Characterization and Wear Behavior of Nano ZrO_2 Reinforced Copper-Zinc Alloy Composites

Prasad H Nayak, Srinivas H K, Madeva Nagaral, V Auradi

***Abstract**: In the present investigation, an endeavor has been made to create copper-zinc-nano ZrO_2 particulates strengthened composites by utilizing liquid stir technique. 4, 8 and 12 wt. % of nano ZrO_2 particulates were added to the Cu-10 wt. % Zn base grid. Microstructural studies were finished by utilizing SEM and EDS examinations. Wear behavior of Cu-Zn-4, 8, 12 wt. % of nano ZrO_2 composites were assessed according to ASTM G99 benchmarks. Scanning electron micrographs uncovered the uniform dispersion of nano ZrO_2 particulates in the copper zinc composite network. EDS examination affirmed the nearness of Zr and O components in nano ZrO_2 strengthened composites. The experiments were conducted at a constant speed of 400rpm and sliding distance of 3000m over a varying load of 1, 2, 3 and 4 kg. Similarly, at a constant load of 4 kg and sliding distance of 3000m over a varying sliding speed of 100, 200, 300 and 400rpm. The results showed that the wear resistance of Cu-Zn-4, 8% and 12% ZrO_2 nano composites were superior than the as cast alloy. As load and speed increased the height loss in the composites and alloy was increased. Worn surface morphology was studied by using SEM.*

Keywords: Cu-Zn Alloy, Nano ZrO_2 Particulates, Scanning Electron Microscope, Wear, Worn Surface

I. INTRODUCTION

Wear is the progressive loss of material due to the relative motion between metal to metal contact surfaces. Wear and friction are surface phenomena, which are of high concern particularly in the applications of industrial components such as such as, gears, bearings, cams, structures etc., resulting to huge economic losses because of the metal to metal contact and sometimes leading to disastrous failure [1]. Hence, it is of extreme importance to improve the wear life. More attention has been aimed towards particles reinforced composites for tribo-logical applications due to the benefits of MMCs [2].

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Using metal matrix composites the wear resistance as well as anti-friction resistance of the materials would enhance. Metal matrix composites are the kind of composites, which are used in the various fields due to their low density, low coast, easy fabrication along with their increased mechanical and physical properties and high wear resistance [3, 4].

The composites usually consist of fiber or particulate phase which is stronger & stiffer when compared with the matrix phase. The fiber or particulates commonly known as reinforcement phase have good mechanical, thermal & electrical properties when compared to the matrix phase [5]. The matrix phase in composites has several functions. Mainly it helps in binding the reinforcement strongly & serves as the medium to transmit the externally applied stress to reinforcement i.e., matrix takes very less portion of stress. Matrix also protects the individual fibers from surface damage which may be caused due to chemical reactions or mechanical damage. It is also important that the bonding between fiber & matrix is high so that there is no easy fiber pull out. The stronger the interface between the matrix & reinforcement the stronger will be the composite i.e., the mechanical properties of composite depends upon the bonding strength at the interface [6]. The reinforcement plays the major role in enhancing the overall mechanical properties of a composite. The reinforcement embedded in matrix phase is usually stiffer, harder & stronger than the later one. Also, they contribute towards enhancement of co-efficient of thermal expansion, conductivity etc. Among any of other commonly used metals, copper is one characterized by the best thermal conductivity and resistance to corrosion which explains why it is commonly chosen in the first instance for metal material. On the other hand, having very low mechanical properties, it has to be strengthened by ceramic particles, for example, which is one of the most reliable methods of reinforcement. Copper based metal lattice composites (CMCs) have discovered more prominent applications in the field of car, air ships and machine apparatus enterprises attributable to their low thickness and associative high wear opposition, quality, consumption obstruction, firmness and warm conductivity. Copper and its combination are to a great extent utilized as a material for heading [7, 8]. Since copper-based materials have a relativity high temperature and low wear obstruction, the copper network has been effectively fortified with nano zirconium oxide and graphite particles, proceeds or irregular strands, called metal matrix composite (MMCs). There is a globally developing attention in assembling clay particulate fortified metal grid materials which forms joined properties of its fortifications and display enhanced physical and tribo-mechanical properties.

In the present investigation, copper-10%Zn amalgam-based composites were manufactured by stir process. Nano ZrO_2 particulates were utilized as the support. The 4, 8 and 12 wt. level of earthenware production fortifications were taken to create the copper-ZrO_2 composites. The composites evaluated for wear properties at varying applied loads and sliding speeds as per ASTM G99 standard.

II. EXPERIMENTAL STUDY

Table1-I: The chemical composition of Cu-Zn alloy

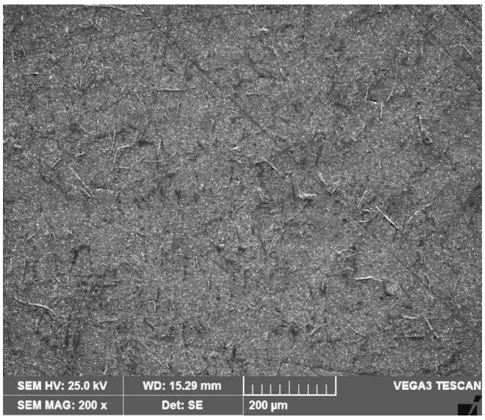
Elements	Content wt. %
Cu	89.20
Zn	9.90
Others	0.90

The Copper-Zn-nano ZrO_2 composites created in this investigation contains 4, 8 and 12 wt. % of artistic nano ZrO_2 particulates. The density of copper-zinc compound is 8.737 g/cm^3 and that of ZrO_2 is 5.68 g/cm^3. The density of composites diminishes with expansion of nano ZrO_2 particulates. The concoction creation of copper-zinc combination is appeared in the Table 1.The fabrication of copper-zinc-ZrO_2 composites were prepared by stir casting technique. The preparation of copper-zinc-nano ZrO_2 composites was accomplished by two-stage stir casting technique. Pre calculated quantity of Cu-Zn alloy ingots were charged into the heating furnace to liquefy. Though the Cu-Zn alloy melts at 1080˚C, the melting furnace was superheated to a temperature of 1150˚C. Thermocouples were used to measure temperature. The melt metal in crucible was then degassed to remove unwanted byproducts using a chemical called hexa-chloro-ethane (C_2Cl_6) up to 3 mins. A steel impeller used was coated with a ceramic material known as zirconium which is used to agitate by rotating the molten metal such that the vortex is created. The process of stirring was carried out at a speed of 300 rpm & the impeller was immersed for about 60% height of molten metal from the top surface of melt within the crucible. Simultaneously during the process of stirring the pre-calculated amount of reinforcement was added into the vortex in two-stages, to ensure good wet-ability stirring was continued for up to 5 mins. The reinforcing materials ZrO_2 was preheated up to 500˚C in oven to remove moisture content before adding it into molten metal vortex. Now, Cu-Zn alloy along with 4 wt. % ZrO_2 particulates were poured into solid cast iron mould to get a composite after solidification. Similarly, Cu-Zn-8 and 12 wt. % of ZrO_2 composites were fabricated for the further studies. The microstructural analysis completed by utilizing SEM instrument. Tests around 5 mm thickness across taken from the casting samples and were cleaned appropriately. A reagent named Keller's was utilized to etch the examples.

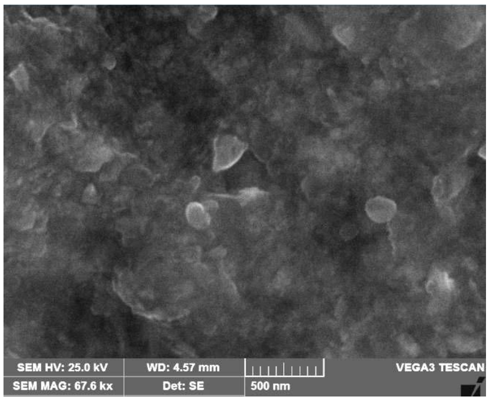
Dry sliding wear test were carried out for Cu-Zn alloy and nano ZrO_2 composites using DUCOM made pin on disc equipment against specimen size of ASTM G99 standards [9] which were machined and polished metallographically. The disc is made of EN 31 steel having a surface roughness of 0.1. Cylindrically machined pins having a length 30mm and diameter 8mm were placed vertically inside a stationary pin holder. The specimen end surfaces were flat and polished metallurgically. At first the specimen was estimated by utilizing an electronic gauging machine with a least count of 0.0001 g. The analyses were led at a consistent load of 4kg and sliding distance of 3000m over a speed of 100, 200, 300 and 400 rpm. Correspondingly, the other arrangement of trials was directed at steady sped of 400 rpm and sliding distance of 3000m and with changing load of 1kg, 2kg, 3kg, and 4kg. After each trial of running the sample was evacuated, cleaned with acetone, dried and weighed to decide the weight reduction because of wear. The wear of the specimen was expressed by height loss in microns.

III. RESULTS AND DISCUSSION

A. Microstructural Analysis



(a)



(b)

Fig. 1: SEM micrographs of (a) as cast copper-zinc alloy (b) copper-12 wt. % ZrO_2 composite

Fig. 1(a) shows microstructure of as cast copper-10% zinc alloy, fig. 1b represents Cu-Zn-12 wt.% of nano ZrO_2 composites. The SEM micrographs reveal almost uniform distribution of ZrO_2 particulates in the matrix as observed in the fig. 1b. Uniformly distributed particulates increase the overall strength and other properties reducing the porosity of the MMC.Fig. 2 is the EDS spectrum of copper-zinc and 12 wt.% of nano ZrO_2 reinforced composites. EDS spectrum revealed the presence of nano ZrO_2 particles in the copper-zinc alloy matrix in the form of Zr and O elements along with Cu and Zn matrix elements.

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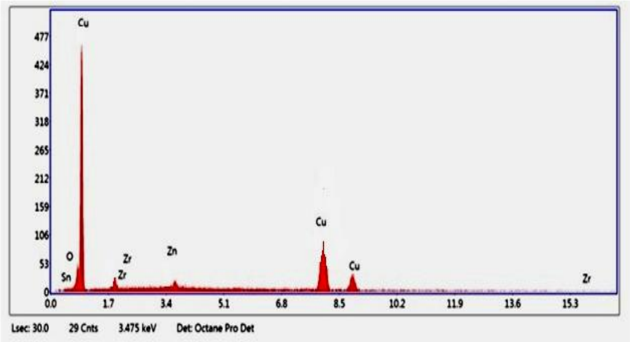


Fig. 2: EDS spectrum of copper-zinc-12 wt. % ZrO_2 composite

B. Wear Properties

Fig. 3 shows the varying load at 400rpm along x axis for Cu-10% Zn alloy and nano ZrO_2 composites wear loss along y axis**.** As the load increases from 1 kg to 4 kg the wear loss is increased, and it is lesser in the case of nano ZrO_2 reinforced composites.At higher loads, higher wear misfortune is observed for framework compound and the composites. At greatest loads the temperature of sliding surface and the pin surpasses the critical value. As load increased on the pin there is an expansion in the volumetric wear loss of both the framework combination and nano ZrO_2 composites. In any case, it is seen that the wear loss of the composites lessens with 4, 8 and 12 wt. % nano ZrO_2 fortifications in the network combination. This enhancement in the opposition of the composites as for wear is predominantly with wt. % of support and because of the high hardness of zirconium oxide particulates which fills in as the snag for the material misfortune [10-12].

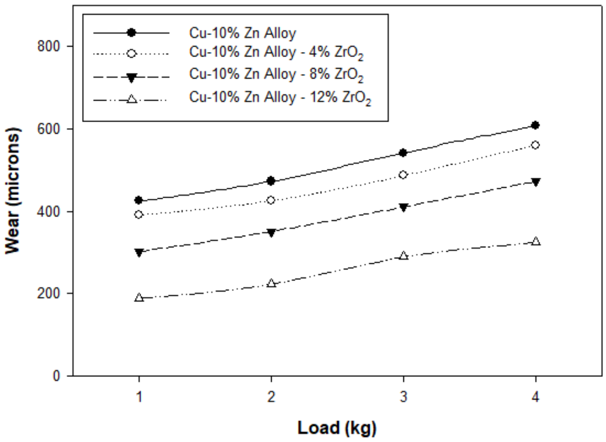


Fig. 3: Wear loss of Cu-10%Zn alloy and nano ZrO_2 composites at varying loads and 400rpm constant speed

Fig. 4 shows the wear loss of Cu-10%Zn matrix alloy along with ZrO_2 composites on sliding speed. As the sliding speed is increased from 100 rpm to 400 rpm, the loss due to wear is increased for both Cu-10%Zn matrix alloy and its constituent composites.Additionally, as sliding speed is kept increasing there is increase in wear loss also because of softening of the composite at increased temperature due to rubbing action. The increase in temperature resulting due to higher sliding speeds also leads to plastic deformation of the test piece [13, 14]. Therefore, there is increased delamination contributing to enhanced wear loss.

Further, Cu-10%Zn alloy with 4, 8 and 12 wt.% of nano ZrO2 composites exhibits the superior resistance to wear as compared to Cu-Zn base matrix. The decreased height loss as the wt.% of the reinforcement increase is due to presence nano ZrO_2 particles in the base Cu-Zn alloy matrix. These nano particles act as a barrier for the wear loss and protects the matrix.

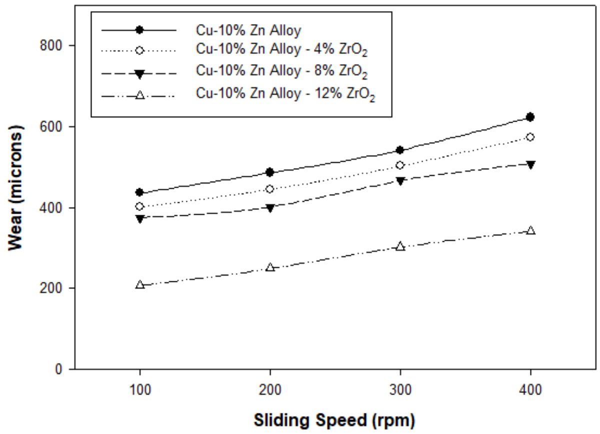
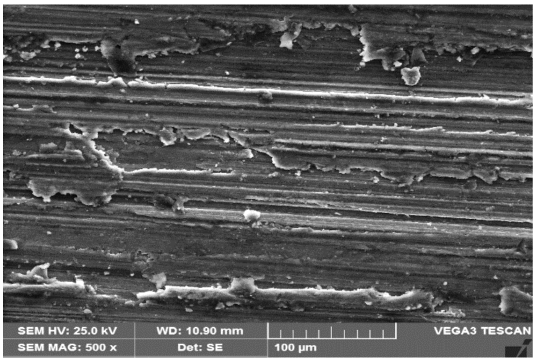


Fig. 4: Wear loss of Cu-10%Zn alloy and nano ZrO_2 composites at 4 kg constant load and different speeds

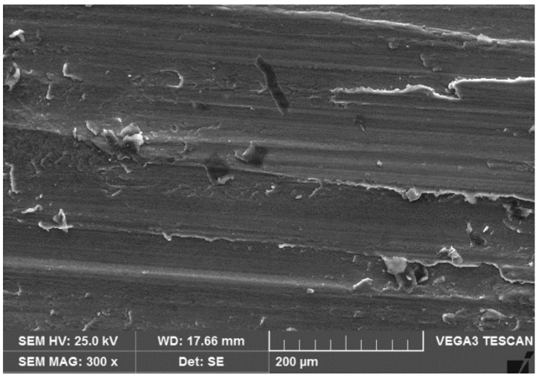
C. Worn Surface Morphology

Worn surface studies of as cast Cu-10% Zn alloy and nano ZrO_2 reinforced composites are examined by using SEM microphotographs. Fig. 5 characterize the wear worn surfaces of matrix material Cu-Zn alloy (fig. 5a) and the nano composite which is tested at 4 kg load and 400rpm sliding speed by reinforcing of 12 wt. % of nano ZrO_2 (fig. 5b) particles in base materials.

From fig. 5a it shows in the sliding direction the edges and depressions running parallel to each other. It can be seen from the micrograph the cracks are deeper and more widespread in lattice combination Cu-10%Zn when compared with the nano composites under comparable conditions. Because of sliding of oxide molecule in the reinforced composite it might be seen from fig.5b that a break likewise on the well-used outer surface of the Cu-10%Zn-12 wt. % ZrO_2 nano composite. On account of nano composites, a thick layer could be seen, which shields the basic matrix from being in contact with the sliding partner and along these lines minimizing the volumetric wear misfortune. Therefore, the layer framed on the nano composites gives a self-protective cover to the hidden material as a result repressing the metal-metal contact.



(a)



(b)

Fig. 5: Shows the SEM microphotographs of worn surfaces of (a) Cu-10%Zn alloy (b) Cu-10%Zn-12 wt.% ZrO_2 composites at 4 kg load and 400rpm speed

IV. CONCLUSIONS

Cu-10%Zn alloy-based composites with 4, 8 and 12 wt.% of nano ZrO_2 are fabricated by using the stir casting method. The casted composites are tested for the microstructural analysis using SEM and EDS. The composites with 12 wt. % of nano ZrO_2 particles are studied for SEM, the micrograph confirms the distribution of nano particles in the base copper-10% zinc alloy matrix. Further, EDS analysis confirmed the presence of Zr and O elements in the copper-zinc matrix. Dry sliding wear behavior test is conducted using pin-on-disc machine to know the effect of nano particles on wear behavior of copper-zinc alloy at varying loads and speeds. As load and speed increases, the wear loss is increased in base matrix and in ZrO_2 reinforced composites. Further, Cu-10%Zn alloy with 12 wt. % of nano ZrO2 reinforced composites are exhibited the more wear resistance as compared to base and other composites. Worn surface morphology has shown the wear behavior in Cu-Zn matrix and its nano composites.

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