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Microstructure and Mechanical Behavior of Nano Zro_2 Reinforced Copper-Zinc Alloy Composite

Raj Kumar[1*], Jayasheel I Harti[2], Sahadeva G N[3], Madeva Nagaral[4]
[1*]PG Scholar, Department of Mechanical Engineering, East Point College of Engineering and Technology, Bangalore-560049, Karnataka, India
[2]Assistant Professor, Department of Mechanical Engineering, East Point College of Engineering and Technology, Bangalore-560049, Karnataka, India
[3]Professor and HOD, Department of Mechanical Engineering, East Point College of Engineering and Technology, Bangalore-560049, Karnataka, India
[4]Design Engineer, Aircraft Research and Design Centre, HAL, Bangalore-560037, Karnataka, India
Correspondence Author: Raj Kumar

ABSTRACT
The paper is the result of investigations made on microstructure and mechanical behavior of 3 and 6 weight percentage of nano sized ZrO_2 reinforced to copper alloy (90% Cu and 10% Zn) composites. Copper matrix composite having nano zirconium oxide was fabricated by liquid stir casting method. The microstructure of the composites was examined by scanning electron microscopy and electron dispersive spectrum. Further, mechanical behavior of composites was studied. Tensile properties like hardness, ultimate tensile strength, yield strength and compression strength were evaluated as per ASTM standards. Microstructural observation revealed uniform distribution of ZrO_2 reinforcement particles in the matrix and particulates were confirmed by scanning electron microscope. The analysis disclosed hardness, ultimate tensile strength, and yield strength of composites increased due to addition of reinforcements.
KEYWORDS: Bronze composite material, Nano zirconium oxide, Ultimate Tensile Strength, Yield

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I. INTRODUCTION

Copper based metal matrix composites (CMCs) have broad applications in the field of automobile aerospace and machine tool industries due to its low density and high wear resistance. Copper matrix has high strength, corrosion resistance and high thermal conductivity which make CMCs more suitable for different applications. The copper and its alloy are widely used as a material for bearings. The copper matrix composites are fabricated by adding nano sized ceramic particles such as ZrO_2 in the copper matrix which results in enhanced mechanical properties. The ZrO_2 is considered as the superior reinforcement due to its high strength, high wear, and impact resistant, high melting point, low coefficient of thermal expansion and good chemical stability [1].

Shaaz Abulais et al. [2] through the testing of silicon carbide and aluminum oxide in copper concludes that ultimate tensile strength and the yield strength of copper increases with the addition of sic and Al_2O_3. Their studies also concluded that properties such as Young's modulus and shear modulus improved proportionally with the additional reinforcement. According to their find, the density of the material and its Poisson's ratio reduces with increase in reinforcement percentage i.e. these are inversely proportional with reinforcement percentage. There is a tremendous improvement in the hardness of the material with the introduction of reinforcements. In his study of microstructure, he concluded that Al_2O_3, SiC and carbon phase are clearly visible but the mixture is not homogeneous in nature so this composite is of discontinuous type.

T.Ram et al. [3] studied the wear behavior of Gr+Cu/SiC hybrid composite in two single layers and three multilayer configurations. The presence of a layer structure in the composite found that the breaking and wear resistance of the composite are increased. Breaking behavior and wear rate was found to be better by using small size particles. For providing better breaking layered structure is more effective, especially at sliding speed of 30 to 35 m/s. Single layer composites founds best in terms of crack growth resistance when compared with multilayer composites.

Bekir et al. [4] came to a conclusion that there is a decrease in the surface roughness of CuSn10, CuZn30, and pure Sn but there is an increase in values in pure copper and pure zinc bearings. The highest coefficient of friction was seen in CuSn10 and pure copper while the lowest coefficient of friction was observed in pure Sn and pure Zn bearings. The bearing in which the highest temperature occurred was made up of CuSn10 and CuZn30.the lowest temperature of bearing was observed in pure Cu, Pure Sn, and pure Zn bearings. Also observed that the highest wear loss was seen in CuZn30 bearings while the wear loss was lowest in pure Zn, pure Cu, and pure Sn bearings. The journal wear loss was highest in pure copper bearings and lowest in CuSn10 and pure Zn bearings. The bearing wear rate was higher in CuSn10 and CuZn30 bearings whereas the lowest wear rate was recorded in pure Zn bearings. They came to a conclusion that mechanical properties were highest in CuSn10 and CuZn30 bearing materials while these properties were lowest in pure Zinc and pure Tin bearing materials.

Jitendra Kumar et al. [5] revealed that the liquid metallurgical technique (stir casting) is quite successful in the preparation of copper graphite composite with 5%, 10%, and 15% weight. The particles are uniformly distributed in the matrix system when subjected to scanning electron microscope. There is an increase in the wear resistance of the composite when compared to that of pure copper thus the volumetric wear loss of composite material is less when compared to the volumetric wear loss of pure copper when it is subjected to the sliding distance under an applied load. He also observed that the tribological properties of the base metal increase with the addition of graphite and are highest with an addition of 15% weight of graphite reinforcement.

P.Prabhakara Rao et.al. [6] studied that with the increase in Al_2O_3 reinforcement there is an increase in the hardness value. By increasing in alumina weight percentage there is decrease in a density. Compression strength slightly decreases with increase in Al_2O_3 with the increase in percentage weight of aluminium microstructure reveals the present of voids and grain size also considerably increasing. By increasing the reinforcement content he found that there is an increase in porosity values

II. EXPERIMENTAL WORK:

2.1 Material

The present study use 120 nano meter sized ZrO_2 as reinforcement and Cu-Zn alloy are used as the matrix material. Copper alloy is used for the matrix and ZrO_2 is further added as reinforcement in 3 and 6 weight percentages respectively in the copper alloy.

2.2 Preparation of Copper alloy Composites

The composites used in the experiment contain 3 wt. % and 6wt. % of ZrO2 and 10 wt. % of zinc in copper matrix. The fabrication of the composite is done by stir casting method. ZrO_2 is added in 3% and 6% of weight. The metal is placed in a graphite crucible and then the crucible is placed inside the electric furnace. The reinforcement particle is preheated at 300°C in a pre-heater to overcome the wet ability of the particles. The reinforcement of 10 wt. % Zn and 3% ZrO_2 is added in the molten copper. The mixing of the matrix and the reinforcement is done by using stirrer coated with zirconium to form the vortex. The stirrer is connected to the motor which runs at the speed of 300 rpm. Once the vortex is formed the nano particles of ZrO_2 is added in the molten metal at constant feed rate, which results in uniformly distribution of particles in the matrix. After stirring continuously the molten metal is poured into a die which is already preheated. The prepared nano composites are then machined as per the standards for characterization purpose.

2.3 Testing of Composites

Vegas Tescan made scanning electron microscope is used to conduct the micro structural analysis of the prepared composite material. The sample of diameter 15 mm is cut from the prepared cast then it is polished and tested for the better result. Keller's reagent is used for etching the sample.

Indentation response of a cast Copper matrix alloy and its micro composites were evaluated by Brinell hardness tester. The required specimens were prepared according to standard metallographic procedures. The experiments were carried out by applying a load of 500kgf and dwell time of 30 seconds. The indentation load depth values were recorded and the hardness was determined. For each sample, the indentation test was repeated 3 times and the averaged data were reported.

Tensile test specimens were machined from the cast samples. The tensile specimens of circular cross section with a diameter of 9 mm and gauge length of 45mm were prepared according to the ASTM E8 standard testing procedure using Universal Testing Machine. All the tests were conducted in a displacement control mode at a rate of 0.1 mm/min. Multiple tests were conducted and the best results were averaged. Various tensile properties like ultimate tensile strength, yield strength and percentage elongation were evaluated for as cast Copper alloy. Figure 1 showing the tensile test specimen dimensions used to conduct the experiments.

Compression test is carried out on the cylindrical specimen having the cross-sectional area 340 mm^2 machined and cutout from the cast and UTM is used for the compression test.

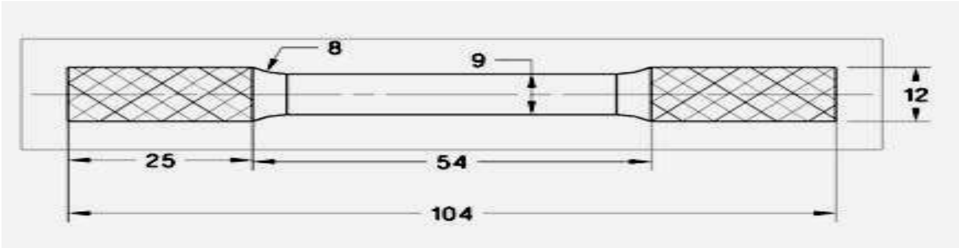

Figure 1: Tensile specimen and its dimensions in mm

III. RESULTS AND DISCUSSION

3.1 Microstructure Study

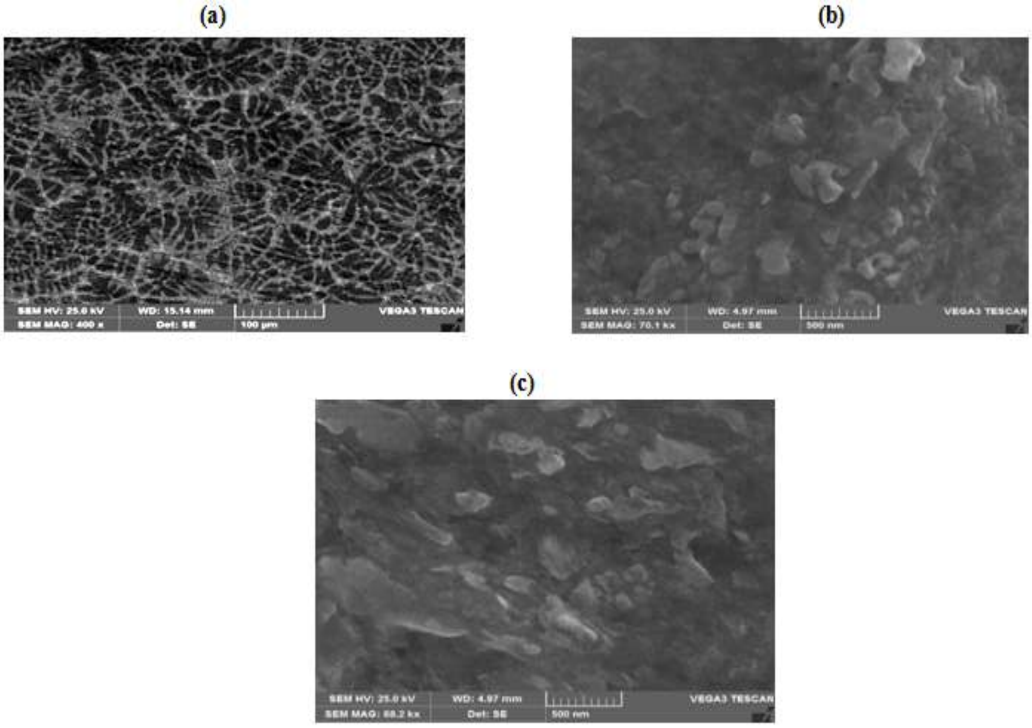

Figure 2: a-b-c Showing the scanning electron micro photographs of (a) Copper-Zinc alloy (b) Copper-Zinc reinforced with 3 wt. % of ZrO_2 (b) Copper alloy reinforced with 6wt % of ZrO_2.

Figure 2 (a-b-c) shows the SEM microphotographs of Copper alloy as cast and Copper with 3 and 6 wt. % of Nano ZrO_2 particulate composites. This reveals the uniform distribution of reinforcement and very low agglomeration and segregation of particles, and porosity. Both the figures as shown in the figure 2 (a) clearly shows and even distribution of zinc in the copper matrix and (b-c) shows the proper distribution of Nano ZrO_2 in the Copper alloy matrix. There is no evidence of casting defect such as porosity, shrinkages, slag inclusion and cracks which is indicative of sound castings. In this, wetting effect between particles and molten Copper alloy matrix also retards the movement of the reinforcement, thus, the particles can remain suspended for a long time in the melt leading to uniform distribution.

3.2 Tensile Properties

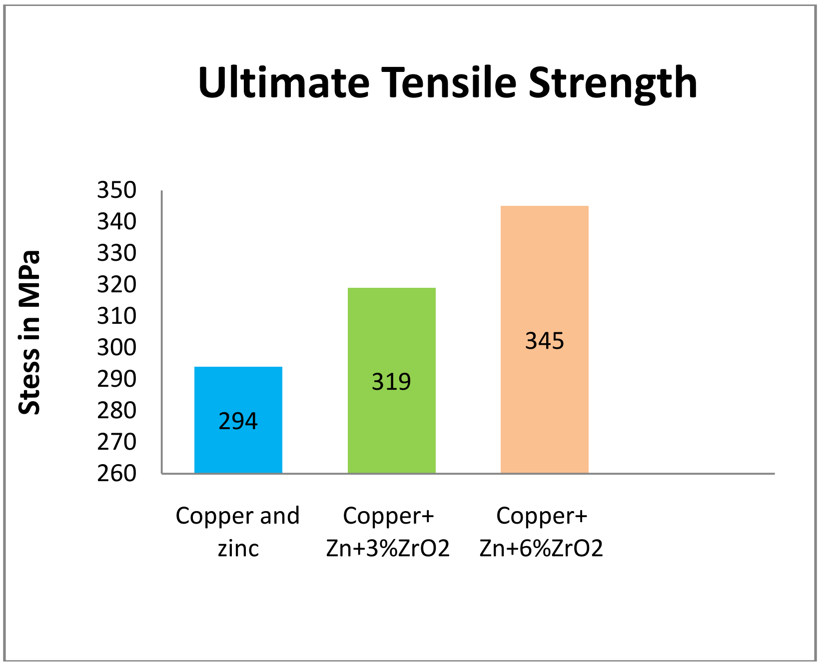

Figure 3a: Ultimate tensile strength of Copper alloy composites

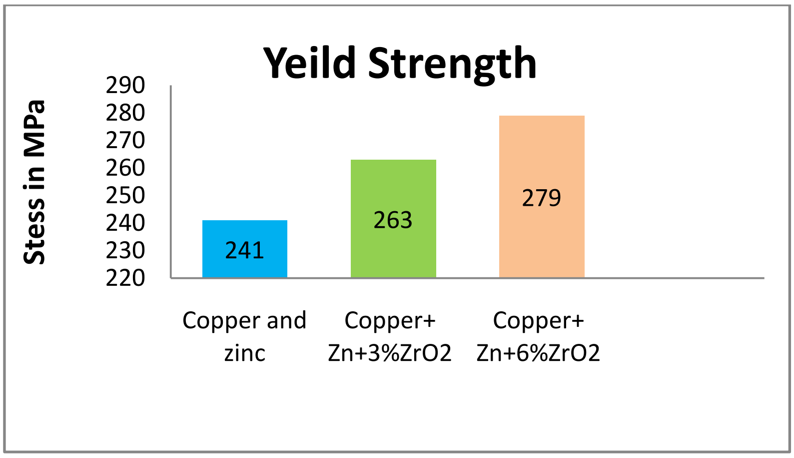

Figure 3b: Yield strength of Copper Alloy and 3 &6 wt. % of Nano ZrO_2 composites

Figure 3a, shows there is gradual increase in the UTS with 3 % wt. and 6 % wt. addition of ZrO_2 as reinforcement is the fact that the properties of ZrO_2 particulates control the mechanical properties of the composite showing the intense tensile strength. The variation in the UTS is may be because of matrix fortifying with increase in reinforcement size [7, 8].

Figure 3b indicates yield strength improved from 241 MPa to 279 MPa with addition of reinforcements. The enhancement in the yield strength is due to the close packing of ZrO_2 particles providing molecule strength with the Copper Matrix composite [9-11].

3.3 Hardness Study

Brinell hardness test was conducted on the specimens of Copper Zinc alloy and copper zinc alloy with 3 % wt. and 6 % wt. addition of ZrO_2, with ball diameter 10mm, load 500kg and the values obtained are in the range 79 to 99 BHN as shown in figure 4. The values indicate that there is gradual increase in the hardness because of the hard zirconium oxide inclusion. As the percentage of particulate increased the hardness also increased parallel.

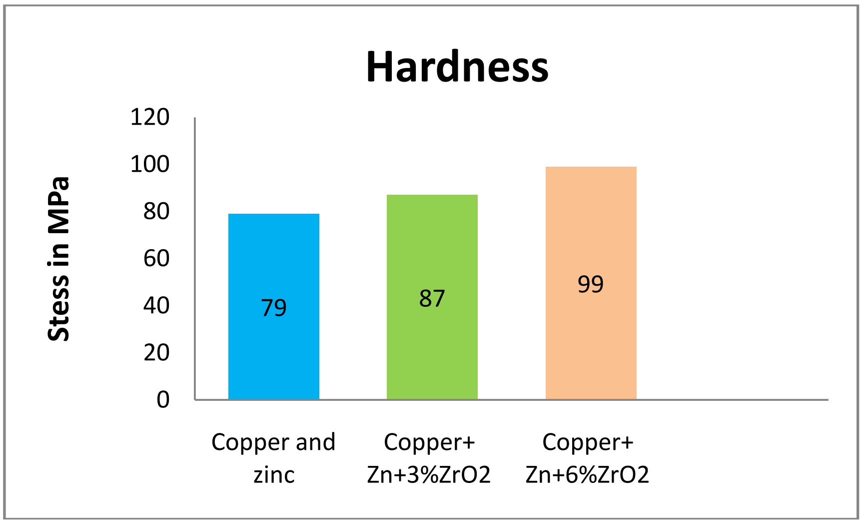

Figure 3.4: Hardness of Copper Zinc alloy and copper zinc alloy with 3 % wt. and 6 % wt. addition of ZrO_2

3.4 Compression Test

Compression test was conducted on the specimens of area 340 mm^2 Copper Zinc alloy and copper zinc alloy with 3 % wt. and 6 % wt. addition of ZrO_2 on the Universal Testing Machine. The compressive strength of the copper zinc alloy increased with the increase of the ZrO_2 reinforcement. From the figure 5 it is shown that compressive strength varies from 640 N/mm^2 to 767N/mm^2.

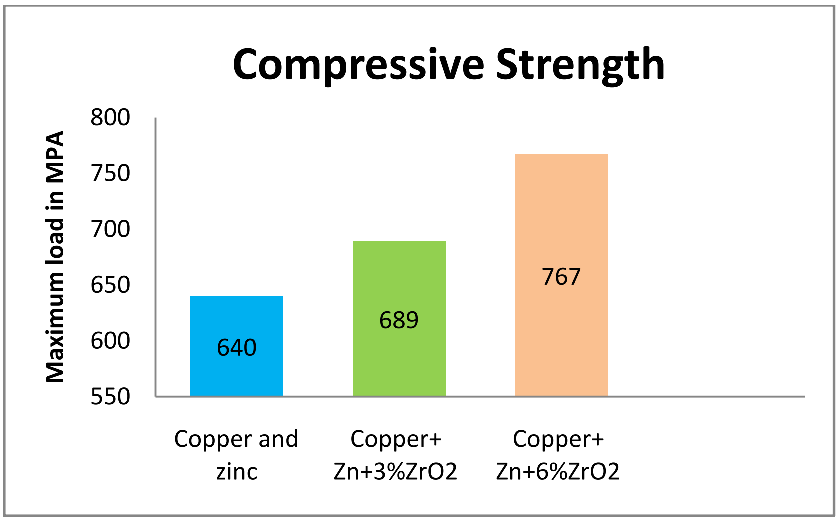

Figure 5: Compressive Strength of Copper Zinc alloy and copper zinc alloy with 3 % wt and 6 % wt of ZrO_2

IV. CONCLUSIONS

The mechanical investigations of the Copper alloy and ZrO_2 composites materials produced by stir casting are remarked as below:

- The liquid metallurgy technique was successfully adopted in the preparation of Copper alloy and 3 wt. % and 6 wt. % nano ZrO_2 composites.
- The microstructural studies revealed the uniform distribution of the nano ZrO_2 particulates in the Copper alloy matrix.
- The ultimate tensile strength and yield strength properties of the composites found to be higher than that of base matrix.
- Improvements in hardness of the Copper alloy matrix were obtained with the addition of nano ZrO_2 particulates.
- The compressive strength of the composite increase with increase in the addition of ZrO_2 particles.

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