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EXPERIMENTAL INVESTIGATION OF SELF-LUBRICATING SLIDING BEARINGS

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Abstract
Self-lubricating sliding bearings are widely used in numerous industrial applications, primary regarding their specific lubrication mechanism. This lubrication mechanism is a main advantage compared with classical sliding bearings, where their production is not so complicate and makes lower price. This kind of bearing could be simple to assembly and in operating produce less noise and vibrations. According to their material and type of operating, self-lubricating sliding bearings could operate with oil (grease) in its own material structure or even without any amount of lubricant. Besides numerical analysis and calculations, at Faculty of Mechanical Engineering, University of Belgrade numerous experimental investigations of those bearings have been conducted, regarding own laboratory with test rig. This paper presents only selected results of those experiments, where portable DAQ acquisition with LabVIEW software tool was applied.

Keywords: *Self-lubricating sliding bearings. Experiments, friction coefficient, data acquisition*

1. INTRODUCTION

Self-lubricating sliding bearings are common in use nowadays, which means they are been applied in most of machines we need for use in our everyday work and live. We can easy understand this fact if we know several advantages this sort of bearing compared with classical 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 opearting, those bearings are very practical for maintenance and they

have long operating life, which are probably most important reasons for their universal use. There are two different sorts of self-lubricating sliding bearings:

- Sliding bearings that work without using any amount of oil or grease. These bearings are made of special plastics, graphite or some ceramics materials.
- Sliding bearings that contain lubricant, either in special storage or in their own material structure. The example and best known in this group are porous metal bearings made by sintering process and they are the product of powder metallurgy [1] (Cheng, 1986).

Mechanism of self-lubrication in porous metal bearings makes lubrication process better, but coefficient of friction still takes values in wide interval. That can be understand if we know that in bearing life it works in regimes from boundary to hydrodynamics lubrication. Lubrication quality and kind of regime are been defined due to all parameters which have impact to friction. Besides working regime parameters, bearing temperature, quality and quantity of oil supply, a significant impact has doubtless a coefficient of friction value that used to be measure due to experimental investigations. Those investigations are been conducted on special test rigs and equipment in aim to simulate real working conditions subjected to explore main parameters trend such are among others, temperature and coefficient of friction values during the sliding bearing exploitation.

2. TEST RIGS AND DAQ EQUIPMENT

Experimental investigations of self-lubricating sliding bearings are carrying out in Laboratory of Machine Design Department on Mechanical Engineering Faculty, University of Belgrade. The Department has a long tradition in investigations of bearing, where realization of those experiments is been done using two different test rigs during last several decades. The first version of test rig USL 1 (*Figure 1*), has been designed, manufactured and installed 1988. by Prof. Janković, since than started experiments of self lubricated sliding bearings [2]. Numerous tests and investigations of porous metal bearings are conducted in the Laboratory, among them significant are "*pv*" bearing curve determination, such as dependence of temperature and coefficient of friction during the exploitation of those bearings. Some results of theoretical analysis and experiments done on this test rig were published, among them could be mentioned [3].

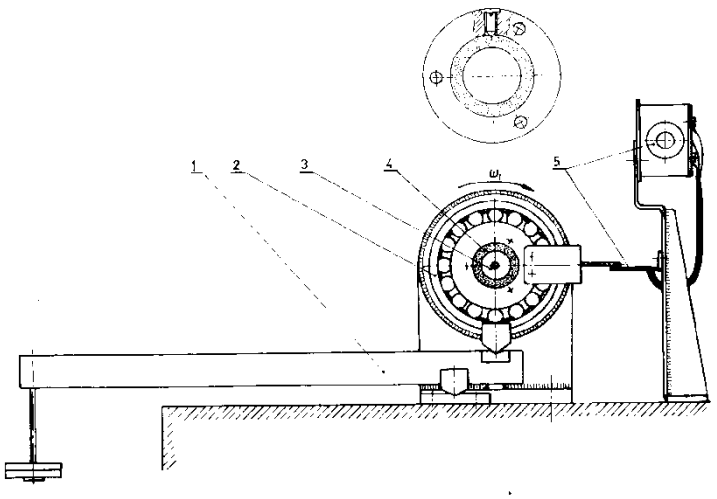

Figure 1. Concept for testing self-lubricating sliding bearings

New testing machine, based on same concept, but improved, under the name USL 5-30 is been designed in cooperation with bearings factory "Sinter" from Užice, Serbia, started at the end of last Century (*Figure 2*). Compared with old test rig, testing with new one could have more various, means wider range of bearing diameter and more precise control of rotational velocity. Experiments on new one system USL 5-30 are more efficient, much easier to realise and give results that better fit to real operating conditions. Using this test rig system for experiments it is possible to apply portable NI DAQ system [4]. Main reason for DAQ applying in this measurement is need of continually following two channels for friction torque by DNS and bearing temperature simultaneously. Even not necessary to have high sample rate for this kind of experiments, advantages of getting results and its disposal for further analyses is evident (*Figure 3*).

Figure 2. New test machine for experimental investigations

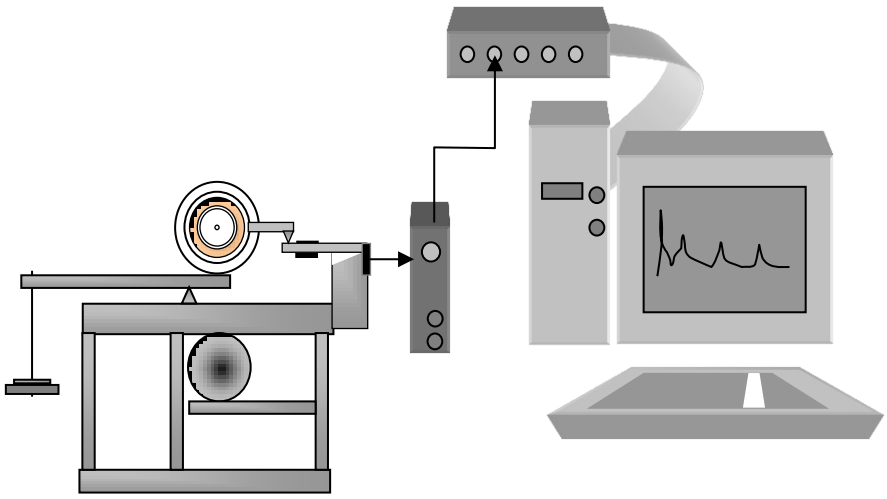

Figure 3. Elements of DAQ equipment

3. EXPERIMENTS PROCEDURE AND SAMPLES

Procedure for experimental investigations of sliding bearings used to be grouped into three parts, depending on the properties or the purpose of the research:

- Experimental study of mechanical and tribological characteristics of bearing materials,
- Investigation of oil or grease behavior for the bearing lubrication improvement and
- Experimental study of sliding bearing working performances.

Before one can access the experimental research it is necessary to make the program and the research methodology which must be in accordance with technical and other capabilities that are available. When it comes to self-lubricating bearings in general, one can organize several phases of which been constitute their experimental research:

- Preparation of the samples, the detailed control, laboratory analysis and measurement;
- Warm up (running in) of bearing samples before the official test;
- Execution of the planned experiments and
- Collection, processing and analysis of results obtained by experiments.

Here are presented just a part of experimental investigations attended to study sliding bearing working performances [5]. Samples for testing have dimensions Φ20 / Φ30 × 20mm, as a common dimension for some household and agriculture machines purpose. A small bearing peaces of cylindrical shape were cut into sections aimed to analyze their inner surface before and after the experiments in working conditions (*Figure 4*).

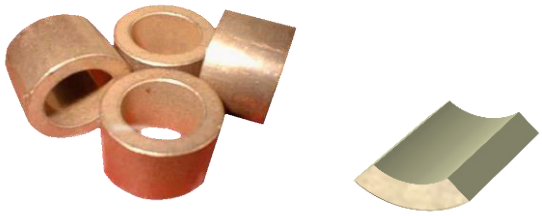

Figure 4. Porous bearing samples with segment for surface analysis

Bearings were selected from two kinds of materials: sintered bronze (CuSn10) and same material with addition of 1% of C (graphite) with corresponding physical characteristics (*Table 1*). Before testing realization, complete physical and metallographic analysis and samples selection has been conducted.

Table 1 Bearing material characteristics

Material		CuSn10	CuSn10 + 1%C
density,	g/cm^3	6,4 … 6,5	6,54 … 6,58
open porosity,	%	22,45 … 23,17	18,3 … 19,3
radial fracture force,	N	3500 … 3600	1750 … 1900
hardness,	HB	33,26 … 36,24	33 … 36

Before testing of temperature and coefficient of friction trends, all selected bearings were worked out a couple of hours, just to be prepared aim to simulate real exploitation conditions. Measuring of operating temperature and coefficient of friction rates for running bearings were been worked out. The dependence of those parameters in time has been done under boundary conditions of "pv" characteristics: radial load of F = 170 N and rotation speed n = 4780 rpm.

Experiments are been conducted under the common external environmental conditions, temperature about 20±3^{0}C and the air humidity range (40…70)%.

4. RESULTS AND COMMENTS

This investigations shows that both temperature and coefficient of friction values of porous metal bearing become constant after (30...50) minutes and it's dependence from time can be best polynomial approximate. It used to be said that those results represent only a single regime of investigation (*Figure 5*), where similar tests are performed for other characteristic working regimes. Presented results are in correlation with some theoretical and previous experimental investigations, those are showing that self-lubricating bearings are become to be stable with friction coefficient and temperature and it could gives us a conclusion about necessary testing time aimed to simulate real working conditions.

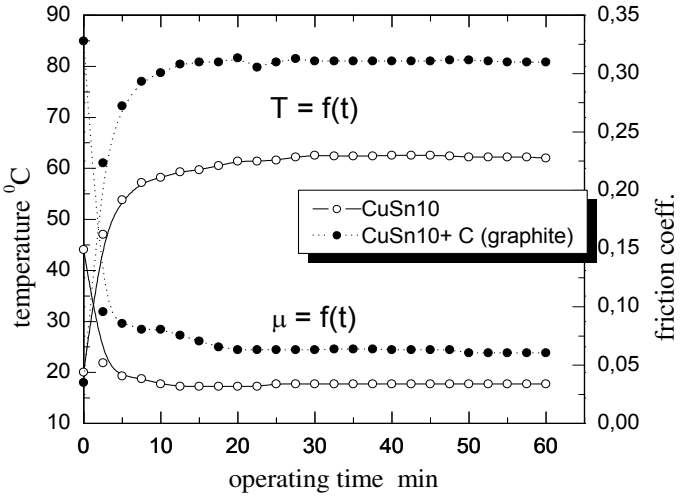

Figure 5. Trend of bearing temperature and coefficient of friction due to a working time

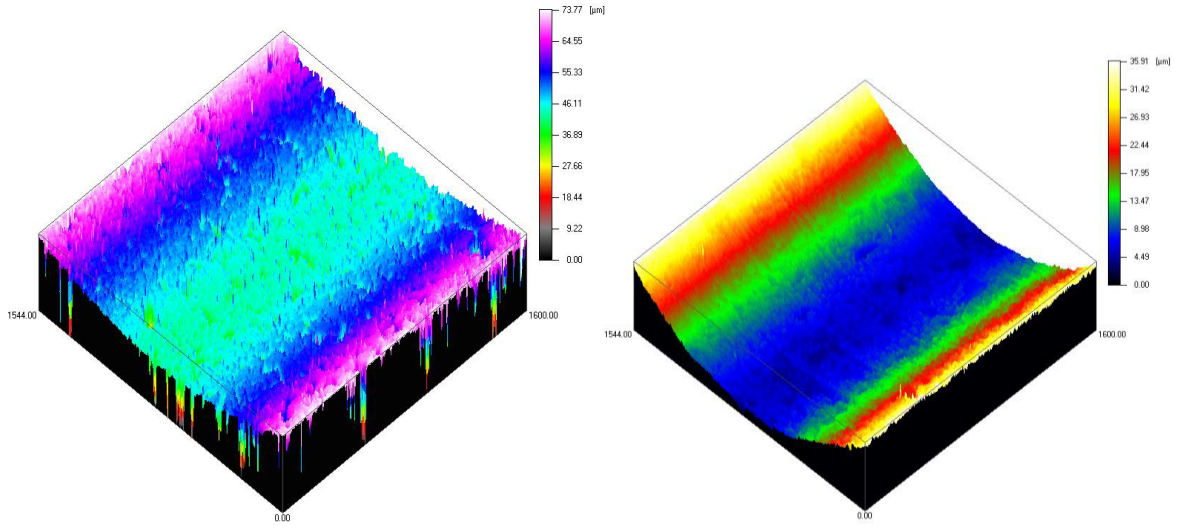

Figure 6. Bearing surface segment (before and after experiments)

Bearing surface and profile analysis, before and after experiments were also been made and this measurement has been conducted on testing center "Nanofocus AG" in AC2T, Center for Competence in Tribology W. Neustadt, Austria. It is very interesting and easy to observe differences of those surfaces (*Figure 6*). It is easy to observ that pores on the surface were almost closed after some period of work due to a wear process and contact in shaft bearing interface, that obviously dominant occurs in starting period of bearing exploitation.

After this short results overview, here used to be said that testing of second group of self-lubricating bearings those are working without any lubricant are in starting phase, because of significant expansion of polymer materials last years. By eliminating lubrication from machinery, equipment manufacturers can minimize the costs and risks associated with maintenance for the end user. Because of lubrication problem and costs, which are dominant during the working life, a possible solution is to apply dry running plastic sliding bearing. Plastic bearings are produced on polymer basis which is optimized with fibre reinforcement and solid lubricants. They are an ideal solution for machinery that requires clean and oil-free operation [6]. Plastic bearings are doing well in dirty environments since there is no oil to attract dust and dirt. Some composites with polymer thin surface could be also very interesting material for further investigations this kind of bearings [7].

5. CONCLUSIONS

Numerous experimental investigations were been focused on "pv" characteristics determination, temperature and friction quality trends in operating. Experiments presented here, made on porous metal bearings show that temperature and coefficient of friction values become constant about hour of work under the corresponding load. Those relations can be best approximate by polynomial (*Figure 5*), for most of typical regimes in bearing exploitation.

According to presented results, one could conclude that C (graphite) content in sintered bronze has respectable influence on friction, wear and temperature rates regarding its solid lubricant performances. Appropriate value of the graphite content must be determined for any particular case taking in account not only the tribological properties. The mechanical properties of the obtained sintered material used also to be considered, since the higher content of graphite (more than 1-3% or higher) tends to decrease them and make them not useful for the bearing purpose.

Bearing-shaft interface should also take into account consider porous surface character as an important parameter for its behaviour. Numerous channels in material structure started from open pores on the surface and going into the bearing volume, some of them almost 0,1mm deep from the surface (*Figure 6*). But after several hours in exploitation, size beds became quite smooth, that could be observed on the surface. One can see there are no more deep pores, just a bearing surface with roughness less than 10μm, which means that pores in interface are been closed for further exploitation process.

The results shown in this paper are only a couple among lot of them made during a long period in the Laboratory of Machine Design Department. New acquisition system with some new composite and polymer materials, we are currently dealing with, allow further experimental investigations in this field on Mechanical Engineering Faculty University of Belgrade.

6. REFERENCES

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