TRIBOLOGICAL PROPERTIES OF SELF-LUBRICATING SLIDING BEARINGS MADE OF PTFE AND POM-BASED COMPOSITE MATERIALS

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Abstract: *Self-lubricating sliding bearings made of polymer materials are used when lubrication is impossible due to construction reasons, or lubricant could spoil the product (i.e. in food industry), in chemically active environments which could affect the metal bearings, etc. In this paper there are presented the results of starting tribological tests on self-lubricated sliding bearings made of composite materials with PTFE and POM base. Above mentioned tests were carried using own testing machine USL 5-30 designed for investigation of self-lubricating sliding bearings. In this paper authors are going to present some of starting obtained results, such are friction coefficient and operating temperature trends due to an operating time. Even those are starting investigations for this kind of bearing; authors are going to try to obtain some values of the wear rate for both of materials.*

Keywords: *self-lubricating bearings, polymer bearings, PTFE, POM, friction, experiments.*

1. INTRODUCTION

Sliding bearings are applied when it comes to special design or functional constraints. For example design constraint such is dimension of the sleeve diameter could impose usage of sliding bearings. If sleeve diameter is less than 15 mm or greater than 300 mm, there are usually mounted sliding bearings. Sliding bearings are usually applied at high shaft speeds or in case when low level of vibration and noise is requested. These two examples represent functional constraints.

Most of machine and equipment manufacturers are trying to eliminate or at least to reduce lubrication systems in aim to settle production costs down without sacrificing machine performances. According to numerous studies, analyses and investigations, more than 50 % of bearing failures are lubrication related.

Self-lubricating sliding bearings are widely used nowadays, primary because of above mentioned reasons. They have been applied in wide range of machine types, used in every day's situations. This fact can be easily understood if it was known several advantages of this type of bearings compared to commercial sliding and rolling bearings. Generally, their production is pretty simple, which makes the price lower, for simple mounting they could be made in segments, and in operating they produce less noise and vibrations. Regarding the fact that they do not need any additional lubrication during the operation process, those bearings are very convenient for maintenance and they have long operating life. There are two

different types of self-lubricating sliding bearings:

1. Sliding bearings that work without oil or grease.
2. Sliding bearings that contain lubricant, either in special storage or in their own material structure, for example porous metal bearings.

Sliding bearing with special material structure, as porous metal bearings belongs to group 2, were intense investigated and their advantages were presented [1,2].

Sliding bearings made of composite materials with polymer matrix, which are subject of this paper belong to the group of self-lubricating bearings operating without oil or grease. There is a filler added to the base material which purpose is to reduce the coefficient of friction of the base material and therefore to eliminate the need for additional lubrication. Application of these bearings take place if:

- Lubrication isn't efficient due to very high or very low temperatures, operation in vacuum or chemically active environment.
- Lubrication could spoil the product (e.g. food Industry).
- Lubrication is not possible or too difficult due to design reasons (e.g. household appliance).

2. PROPERTIES OF EXAMINED SLIDING BEARINGS

In this paper authors were dealing with examination of two types of polymer layer composite bearings. First observed in the paper was PTFE-based composite bearing, metaphorically called "The Long Runner" with wall structure shown in Figure 1. This type of dry sliding bearing is designed to operate without lubricant and it is particularly suitable for high loads and medium speed applications. Its operating temperature is up to 250 °C and best using sliding velocity is up to 2 m/s. Some typical applications of these bearings are in automotive industry, materials handling equipment, home appliances and consumer goods, textile machinery etc.
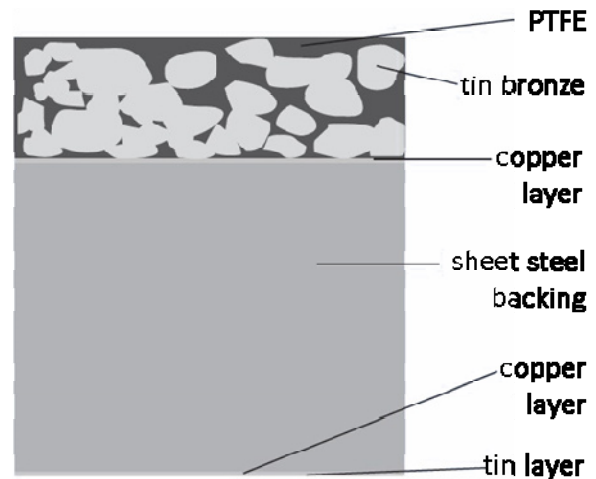

Figure 1. Cross-section of PTFE composite

POM composite sliding bearing, as another examined in this paper is specially designed to operate with boundary lubrication. This kind of bearing requires only a trace of lubricant to operate satisfactorily for long periods, so they are considered as pre-lubricated bearings. The sliding surface has a highly effective grease retention system with lubrication pockets, which serve as "lubricant reservoirs". This POM composite consists of three bonded layers: copper plated steel backing strip and a sintered porous tin bronze matrix covered with an acetyl (POM) resin (Fig. 2).
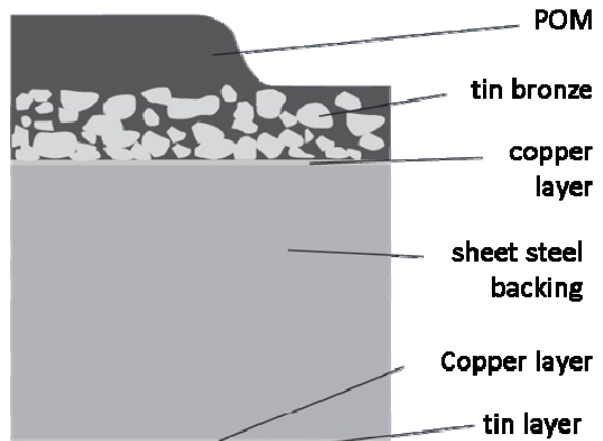

Figure 2. Cross-section of POM composite

Dimensions of examined bearing samples are selected due to a possibility of comparison with properties of porous metal bearings and taking into account constructive performances of own test rig using for experiments.

Examined selected samples for testing have dimensions of Ø20 / Ø23 × 20 mm, as a common size for some of their typical applications. In combination with shafts made

of steel 16MnCr5 (hardness: 60 HRC), loose fit in shaft-bearing interface was defined by Ø20 H7/f7, where an operating clearance in testing belongs to range 20 – 62 µm.

3. EQUIPMENT FOR FRICTION COEFFICIENT AND TEMPERATURE ANALYSIS TESTS

Experiments of sliding bearings are carried out at Mechanical Engineering Faculty, Laboratory of Machine Design Department. For experiments is used own testing rig named as USL 5-30 (Fig. 3), composed on USL1 idea [3] in cooperation with bearing manufacturer.
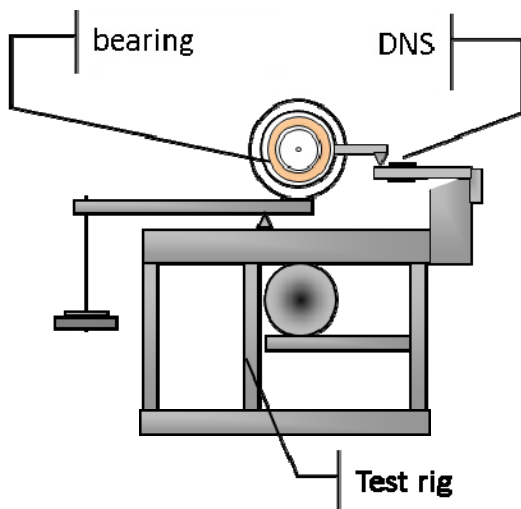

Figure 3. USL 5-30 test rig system

Using this test rig system for experiments it was convenient to apply portable DAQ system (Fig. 4) with main components: SC-2345 Carrier, modules SCC-SG24 for full bridge strain measurement and SCC-TC02 for temperature measurement (Fig. 5) [4].
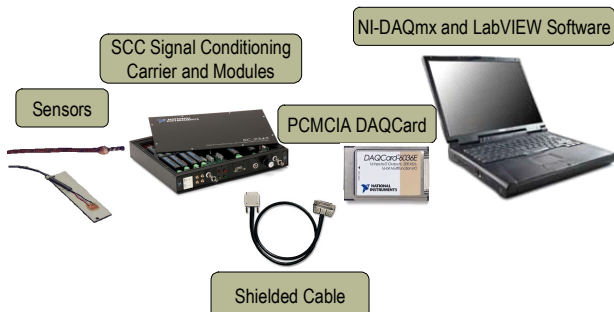

Figure 4. Components of portable DAQ system

The main reason to apply DAQ in this measurement is a need to follow continuously values of both: friction torque and bearing temperature. It is not even necessary to obtain high sample rate for this experiments, advantages of getting results and its disposal for further analyses is obvious.

Figure 5. SCC Carrier and modules

4. FRICTION MEASUREMENT

An idea for friction torque determination in the bearing-shaft interface is simply based on cantilever bending measurement with outer bearing surface as a load [2,5]. This principle is used by means of strain gauges applied onto cantilever (Fig. 6), where further is possible to calculate bearing friction coefficient. Before the experiment, it was necessary to calibrate the measuring device in order to determine constant c. To simplify the final equation, constant c is grouped with other constants, g and l to obtain one single constant $K_{l/r}$.
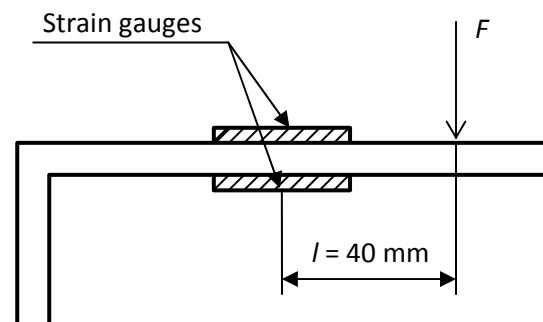

Figure 6. Cantilever for measuring fiction torque

Equation (1) shows well-known dependence of friction torque, friction coefficient, normal load and diameter:

$$T_\mu = F_\mu \cdot \frac{d}{2} = \mu \cdot W \cdot \frac{d}{2} \qquad (1)$$

T_μ – friction torque; μ – friction coefficient; W – radial force applied onto the bearing; d – bearing diameter.

On the other hand, that moment could be measured by means of cantilever with strain gauges applied on it:

$$T_\mu = F \cdot l = \frac{g \cdot l}{c} \cdot s = K_{l/r} \cdot s \qquad (2)$$

g – acceleration of gravity; c – constant of the measuring device; s – reading of the measurement.

Equations (1) and (2) were used aimed to calculate bearing friction coefficient:

$$\mu = \frac{2 \cdot K_{l/r} \cdot s}{W \cdot d} . \qquad (3)$$

5. RESULTS AND ANALYSIS

After preparation and control of samples starts worm up (running-in) phase, all before the official tests. Execution of the planned experiments is followed by collection, processing and analysis of results obtained by experimentation.

For mentioned composite materials (PTFE and POM layer), the temperature and friction coefficient trend was obtained due to a time under the following parameters of load and velocity:

- Radial load: W = 92 N,
- Rotation speed: n = 995 rpm.

This working regime for experiments is selected by using results of polymer materials studies [6]. Bearing manufacturer catalogues [7] were also assisted as a source for "*pv* characteristics*" and guide in proper selection. According to typical bearing applications and corresponding operating performances [8], authors were focused on higher velocity and lower load. Contact pressure in this case is relative low p = 0.3 N/mm^2, with sliding velocity of v = 1m/s.

Measurement of operating temperature and friction coefficient of sliding bearings were performed simultaneously for both mentioned composite materials, where obtained results could be presented by diagrams in Figure 7 (for PTFE) and Figure 8 (for POM). Shown results are selected from several samples those are tested in same operating conditions and represents typical bearing performances.
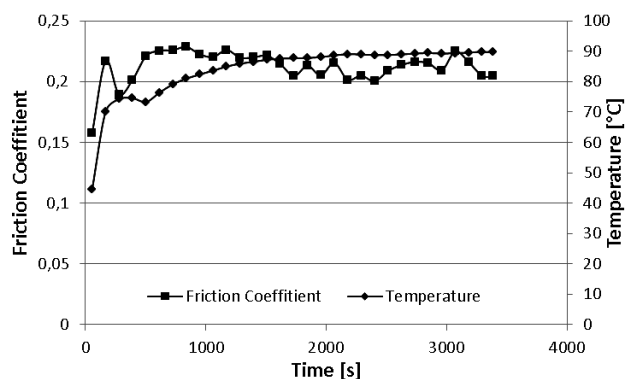
Figure 7. Bearing temperature and coefficient of friction due to a working time (PTFE)
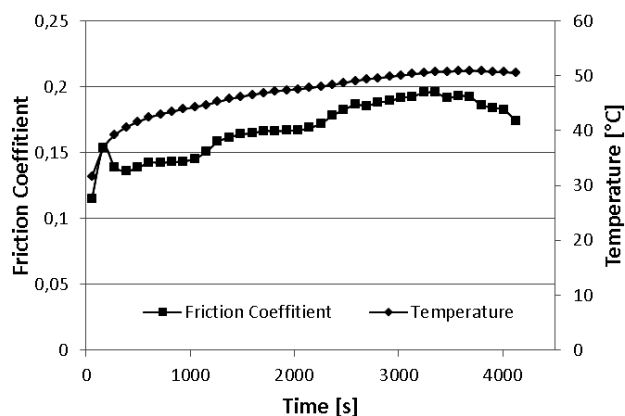
Figure 8. Bearing temperature and coefficient of friction due to a working time (POM)

Conducted bearing tests show that temperature and also coefficient of friction values become to be a constant after (45...60) minutes. From above shown diagrams it is easy to see that bearings with PTFE kept almost constant temperature values those are significant higher compared with POM composite. Possible explanation could be a fact that POM samples used to be lubricated before the start with a bit lubricant amount kept in small depots on the surface during the operating. Values of friction coefficient measured in investigation takes expected values from "*pv* range characteristics" given in manufacturer catalogue.

6. CONCLUSION

Similar as tests for porous metal bearings [9], this investigation shows as expected, that both temperature and coefficient of friction values of tested bearing become constant till 1 hour of operating and that their dependence from time could be polynomial approximate.

Experiments show that bearings with PTFE layer rich higher temperature values than samples in POM composite, which could be explained by a bit lubricant amount applied from start and kept in small depots on the surface during the operating. From another side friction coefficient for both composite materials take predicted values for relative low bearing load and high sliding velocity, according to manufacturer catalogue.

Determination of wear rate as a significant tribology parameter requests lot of experiments aimed to make some worthy conclusion. Taking into account that up-to-date investigations are still in progress, authors in this moment could just offer an observation concerning wear rate comparison between PTFE and POM materials. Results of experiments under above mentioned operating conditions show that samples with PTFE layer lost about 0.1 % of mass for a few hours of testing, while POM samples maintain their weight. It could be explained following the fact that POM bearings with depots retain lubricant and thus less wear in exploitation.

It used to be said that presented results represents only a single regime investigation, where similar tests performing are in progress for other working regimes typical for this kind of bearings.

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