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Preliminary experimental research on friction characteristics of a thick gravitational casted babbit layer on steel substrate

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Abstract. The ability of the antifriction materials to withstand with no lubrication for a while can be a solution for the catastrophic failure of automotive journal bearings from the internal combustion engines in accidental breakdown of the oil pump. A thick layer of antifriction material (babbit) was deposited by gravitational casting on a steel disk substrate. Four tribological disk samples coated with babbit are tested against a steel shoe on Amsler tribometer at different speeds and loads in dry friction. The values of the friction coefficient versus speed and load are presented, the obtained results indicating a mild wear regime, recommending the new babbit as a possible coating for the bushes of the journal bearings in automotive internal combustion engines. Further tests must be dedicated to the establishment of the wear intensity of the steel shoe - babbit disk tribological pair, both for motor oil lubricated and dry friction conditions.

1. Introduction

Accidental breakdown of the oil pump in automobiles can generate catastrophic failure of the internal combustion engines, starting from the seizure of the journal bearings. In such conditions the interruption of the oil supply and the high temperature can leave the bearings without any lubricant.

To withstand for a while in dry friction, new antifriction materials are necessary for the journal bearings bushes. In order to find a solution for the previous mentioned problems, new antifriction materials (babbits) must be developed and tested on tribometers before to implement them in real machines.

Many technical papers focused on the analysis of the mechanical and tribological properties of the different antifriction materials. Dinescu and Valentin [1] presented the characteristics of certain antifriction materials used in the production of the friction bearings from the military technique. Valeeva et al. [2] experimentally studied the wear resistance of the B83 babbit obtained by different methods. It is emphasised that the babbit bearings possess good conformability or capability of adapting to slight shifts or misalignments of the shaft.

Accelerated wear of the babbit coated journal bearings was observed in liquid petroleum gas (LPG) combustion engines [3]. Kobernik et al. [4] emphasize the performances of the plasma-powder deposition of babbit alloys over the cast alloys by tests on sleeve – disk specimens in dry friction. The lining of the steel with antifriction alloys by casting is instead cheaper than plasma deposition. Ünlü [5] shows by experimental research that SnPbCuSb (white metal) is a suited material for bearings, the coefficient of friction in oil lubricated SnPbCuSb / steel contacts being small.

The aim of this paper is the determination on Amsler tribometer of the dry friction coefficient for a new antifriction material deposited by gravitational casting on a steel substrate, running against a steel shoe at different speeds and loads.

2. Test rig

The Amsler testing machine is generally used to laboratory measurements of the friction and wear of gears, cams, rolling bearings and other rotating elements. To simulate the running of sliding journal bearings, the upper disk is replaced with a stationary shoe (figure 1).

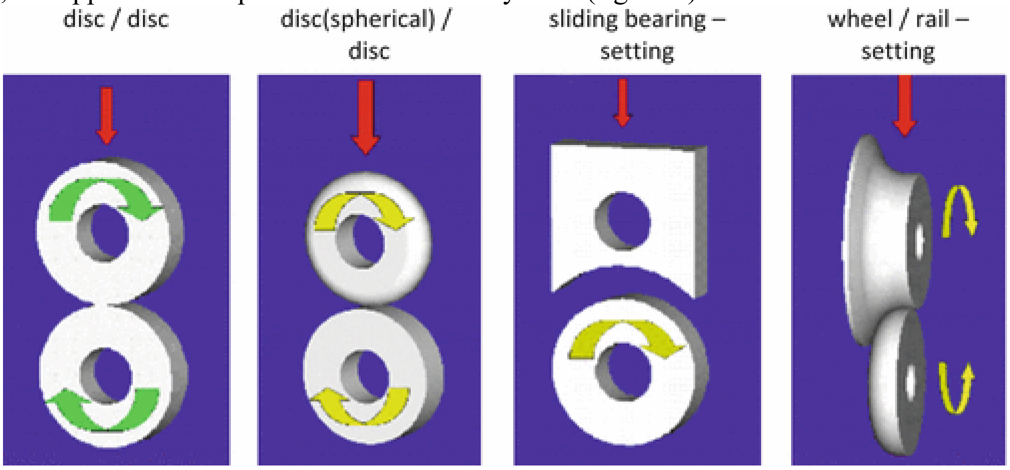
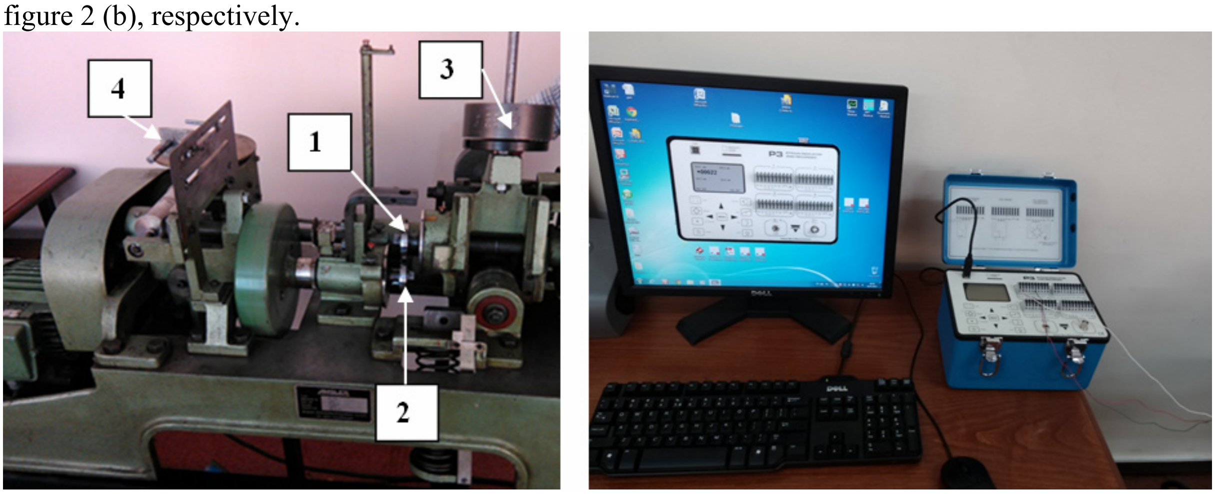


Figure 1. Different tribological couples that can be tested on the Amsler machine.

General views of the testing machine and data acquisition system are represented in figure 2 (a) and figure 2 (b), respectively.



(a) (b)

Figure 2. (a) General view of Amsler machine; (b) data acquisition system.

In the general view of the Amsler machine, (1) is the upper stationary steel shoe, (2) is the lower rotating steel disk lined with antifriction material, (3) is the dead load applied on disk-shoe contact, and (4) is the metallic leaf with two strain gages brazed on it and connected in half bridge. A pin is linked by the kinematic chain acted by the friction force that appears between the disk and shoe pair during running at a given speed and load. This pin is pushing on the metallic leaf (4), monitoring the friction torque variation in the studied tribological contact.

The data acquisition system is presented in figure 2 (b), being composed by the Vishay P3 data acquisition system and a desktop computer with the related soft. All the experimental data were post-processed by LabVIEW software.

3. Materials

Disk samples of antifriction material deposited by casting on a steel substrate and one steel shoe are tested on the Amsler machine. The chemical composition of the disk samples is obtained by EDAX analysis (figure 3 and table 1).

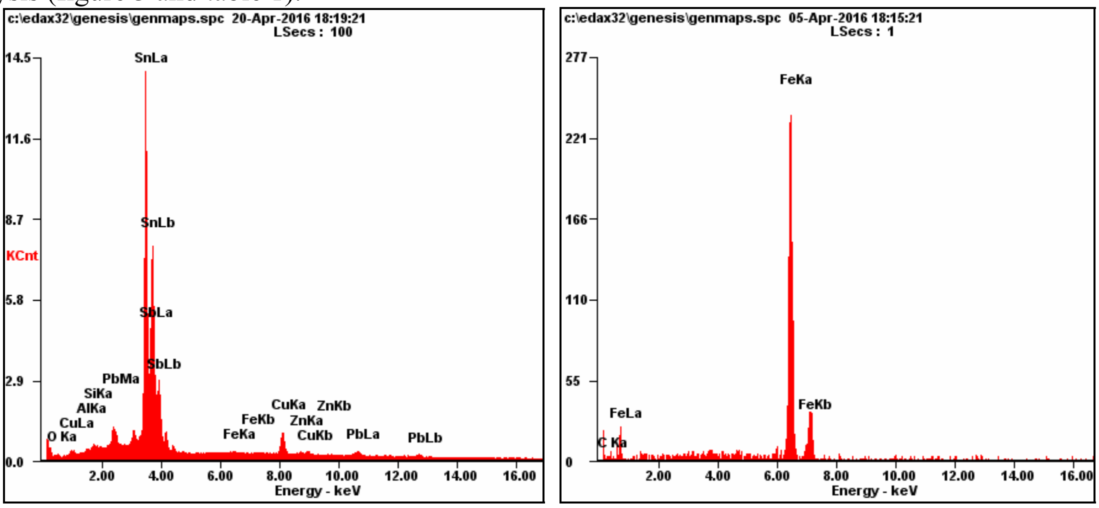


Figure 3. EDAX analysis of the disk samples: antifriction lining (left) and steel substrate (right).

Table 1. Chemical composition of tested materials.

Part	*Element*	*Wt%*	*Part*	*Element*	*Wt%*	*At%*
	SbL	12.91… 14.70	*Disk*	***CK***	0.23	3.32
Antifriction	***SnL***	70.40... 72.70		***FeK***	99.77	96.68
lining of	***CuK***	3.90… 5.35		CK	1.05	7.24
disks	***PbL***	5.53… 5.96	*Shoe*	FeK	98.95	92.76

In table 1 is indicated the chemical composition of tested materials: the antifriction lining of the disk (left); the steel disk substrate and steel shoe (right). Beside the main elements from table 1, the antifriction lining contains also OK (1.77 wt %), AlK (0.35… 0.82 wt %), SiK (0.51 wt%), FeK (0.41 wt%), ZnK (0.33 wt %).

4. Friction torque and friction force computation.

The calibration of the strain gauges measuring system is realised by dead weight method. The gravitational force of the dead weight acts on the metallic leaf with strain gauges and create the same effect as the friction torque between the disk and shoe in normal running of the AMSLER machine. The bending torque created by the dead weight during calibration offers the torque – strain experimental curve of the metallic leaf with strain gauges (equation 1). During the tests the friction torque produced by the friction force within the disk and shoe contact acts by a kinematics chain and a pin on the metallic leaf with strain gauges in the same place as the resultant force created by dead weight. The real scale of the Amsler machine regarding the measured friction torque is correlated with the friction torque obtained by calibration, equation (1). In this way the variation of the friction torque in real time can be obtained by data acquisition. Following the calibration, we get a linear variation of the friction torque with the strain of the gauges. The empirical relationship between the friction torque and the strain is:

$$M_f = C_1 \cdot \varepsilon = 0.167 \cdot \varepsilon \tag{1}$$

M_f = friction torque between the disk and shoe, [N.mm];
ε = strain of the metallic leaf with strain gauges, [μm]. The constant C_1 is not dimensionless ($C_1 = 167 \cdot 10^{-3} [N]$).

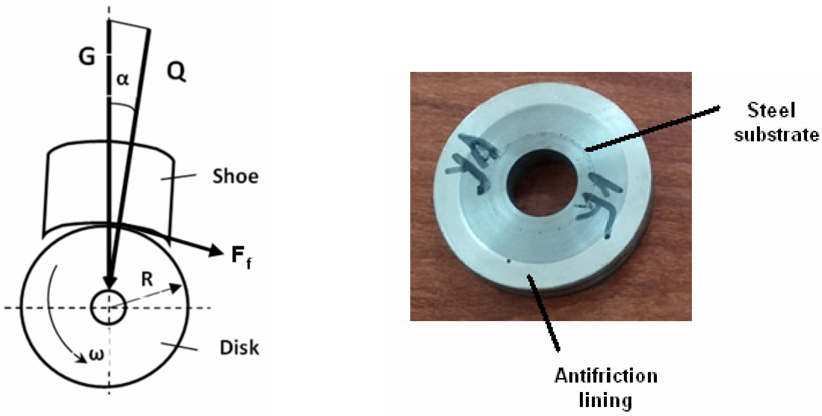


Figure 4. Shoe on disk tribological contact (left), and an experimental disk sample of antifriction lining casted on steel substrate (right).

The friction torque, M_f, the friction force, F_f, and the friction coefficient μ are computed with equations (2), (3), (4), and (5), respectively.

$$M_f = F_f \cdot R \tag{2}$$

$$F_f = \frac{M_f}{R} \tag{3}$$

$$F_f = \mu \cdot Q = \mu \cdot G \cdot \cos(\alpha) \tag{4}$$

$$\mu = \frac{F_f}{G \cdot \cos(\alpha)} = \frac{M_f}{R \cdot G \cdot \cos(\alpha)} \tag{5}$$

$\alpha = 13.7^0$ is the angle between disk and shoe contact load and the vertical direction;
R = radius of the disk, 24.5 mm;
ω = angular speed, in rad/s;
G = applied load, in N;
Q = normal applied load, in N.

5. Results

During dry friction tests, four antifriction disks, noted as Y1… Y4, were tested against the same steel shoe on the Amsler machine. 24 different tests were carried out for different speeds (50, 100, 150 and 200 rpm) and loads (10, 20 … 60 N). Each test lasted 10 minutes, at constant load and speed.

Data acquisition was realised with the Vishay P3 acquisition system. The saved data were post-processed by a LabVIEW program, by filtered the signal using a smoothing filter and computing the mean friction torque and mean friction coefficient.

5.1. Friction torque evolution versus speed and load

The friction torque within the tribological contact strongly depends on the applied load, and remains almost the same as a function of speed (figure 5). The wear particles act as a solid lubricant, directly

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affecting the variation of the friction coefficient. The removal rate of the solid lubricant depends on the running conditions.

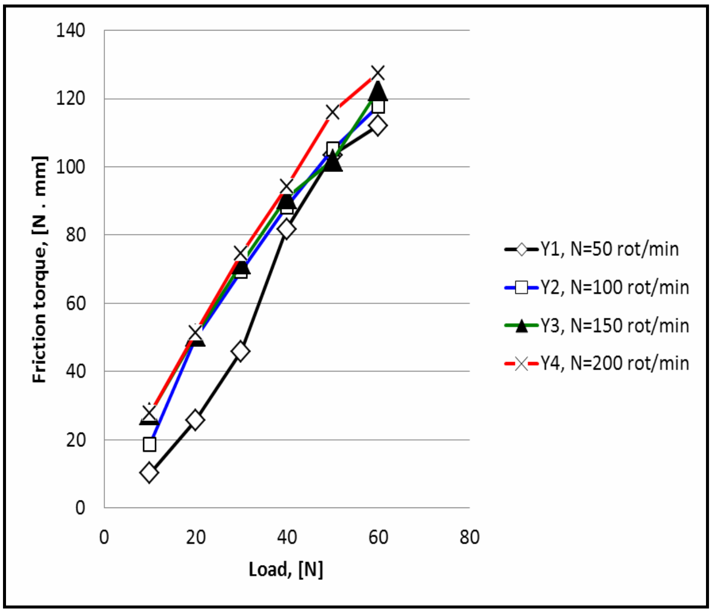

Figure 5. Friction torque evolution versus load and speed.

5.2. Friction coefficient evolution versus speed and load

The friction coefficient evolution versus speed and load is represented in figure 6.

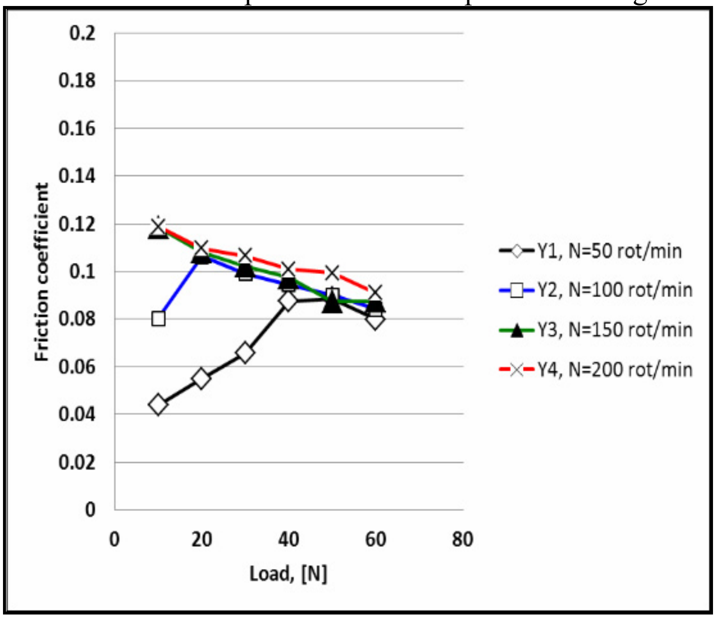

Figure 6. Friction coefficient evolution versus load and speed.

The influence of the speed on the friction coefficient is greater at light loads and low sliding speed (less than 0.25 m/s). At low speed (50 rpm, sliding speed 0.128 m/s) the friction coefficient is varying between 0.04 and 0.09. At higher sliding speeds (over 0.4 m/s), the friction coefficient slightly decreases when increasing the load, but remains in a close range (0.12.. 0.08).

This can be explained due to the effect of the Sn, Pb, Cu, and Al wear particles. A decrease of the friction coefficient versus load in steel-aluminium contacts is reported in [6].

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The microscopy of the contact surfaces reveals that a black solid lubricant powder is present on the contact surfaces, protecting the surfaces as a solid lubricant (figure 7). The results of EDAX analysis show the next chemical composition of the solid wear particles: OK: 2.. 5.15% wt; AlK: 1.43.. 2.27 % wt; SnL: 73.16.. 84.83 %; FeK: 5.37.. 5.42 % wt; CuK: 2.58… 6.8 % wt; PbL: 7.99.. 9.15 % wt.

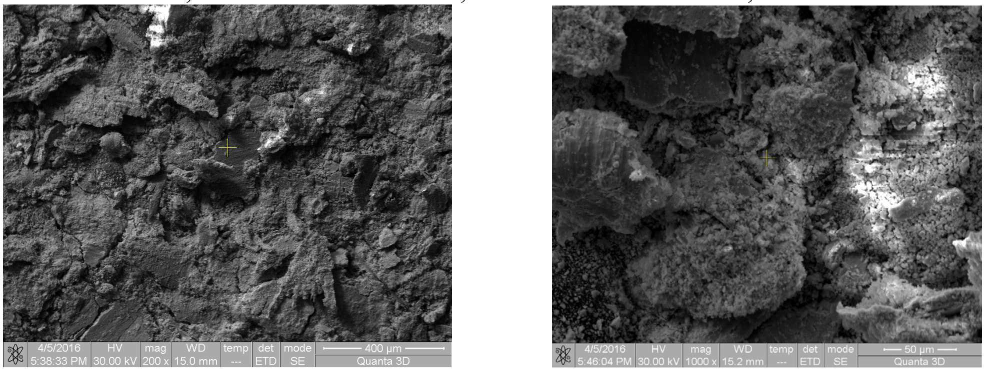

Figure 7. Microscopy images of the wear powder at 200 X (left) and 1000 X (right)

6. Conclusions

The ability of the antifriction materials to withstand with no lubrication for a while can be a solution for the catastrophic failure of automotive journal bearings from the internal combustion engines in accidental breakdown of the oil pump. A thick layer of antifriction material (babbit) was deposited by gravitational casting on a steel disk substrate. Four tribological disk samples coated with babbit are tested against a steel shoe on Amsler tribometer at different speeds and loads in dry friction. The values of the friction torque and friction coefficient versus speed and load are presented, the obtained results indicating a mild wear regime for short periods of time even in dry conditions, recommending the new babbit as a possible coating for the bushes of the journal bearings in automotive internal combustion engines. Further tests must be dedicated to the establishment of the wear intensity of the steel - babbit tribological pair, both for motor oil lubricated and dry friction conditions.

7. References

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