ABRASIVE WEAR BEHAVIOR OF POWDER METALLURGY CUSN10-GRAPHITE METAL MATRIX COMPOSITES PRODUCED BY POWDER METALLURGY

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ABSTRACT: In this study, CuSn10 metal matrix composites (MMCs) reinforced with 0, 1, 3 and 5 vol.% graphite particulates, respectively, were produced by powder metallurgy.SiC abrasive papers of grit size 400, having an average particle size of 38 μm, were used. The applied loads were selected as 60N. The tests were carried out under sliding speeds of 0.8 m/s. In all tests, the sliding distances were chosen in the range of 50-500m. The effects of sliding distance and graphite particle content on the abrasive wear properties of the composites have been evaluated. The microstructure evolution of composites and the main wear mechanisms were identified using a scanning electron microscope. A decrease in hardness and density of the sintered CuSn10-graphite composites was observed with increase in graphite content. According to results, the abrasive wear resistance of metal matrix composites could be increased by incorporation of graphite particles.

1. INTRODUCTION

Metal-matrix composites (MMCs) have received substantial attention from the aerospace and automotive industries because of their improved strength, high elastic modulus and increased wear resistance over conventional monolithic base alloys during the last decade. Improvements in mechanical properties and wear resistance of MMCs have already been demonstrated for a variety of reinforcements [Kök, 2006;Canakci, 2011;Abachi et al. 2006;Srivastava and Das;Veeresh Kumar et al. 2012;Cui et al. 2012]. These composites are usually supplied through the conventional engineering processes of powder metallurgy, leading to complicated microstructures that comprise copper, graphite, binder carbon, and sintering-induced micropores, even if they look like macroscopically uniform [Futami et al. 2008].Graphite as solid lubricants is widely used because of low cost and excellent lubrication performance. The lubrication roles of graphite were extensively investigated and entirely understood [Lu et al. 1999;Zhan et al. 2004; Chen et al. 2008]. However, solid lubricants having similar structures possess different lubrication roles and their lubrication degrees were not identical in a way. The principal objective of this investigation was to produceCuSn10-graphite composites by powder metallurgy, evaluate the abrasive wear behavior of CuSn10 alloy and its composite under two-body abrasive wear testing condition and examine the effect of graphite content, applied load, sliding distance and abrasive grid size on the abrasive wear behavior of the composites as compared to that of the CuSn10 matrix alloy.

2. EXPERIMENTAL PROCEDURE

In this study, CuSn10 alloy powders (d_{50}=30μm) and graphite particles (d_{50}=28μm) were used as the matrix

material and reinforcement particles, respectively. The powder mixtures were sealed in tungsten carbide vial together with tungsten carbide balls in a ratio of 10:1 and milled for 0.5h with rotation speed of 200rpm in a Fritsch "Pulverisette 7, Premium line" planetary ball mill. The samples for abrasive wear tests produced from CuSn10-graphite particles mixtures containing various amounts of graphite particles as well as the unreinforced CuSn10alloy powders by cold pressing in a steel die having the internal dimensions of 10x10x40 mm at 700 Mpa. The compacted green bulks were sintered at 800 °C for 2h under protective pure argon gas in a tube furnace.

A pin-on-disc with emery paper apparatus was used to investigate the wear characteristics of composites and CuSn10 alloy, as shown in Fig. 1.SiC papers with 38µm size, fixed on a rotating 155 mm diameter and 10 mm thick steel disc with the help of four rectangular clamps, were employed as abrasive mediums. The tests were carried out in air at room temperature at a load of 60N.Theendsofthespecimensweresequentially polishedwithabrasivepaperofgrades600,800and 1000.Wear tests were conducted in dry conditions in order to avoid effect of lubricating medium. A fixed track diameter of 100mm was used in all the tests.

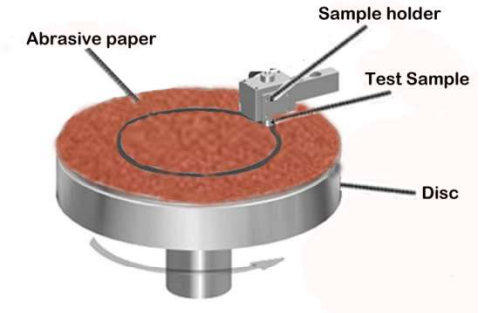


Fig. 1: The schematic view of the abrasion wear test apparatus.

3. RESULTS AND DISCUSSIONS

3.1. Microstructural Observation

SEM image of CuSn10-graphite composites reinforced with 3 wt% graphite particles is shown in Fig. 2. In images, light grey areas indicate CuSn10 alloy matrix and dark areas indicate the graphite particles. Particles which dispersed in CuSn10 matrix semi-homogeneously, generally stuck between points of contact of CuSn10 matrix powders. If reinforcement particles in the composites do not disperse uniformly, this affects mechanical and electrical properties of composites negatively.

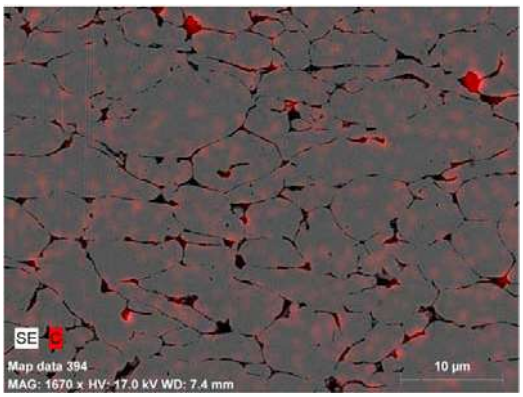


Fig. 2:Scanning electron micrographs of the CuSn10-3 vol. % graphite composite.

The values of relative density, porosity and hardness of unreinforced CuSn10 alloy and composites are presented in Table 1. It is seen that the porosity content of the unreinforced compact are considerably lower than the composites. The relative density of unreinforced CuSn10 alloy was determined as 98.5%. The results showed that the density of composites decreased from 97.5 to 92 % with increasing the graphite particle volume fraction from 1% to 5%. This is due to the density of graphite particles being much lower than that of CuSn10 powders. In spite of the good interfacial bonding between CuSn10 and graphite, graphite particles between CuSn10 matrix

powders prevents the contact of particle and particle due to agglomeration of

Table 1. Physical characteristics of the CuSn10 alloy and CuSn10-graphite composites.

Code	Composition (vol.%)	Density (g/cm^3)	Porosity (%)	Hardness (BSD)
C_o	CuSn10 Alloy	8.57	1.5	112
C_1	CuSn10-1% graphite	8.41	2.5	108
C_2	CuSn10-3% graphite	8.1	5	105
C_3	CuSn10-5% graphite	7.6	8	100

graphite particles during the consolidation process. As can be seen from the Table 1, composite hardnessdecreasedwithincreasing the graphite content. This is a result of the decrease in density.

Fig. 3 show the effect of sliding distance on the average wear loss of the composites with SiC abrasive. It was observed that the wear loss increases with increasing sliding distance (Fig. 3) for all the materials studied.In the case of higher graphite content composites (5 vol.%),

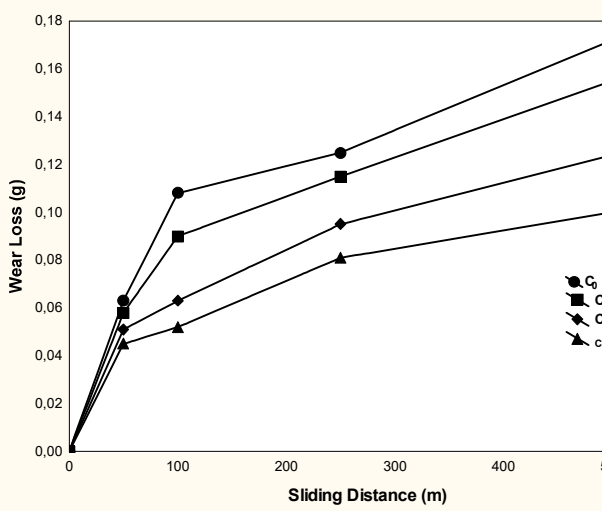


Fig. 3: Variation of the weight loss of CuSn10-graphite composites containing different graphite content at the sliding distance of 500m with the given abrasive grit size of 400 and a load of 60N.

Fig. 4 shows the wear surfaces of the CuSn10-graphite composites. In image, an arrow mark is shown to indicate the sliding direction. The continuous longitudinal grooves parallel to the sliding direction on the worn surfaces are deep in the graphite reinforced composites (Fig. 4). The worn out surface of the composites suggests that the wear mechanism is by the plowing of the surface by SiC abrading particles.SEM images exhibited that wear progressedby grooving action of the abrasive particles.

The SiC abrasive particles with sharp edges cause micro-ploughing and grooving in the surface of CuSn10 alloy. Material in the form of chips is removed from the grooves.

the graphite smears out at contact surface. This reduces the metal to metal contact. Due to the inherent self lubricity of smeared out graphite film, the composites with higher graphite exhibited lower wear rates. Though 1vol% graphite composites are having availability of graphitic film at the contact surface is scarce, which results in reduced lubrication effects and thereby results in higher wear rate. However, with 5vol% graphite composite, the amount of graphite addition is sufficient enough to produce the self lubricative effect.

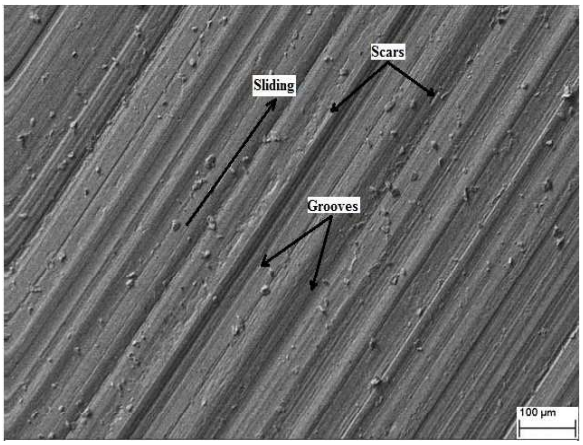


Fig. 4: SEM images of worn surfaces of CuSn10-graphitecomposites

Fig. 5 shows typical SEM micrographs of wear debris morphology of the CuSn10-graphite composites at 60N and 500m. The wear debris is in the form of fine particles and ribbon-type metallic chips, as shown in Fig.4. The formation of fine debris may be due to continuous rubbing action of samples on the wear track while ribbon-type debris are the characteristics of cutting and ploughing action of hard abrasive particles [4].

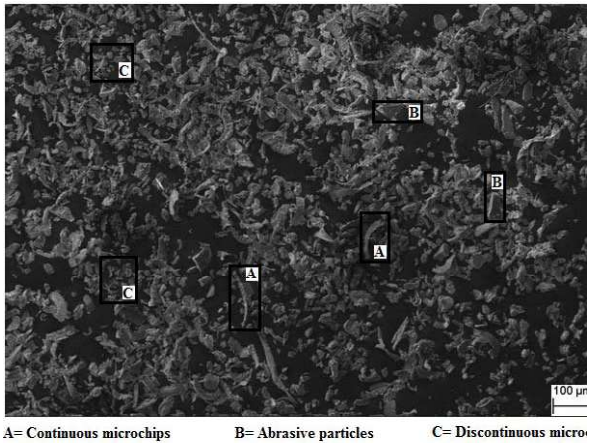


Fig. 5: SEM images of the wear debris of CuSn10-graphite composites

4. CONCLUSIONS

1- A decrease in hardness and density of powder metallurgy CuSn10-graphite composites were observed with increase in graphite content. The increase in amount of graphite leads to a decrease in densification of materials during consolidation process due to agglomeration of graphite particles during the consolidation process.

2-The wear resistance of powder metallurgy CuSn10-graphite composites was found to be considerably higher than that of the unreinforced CuSn10 alloyand increased with increasing particle content.

3- Plastic deformation (micro cutting and microploughing) was identified as the main wear mechanismoperating on the worn surfaces of the composites studied. The wear loss of the matrix alloy and the composites increased with increasing the sliding distance.

Acknowledgments

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