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TEMPERATURE INFLUENCE ON THE FRICTION COEFFICIENT OF THE PA46 POLYAMIDE – STEEL TYPE CONTACTS

Mihai-Tiberiu LATES[1], Catalin GAVRILA[2]
[1]"Transilvania" University of Brasov, Product Design, Mechatronics and Environment Department, latesmt@unitbv.ro
[2]"Transilvania" University of Brasov, Product Design, Mechatronics and Environment Department, cgavrila@unitbv.ro

Abstract**—**The PA46 polyamide material has a wide application in engineering due to its good mechanical behaviour in transmissions with variable temperature – gears, slides, cams, bearings, guides for chains. In contact with steel materials, small values of the friction coefficients are obtained. The paper presents the testing procedure and the analysis of the obtained results for tests regarding the polyamide/steel type contacts, by considering a variable temperature.

Keywords**—**polyamide, friction, steel plate, temperature.

I. Introduction

IN order to obtain high wear, abrasion and vibration resistance – noise reduction – the polyamide type materials are used, in the last period, to design mechanical components. These mechanical elements – gears, slides, cams, bearings, guides for chains – made from polyamide, are characterised also by high impact resistance, good heat resistance and with good physical properties – high tensile strength and modulus of elasticity [1].

Another optimization direction is the weight reduction of the mechanical components with directly influence on the masses and inertias; the materials which are accomplishing this condition should be, on the other hand, with the same main mechanical properties as the steel type materials. One of the materials which are accomplishing these conditions is the polyamide; high values of the elastic modulus are inducing small values of the deformations and high values for the hardness are reducing the wear. In the case of small forces, even with temperatures up to 90^{o} C, a linear elastic behaviour may be assumed for the polyamides [1], [2].

In the case of sliding mechanical contacts – cam/plate cam followers, gears, chain/guides, guides – one of the mechanical parts is made by steel and the other part by polyamide [3]; the reason is that this solution offers small values for the friction coefficients and high values for durability [4] – [6].

In the case of all these mechanical contacts, in order to reduce the wear these contacts are lubricated and due to the functioning conditions, an increase of the local temperature is noticed. The paper presents the influence of the temperature variation on the friction coefficient in the case of lubricated PA46 polyamide – steel type contacts.

II. The Equipments

The equipment where the tests are performed is a 2 axes tribometer which allows measurements for the normal and tangential forces – Fig. 1.

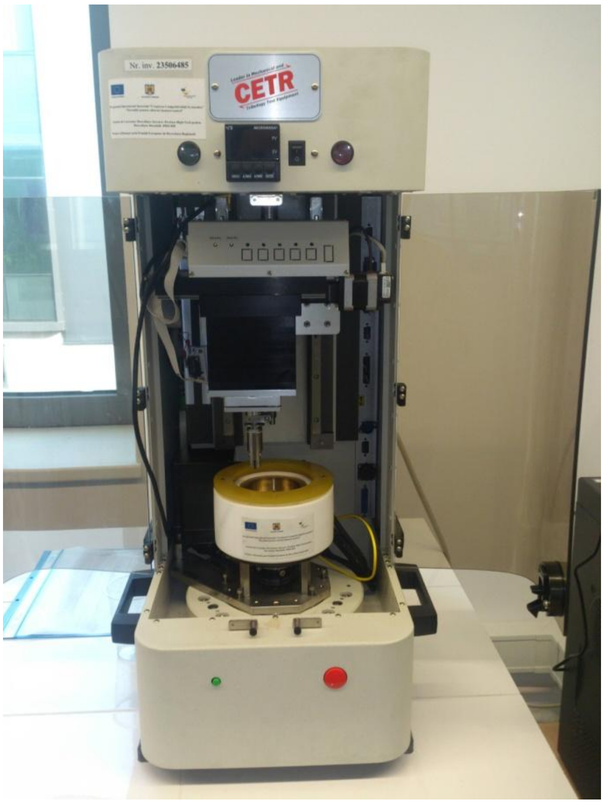

Fig. 1. The tribometer

The tribometer may measures forces up to 1000 N with a resolution of 50 mN; the vertical stroke is 150 mm with a speed adjustable between 0.001 and 10 m/s. The lateral positioning stroke is 75 mm with the speed between 0.01 and 10 m/s; the lateral positioning resolution is 2 μm. The maximum heater's temperature is 150 ^{o}C – Fig. 2. The rotational speed can be adjusted between 0.001 and 5000 rpm, in 2 directions.

Fig. 2. The heater

On the tribometer there may be performed wear tests and Stribeck tests; the friction coefficient is determined as the ratio between the measured values of the vertical force and of the tangential force.

Fig. 3. The polyamide disk

The polyamide disk – Fig. 3 – is made from PA46 polyamide and has a diameter of 50 mm; the disk is mounted inside the rotational device of the tribometer – Fig. 4 which is lubricated and heated.

The steel plate is mounted in a holder which is fixed in the vertical guide – Fig. 5.

The upper device may be used with or without a suspension in order to damp the shocks; in the case of friction coefficient tests the suspension is not used due to the measurements accuracy.

Fig. 4. The polyamide disk mounted inside the rotational device

Fig. 5. The steel plate holder

III. THE TESTS

The tests were performed in 2 steps; first is made a running-in test for a period of 2 hours, with a rotation of the disk of 500 rpm and with the position of the steel plate on a radius of 20 mm from the centre of the disk. The normal force has the value of 5 N, calculated from the condition of hydrodynamic friction between the disk made by PA46 polyamide and the front face of the steel plate.

The variation in time of the dynamic friction coefficient is presented in Fig. 6. The dynamic friction coefficient has a descendent variation during the running-in period due to the polishing action of the harder material (the steel plate) on the weaker material (the PA46 polyamide); after 100 minutes of running-in, the dynamic friction coefficient has a stabilised value at around 0.12.

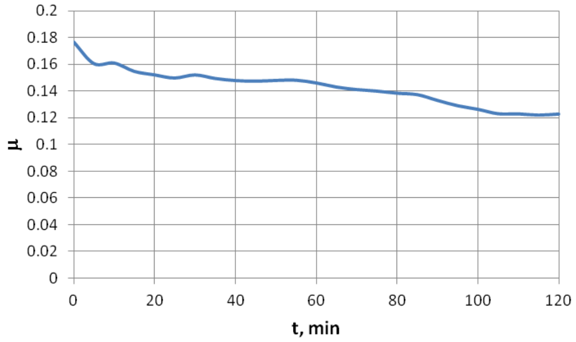

Fig. 6. The dynamic friction coefficient

The evolution of the wear during the running-in test is presented in Fig. 7. The wear has a small decreasing variation and it is stabilised at a value of 70 μm after 100 minutes of running in.

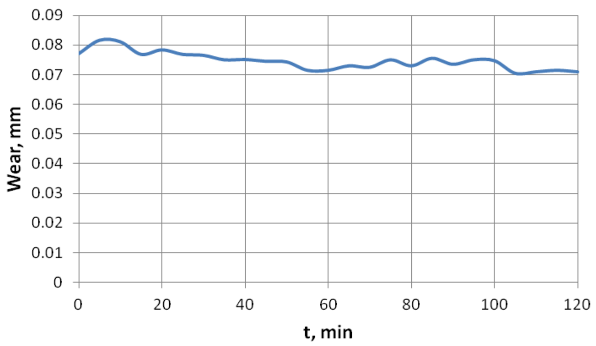

Fig. 7. The evolution of the wear in time

After the running-in tests, there are performed tests where the heater's temperature has a variation between 20 and 90 ^{o}C; the normal force is set up to 9 N due to the reason that for this value the lubrication is a mixed one. The rotational speed of the disk is equal with 500 rpm and with the position of the steel plate is on a radius of 20 mm from the centre of the disk. In order to validate the results, there are performed two sets of tests.

In Fig. 8 is presented the variation of the dynamic friction coefficient with the temperature for the two tests which have been performed on the tribometer; *Poly* represents the trend lines for the two tests which are created by using 2 degrees polynomial functions.

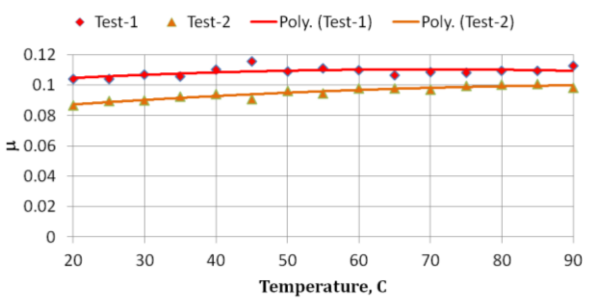

Fig. 8. The variation of the dynamic friction coefficient with the temperature

The dynamic friction coefficient has a smooth increase with the variation of the temperature and it has an average value of 0.1, value which is validated by the tests results from [7].

The variation of the wear with the temperature is presented in Fig. 9. The wear is decreasing with the increasing of the temperature due to the properties of the PA46 polyamide which is recommended to be used at high temperatures [5].

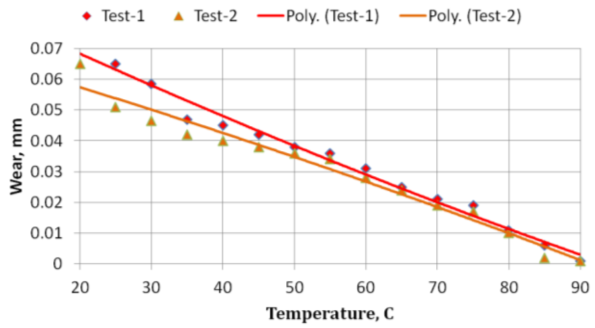

Fig. 9. The variation of the wear with the temperature

The wear track on the PA46 polyamide disk, magnified on a microscope, is presented in Fig. 10; its limits are determined by the lateral faces of the steel plate and they have a bigger depth due to the sharp corners of the plates. The wear track limit from the right side is higher because this side is placed on a bigger radius according to the rotational motion.

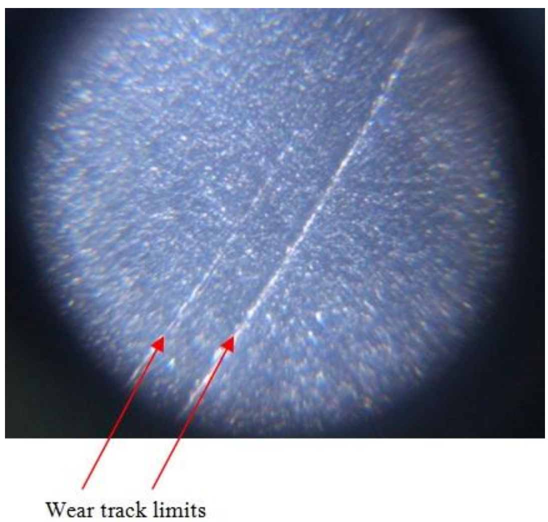

Fig. 10. The wear track on the PA46 polyamide disk

The wear on the steel plate is presented in Fig. 11; the shape of the wear is a circular one due to the rotational motion of the disk. Due to the clearances on the holder, the steel plate doesn't have a contact on the entire width of it. Anyhow, this is a testing which reproduces a real functioning condition – for instance the steel plate could be a link from a chain which is in contact with the active face of a tensioning guide, made from PA46 polyamide. In this case, the chain links have also oscillations in the vertical and horizontal plane, meaning that they could have a mechanical contact with the guide only on a part of their width, depending on the error from the normal position of them to the guide.

Fig. 11. The wear track on the steel plate

IV. CONCLUSION

The PA46 polyamide – steel type contacts are used in mechanical transmissions with a wide range of variable temperatures due to the polyamide's mechanical properties – a linear elastic behaviour can be assumed for the polyamide in the range of temperatures between 20 ^{o}C and 90 ^{o}C; this is the case of the sliding mechanical contacts as: cam/plate cam followers, gears, chain/guides, guides where one of the mechanical parts is made by steel and the other part by polyamide.

The paper presents the test procedure for the study of the dynamic friction coefficient and of the wear for the PA46 polyamide – steel plate type contacts when the temperature is variable between 20 ^{o}C and 90 ^{o}C. The testing procedure – the running in test and the test with the variable temperature – can be applied for any other type of contacts when the variation of the temperature should be considered. In order to validate the results, there are performed two sets of tests for the variable temperature.

The dynamic friction coefficient has a descendent variation during the running-in period due to the polishing action of the harder material (the steel plate) on the weaker material (the PA46 polyamide); after 100 minutes of running-in, the dynamic friction coefficient has a stabilised value at around 0.12, value which is close to the value from the references [7].

The dynamic friction coefficient has a smooth increase with the variation of the temperature and it has an average value of 0.1, value which is also validated by the tests results from [7].

The variation of the wear with the temperature is decreasing with the increasing of the temperature due to the properties of the PA46 polyamide which is recommended to be used at high temperatures [5].

The limits of the wear track on the PA46 polyamide disk are determined by the lateral faces of the steel plate and they have a bigger depth due to the sharp corners of the plates. The wear track limit from the right side is higher because this side is placed on a bigger radius according to the rotational motion.

The shape of the wear on the steel plate is a circular one due to the rotational motion of the disk. Due to the clearances on the holder, the steel plate doesn't have a contact on the entire width of it. Anyhow, this is a testing which reproduces a real functioning condition – for instance the steel plate could be a link from a chain which is in contact with the active face of a tensioning guide, made from PA46 polyamide.

In conclusion, the PA46 polyamide – steel plate contacts are suitable to be used in working conditions with variable temperatures due to the small values of the friction coefficient and the small values of the wear.

REFERENCES

[1] B. Mouhmid, A. Imad, N. Benseddiq, D. Lecompte, An experimental analysis of fracture mechanics of short glass fibre reinforced polyamide 6.6 (SGFR-PA66) in *Journal of Composite Science and Technology*, nr. 69, pp. 2521 – 2526, 2009.

[2] M. De Monte, E. Moosbruger, M. Quaresimin, Influence of temperatura and thickness on the off-axis behavior of short glass fiber reinforced polyamide 6.6 – Quasi-static loading in *Journal of Composites*, part A, nr. 41, pp. 859 – 871, 2010.

[3] R. Velicu, Design methodology for a planetary multiplicator with synchronous belts or chains in *Annals of the Oradea University Fascicle of Management and Technological Engineering*, vol XI (XXI), nr. 2, pp. 2.122-2.127, 2012.

[4] R. Papuc, R. Velicu, Tribological study of guide-chain contact in *Annals of the Oradea University Fascicle of Management and Technological Engineering*, vol XII (XXII), nr. 1, pp. 257-260, 2013.

[5] F.-C. Chiu, G.-F. Kao, Polyamide 46/multi-walled carbon nanotube nanocomposites with enhanced thermal, electrical and mechanical properties in Composites, Part A, nr. 43, pp. 208 – 218, 2012.

[6] T. Hyakutake, M. Inagaki, M. Matsuda, N. Hakamada, Y. Teramachi, Measurement of friction in timing chains in *Journal of Society of Automotive Engineers of Japan*, nr. 22, pp. 343 – 347, 2001.

[7] J. van Ruiten, R. Proost, M. Meuwissen, How the choise of the polyamide type in timing chains tensioning systems affects the CO_2 emission and fuel economy of internal combustion engines in *Presentation at VDI Veetiltrieb un Zylinderkopf 2012*, November 28th, 2012.