FRICTION PHENOMENON IN POLYAMIDE – STEEL PLATE FRONT FACE TYPE CONTACTS

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Abstract**—**The applications of polyamide type mechanical components are referring on journal bearings, cams, guides, chain drive transmissions – the guide/chain contact, taps – the screw/nut contact; gear transmissions. The paper presents the analysis of the friction phenomenon in polyamide – steel plate front face type contacts by performing tests on a tribometer test rig. The results are offering information about the variation of the sliding friction coefficient, the flatness error and the wear rat. The conclusions are presenting recommendations regarding the applications and the functioning conditions of the polyamide (PA66) type mechanical components.

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

I. Introduction

THE polyamide type materials are characterized by high durability due to their good behaviour in the case of wear functioning conditions; the reason is that, the polyamide type materials have small friction coefficients when they are combined with steel materials in mechanical contacts, high values for the hardness and high values for the Young's modulus which allows small deformations in the case of high forces.

The polyamide materials have high mechanical strengths for combined stresses, have high stiffness and are approx. 7.5 times much lighter than the same volume bronze type materials (anti friction material) but much cheaper than these [1]. The polyamide type materials are used in applications with a wide range of temperatures (-260°C ... 80°C), with sliding frictions, with high impact forces, with corrosive environments or with adhesive working conditions [2].

The mechanical characteristics of the polyamide type materials are established in literature [1], [2] and show which are the testing procedures used to determine these properties and also confirm the high values for the Young's coefficient E=2800 - 3300 MPa and for the density ρ=1.14 - 1.16 kg/m^3. The references [1], [2] present that the mechanical behaviour of the polyamide type material could be approximated as an elastically one, in the same range as for a steel type material, in the case of small forces.

The applications of polyamide – steel type contacts are referring mainly in mechanical systems where the durability of the mechanical contact is an functioning condition (journal bearings; cams; guides; chain drive transmissions – the guide/chain contact; taps – the screw/nut contact; gear transmissions – Fig. 1 presents a gear made from polyamide, which is part of a solar tracking system installed at the Transilvania University's hill from Brasov, Romania), in the field of mechanical industry, medicine, machines in food industry [3].

Fig. 1. Solar tracking system with polyamide gear

The references [4]-[6] presents that the polyamide type materials (PA66) are used in a wide area of chain drive transmissions (as guide's materials) due to their good friction behaviour (dynamic friction coefficients close to 0.1 ... 0.13 [5], [6]). The reason is that an optimization aim of the chain drive transmission is to reduce the guide-chain contact friction (the guide-chain friction represents almost 27% from the total chain drive friction [7], [8]).

The paper presents the analysis of the friction phenomenon in the case of the polyamide – steel plate front face type contacts as application in the case of guide/chains contacts, cams and gear transmissions and shows recommendations regarding the functioning conditions of polyamide – front face type contacts.

II. The Testing Equipments

The tests should be able to offers results regarding the values of the dynamic and the static friction coefficients of the polyamide – steel plate front face type contacts. The dynamic friction coefficient can be measured during a continuous relative motion; the value of the static friction coefficient can be obtained at the beginning of the relative motion or at the moment that the direction of the relative motion is changed to the opposite direction. An experimental equipment which allows these types of motion is a pin on disk type test rig which can be adapted for the desired tests; the disk is made from polyamide type material and the pin is adapted to a holder which includes the steel plate.

The rough disks are made by PA66 polyamide by pouring and then are cut in slices – Fig. 2.

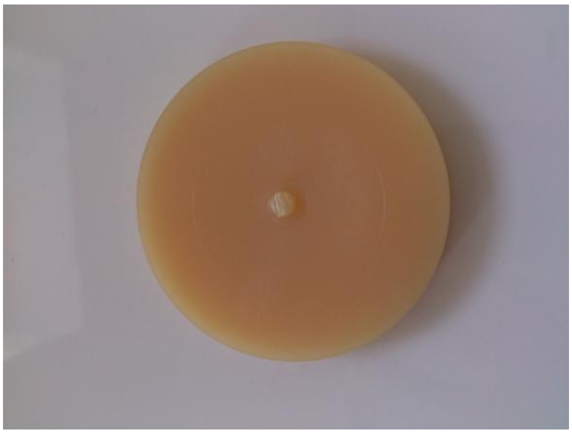

Fig. 2. The PA66 polyamide rough disk

The rough disks are machined in order to obtain an adequate quality of the surface and to achieve the mounting possibility on the test rig; the draft drawings are presented in the Fig. 3.

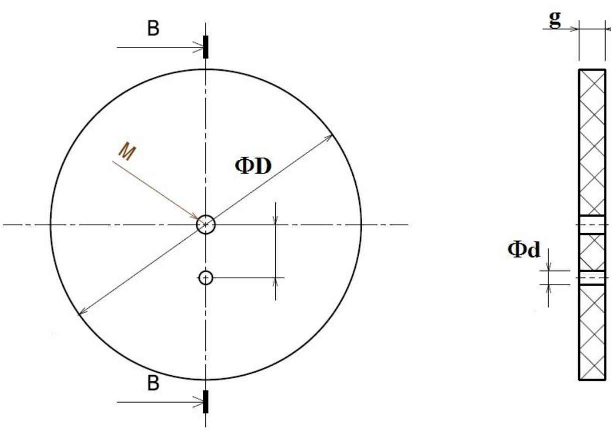

Fig. 3. The PA66 disks draft drawing

The final shape of the machined disk is presented in the Fig. 4.

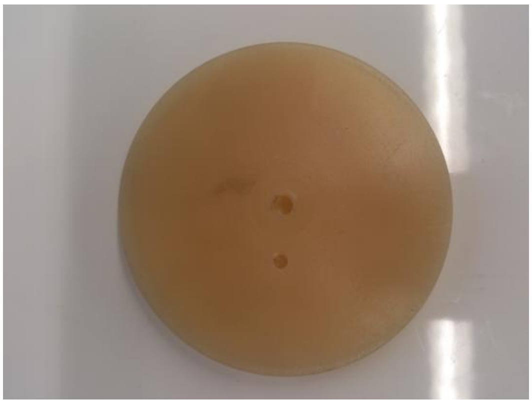

Fig. 4. The machined disk

The steel plate holder's drawing is presented in the Fig. 5; the steel plate 1 is mounted inside the holder and is fixed with the clip 2 and with the cap of the screw 3. The steel plate is positioned with the front face normal to the holder's axis in order to create a contact between it and the PA66 polyamide disk from bellow.

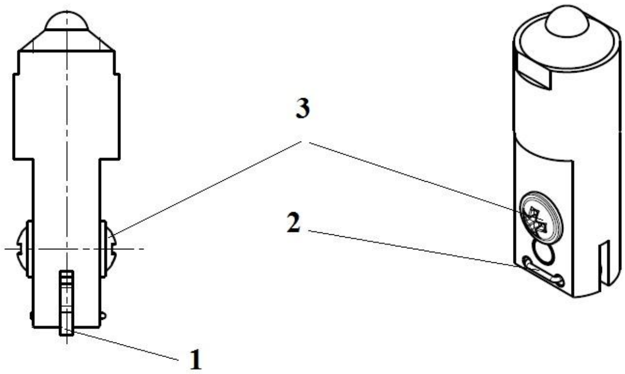

Fig. 5. The drawing of the steel plate holder

The holder is presented in the Fig.6.

Fig. 6. The holder

The test rig which is used to perform the tests in order obtain the values of the friction coefficient is a pin on disk type tribometer – Fig. 7.

Fig. 7. The tribometer

The tribometer with its pin on disk module – Fig. 8 – allows measurements in the range of 0.1 ... 1000 N for the normal force with a resolution of 50 mN. The disk rotation can be controlled in the range of 0.001 ... 5000 rpm. The test rig is useful to perform wear tests, friction coefficient measurements and Stribeck tests.

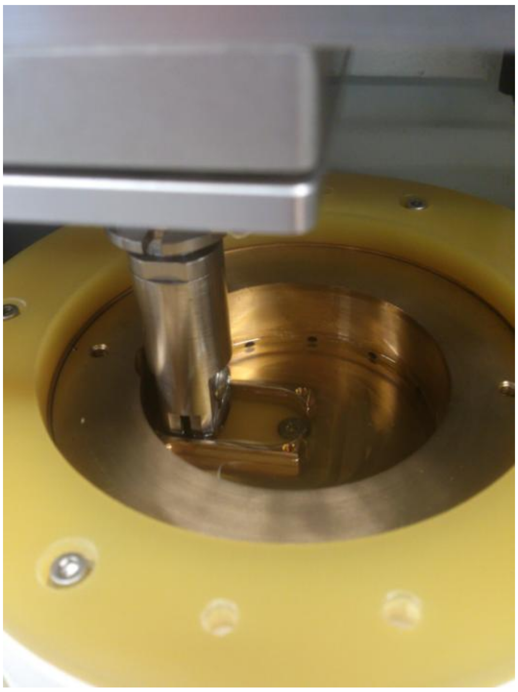

Fig. 8. The pin on disk module

The PA66 disk is mounted inside the rotary device from bellow; the steel plate is mounted in the holder and is acting with the normal force on the disk.

III. The Tests

The tests were performed by acting with a normal force of 5 N, calculated from the condition of hydrodynamic friction between the disk and front face of the steel plate. The disk has a rotation of 500 rpm during 2 hours. Fig. 9 shows the variation of the dynamic friction coefficient μ during the tests.

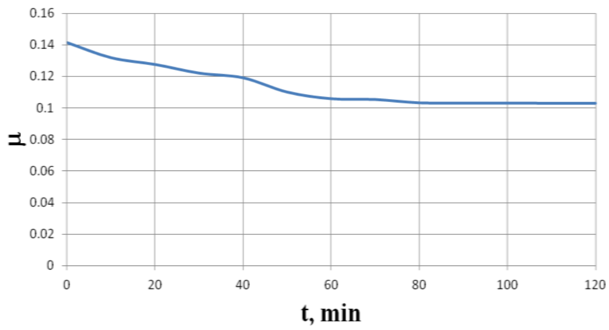

Fig. 9. The dynamic friction coefficient

According to the Fig. 9 the dynamic friction coefficient is stabilised after 80 minutes of run-in and its value is close to 0.1 (0.1028) which is in concordance with the values of it presented in the references (0.1 ... 0.13 [5], [6]). The stabilisation of the dynamic friction coefficient is relatively fast, so this means that the running in period of the polyamide/steel contacts made mechanical transmissions is short.

The variation of the flatness error *e* is presented in the Fig. 10. This error is influencing the shocks and vibrations in the system; Fig. 10 shows that the flatness error decreases in time and is stabilised after 60 minutes of running in at a value of 6 μm, which is small and it has a small influence on the shocks and vibrations.

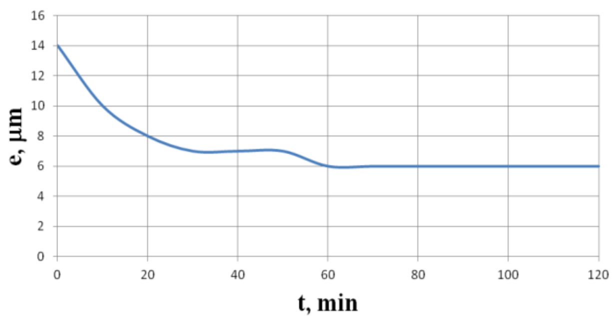

Fig. 10. The flatness error

Fig. 11 presents the variation of the wear rate *w* for the peaks and the holes from the disk's surface. High wear rate is obtained for the peaks; the wear rate for the peaks and the holes from the disk's surface is stabilised after 80 minutes of running in.

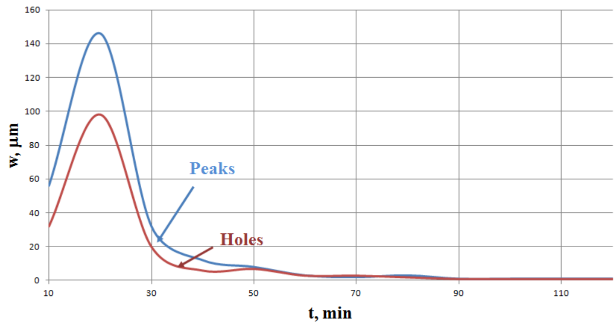

Fig. 11. The wear rate

The Stribeck test is performed in order to identify the lubricated friction when the dynamic friction coefficient has the minimum value. The rotation of the disk is variable between 5 ... 3000 rpm and the normal force is 5 N. Fig. 12 shows that the lubricated friction appears at 800 rpm; anyhow, the variation of the dynamic friction coefficient is small.

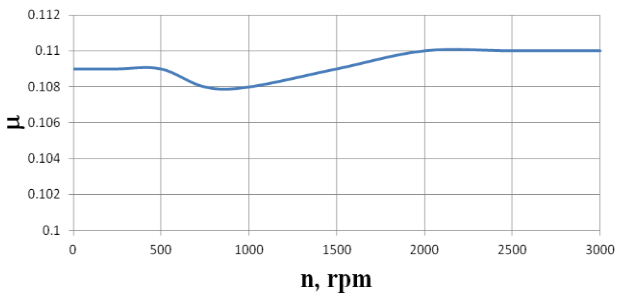

Fig. 12. The Stribeck curve

According to the results from the tests the polyamide (PA66) type mechanical components are suitable to be used with high efficiency (due to the small value of the friction coefficient) in mechanical transmissions with small running-in periods.

IV. Conclusion

The polyamide type materials are widely used in mechanical transmissions due to their resistance to wear and high resistance to tensile stresses. The applications of polyamide – steel plate front face type contacts are referring on journal bearings, cams, guides, chain drive transmissions – the guide/chain contact, taps – the screw/nut contact, gear transmissions, all of these characterised by sliding frictions. The paper presents the tests results regarding the sliding friction between the mentioned types of contacts.

The testing methodology presented in the article can be applied to other pairs of materials (polyamide/polyamide, metal/metal) and allows the study of the sliding friction (as it is presented in the paper) and of the rolling friction – for instance, the upper element can hold a ball.

The dynamic friction coefficient µ for sliding motion has small values (0.1028), comparable with the references and its value stabilises relatively fast (after 80 minutes); this shows that the running in period for the mechanical transmissions which have polyamide type (PA66) components is short.

The flatness error *e*, according to the measurements, is stabilised after 60 minutes of running in at a small value – 6 µm; according to that, the usage of PA66 type materials in mechanical transmissions induce small errors with small shocks and vibrations in the transmissions.

In the first period of running-in, the wear rate *w* is relative high (up to 150 µm for the peaks on the disk's front face) and after this period it decreases dramatically to almost zero. That assures a constant coefficient of friction and a small amount of abrasive particles from the PA66 disk. The tests show that for high rotations (3000 rpm – the Stribeck test) the friction coefficient is still stabilised at the value of 0.11.

Due to their mechanical properties and due to their behaviour in mechanical transmissions, the polyamide (PA66) type mechanical components are suitable to be used with high efficiency (due to their small friction coefficients) in mechanical transmissions with small running-in periods.

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