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TRIBOLOGY OF COMPOSITE MATERIALS ON THE BASIS OF MAGNESIUM ALLOY WITH POWDER FILLER OF *SiC*

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Abstract: *The work presents the investigation results of the contact tribological parameters of a tool steel with a metal composite material on the basis of magnesium containing a fine-dispersed powder filler of SiC. It was determined that the friction coefficient has lower values at a higher normal load. That can be explained by a decrease in the molecular component of the friction coefficient due to advanced normal pressure in relation to tangential stresses in a contact zone. During the examination of wear rate it was noted that the smallest wearing of composite materials is observed at lower normal loads on the contact surface. At the same time there is a general tendency towards a decrease in the magnitude of wear both with increasing the particle size of the powder filler of SiC and the volume of the powder filler.*

KEY WORDS: metal composite material; powder filler; silicone carbide; friction coefficient; frictional constraint; strength of adhesive shear bonds; wear rate.

I. Introduction

In modern engineering, in particular, in tribology application, the use of light alloys with a high complex of mechanical properties is one of the methods for reducing machine weight. The use of magnesium as a structural material is a good method and it is determined by an excellent correlation as strength/weight that is better than Al and many other light metals and alloys [1-3]. The magnesium strength can be increased without a significant change of density because of adding into it a small amount of the dispersed powder filler of silicone carbide. During this process there were obtained satisfactory results [3-5]. High damping capacity of the magnesium alloys make it possible to use them efficiently for producing wheels, various products of automotive and aerospace engineering, rollers of load tracks [6], etc. However, these materials have low wear resistance [7].

Wear resistance can be increased by means of an enhancement in the material strength because of adding the dispersed powder fillers in the magnesium alloys. In recent years, there has been conducted intensive research of matrix composite materials on the basis of magnesium [8, 9] containing micro-particles of silicone carbide. These investigations are of great interest for tribology as a subject of research with a view to producing friction units out of the composite materials.

The given investigation presents the results of determination of wear rate, integral quantity of the friction coefficient, and also its molecular components depending on the content of the powder filler of silicone carbide.

II. Methods and materials

The magnesium alloy *AZ91D* composed of: *89.89%Mg – 9.0%Al – 0.68%Zn – 0.13%Mn* was used as a basic material in the investigations. In comparison tests there were used matrix composite materials containing a dispersed powder filler of *SiC*. Table 1 presents the versions of the composite materials distinguished by a degree of dispersion and a quantity of the added powder of *SiC*.

Table 1. Versions of composite materials used in the research

Composition	Mean size of SiC particles, *μm*	Amount of powder in the volume of alloy, % *by wt*
AZ91D	-	-
AZ91D + SiC	5	3
AZ91D + SiC	11	3
AZ91D + SiC	11	6
AZ91D + SiC	15	3

Fig. 1 Test pattern is shown.

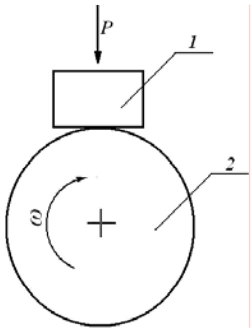

Fig.2. Test pattern: 1 – test specimen; 2 – revolving steel disc

All the tests were carried out at normal loads *10N* and *50N* and at numbers of the disc revolutions 250 rpm and 1000 rpm according to the plan of an experiment shown in table 2.

Table 2. Plan of carrying out the experiment for each version of test materials

Normal load, *N*	Number of disc revolutions, *rpm*	Test period, *min**
50	1000	7.5
10	1000	7.5
50	250	30.0
10	250	30.0

* The test period was determined from the equality condition of slip distance.

In the process of carrying out the tests there were recorded a frictional force *(F)*, mean bulk temperature of the composite element of the friction couple (T_V) and a magnitude of the linear wear of the composite sample *(Δh)*.

The wear of the discs produced out of tool steel *SKD11 (85.21% Fe - 11.6% Cr - 1.48% C)* that are tempered to the hardness of *HRC58…65* was ignored because of its small quantity as compared to the wear of the test samples.

After the tests there was made a calculation of the friction coefficient *(μ)* by the formulation:

$$\mu = F/P, \qquad (2)$$

where: *F* – frictional force, *N*; *P* – normal load, *N*.

According to the formulation (4) there was determined the magnitude of the wear rate *(J)*:

$$J = \Delta h/L, \qquad (3)$$

where: *Δh* – wear rate, (linear wear) or height of the layer removed, m; *L* – slip distance, m.

The investigations estimating the molecular component of the friction coefficient were carried out according to the scheme that is presented in Fig. 2 [10].

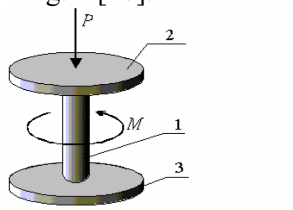

Fig. 2. Test pattern for determing the molecular component of the friction coefficient: 1 – indenter; 2 – test specimens

Shear strength τ_n is determined from the correlation:

$$\tau_n = 0,75 \cdot \frac{M}{\pi \cdot \left(\frac{d_{1,2}}{2}\right)^3}, \qquad (4)$$

where $d_{1,2}$ – diameters of imprints on the test specimens.

Adhesive component of the friction coefficient is determined as follows:

$$f_M = \frac{\tau_n}{p_r}, \qquad (5)$$

where

$$p_r = \frac{P}{\pi \cdot \left(\frac{d_{1,2}}{2}\right)^2}$$

III Comparative evaluation of the friction coefficient «*AZ91D + SiC – SKD11*»

The diagrams with the results of tribological tests are presented in Fig. 3 and 4.

The analysis of the diagrams of dependences «Friction coefficient – filler particles size» (Fig. 3) and «friction coefficient – a filler volume» (Fig. 4) shows the fact that under other equal conditions a normal load in a contact zone influences mostly the change of the friction coefficient. Moreover, the friction coefficient increases while the normal load decreases. The diagrams show that the particles size of *SiC* influences the change of the friction coefficient in the conditions of smaller normal load more than at great values of the load.

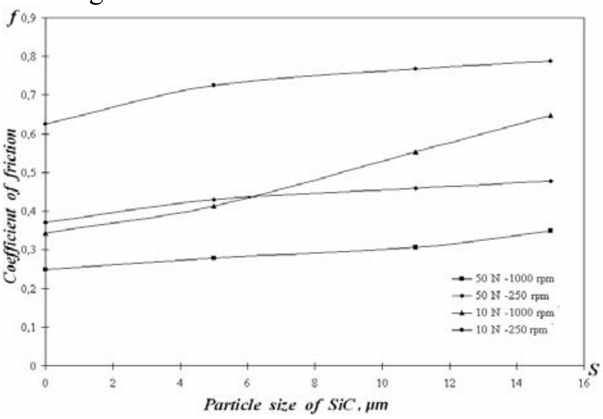

Fig. 3. Friction coefficient dependence on particle size of silicone carbide

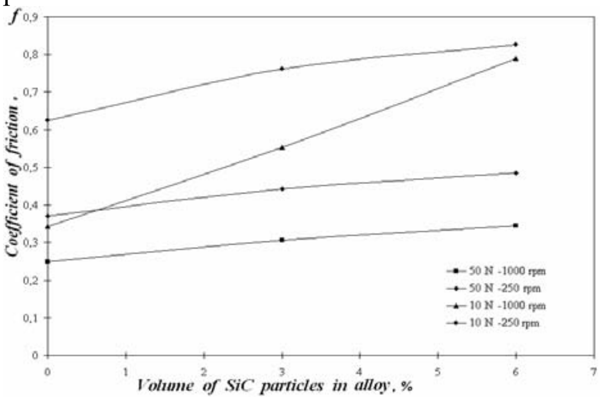

Fig. 4. Friction coefficient dependence on the volume of powder filler

Lower values of the friction coefficient are observed with increasing the rate of the relative slip. That can be explained by failure of adhesive bridge bonds (molecular interaction) in the investigated friction couple.

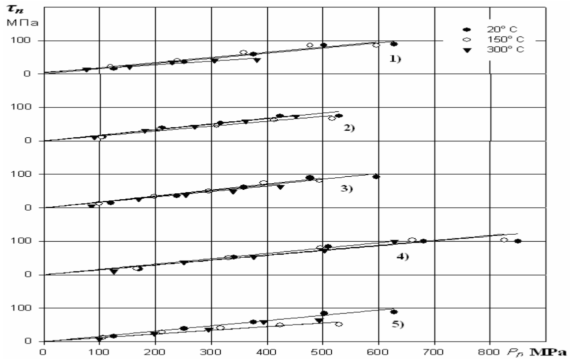

Fig. 5 Dependence of adhesive shear bonds strength on normal pressure on the contact: **1) -** *AZ91D - SKD11;* **2) -** *AZ91D + SiC (S = 5 mcm; V = 3%) - SKD11;* **3) -** *AZ91D + SiC (S = 11 mcm; V = 3%) - SKD11;* **4) -** *AZ91D + SiC (S = 11 mcm; V = 6%) - SKD11;* **5) -** *AZ91D + SiC (S = 15 mcm; V = 3%) - SKD11*

The reduction of the friction coefficient with increasing the normal load can be explained by the results of estimation of the adhesive shear bonds strength. Fig. 5 presents the dependence $\tau_n = f(p_r)$ that indicates the fact that an increase of the normal pressure considerably advance an increase of the adhesive shear bonds strength. That indicates the fact that the molecular component of the friction coefficient decreases [11]. Besides, an additive effect of the friction coefficient decrease can be obtained due to temperature growth and localized formation of fusible eutectics *(Mg – Al)*. Moreover, judging by the nature of the curves change on the diagrams (Fig. 3 and 4), the powder filler of *SiC* doesn't influence considerably the friction coefficient decrease.

At the same time an increase of the normal pressure and the presence of the dispersed particles of the abrasive powder of *SiC* can make for the temperature growth in the contact zone.

It is known that an increase in the speed of the relative slip results in a considerable enhancement of the contact temperature due to the transformation of the friction power into heat energy [12].

IV Wear examination

The results of the composite materials wear on the basis of the magnesium alloy *AZ91D* with the powder filler of *SiC* are presented in Fig. 6 and 7.

The presented diagrams show a complex behavior of the wear rate depending on the particles size and volume of the powder filler of *SiC* and also the conditions of the test operations.

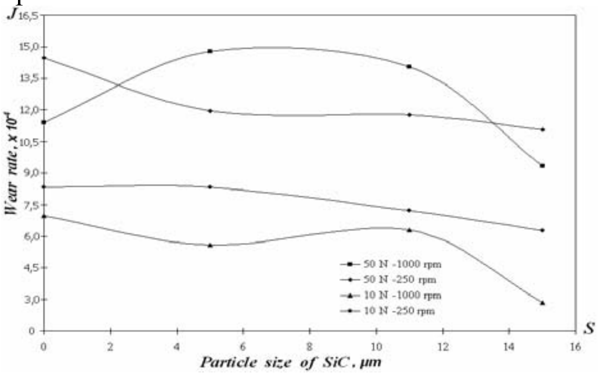

Fig. 6. Dependence of wear rate on the particles size of *SiC*

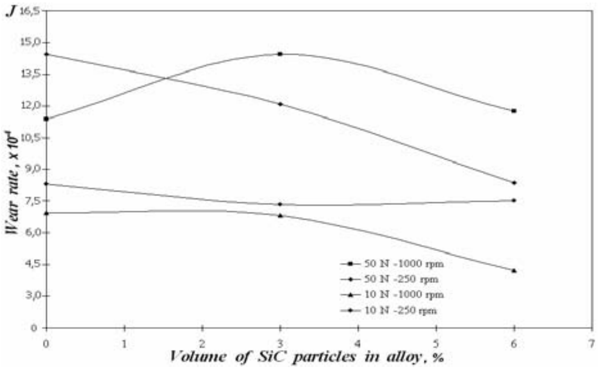

Fig. 7. Dependence of wear rate on the volume of the powder filler

As it is shown in the presented diagrams, the smaller wear of the composite materials is observed on the contact surface at low normal loads. Moreover, there is a general tendency for the wear rate decrease both with increasing the particles size of the filler of *SiC* and with increasing the volume of the powder filler. That can be explained by the fact that the particles of the filler of *SiC* have higher hardness as compared to the steel and they make for glazing the contact surface of the steel disc because of an abrasive effect.

One can suppose that the wear rate decrease also deals with an increase of the composite materials hardness on the contact surface. That can occur as a result of dispersed and strain strengthening of the composite materials surface coatings.

V Conclusion

On the basis of the conducted investigations in the friction couples «composite materials – steel» it was determined the following:

1. There was determined a decrease in the friction coefficient with increasing the normal load and the speed of the relative slip. That occurs because of the reduction of the molecular component of the friction coefficient and the possible appearance of a liquid phase during the melting of the fusible eutectics composing of *Mg - Al* as a result of frictional heating. In this case the boundary friction is close to the hydrodynamic one;
2. The wear rate value has a general tendency for reduction with increasing the particles size and the amount of the powder filler of *SiC*. The wear decrease can be explained by an increase in the hardness of the composite materials. That takes place as a result of dispersed and strain strengthening of the composite materials surface coatings.

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