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Tribological studies of composite material based on CuZn38Al2Mn1Fe brass strengthened with δ-alumina fibres

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Abstract

The results of tribological studies (friction coefficient, wear resistance) of the frictional couple of composite material based on CuZn38Al2Mn1Fe brass strengthened with δ-alumina fibres (Saffil) and cast iron are shown in this paper. The wear investigations were conducted applying the tribological pin-on-disc tester and the friction forces between composite materials containing 10 and 20 vol. % of δ-alumina fibres (Saffil) and cast iron were registered. Wear was determined on the base of the specimen mass loss after 1, 3,5 and 8.5 km of friction distance.

Keywords: Metal matrix composite, Coefficient of friction, Wear resistance, Copper alloy

1. Introduction

Copper alloys are one of the most commonly used materials for various engineering applications, although one of the factors limiting the wider application of copper and copper alloys is from the one hand relatively low mechanical strength and on the other hand the large density [1]. These restrictions has been overcome by utilizing the suitable strengthening dispersion of second high strength phase in the metal matrix effecting on the increase of mechanical properties.[2] The most popular are ceramic reinforcements like silicon carbide (SiC), alumina (Al_2O_3) and recently the tungsten carbide (WC). Silicon carbide (SiC) is recognized as one of the potential candidates for electronic packaging and thermal management applications [3,4]. Composite material WC/Cu is applied as the electrical contacts, resistance welding electrodes and electrodes for automatic welding [3]. Metal matrix composite materials reinforcement by Al_2O_3 were developed by various methods and also found wide application where the high electrical conductivity, high thermal conductivity and high strength and low wear resistance are required [2,3].

Composite materials based on copper and copper strengthened with ceramic particles alloys can be manufactured by powder metallurgy methods consisting of cold or hot pressing of powder blends (matrix and strengthening ceramic powder), sintering and cold or hot plastic working. According to the fact that during sintering the diffusional transport of matter is hindered by ceramic particles and the final densities can reach only 85-90% then the additional plastic hot or cold working is required [2].

Taking into account the complexity of PM process, in this work the squeeze casting method of manufacturing of composite copper base materials was elaborated, although to principal technological difficulties belong the high squeeze casting temperatures, relatively high temperatures of ceramic performs, higher temperatures of forms and punches than in conventional squeeze casting of Al-based alloys and the necessity of application for tools of temperature resistant tool steels[5,6]. Metal ceramic composite materials on the base of CuZn38Al2Mn1Fe brass containing 10 vol.% and 20 vol.% of δ-alumina Saffil fibres were manufactured and further investigated by wearing against cast iron.

2. Experimental methods

2.1. Material

Metal matrix composite materials were manufactured by squeeze casting with CuZn38Al2Mn1Fe brass of porous preforms made of δ-alumina SAFFIL fibres manufactured by SGL Carbon Ltd. and characterized by the open porosities of 10 and 20%.

a)

b)

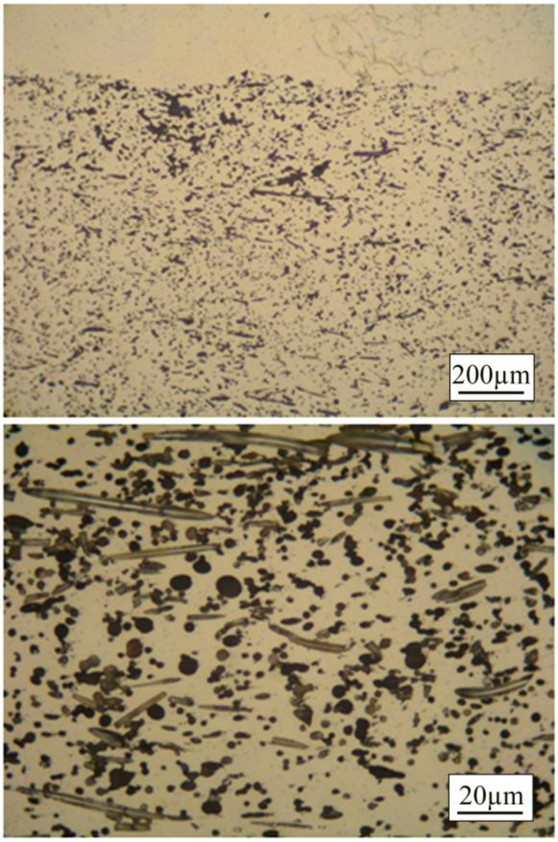

Fig. 1. Microstructure of the CuZn38Al2Mn1Fe brass with with SAFFIL fibres a) border zone of composite material containing 10 vol. % of Saffil fibres b) material containing 20 vol. % of fibres

The production technology of porous fibre preforms consisted of mixing of ceramic fibres in an inorganic binder and organic compound applying defined amounts of binder and ceramic fibres. Then the mixture was poured into a mould giving simultaneously the possibility of shape forming. The final stage of production process was firing of preforms and after this process stable and hard ceramic preforms were obtained characterized by the mechanical strength sufficient for handling and squeeze casting [4]. Brass was overheated to the temperature of 1100^o C and poured into the heated die and the squeeze casting pressure of 60 MPa was applied. The metallographic structure of composite CuZn38Al2Mn1Fe brass containing 20 vol. % of Saffil fibres is shown at the Fig.1 and the matrix of composite materials is composed of the β'–phase with the precipitations of iron phase.

Brinell hardness measurements showed that the hardness of the brass increases considerably with addition of ceramic fibres and Hardness of not reinforced CuZn38Al2Mn1Fe brass is 177 HB, it increases to 208 HB with addition of 10 vol.% of Saffil fibres and it increases to 265 HB with 20 vol.% of Saffil

2.2. Tribological examinations

The wear investigations were conducted applying the tribological pin-on-disc tester T-01M manufactured by the MCMET Radom, used for the determination of tribological properties of engineering materials normally applied for sliding joints of machines. T-01M tester makes possible determination of wear resistance and friction coefficients for a pair of materials sliding against each other, depending on sliding velocity and applied load. Technical specifications of T-01M tester applied in the experimental studies is given below:

- nominal pin diameter: 7,1 mm and nominal disk diameter: 90 mm
- wear track radius: 30mm
- applied load: 40N
- superficial pressure: 1MPa

Experiments can be carried out in accordance with the ASTM G99 and DIN 50324 standards. The specimens of diameter 7,1mm made of brass based composite materials and were fastened in the immovable position and pressed down with the pressure of 0.4 MPa to the counter-specimen (disc). The counter-specimen was cut-out from cast iron brake disk and was rotating with a speed of 318 r.p.m (linear velocity of 1m/s).

The experiments were carried out without application of lubricant, the friction forces were recorded and the specimen mass loss was controlled after 1, 3.5 and 8.5 km. Some fractions of matrix material from the specimen were transferred to the disc surface adhering to the surface of cast iron. Coefficients of friction generally decrease with sliding time and the mean of friction coefficient increases with increasing reinforcement content. The steady-state coefficients of friction are summarized in Table 1.

Table 1.
The mean of friction coefficient after different wear distances

µ Materials	µ (after distance) 1km	3.5km	8.5km
Brass (cast)	0.478	0.456	0.421
Brass (pig-sow)	0.441	0.430	0.421
Brass -10% Al_2O_3	0.586	0.512	0.466
Brass- 20% Al_2O_3	0.581	0.585	0.622

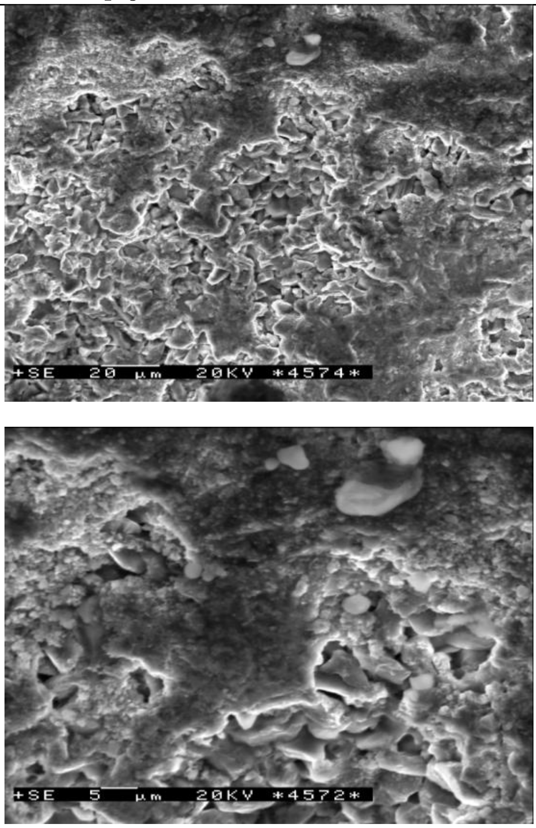

Fig. 2. SEM of wear surface of composite material with 10% of Al_2O_3 after wear distance of 8.5 km

The SEM observations of wear surface shown at the Fig.2. revealed debris of fibres gathering at the holes and irregularities of the wear surface improving the wear resistance of composite materials.

2.3. Roughness analysis

Roughness surfaces were analyzed by profilometer Form Talysurf 120L Rank Taylor Hobson Limited Company used for examination of surface roughness and waviness. The profilometer displayed the roughness curves by ball stylus arm from diamond. The measurements were performed at the cast iron specimens (in three places) used in wear tests and at the samples made of CuZn38Al2Mn1Fe brass and brass based composite materials with the strengthening Saffil fibres.

The roughness profiles investigated after the wear tests are shown at Fig.3 and the roughness parameters Ra are shown at the Table 2. The roughness profile for clear iron-cast disc is shown at the Fig. 3a. Profile of cast iron disc after wear tests with the application of unreinforced brass as the specimen (Fig.3b) at the measurement interval d have shown the build up of the brass layers on the surface friction. Wear test with the application of the specimen of CuZn38Al2Mn1Fe brass with 10 vol.% of Saffil fibres revealed the local loss of material. Comparing with results obtained for the specimen made of the not strengthened brass weared against the iron-cast disc the roughness height Rz in this region decreased to about 8 µm (better smoothness of the counter sample) and the deviation of profile from the mean Ra decreased from 3 to 1 µm.

Table 2.
The mean of the arithmetic mean of the absolute departures of the roughness profile from the mean line (Ra)

Materials	Ra [µm]
Clear iron-cast disc	3.0321
Brass (cast)	3.4255
Brass (pig-sow)	2.7769
Brass -10% Al_2O_3	0.9767
Brass- 20% Al_2O_3	0.9095

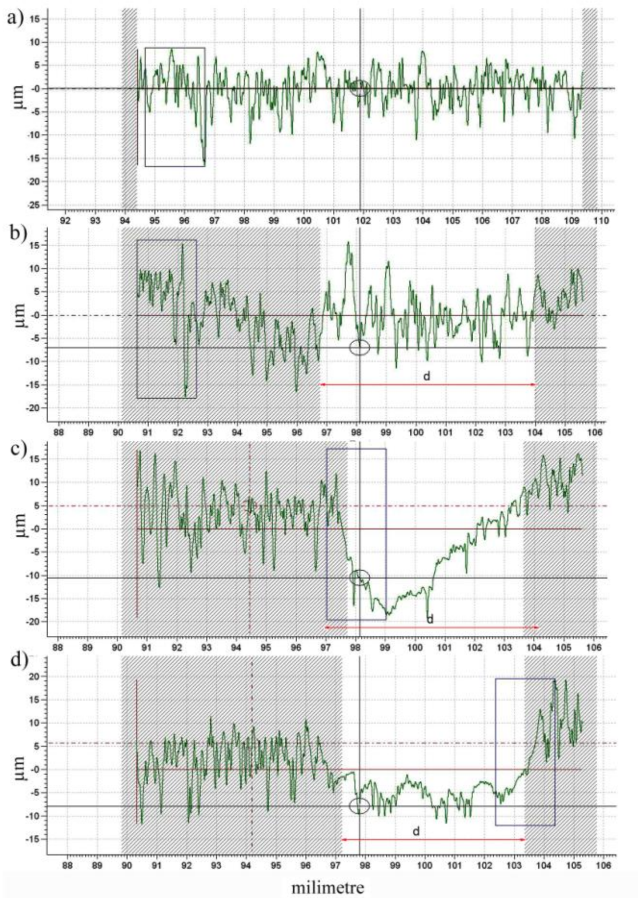

Fig. 3. The roughness profiles of discs from cast-iron after wear distance of 8.5 km, a) for clear disk from cast iron b) after wear against not reinforced CuZn38Al2Mn1Fe brass c) after wear against composite material brass – 10 vol. % of Saffil d) after wear against brass -20 vol.% of Saffil

For the wear investigations applying as the sample the composite material based on CuZn38Al2Mn1Fe brass containing 20 vol.% of Saffil fibres it can be seen the material loss at the interval d. This loss is considerably smaller comparing to the wear test with the application of the sample made of CuZn38Al2Mn1Fe brass-10 vol.% of fibres and has the mean depth of 7 µm. The roughness height Rz comparing to the sample

containing 10 vol.% of fibres was smaller of about 25% (better smoothness) and the deviation of the profile was unchanged.

The results of wear of investigated materials is shown at the Fig.4 and the highest resistance to wear show composite materials with CuZn38Al2Mn1Fe brass matrix containing ceramic Saffil fibres.

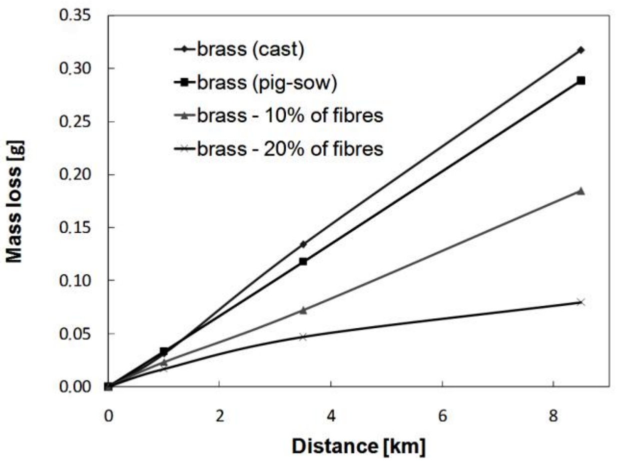

Fig. 4. Change of mass loss as the function of the wear distance

3. Conclusions

The coefficient of friction in couples CuZn38Al2Mn1Fe brass and cast-iron disc are steady in all experiments The coefficients of friction increase with increasing Saffil fibre content in CuZn38Al2Mn1Fe brass matrix. On the other hand materials containing ceramic fibres are characterized by the best wear resistance comparing to unreinforced brass.

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