WEAR SIMULATION OF THE POLYMER BASED COMPOSITE SLIDING BEARINGS BY MEANS OF ANSYS

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Abstract: Polymer based composite sliding bearings are increasingly applied in many industries, due to their economic (usually low cost of production) and technical (good tribological properties) benefits. In order to predict their life cycle, it is necessary to perform numerous experiments and evaluate their wear rate. This is generally quite expensive and time consuming.

By applying only one series of the experiments and determining Archard's wear coefficient, and embedding it into the code of the Ansys software, it is possible to simulate the wear, and thus save the time and the financial resources. This paper explains the procedure of the wear simulation in case of known Archard's coefficient, for sliding bearings made of PTFE polyamide composite material in contact with shaft of steel. The output of the simulation is the contact pressure in relation of time and the amount of worn volume for 3 revolutions of the shaft.

Keywords: wear simulation, polymer sliding bearings, Archard's coefficient, Ansys.

1. INTRODUCTION

Sliding or a plane bearings are increasingly applied in various industries, due to their simplicity in production and economic advantages. If compared to roller bearings, they are significantly cheaper to produce. Making sliding bearings of polymer materials leads to the further evolution, since they are light weighted, and usually have low friction coefficient in contact with steel. They could run dry or initially lubricated, which makes them applicable in the "clean industries" (pharmaceutical, food etc.).

Wear calculations are very important in order to predict the life cycle of a certain component, and thus schedule the forehand replacement or prevent the failure. Wear tests are usually expensive and time consuming, so the alternative approaches were introduced. One of the youngest is the numerical calculation. Hand by hand with the evolution of the computer technology, the numerical methods were developing. They started and took very important place in strain/stress analysis, but recently their application expands to the wear simulations.

Although the idea of the wear calculations dates from the mid of the 20th century [1], the real breakthrough happened during the '90s by authors Podra and Anderson ([2], [3]). Later at 2010, Anderson gave a detailed summery in subject of wear simulation, its application and constraints [4]. Benabdallah and Olender [5]

performed 2D wear simulation of POM. By means of pin-on-disc configurations they obtained necessary input values. The development of an inclination in the wearing profile of the pin was predicted by the simulation. They used adaptive mesh and different working regimes: v = 0.1..1 m/s, s = 20..80 km and p = 1..10 Mpa.

2. PRINCIPLES OF THE WEAR SIMULATION

Analysing the literature it is noticed that the most common approach to simulate the wearing process is the one that applies the Archard´s wear formula:

$$\Delta V = K \cdot \frac{L \cdot F}{H}$$

Where stands: ΔV-worn volume, L-sliding distance, F-radial load, and H hardness of the softer material in contact (in this case PTFE polyamide).

Applying this formula, the wear could be simulated by FEM. In this case, it was performed in software ANSYS 18.1.

2.1 Determination of the input data for the wear simulation

In order to perform numerical simulation of the wearing process, it is necessary to obtain input data. Some of these data are read from the producer's catalogue, while the others are determined by experimental research.

The examined bearings are made of PTFE polyamide which characteristics are given in Table 1.

Table 1: PTFE Polyamide sliding bearing´s characteristics

Permissible load, N/mm^2 (dynamic/static)	40/80
Permissible sliding velocity, m/s	1
Friction coefficient	0.06..0.15
Temperature range °C	-30..+110
Density kg/m^3	1380

But beyond these characteristics, it is necessary to define Young´s modulus and

Poisons ratio of the PTFE polyamide, which are according to the literature ([6], [7]):

$$E=2100 \text{ N/mm}^2$$
$$v=0.4$$

The most demanding part of experimental research is to determine Archard´s wear coefficient K. Detailed steps and results regarding to this topic were processed and published in previous articles [8]. Wear coefficient in case of PTFE polyamide is:

$$K = 1.2196 \cdot 10^{-6}$$

Micro-hardness of the examined material H should also be determined experimentally. According to the referent literature [8], this it is done by Micro-Vickers method. By means of the micro Vickers hardness tester TH710, this value is determined to be:

$$H = 10 \text{ kg/mm}^3 = 98.07 \cdot 10^6 \text{ N/m}^3$$

Other input values such are: sliding distance L, sliding velocity v, and contact pressure p, are defined with respect to working regime, pv-characteristics of the specimen bearing and referent literature [5]. These values are:

$$L = 20000 \text{ m}$$
$$p = 1 \text{ MPa}$$
$$v = 1 \text{ m/s}$$

3. NUMERICAL SIMULATION SETUP

The numerical simulation is performed in "Transient Analysis", module of the software ANSYS 18.1, which executes time dependent phenomena. It is necessary to define contact properties in the tribo-pair. In this case, the contact is defined as a frictional between one rigid (shaft) and one flexible body (bearing), with friction coefficient 0.8, which is also confirmed experimentally. Additional contact properties between the shaft and the sample are defined in a custom code. These properties are Archard's coefficient and the sample's hardness, exponents m and n, that

comprehend the influence of the contact pressure and sliding velocity. It was simulated 3 full revolutions of the shaft in contact with the sample. In order to provide more data for analysis, 15 sub-steps were created (five steps per revolution).

4. RESULTS

The results of the numerical simulation of wear are contact pressure (Figure 1), readable in each of 15 steps, and the volume of the sample at the beginning and the end of the process of wearing. Contact pressure is also determined by applying Herzian formula, and the results were consistent.

At the Figure 2, there could be noted three pressure segments: 6.05 to 6.03, 6.01 to 5.99 and 5.97 to 5.95. Each pressure segment corresponds to the one separate revolution of the shaft. There is observed a decrease in contact pressure, which is explained by the material removal.
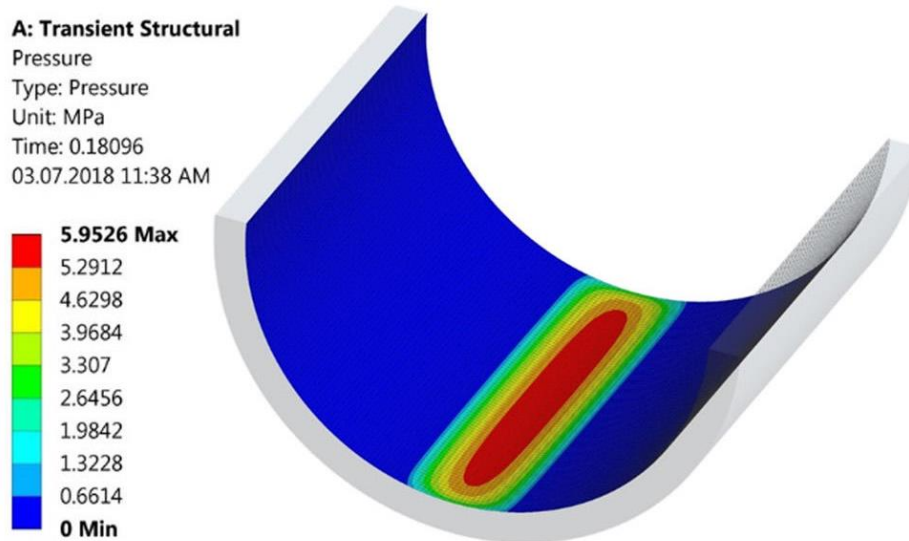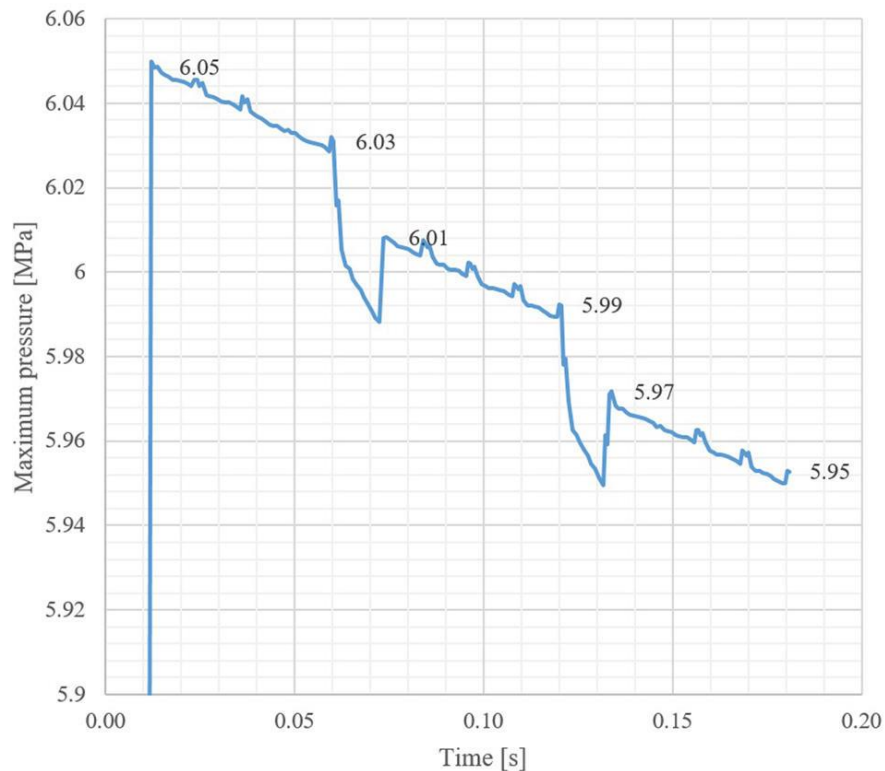

Figure 1. Calculated contact pressure

Figure 2. The pressure decrease during 3 full revolutions of the shaf

Between the segments, there are also spotted sharp decreases of the contact pressure (6.03 to 6.01 and 5.99 to 5.97), which are caused by the increase of contact surface with every next revolution. Initially, the contact between two different size cylinders is line, but due to the material removal, the line transfers to the surface with an increasing trend with every next revolution. Due to this increase of the contact surface, the pressure between two revolutions sharply decreases. The quantitative amount of the wear is given through calculated volumes of the sample before and after wearing. These volumes are respectively 947.8 and 947.61 mm^3, which gives 0.19 mm^3 in difference. Since the number of the revolutions in the experiments is cca. 285000, the calculated worn volume is not comparable to the experiment. The three revolutions are simply not enough to compare with the experiment, especially if taken into account that the wearing process is not uniform in time.

5. CONCLUSIONS

In this paper it was presented the result of the numerical simulation of wear, in case of the sliding bearing / shaft contact. The outputs of the calculation are contact pressure, its diagram over time and volume before and after the wearing. Contact pressure is confirmed in high correlation with the analytical (Herzian) calculation.

It was noted the constant decrease of the contact pressure, which is in correlation with the wearing process.

Since the numerical calculation is highly strenuous for the computer, it was limited to only three revolutions of the shaft. Hence, the result was not comparable to the experiment. The possible solution is to simplify the model to 2D.

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