INFLUENCE OF NANO ZRO_2 PARTICLES ON THE MECHANICAL BEHAVIOR OF COPPER ALLOY COMPOSITES

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Abstract: The paper is the result of investigations made on microstructure and mechanical behavior of 4 weight percentage of nano sized ZrO_2 reinforced to copper alloy (90% Cu and 10% Sn) 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. Further, mechanical behavior of composites was studied. Tensile properties like hardness, ultimate tensile strength; yield strength were evaluated as per ASTM standards. Microstructural observation revealed uniform distribution of reinforcement particles in the matrix. The analysis disclosed hardness, ultimate tensile strength, and yield strength of composites increased due to addition of reinforcements.

Index Terms - Bronze composite material, Nano zirconium oxide, Ultimate Tensile Strength, Yield Strength, Stir casting.

I. INTRODUCTION

Copper based metal matrix composites (CMCs) have found greater applications in the field of automotive, aircrafts and machine tool industries owing to their low density and concomitant high wear resistance, strength, corrosion resistance, stiffness and thermal conductivity [1]. Copper and its alloy are largely used as a material for bearings. CMCs are fabricated by incorporating nano sized ceramic particles, such as ZrO_2 and Al_2O_3 into the copper matrix. Zirconium Oxide is a superior reinforcement material due to its high hardness, high strength, high wear and impact resistance, high melting point, low coefficient of thermal expansion and good chemical stability. Bekir Sadik [2] investigated the mechanical and tribological properties of journal bearing metals. He found that the wear values of CuSn10 and CuZn30 were decreased as compared to AlCuMg2, ZnAl and SnPbCuSb. And they investigated that the mechanical properties of CuSn10 and CuZn30 and AlCuMg2 bearing materials were better than ZnAl and SuPbCuSb bearing materials [3]. Kulasa et al. synthesized the CuSn10 and graphite particulate in order to improve the wettability of the graphite particle 0.4% Ti introduced into the metal matrix composite by stirring process and reported that lowest average value of the coefficient of friction and wear was observed in CuSn10/graphite composite with 0.4% Ti [4]. Jitendra Kumar et al synthesized copper and graphite by stir casting and observed that copper-15 wt.% of graphite exhibits superior mechanical and tribological properties compared to copper -10wt.% graphite and copper -10 wt.% graphite composite. As graphite is a soft material and has low strength it is observed that the impact strength of the composite decreases. The wear resistance of the copper-graphite composite is improved significantly by graphite reinforcement [5]. Shikhar Gupta et al. investigated copper-graphite metal matrix composite by powder metallurgy and analyzed the mechanical properties like hardness and density and he found that density decreases as wt% of graphite increases and electrical conductivity decreases as wt% of graphite increases [6]. Bronze is used as bearing material to have high wear resistance. Tin bronze (90%Cu and 10%Sn) is most suitable bearing material at high temperature, high loads and corrosive conditions [7]. The conventional mechanical stir casting method can be used to disperse ZrO_2 particles in molten copper alloy without agglomeration and clustering. Mechanical and tribological properties are reviewed of different routes [10]. In the present work an attempt has been made to develop Cu alloy and nano ZrO_2 composites by using stir casting method. Cu alloy-4wt. % nano ZrO_2 composites were evaluated for the mechanical properties.

II. EXPERIMENTAL WORK

2.1 Materials

The current study nano sized ZrO_2 as reinforcement and Copper alloy as matrix material with chemical compositions as shown in the below Table 2.1 is used for the study.

Table 2.1: Composition of Copper alloy

Element	Cu	Sn	Mg	Si	Mn	Zn	Cr	Other
% by Wt	84	15	0.30	0.20	0.10	0.20	0.05	0.10

2.2 Preparation of Copper alloy Composites

The composites containing 4 wt. % of nano ZrO_2 particulates and were prepared from stir casting process technique. Initially the required amount of reinforcements and the cast iron die are preheated to a temperature of 350°C-400°C. On the other part, the calculated amount of copper and tin was weighed and placed in a graphite crucible inside an electric furnace and heated to temperature of about 993°C. After the complete melting of copper, the Tin is introduced into the molten melt due to the low melting point of tin at 223°C. The molten melt is disturbed by dipping a zirconium coated mechanical stirrer to form a clear vortex by stirring mechanism at a speed of 300rpm. Once the vortex is formed then the preheated nano ceramic particles with the proper proportion ratio of 4 wt% nano ZrO_2 is introduced into the molten melt at constant feed rate, which involves in dividing the entire weight mixture of nano ZrO_2 .The continues stirring process is carried out before and after the pouring of mixture of reinforcements to avoid clustering of particulates and to have uniform homogenous distribution of nano particulates in the melt. After continues stirring, the entire molten metal was poured into preheated cast iron die. The prepared nano composites were machined as per the standards for characterization purpose.

2.3 Testing of Composites

The microstructural study was carried out on the prepared composites using Vegas Tescan made scanning electron microscope. The test sample is 5-6 mm in diameter cut from the castings and polished thoroughly, for etching the sample Keller's reagent was used.

Indentation response of as 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 250 kgf 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 Instron made 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 2.1 showing the tensile test specimen dimensions used to conduct the experiments.

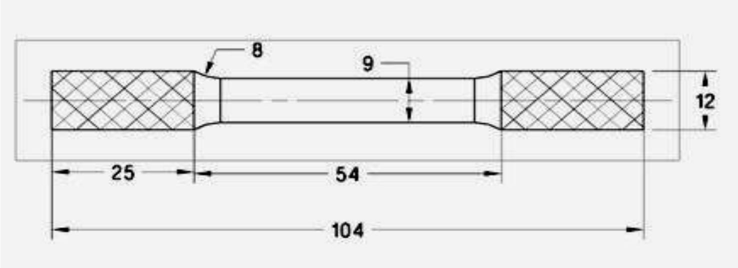
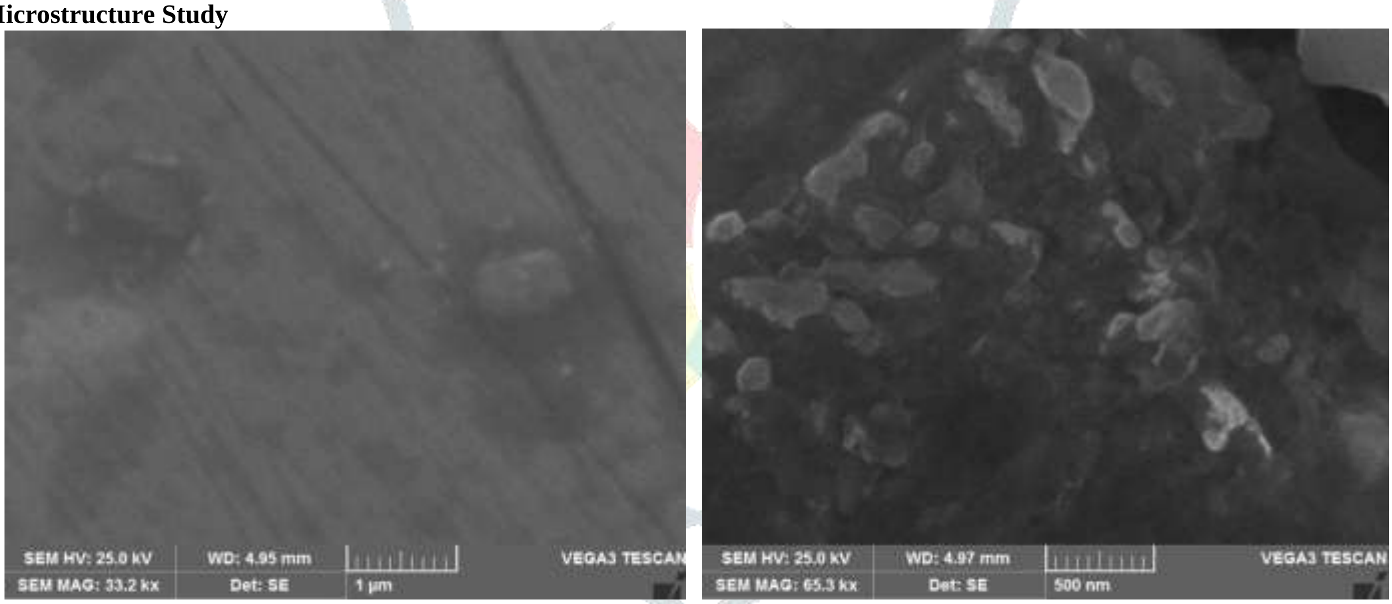


Figure 2.1: Tensile specimen and its dimensions in mm

III. Results and Discussion

3.1 Microstructure Study



(a) (b)

Figure 3.1: Showing the scanning electron microphotographs of (a) cast Copper alloy (b) 4wt% of ZrO_2

Figure 3.1 shows the SEM microphotographs of copper alloy as cast and copper with 4 wt. % of nano ZrO_2 particulate composites. This reveals the uniform distribution of reinforcement and very low agglomeration and segregation of particles, and porosity.

Figure 3.1 (b) clearly shows and even distribution of nano ZrO_2 in the copper alloy matrix. There is no evidence of casting defects 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.

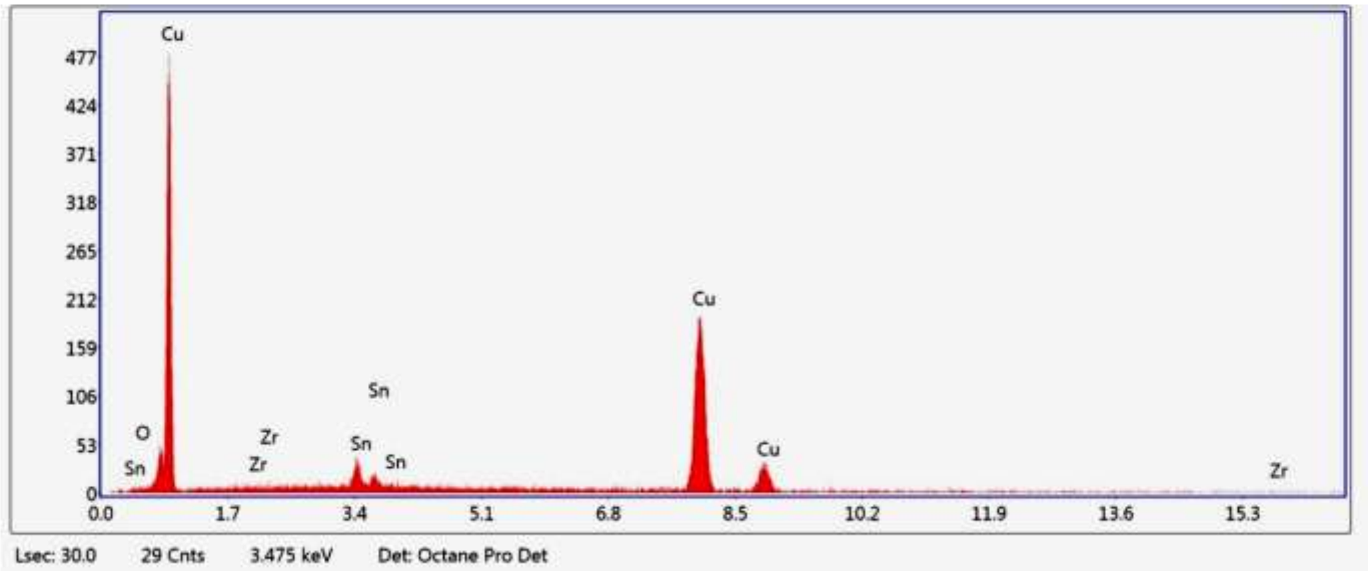


Figure 3.2: showing the EDS spectrum of copper-4wt. % of ZrO_2 composites

In order to confirm the presence of ZrO_2 energy dispersive spectroscope analysis was carried out at the edge of the reinforcement particle and Copper alloy matrix. The EDS spectrum reveals the presence of Cu, Sn, Zr and Mg in the interface reaction layer (Figure 3.2).

3.2 Tensile Properties

Figure 3.3 shows there is gradual increase in the UTS with 4 % wt. addition of ZrO_2 and Gr due to 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.

Figure 3.4 indicates yield strength improved from 281 MPa to 310 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 lattice in turn composite.

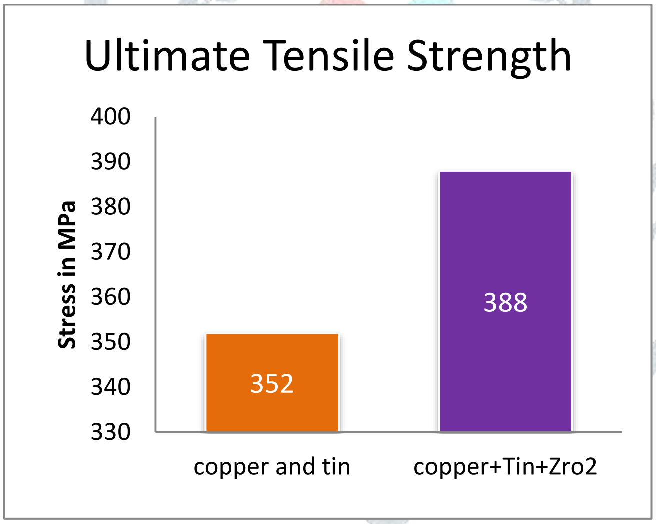


Figure 3.3: Ultimate tensile strength of Copper alloy composites.

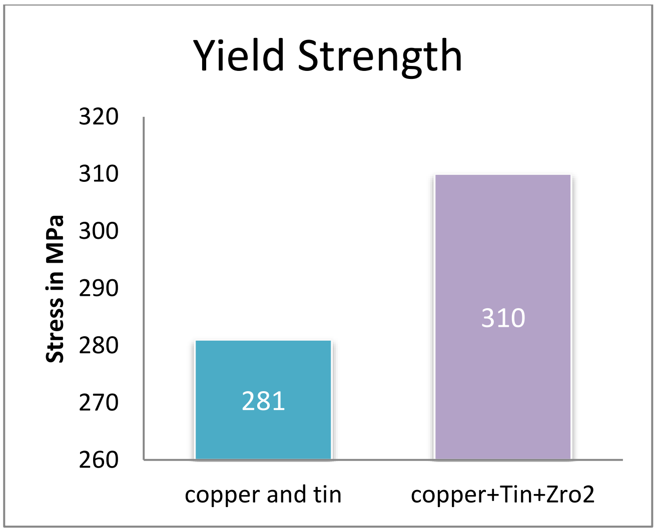


Figure 3.4: Yield strength of Copper Alloy and 4 wt. % of Nano Zro2 composites

3.3 Hardness Study

Brinell hardness test was conducted on the specimens of Copper alloy with 4 % wt. addition of ZrO_2, with ball diameter 10 mm, load 500Kg and the values obtained are in the range 54 to 86 BHN evident from the graph 6. 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.

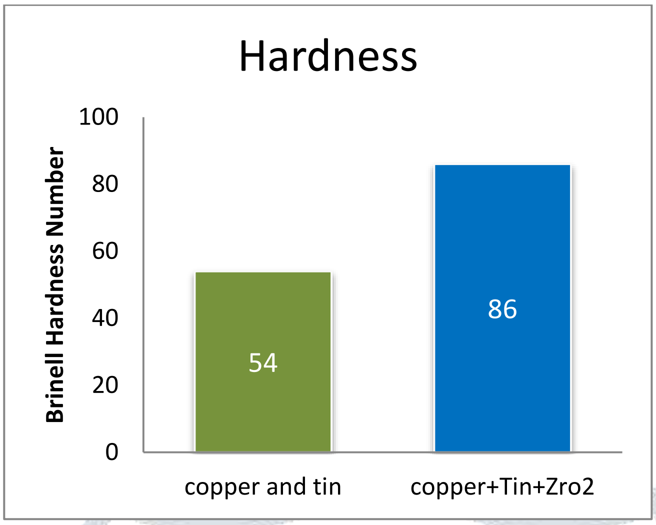


Figure 3.5: Hardness of Copper alloy and 4 wt. % of nano ZrO_2 composites

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 4 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.

V. REFERENCES

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