the tribometer equipped with the ball on disk module may be performed tests where the rotational speed of the disk can be set up as $n=0.001 \dots 5000$ rpm in two directions and with the maximum normal load $F=1000$ N with a resolution of $R_r = 50$ mN. According to the technical specifications, the vertical stroke of 150 mm may be achieved with a speed of $v_v=0.001 \dots 10$ mm/s; The lateral positioning stroke is up to 75 mm with a speed of $v_l = 0.01 \dots 10$ mm/s. The tribometer is equipped with heater which can heat up the oil bath to 150°C .

3. The tests

For the tests there are used ball on disk type contacts where the ball is made of steel and the disks are made by two type of polyamides [10]: unfilled white – the common used – and a new type, the MoS₂ + Carbon black – figure 2. The results are given as relative values of the carbon black (named PA-B) to the unfilled white (named PA-W) due to confidential reasons imposed by the producing company.

The tests begin with a one hour running-in at 500 rpm, a constant vertical position of the ball, at ambient temperature.

After the running-in process there are made tests, for two types of polyamides at 90°C and 120°C, at loads of 3 N, 5 N, 7 N and at rotational speeds of 5 rpm, 1500 rpm and 3000 rpm.

In order to achieve the repeatability of the test, there are performed 5 times of sets for each set of input parameters.

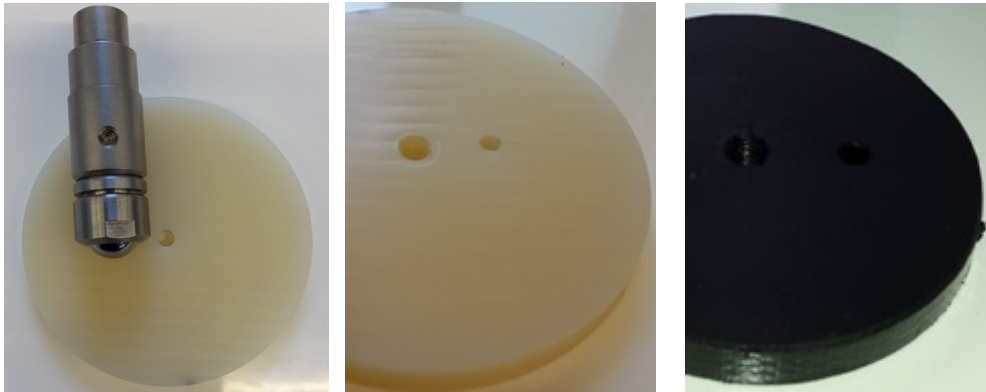


Figure 2. The ball on disk contact by using a steel ball and two polyamide disks.

4. Results and conclusions

The results are giving information about the frictional behaviour of the tested polyamides (the carbon black relative PA-B to the unfilled white PA-W) in the case of different temperatures, speeds and loadings.

The influence of the temperature on the friction coefficient for the steel ball and the polyamide contacts is presented in the next figures. Due to confidentiality reason, these figures present the percentage variation of the friction coefficient at 120°C relative to the friction coefficient at 90°C depending on the normal load, in figure 3 and depending on the rotational speed, in figure 4.

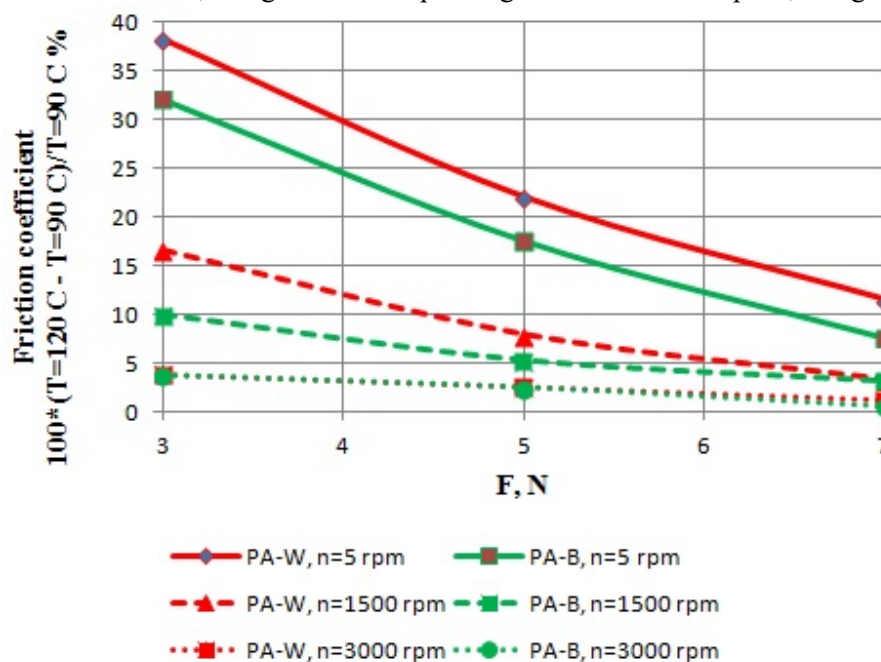


Figure 3. The friction coefficient at 120°C relative to 90°C, depending on the normal load.

The friction coefficient in the case of increasing the local temperature from 90°C to 120°C has bigger values for the upper temperature for all the tested cases. The relative variation of it is quiet big for small normal loads (up to approx. 40% for PA-W) and is much smaller for higher loadings (less than 5% for PA-W and PA-B for loads equal with 7 N); for the two polyamides the percentage variation of the friction coefficient is decreasing with the increasing of the normal load.

For the same testing conditions, the PA-W polyamide has a higher variation of the friction coefficient with the temperature, than the PA-B polyamide; this variation is almost the same for high loads – 7 N.

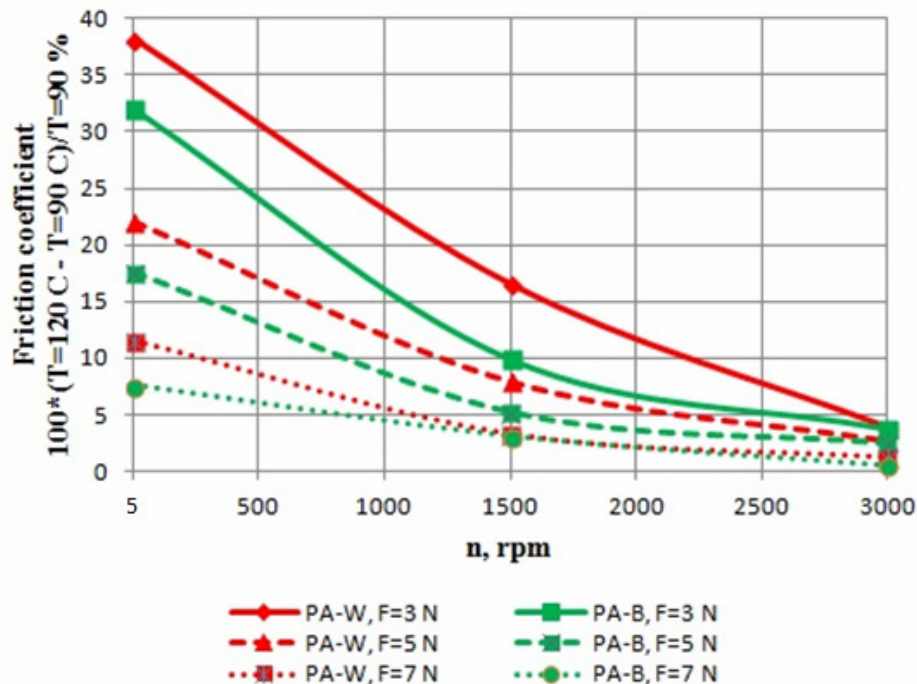


Figure 4. The friction coefficient at 120°C relative to 90°C, depending on the rotational speed.

According to the results presented in figure 4, the percentage variation of the friction coefficient is decreasing with the increasing of the rotational speed, for both tested polyamides; higher values, for the same testing conditions may be found in the case of PA-W polyamide.

The next figures, due to confidentiality reasons, present the percentage variation of the friction coefficient for the PA-B polyamide relative to the PA-W polyamide, depending on the test parameters – the normal load, the rotational speed and the temperature.

Figure 5 presents the percentage variation of the friction coefficient for the PA-B polyamide relative to the PA-W polyamide depending on the normal load. In all the cases the PA-B polyamide has a smaller friction coefficient than the PA-W polyamide, with higher differences (32 %) in the case of small loads (3 N) and temperatures of 120°C.

Figure 6 presents the percentage variation of the friction coefficient for the PA-B polyamide relative to the PA-W polyamide depending on the normal load; higher differences for the friction coefficient are in the case of small rotational speeds (5 – 1000 rpm) and temperatures of 120°C.

The difference between the value of the friction coefficient of the PA-B polyamide and the value of the friction coefficient of the PA-W polyamide is small (values smaller with maximum 10%) for normal loads higher than 5 N and rotational speeds higher than 1500 rpm; according to the dimension of polyamide disks this rotational speed is equivalent to peripheral speeds with the value of 1.7 m/s.

As general conclusion, in all the cases studied during the tests, the carbon black (PA-B) polyamide has a smaller friction coefficient than the unfilled white (PA-W) polyamide.

The carbon black (PA-B) polyamide has notable smaller friction coefficients in the case of small normal loads (up to 5 N), small speeds (up to 1500 rpm) and high temperatures (120°C).

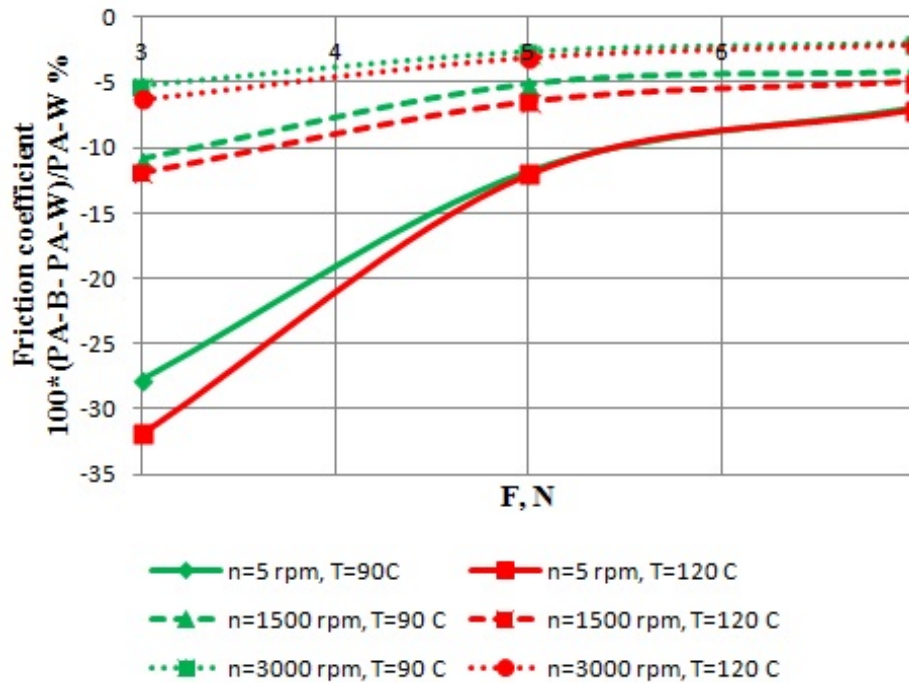


Figure 5. The friction coefficient of PA-B relative to PA-W, depending on the normal load.

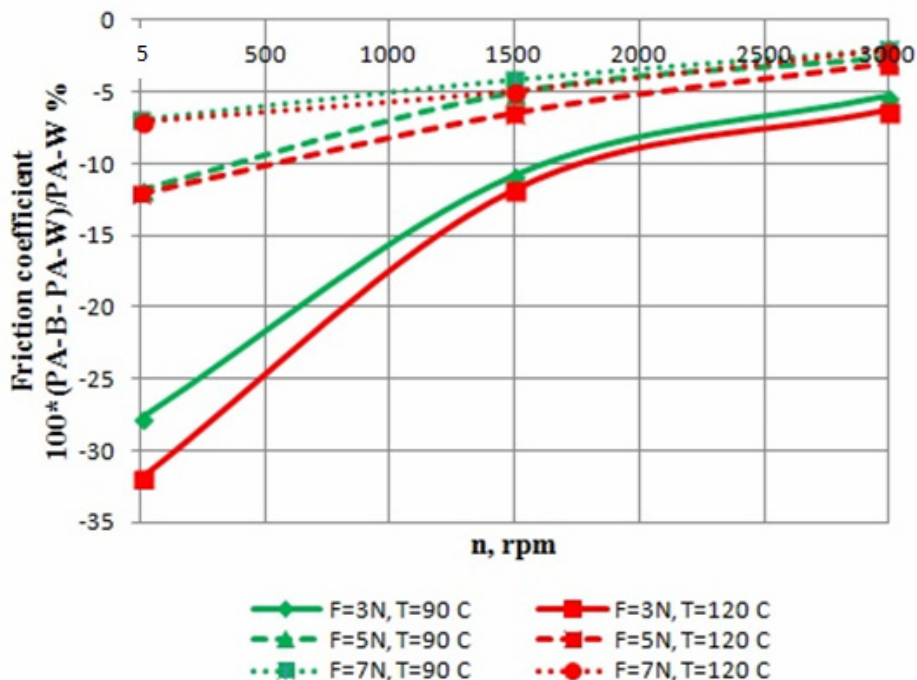


Figure 6. The friction coefficient of PA-B relative to PA-W, depending on the rotational speed.

As practical applications, the carbon black (PA-B) polyamide can be used small loaded rolling ball bearings or ball screws, which are working with small rotational speeds at high temperatures.

5. References

- [1] Mouhmid B, Imad A, Benseddiq N and Lecompte D 2009 An experimental analysis of fracture mechanics of short glass fibre reinforced polyamide 6.6 (SAGFR-PA66) *Composite Science and Technology* **69** pp 2521 – 2526
- [2] De Monte M, Moosbrugger E and Quaresimin M, 2010 Influence of temperature and thickness on the off-axis behavior of short glass fiber reinforced polyamide 6.6 – quasi-static loading *Journal of Composites part A* **41** pp 859 – 871
- [3] Buccella M., Dorigato A, Pasqualini E, Caldara M and Fambri L 2012 Thermo-mechanical properties of Polyamide 6 chemically modified by chain extension with Polyamide/Polycarbonate blend *Journal of Polymer Research* **19** pp 9935 – 9944
- [4] Hsiao S, Wang H, Chou J, Guo W and Tsai T 2012 Synthesis and characterisation of novel organosoluble and thermally stable polyamides bearing triptycene in their backbones *Journal of Polymer Research* **19** pp 9902 – 9911
- [5] Van Ruiten J, Proost R and Meuwissen M 2012 How the choice of the polyamide type in timing chains tensioning systems affects the CO₂ emission and fuel economy of internal combustion engines *Presentation at VDI Veetiltrieb un Zylinderkopf 2012*
- [6] Akiyama M, Yamaguchi T, Matsumoto K and Hokkirigawa K 2010 Friction and wear of polyamide 66 composites filled with RB ceramics particles under dry condition *Tribology Online* **5(2)** pp 87 – 91
- [7] Velicu R 2012 Design methodology for a planetary multiplier with synchronous belts or chains *Annals of the Oradea University, Fascicle of Management and Technological Engineering XI(XXI)* pp 2.122-2.127
- [8] Velicu R and Lateş M 2016 Time depending friction in bearing mountings *Current Solutions in Mechanical Engineering (ICOME 2015)* pp 79-84
- [9] *** UMT Multi-Specimen Test System. Hardware Installation & Application Manual 2009 *Center for Tribology, Dell Ave, Campbell, USA*
- [10] www.perfectpolymers.com/extruded-polyamides.html