COMPARISON OF RESEARCHES OF FRICTION COEFFICIENT IN CONCENTRATED CONTACT FOR THE STRESS: STEEL - STEEL AND STEEL - MAGNESIUM ALLOYS

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Abstract: *Magnesium alloys used in automotive industry because of small density and the good resistance then sometimes mate with the steel elements. The main aim of the researches has been to investigate the friction coefficient in contact between elements made of magnesium alloy AM60 and steel to find the way to decrease such resistance. Difficult mating conditions of such elements can be improved by surface treatment such ie. plasma or laser modification. Values of the friction coefficient have been decreased with the mean stress increase almost linearly. Obtained on the tribotester pin-on-rotating plate, presented in the article, values of friction coefficient between LH15-AM60 have been 2,5 times higher than respective values obtained in the LH15-C45 contact zone and can be twice higher in comparison the values obtained in the case of pin-on-disc tester. It caused of higher value of mean contact stress and mean sliding average speed in the case of ball–on-rotating disc could be.*

Keywords: , STM, MICROSCOPE, STEEL, MAGNESIUM, ALLOY, FRICTION COEFFICIENT

1. Introduction

In the automotive industry there is currently widespread tendency to reduce the weight of all vehicle components. One method is based on the use of lightweight materials in place of steel. Here aluminum alloys are of the largest share. Magnesium alloys lighter up to 25% than aluminum alloys, have not been wider applied hitherto. Car elements made of magnesium alloys can be forging or casting under pressure. So far, magnesium alloy has been used primarily for the design of wheels. The use of magnesium alloys for the design of the body parts has been difficult due to the limited cold deformability. Underdeveloped structurally technology of magnesium is one of the barriers, which limits its use in production. This is despite the high prevalence of magnesium, easy and safe recycling and despite his well-known cases of execution of magnesium sheet metal aerospace components that meet the highest requirements for durability and surface quality.

Magnesium is suitable for structural components and has a low strength to weight ratio and stiffness, particularly in bending and buckling loads.

Magnesium sheets have many advantages in relation to casting and forging. This is due to homogeneous and is accomplished fine-structure with a small number of defects. A higher strength, better ductility from the treatment, the greater load during operation and greater energy absorption by the occurrence of deformation under load is the result. The latter can be used in the design of crumple zone car body. Currently there are methods of manufacturing a thin-walled high-quality surfaces and reproducible mechanical properties.

Compared to other plastics, magnesium alloys have better temperature properties, can operate at much higher temperatures, the thermal expansion is smaller and is easier to use as a secondary raw material.

Magnesium alloys reduce vibration well and are easily machined. The high thermal conductivity make them difficult for ignition and burning. Magnesium alloy disadvantage is its susceptibility to corrosion and the need for careful corrosion protection. Magnesium alloys have poor formability and limited ductility at room temperature ascribed to their hexagonal close-packed (HCP) crystal structure [1].

Nowadays, it is commonly used AZ31 [2, 3], and also AZ61 [2, 3], ZK60 [3], AL60 [4], MA2 [5, 6], AZ91 [6] and WE43 [3] as magnesium alloys for plastic forming. The aim of this paper is presents investigate of the friction resistance in contact between magnesium alloy AM60 and steel and to find the way to decrease such resistance.

2. Methods of improving the wear resistance of magnesium alloys for plastic forming

The behavior of magnesium alloys for forming in friction contact is not sufficiently investigated. It can be cited the results, from [7], obtained during tests for the step of modification of the surface layer for the AZ31 alloy as a result of friction process in the contact with: chlorine-sulfonated polyethylene, plasticized polyvinyl chloride, ebonite, sulfur vulcanized of styrene-butadiene rubber, and polysulphide rubber and polysulfone. There has been a modification of the surface layer of the AZ31 alloy, occurring as a result of the transfer of S, Cl- ions, and fragments of polymer chains containing such ions. It has been observed oxides and unidentified compounds of carbon and hydrogen. The influence of tribochemical modification on the tribological characteristics of joints polymer – metal has been shown.

Technological difficulties arise in the implementation of sliding joints for elements made of magnesium alloys with the elements made ie. of steel. Such difficulties can be overcome by the use of surface treatment for magnesium alloys.

Some new surface treatment technologies of magnesium alloy have been reported such as plasma electrolytic oxidation [8], microarc oxidation [9], electronic beam and laser modification [10-12], ion beam assisted evaporation deposition [13], and chemical plating [14]. Among of them, the normal plasma beam has many advantages: similar power density to laser beam, simple plasma generator, favorable environment, non-limitation to specimen size, and the designed structure of plasma generator according to parts shape and processing condition [15]. Plasma beam [16] can be used as an alternative for laser beam [16-17]. The plasma melting process can be used to improve the wear resistance of AM60 alloy. Such process can be attributed to decrease the amount of porosity, grain size and produce solid solution strengthening. After plasma melting grain size is decreased less than 1pm due to quick cooling rate and β-Mgi7Ali2 is well distributed in melted layer. The plasma melting is a simple and cheap surface modification way for AM60 [16].

3. Mechanical properties of AM60 alloy

Mechanical properties of AM60 alloy have investigated at different strain rates and described in [18]. The impact energy of such alloy has increased nonlinearly with temperature increase. The tensile test have indicated that the mechanical properties have not been sensitive to the strain rates applied (3,3x10-4~0.1) and the plastic deformation was dominated by twining mediated slip. The impact energy is not sensitive to the environmental temperature. It is equal 5.35 J in room temperature. The plane strain fracture toughness and fatigue limit were evaluated and the average values were 7,6 MPa.m1/2 and 25 MPa, respectively [18].

Friction force in the contact between AM60 (Mg6Al0.15Mn) alloy – steel have been investigated and results have been presented in [19]. The morphology of AM60 alloy have been composed of α-Mg matrix and irregular β —precipitation along grain boundaries (Mg17Al12). For AM60 alloy the reduction of aluminum has been accompanied by greatly decreasing of β-phase. Wear tests have been conducted using a pin-on-disc type apparatus. In such test sample made of AM60 alloy has mated with the rotating disc made of steel 5CrNiMo with hardness of HRC=55. The experiments has been carried out under dry friction conditions in an environment of 25 ºC. The speed of the disc employed has been equal 0.628 m·s-1. The AM60 sample has been of dimensions: Ø6 mm x 12 mm and the steel disc has been of dimensions: Ø70 mm x 10 mm. Range of loads has been equal 20-1l0 N.

The surface of the wear test samples was polished to obtain surface roughness Ra up to 0,3 μm. The disc and specimen have been cleaned with acetone to remove any possible traces of grease and other surface contaminants. Basing on data from [19], the course of the friction coefficient against calculated mean contact stress has been elaborated and presented in figure 6. Such course has been of the decreasing power series shape.

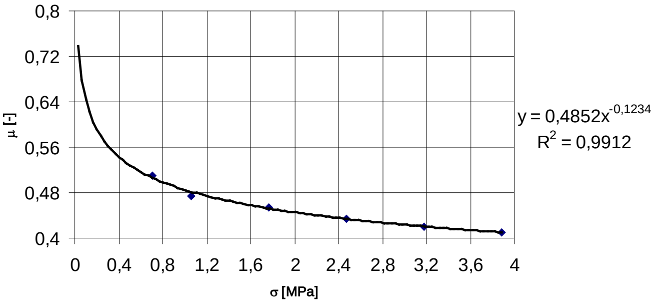

Fig. 1 *Friction coefficient μ against mean contact stress σ_{mean}.*

The friction coefficient have been reduced with increasing the applied load and tend to be steady gradually. Load affects wear behavior by contact area and deformation. In the sliding process the metal surface has been in a elastic-plastic state and the real contacting area has not been linearly related to the load, leading to the decrease of the friction coefficient with the increase of load.

4. Estimation for values of the friction coefficient in the contact ball – plane disc

It has been assumed that values of contact pressure in the contact zone between ball – disc can be calculated from Hertz equations. The friction moment M_t between the ball and rotating disc can be calculated from equation (1) [20]:

$$M_t = 0{,}1875\pi\mu F r_0 \qquad (1)$$

where: F – the force loading contact zone between ball and disc in the tester, μ - the friction coefficient.

The radius r_0 of contact zone between the ball and rotating disc has been calculated from equation (2) [20]:

$$r_0 = \sqrt[3]{\frac{3}{4}\cdot F\left(\frac{1}{r_1}-\frac{1}{r_2}\right)^{-1}\left(\frac{1-\nu_1^2}{E_1}+\frac{1-\nu_2^2}{E_2}\right)} \qquad (2)$$

where: r_1= 0,004 [m] – radius of the ball, $r_1 = \infty$ [m] – curvature radius of the plate, E_1 - the Young module of the ball material, ν_1 - the Poisson number of the ball material, E_2 - the Young module of the disc material, ν_2 - the Poisson number of the disc material.

From equations (1) and (2) the friction coefficient μ can be estimated.

5. Experimental researches

The researches have been carried out on the tribotester for measuring the contact resistance in a concentrated contact ball-disc in conditions of boring motion. The scheme of the tribotester has been presented in the figure 2. It has not been used any additional oil lubrication in the contact zone, so technically dry friction conditions have taken place there. During tests the ball has been fixed and the disc has rotated with the speed 36 rpm. The loading of the ball has been increased in stepwise manner from 7 – 16.9 N.

It has been considered two sets:

1. ball made of the LH15 steel – disc made of AM60 alloy,
2. ball made of the LH15 steel – disc made of C45 steel.

For each value of loading F the value of friction moment M_t between the ball and disc have been measured during test. On the base of them the causes M_t(F) have been obtained.

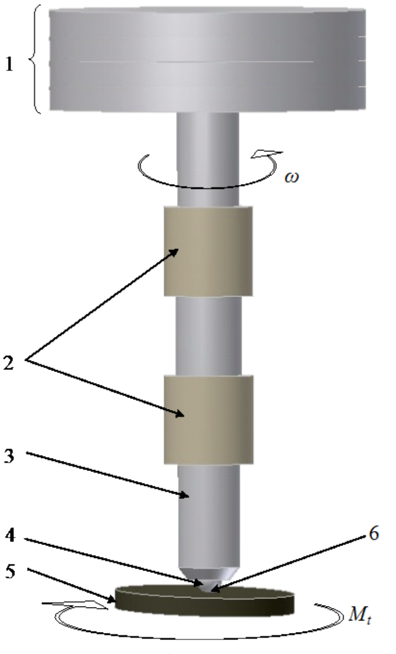

Fig. 2 *The scheme of tribotester; 1 – weights, 2 – air bearing, 3 – stem, 4 – ball, 5 – disc, 6 – contact zone, M_t – the measured friction moment, ω – rotating speed.*

The obtained courses of friction coefficient vs mean contact stress has been presented in the figure 8 – for contact LH15 steel - AM60 alloy, and in figure 9 for contact LH15 – C45.

Values of the calculated friction coefficient have been decreased with the mean stress increase almost linearly. It has been observed in both cases of contact: between ball made of LH15 steel – disc made of AM60 alloy and between ball made of LH15 steel – disc made of C45 steel. Values of friction coefficient between LH15-AM60 have been 2.5 times greater than respective values obtained in the LH15-C45 contact zone. Calculated from equations (1)-(2) values of friction coefficient between AM60 alloy – steel in the case of ball–on-rotating disc tester have been near twice greater in comparison to values obtained in the case of pin-on-disc tester. It can be because of greater value of mean contact stress and mean sliding speed in the case of ball–on-rotating disc tester.

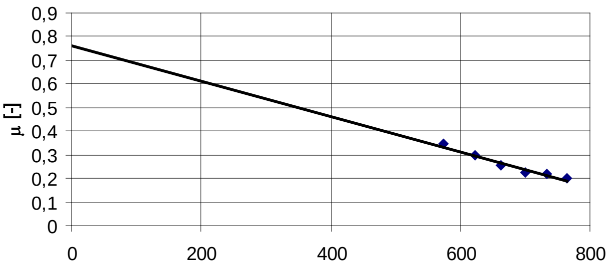

Fig. 3 *The friction coefficient μ vs. mean contact stress σ in contact of LH15 - AM60.*

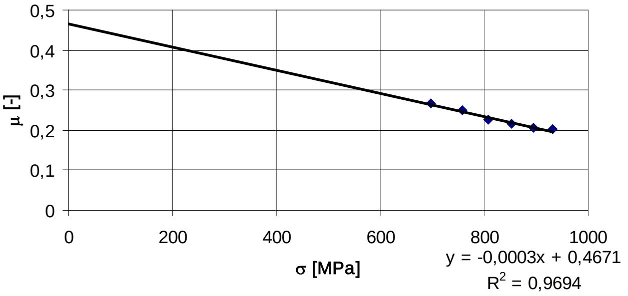

Fig. 3 *The friction coefficient μ vs. mean contact stress σ_{mean}, in contact of LH15 – C45*

6. Conclusion

1. Mating of elements made of magnesium alloys with steel elements can be improved by surface treatment plasma such as electrolytic and microarc oxidation, electronic beam and laser modification, ion beam assisted evaporation deposition or chemical plating.
2. Values of the calculated friction coefficient have been decreased with the mean stress increase almost linearly. It has been observed in both cases of contact: between ball made of LH15 steel – disc made of AM60 alloy and between ball made of LH15 steel – disc made of C45 steel. Values of friction coefficient between LH15-AM60 have been 2,5 times greater than respective values obtained in the LH15-C45 contact zone.
3. Estimated values of friction coefficient between AM60 alloy – steel in the case of ball–on-rotating disc tester can be twice greater in comparison to values obtained in the case of pin-on-disc tester. It can be because of greater value of mean contact stress and mean sliding speed in the case of ball–on-rotating disc tester.
4. High values of the friction coefficient between AM60-steel suggest the necessity of surfaces treatment of AM60 alloy to obtain greater wear resistance. It can be done by plasma or laser treatment

7. References

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