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The Effect of Electroplated Copper and Zinc Coatings on Friction Conditions

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The paper presents the results of investigation of dry friction coefficient for a pin-on-disk couple. The pin was made of steel while the steel disk was electrochemically coated with a 20 μm copper or zinc layer. The pins and disks were ground and subsequently matched to have the same roughness grade. The roughness grade of the disks was 9 before coating whereas after coating it was 9 for copper and 10 for zinc. On the basis of the analysis of the friction surface it was found that copper is characterized by adhesive wear while abrasive wear is characteristic of zinc. The wear after 3600 s of friction (equal to 360 m of distance covered) was of the order of 20 μm. Friction led to transfer of the electroplated metal from the disk onto the steel pin. This process was more intensive for copper than for zinc whereas transfer of iron from the pin onto the disk was considerably less intensive.

Tribological measurements were carried out using T-01M tester. Coefficient of friction as a function of time from 0 to 3600 s (distance covered – 360 m) was determined for three unit pressures: 0.4 MPa, 0.8 MPa and 1.2 MPa. For zinc the μ values ranged from 0.4 to 0.5 and did not depend strongly on time and loads. For copper the coefficient of friction (about 0.2) did not depend on load during the first 120 s; whereas its final values were different at different pressures: 0.63 at 0.4 MPa, 0.75 at 0.8 MPa and 0.8 at 1.2 MPa.

Keywords: electroplated coatings, dry friction, adhesive wear, pin-on-disk tester, coefficient of friction.

1. INTRODUCTION

In order to improve tribological properties of friction couples the surface layer can be modified by means of metallic coatings. These may be obtained by adding organometallics to lubricants with the former being destroyed during the friction process or by coating the couples before the friction process starts. Electroplating is one of the most common methods of depositing metals on friction couples. For many years electroplated coatings have been used to cover metals for decorative, protective and technological purposes. The application of technological electroplated coatings may be important from the tribological point of view in terms of increased wear resistance and a change in the friction coefficient of the modified metal surface.

The research [1 – 11] concerning tribological properties such as wear, motion resistance, roughness and composition of outer layer is supposed to widen the knowledge about this mater. The obtained results are a part of experimental data which is supposed to confirm the proposed model of dry friction [12]. Further results of the model verification will be published later.

2. METHODOLOGY

Tribological tests were carried out using T-01M machine for a pin-on-disc couple. Operation principle of the tester has been described in [1]. The pin and the disc were made of steel 45. The discs were electrochemically coated with copper and zinc.

The samples before coating were electrochemically degreased, rinsed, pickled, rinsed again and dried. Zinc and copper plating conditions were the same: temperature 20 °C, current density 3 A/dm^2 and coating rate 1 μm/min. Before, as well as after, the tribological experiment roughness and composition of the outer layer were measured. The roughness grade was measured using profilograph manufactured by Hommel T-2000 in the Institute of Terotechnology in Radom. The composition of the surface was investigated using X-ray microprobe Cameca Semiprobe SX-50 in the Faculty of Material Engineering, Technical University of Warsaw [14, 15]. The results have already been published [13].

In this paper the results of investigation of dry friction coefficient as a function of time are presented. The points on the graphs are averaged values of 120 one-second consecutive intervals. The experiment was performed for three different loads 0.4 MPa, 0.8 MPa and 1.2 MPa at rubbing speed 0.1 m/s. The tests were carried out in an air-conditioned room. To evaluate the limits of the confidence interval of the average μ t-Student distribution with significance level α = 10 %was employed.

3. TRIBOLOGICAL PROPERTIES OF DRY FRICTION COUPLE STEEL-ELECTROPLATED COPPER AND ZINC

The quantities describing the surface before and after electroplating and after the tribological experiment have already been presented in [13]. It was concluded that after electroplating the roughness of the disc decreased.

On the basis of this data the wear was estimated. On the basis of the analysis of wear, it can be said that copper is characterized by adhesive wear while abrasive wear is characteristic of zinc. In both cases, using X-ray tests, transfer of the coating material to the pin surface was discovered.

The reference point for the influence of electroplated coatings on motion resistance was the steel-steel system (Fig. 1).

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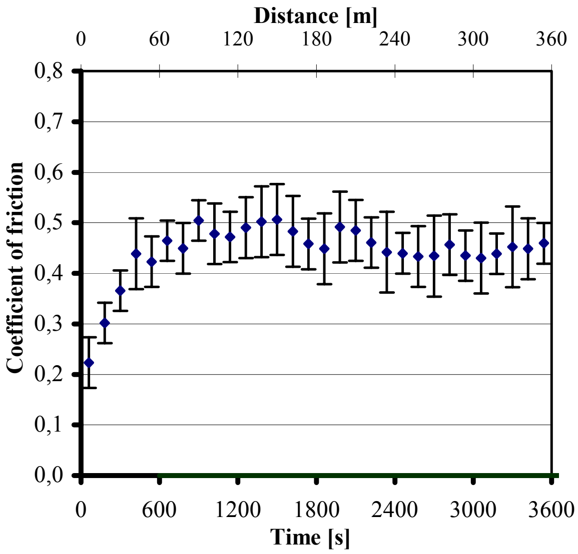

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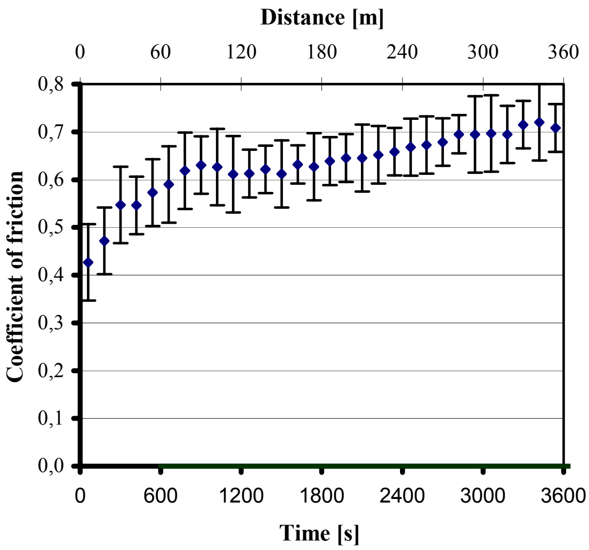

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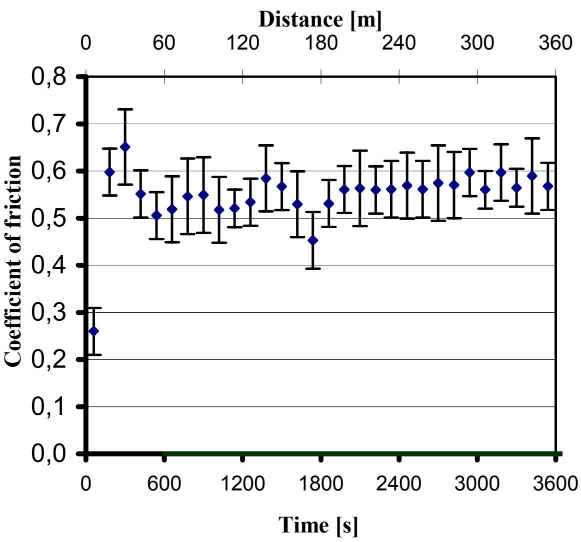

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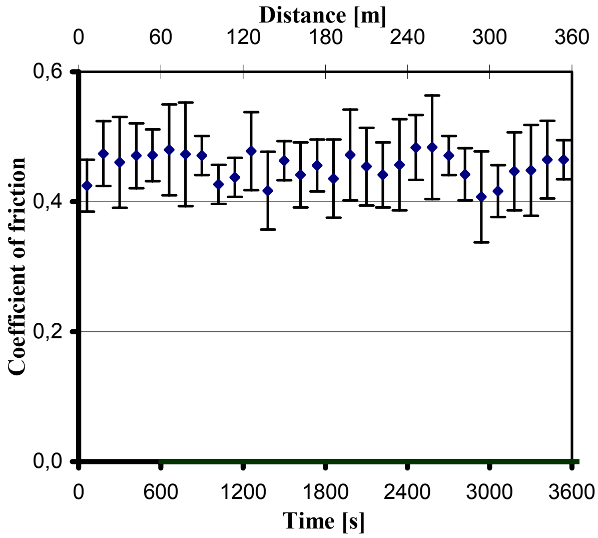
Fig. 1. Course of friction coefficient for the configuration: steel – steel coating for isolated pressure: a – 0.4 MPa, b – 0.8 MPa, c – 1.2 MPa



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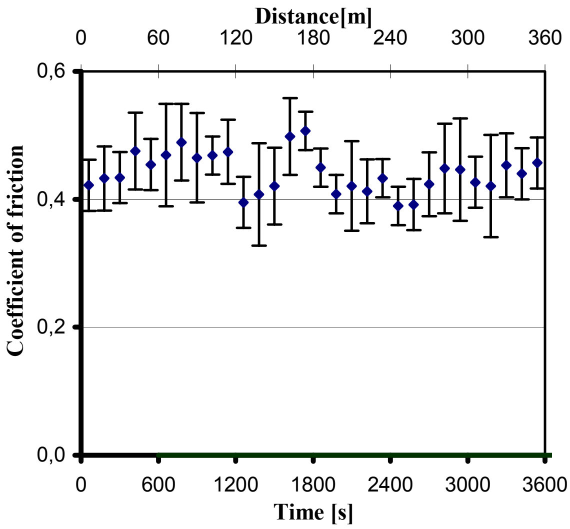

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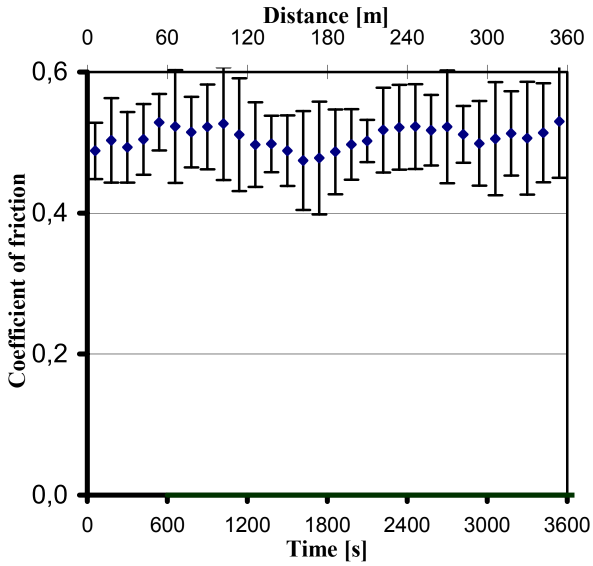

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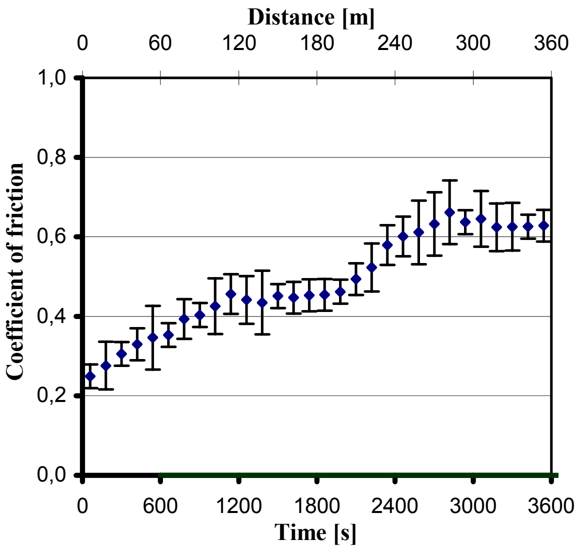
Fig. 2. Course of friction coefficient for the configuration: steel – zinc coating for isolated pressure: a – 0.4 MPa, b – 0.8 MPa, c – 1.2 MPa



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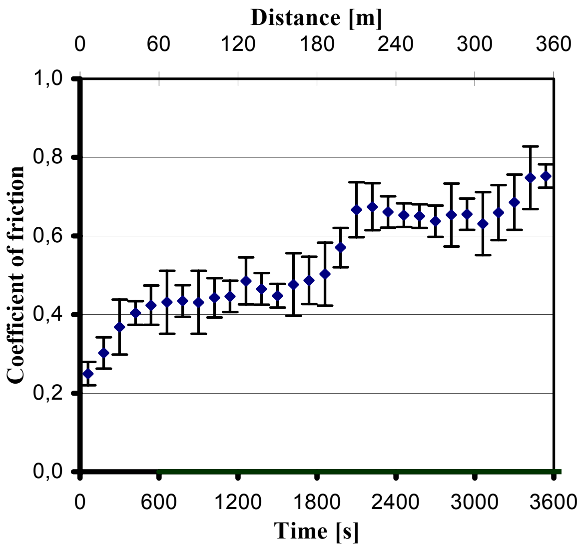

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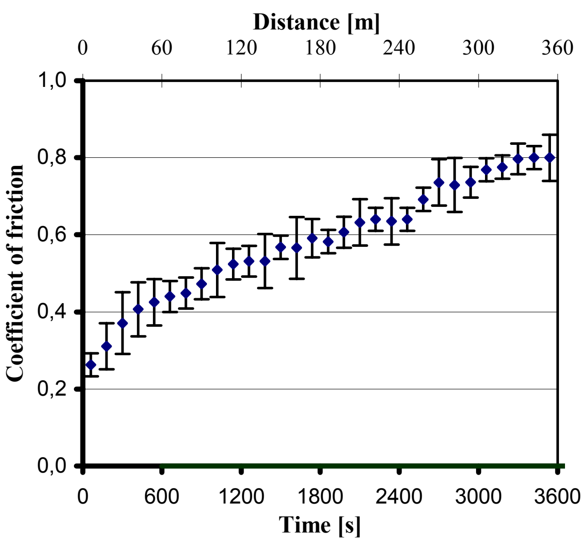

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Fig. 3. Course of friction coefficient for the configuration: steel – copper coating for isolated pressure: a – 0.4 MPa, b – 0.8 MPa, c – 1.2 MPa

In this case for unit pressure 0.4 MPa one can observe upward trend. At 0.8 MPa μ, during the first period, increases quickly. After 600 s stabilizes at 0.5 – 0.6. At 1.2 MPa the friction coefficient increases from 0.4 to 0.6 during first 800 s to reach, finally, 0.71.

For all the considered pressures μ increases with time and load.

For the friction couple steel pin - steel disc electroplated with zinc the μ values ranged from 0.4 to 0.5 and did not depend strongly on time and loads. The observed differences hold in the limits of error (Fig. 2).

In the case of the steel disc electrochemically coated with copper (Fig. 3) one can observe increase of friction coefficient in time. The coefficient of friction did not depend on load during the first 120 s (0.25 at 0.4 MPa, 0.26 at 0.8 MPa, 0.26 at 1.2 MPa), while its final values were different at different pressures (0.63 at 0.4 MPa, 0.75 at 0.8 MPa, 0.8 at 1.2 MPa). One can say that the friction coefficient increases along with unit pressure.

4. CONCLUSIONS

Electrochemical coating of steel disc with copper and zinc results in changing the roughness of the disc. On the basis of the analysis of the friction surface one can conclude that copper is characterized by adhesive wear and zinc by abrasive one. Friction is accompanied by transfer of the electroplated metal from the disc onto the pin and iron from the pin to the disc [12].

Electrochemical coating of the discs with zinc changes motion resistance. For the zinc coating the μ values ranged from 0.4 to 0.5 and did not depend strongly on time and loads. For the copper coating one can say that friction coefficient increases along with time and unit pressure. Comparison of μ for different loads and two boundary averaged time intervals is as follows:

first 120 s	last 120 s
0.4 MPa $\mu_{st} \leq \mu_{Cu} < \mu_{Zn}$	0.4 MPa $\mu_{st} \leq \mu_{Zn} < \mu_{Cu}$
0.8 MPa $\mu_{Cu} \leq \mu_{st} < \mu_{Zn}$	0.8 MPa $\mu_{Zn} < \mu_{st} < \mu_{Cu}$
1.2 MPa $\mu_{Cu} < \mu_{st} \leq< \mu_{Zn}$	1.2 MPa $\mu_{Zn} < \mu_{st} < \mu_{Cu}$

By the above inequalities one can conclude that copper coating reduces motion resistance in the first period – period of lapping. Especially, at highest pressure, the friction coefficient is two times smaller then for the steel-steel system. This fact can be explained by friction of soft electroplated metal over a hard one (steel). Along with friction time motion resistance increases for the steel pin-disc covered with copper system and for all loads is much higher then for the steel-steel system. These changes are accompanied by copper transfer onto the disc. This was confirmed by X-ray tests. Along with time, adhesive forces between copper of the coating and copper transferred to the pin, increase as the result of friction.

Friction couple disc covered with zinc-steel pin reveals the mechanism of abrasive wear. That was confirmed by the analysis of the wear scar. The transfer of zinc from disc to pin was also observed but it was much less intensive then in the case of copper.

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