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Research paper

CALCULATION OF THE ARCHARD'S WEAR COEFFICIENT OF THE POLYMER-BASED COMPOSITE SLIDING BEARINGS

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Abstract: *Prediction and calculation of wear of the mechanical components in contact is one of the most important tasks in modern engineering. Due to time consumptive experiments and quite expensive test rig, it became even more challenging to evaluate wear by means of the computer simulation instead of the real experiments. With rapid improvement of the computer resources, this task became more realistic, and the results are more concurrent to those obtained by experiments. Since the most of the solvers evaluate wear by means of the Archard's equation, to perform the simulation it is mandatory to determine Archard's coefficient K. This paper provides necessary steps, experimental investigations and measurements in order to calculate Archard's coefficient K, as an input value for the simulation of wear of the polymer-based composite sleeve bearings.*

Key words: *Archard's wear, simulation, polymer, sliding bearings*

1. INTRODUCTION

The idea to investigate sliding bearings made of polymer based composites came out of their wide application. It is particularly emphasized when the special requirements of exploitation are demanded. Some of these special requirements could be self-maintaining of bearings, operation in absence of lubrication or constraints related to the bearing dimensions [1]. They can be used in many different branches such are food industry, production of household appliances etc. Since they are quiet cheap if compared to metal, roller bearings, their application is economically justified. But they also have some disadvantages such is significantly lower load capacity. Since these bearings operate in sliding contact, usually with sleeve made of steel, their functionality is strongly influenced by their tribological properties, especially wear.

Testing of the tribological properties could be quiet expensive and long. For these reasons, nowadays trend is to make a numerical model which would provide quite quick and satisfactorily accurate result of a component's wear [2-4]. The most exploited approach of the numerical calculation of wear is the one based on the Archard's equation of wear (1). To perform this simulation it is necessary to determine Archard's constant *K*.

This paper explains the methodology to obtain all the values needed for the calculation of the Archard's constant.

2. THE CONCEPT OF THE DETERMINATION OF THE ARCHARD CONSTANT *K*

Archard's equation (1) states that there are three predominant factors to influence the amount of wear. These factors are sliding distance (*L*), applied radial load (*F*) in case of sliding bearings, and hardness of the tested material (*H*). Influence of all other factors (i.e. roughness of the surface in contact) is taken into account with the Archard's constant *K*.

$$\Delta V = k\frac{LF}{H} \tag{1}$$

In order to determine this constant, it is necessary perform the experiments which will provide the information of the worn volume in dependence of sliding distance and radial load, and afterwards return it into the Archard's equation.

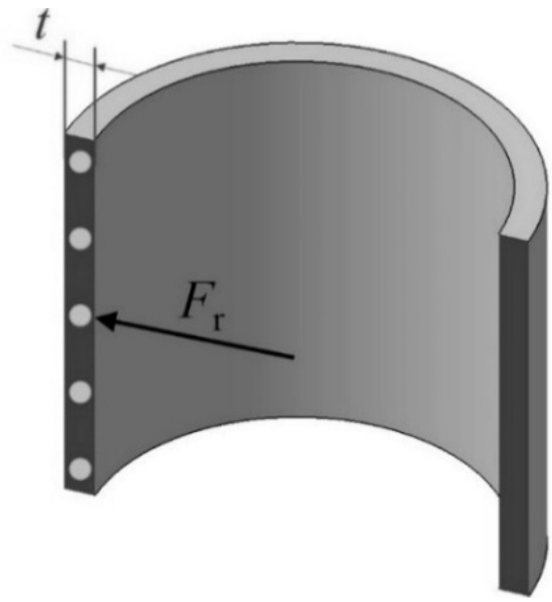

Fig.1. Measurement of the wall thickness in few points along the specimen's length

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First step is to measure the thickness of the bearings wall before the process of wearing. This could be done by means of 3D microscope or other 3D scanning device with high accuracy. The faster, but not so accurate method is to measure the wall thickness (*t*) of the bearing in few points along the height of the cylinder (Figure 1). The more accurate way is to scan whole surface of the bearing which will be subjected to the contact with the sleeve.

Second step is determination of the hardness of the examined bearings, and its conversion to the suitable unit (N/m^2).

Third step is the wearing of the specimen bearing on the appropriate tribometer. For this step it is necessary to define parameters such are sliding distance (*L*), load (*F*) and revolutions per minute (*n*). It is obvious that two of these tree parameters are consisted in the Archards equation, and directly influence onto the Archards constant *K*.

The fourth and the last experimental step is to measure the thickness of the bearings wall after the wearing process, or to scan the surface subjected to wear.
Comparing the data obtained by the first and the fourth step it was determined the decrease of the wall thickness, and based on it, it was calculated worn volume ΔV, which is necessary for the Archard's equation.

3. DESCRIPTION OF THE EXPERIMENT RIG

In order to execute the first and the forth step of the experiment, it was used 3D microscope with designation HIROX KH-7700 3D Microscope (Figure 2). Since it is optical device, this microscope allows determination of wall thickness only in two points which are located at the both sides of the examined bearing. For this reason we are forced to assume that the wearing is uniform along the specimen's length (constant in every cross section).

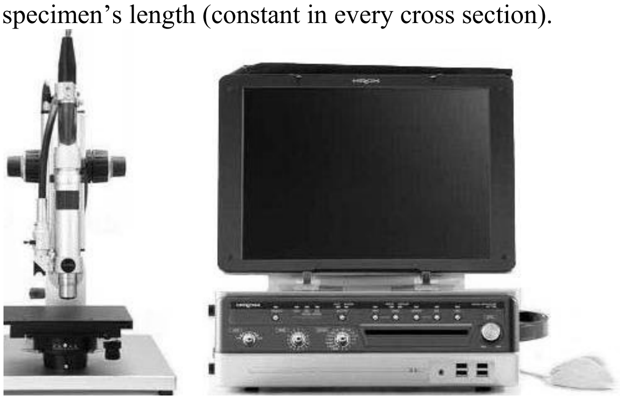

Fig.2. HIROX KH-7700 3D Microscope

Table 1. Characteristics of the Micro Vickers Hardness Tester TH710

Test force	0.098N, 0.245N, 0.49N, 0.98N, 1.96N, 2.94N, 4.9N, 9.8N
Min measuring unit	0.031µm
Max Height of Specimen	80mm
Distance of Indenter to outer wall	95mm
X-Y Testing table	Dimension: 100x100mm Max mobile: 25x25mm
Overall Dimension	405x290x480mm
Conversion Scale	HRA, HRB, HRC, HRD, HRF, HV, HK, HBW, HR15N, HR30N, HR45N, HR15T, HR30T, HR45T
Hardness measuring range	8~2900HV
method of testing force applied	Automatic loading and unloading
Test microscope magnification	400x (Measuring), 100x（observation）
Duration time	0~60s

Determination of the specimen's hardness was performed on the Micro Vickers Hardness Tester TH710 (Figure 3). The characteristics of this tester are provided in the Table 1.

Fig.3. Micro Vickers Hardness Tester TH710

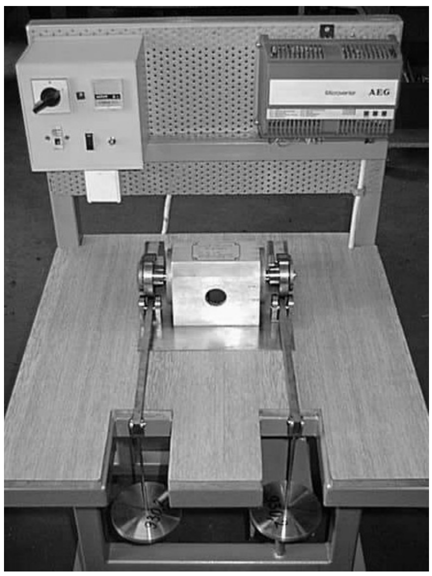

Fig.4. Testing rig – a custom made tribometer with designation USL 5-30

For the experiment of wearing of radial sliding bearings, it was used custom made tribometer with designation USL 5-30 (Figure 4). This testing rig is the property of the Faculty of Mechanical Engineering, University of Belgrade, situated in the laboratory of the Machine Design Department. This tribometer is equipped with frequency inverter which provides the variation of revolutions per minute. This way it is possible to adjust the sliding velocity between bearing and sleeve according to the recommendations taken from the *pv* diagram [5]. The sleeve in contact with bearing is driven by the electric motor and belt transmission. The radial load is applied over a lever. One end of the lever is in contact with the nave in which the specimen is placed, while on the other end of the lever there are hanged the weights. The ratio of lever sides is 10:1. The radial load could be varied by applying different combination of weights.

The acquisition rig used to obtain friction factor and temperature was consisted of NI DAQ (Figure 5) system with the components:

- SC-2345 Carrier
- Module SCC-SG24 for full bridge strain measurement
- Module SCC-TC02 for the temperature measurement

By means of this acquisition system, it is possible to track continually two channels. Through the first channel it was observed friction torque, and through the second – the temperature in contact between the bearing and sleeve.

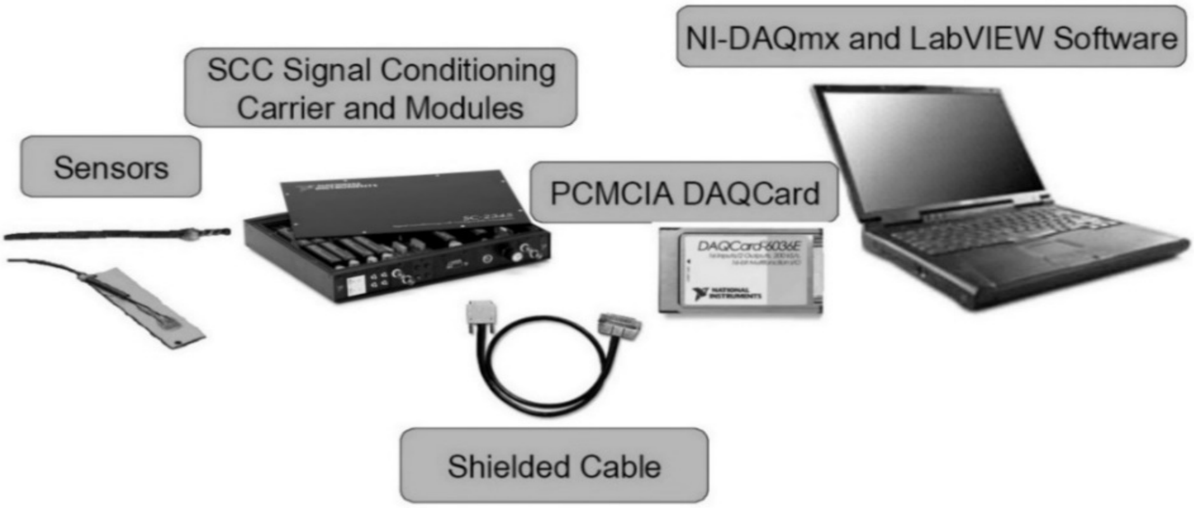

Fig.5. Acquisition rig – DAQ system used for monitoring friction torque and temperature

4. DESCRIPTION OF THE SPECIMEN

PTFE Polyamide combines a thermoplastic as a base material, with PTFE additives and glass-fibre, which results in self-lubricating and low wear performance [5]. They are designed for dry operation, but their performance could be improved by initial lubrication. With a supply of grease, oil, water or other liquid, the operating speed of these bushings can be increased. These bushings are resistant to most lubricating oils and greases. They offer many features and advantages such as:

- Maintenance-free operation,
- Cost efficiency,
- Excellent resistance to corrosive conditions,
- Electrically insulating properties.

Dimensions of examined bushings are Ø20xØ23x20 mm. Additional properties of these bearings are given in Table 2.

Table 2. Characteristics of the PTFE polyamide bushing

Permissible load, N/mm2 (dynamic/static)	40/80
Permissible sliding velocity, m/s	1
Friction coefficient μ	0.06…0.15

5. RESULTS AND ANALYSIS

Regarding to literature [4], the experimental conditions for the pair in contact are following:

- Sliding distance: L=20000 m
- Sliding velocity: v=1 m/s
- Radial load: F≈400 N

There were three samples subjected to the experiment. Readings from the DAQ system showed that the temperature in the sliding contact didn't exceed 70°C, and the friction factor remained in the range 0.02 - 0.10. It could be noted that the friction factor is lower than the one defined by the producer (Table 2.). This could be explained by initial lubrication was applied to specimen.

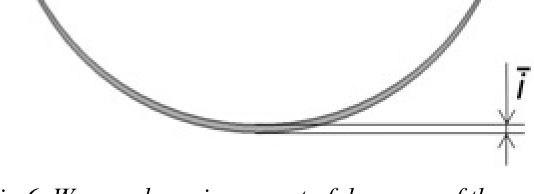

Fig.6. Worn volume in respect of decrease of the wall thickness $\bar{i}$

Analysing the wall thickness of the bearings, it was obtained very good repeatability for each specimen, and the decrease of the thickness was about 0.3 mm (initial thickness 1.5 mm, after the experiment 1.2 mm).

For the decrease of the wall thickness $\bar{i}$=0.2 mm, it was calculated worn volume (Figure 6) of ΔV=1.208·10^{-7} m^3.

The hardness was determined on a Micro Vickers Hardness Tester applying the force 0.025kgf (0,245 N). For the dwell time of the test force it was taken 10 s. Tests on the Micro Vickers Hardness Tester showed that the specimen's hardness is H≈10 HV which corresponds close to 100 N/mm^2.

Combining the data obtained from the above mentioned experiments, it is possible to determine Archard's constant:

$$k = \frac{\Delta VH}{LF} = \frac{1.208 \cdot 10^{-7} \cdot 100 \cdot 10^{6}}{20 \cdot 10^{3} \cdot 400} = 1.51 \cdot 10^{-6} \qquad (2)$$

Obtained data for hardness and Archard constant are in accordance to the existing literature, compared to pure PTFE polymer [6].

Further steps of this investigations are to implement this constant into numerical model and perform the simulation of wear.

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