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INVESTIGATION OF DYNAMIC FRICTION COEFFICIENT IN BRAKE SYSTEMS

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Abstract: *In this paper, the research of friction coefficient changes in the tribopairs carbon-fiber-reinforced silicon carbide (C/SiC) – steel 37Cr4 and C/SiC – steel C22 used in cars brake systems was carried out for the selection of suitable materials and conditions of usage that provide a vehicle with high performance and safety of braking. Brakes made of C/SiC are very effective in sport cars, but they are expensive, which makes it impossible to use such materials for design of both pads and discs in the brake systems of trucks and off-road vehicles. The main goal of this work was to choose the most suitable material for manufacturing of brake discs interacting with C/SiC pads in order to decrease the cost of brake systems without decreasing their performance. According to the results of the research, the tribopair C/SiC – steel C22 could be used in heavy loaded trucks and massive off-road vehicles.*

Keywords: *dynamic friction coefficient, carbon-fiber-reinforced silicon carbide, tribological properties, wear, design of brake systems.*

1. INTRODUCTION

Brakes are one of the most significant parts in any vehicles, such as cars, trucks, trains and aircrafts [1, 2]. Disk brake is the most common type of brakes. It is based on the use of friction between the elements of the brake. These brakes usually consist of brake pads that can be pressed to a brake disc connected to the wheel [3]. Cast iron is widely used for manufacturing of such brakes. This material has good thermal conductivity and anti-vibration capacity [3]. The disadvantage of cast iron brakes is high level of noise and wear rate.

Various materials are used for manufacturing of brake pads. The efficiency of these brake systems depends mostly on the tribological properties of the materials used, as well as on the conditions of their usage [3]. A wide range of research has been carried out on ceramic composite materials and their tribological and mechanical properties for better understanding of the behaviour of such materials in braking systems [2].

In this paper, the experimental research of metallic and ceramic materials was carried out in order to select the optimal tribopairs that could be used for manufacturing of brake systems for trucks and off-road vehicles providing them with high safety and efficiency without increasing the cost.

2. MATERIALS FOR BRAKES

Materials for brake pads can be classified into semi-metallic, metallic, organic and ceramic types [4].

Metallic pads are noisy and produce a lot of dust. Wear rate of such brakes is high [5].

Nowadays, brakes manufacturers use some organic and non-asbestos materials in order to decrease the negative ecological impact and produce environment-friendly brakes [6-10]. These brakes produce less noise, but wear rate is also high.

C/SiC composites are used in braking systems, because they have a lot of advantages, such as low density, high temperature resistance, good tribological properties and low wear rate [11, 12]. The disadvantage of such brakes is their cost. Ceramic composites are expensive. Also, the tribological properties of ceramic pads depend on the temperature. The influence of the temperature in brake systems on the friction processes was studied by V. Dygalo et al. in [13] and N. Benhassine et al. in [14].

Another important issue for brakes is vibrations and their influence on the contact pressure and area, since friction between the elements of brakes depends on these parameters, and, therefore, such effects should be considered during the design process [15, 16]. Also, the contact area and, therefore, the tribological properties depend on the initial surface roughness and the accuracy of manufacturing and assembling of brake system elements [17-19].

3. EXPERIMENTAL RESEARCH

A wide range of measurement machines and methods has been developed for investigation of tribological properties [20].

In this paper, the experimental research of the materials for the design of brakes was carried out with the use of the universal friction machine MTU-1 that is based on a vertical milling machine “JMD-X1” and contains the original friction assembly unit that allows us to save the parallelism of the contacted surfaces [21, 22].

The scheme of the experiment was plate-on-plate. The lower samples were made of C/SiC, the upper samples were made of two types of steel: C22 and 37Cr4. The rotational speed of the upper sample was 300 and 650 rpm, whereas the lower sample was fixed. No lubricants were used. The load on the upper sample was 150, 400 and 600 N. The influence of braking pressure and braking speed on the tribological properties of C/SiC in brakes was investigated by Fan et al. in [23]. Dynamic friction coefficient was measured and analysed during the experiments.

The first set of experiments was carried out during 10 minutes for the tribopairs C/SiC – steel 37Cr4 with the following conditions: rotational speed was 300 rpm, starting load was 400 N.

Figure 1 shows the photographs of the samples after the first experiment.

Figure 1. C/SiC (left) and 37Cr4 (right) samples after the first experiment

In figure 2, the graph of friction coefficient versus time for the tribopair C/SiC – steel 37Cr4 during the first experiment is shown.

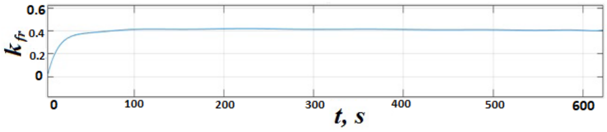

Figure 2. Graph of friction coefficient versus time during the first experiment

As can be seen from the graph in figure 2, the running-in of a friction pair occurs rather quickly, and at a small load the dynamic friction coefficient, having reached a plateau at the level of approximately 0.4, does not depend on time. This indicates a slight destruction of the surface layer and minimal wear.

The second set of experiments was carried out during 15 minutes for the tribopairs C/SiC – steel C22 with the following conditions: rotational speed was 300 rpm, starting load was 150 N.

In Figure 3 the samples after the second experiment are shown.

Figure 3. Steel C22 (left) and C/SiC (right) samples after the second experiment

In Figure 4, the graph of friction coefficient versus time for the tribopair C/SiC – steel C22 during the second experiment is presented.

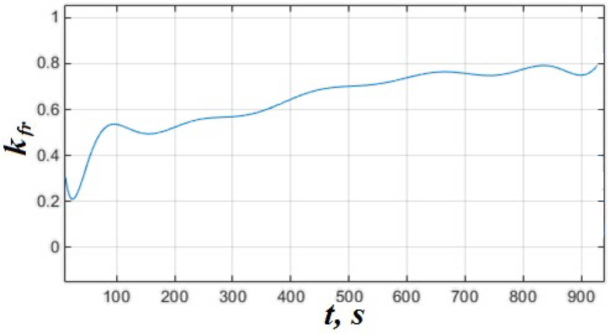

Figure 4. Graph of friction coefficient versus time during the second experiment

Figure 5. C/SiC (left) and Steel 37Cr4 (right) samples after the third experiment

It can be noticed from the graph in figure 4 that this tribopair at the beginning of the experiment behaves unstably, which is associated with a low hardness of C22. Surface running-in is observed during the entire experiment. Plastic deformation is observed on the surface of the sample made of C22, which increases the friction coefficient. The wear rate of such a pair will be high enough, the average coefficient of friction is 0.6.

The third set of experiments was carried out for the tribopairs C/SiC – steel 37Cr4 with the following conditions: rotational speed was 650 rpm, starting load was 600 N.

In Figure 5 the samples after the third experiment are shown.

In Figure 6, the graph of friction coefficient versus time for the tribopair C/SiC – steel 37Cr4 during the third experiment is presented.

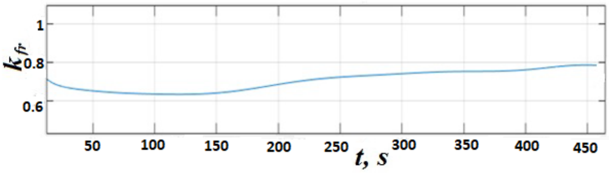

Figure 6. Graph of friction coefficient versus time during the third experiment

It can be observed from the graph that after the running-in, the oxide films are destroyed, the particles of oxides are dispersed and act as an additional abrasive without leaving the contact zone, which leads to the continuing growth of the friction coefficient. The average coefficient of friction is 0.75.

The last set of experiments was carried out during 15 minutes for the tribopairs C/SiC – steel C22 with the following conditions: rotational speed was 650 rpm, starting load was 600 N.

In Figure 7 the samples after the last experiment are presented.

Figure 7. C/SiC (left) and Steel C22 (right) samples after the last experiment

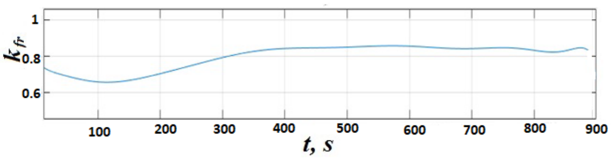

Figure 8. Graph of friction coefficient versus time during the last experiment

In Figure 8, the graph of friction coefficient versus time for the tribopair C/SiC – steel C22 during the last experiment is shown.

The graph in Fig. 8 shows that this tribopair after running-in also has an increase in the coefficient of friction, which is associated with the destruction of the surface layer. Further, wear particles act as abrasive, but the friction coefficient has small changes. The average coefficient of friction is 0.8.

4. CONCLUSION

The results of the experiment show that friction coefficient in the tribopair C/SiC – steel 37Cr4 increased in the beginning and then remained virtually constant during the experiment whereas in the tribopair C/SiC – steel C22 it increased during the whole experiment. This could be explained by the fact that in the second tribopair wear particles do not leave the contact area and charge the material acting as an abrasive. However, friction coefficient in the tribopair C/SiC – steel C22 is greater than friction coefficient in the tribopair C/SiC – steel 37Cr4, which means that use of steel C22 can help us reduce the braking distance, but wear of braking system parts is higher in that case.

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