Evaluation of Mechanical Characteristics of Cobalt Reinforced Bronze based Composites

Sreenivasa R
Dept. of Mechanical Engineering
Jain Institute of Technology, Davanagere
Karnataka, India

Pavan C P[2], Kirankumar C M[3],
Muhammad Suhaib[4], Mudasir Khan[5]
[2,3,4,5]Dept. of Mechanical Engineering
Jain Institute of Technology, Davanagere
Karnataka, India

***Abstract*— For mechanical properties the effect of cobalt reinforced bronze-based metal matrix composites has been investigated. In a bronze matrix, cobalt metal powders of 40µm particle size were reinforced to produce composite samples of ratios 2, 4, 6 & 8% of weight using stir casting technique. A series of tests were performed for the manufactured composite specimens to determine the mechanical characteristics under tension, compression and shear as per ASTM standards. The same is true of base alloy. From the investigation it was found that there was an increase in tension, compression and shear characteristics up to 6% additional weight of cobalt reinforcement in bronze matrix further decreased tension, compression and shear characteristics for 8% additional weight of cobalt reinforcement in bronze matrix. To describe the impact of cobalt, scanning electron microscopy and Energy dispersive X-Ray analysis were performed. A scanning electron microscopy was used to further analyze the damaged specimens to identify the fracture.**

Keywords: Bronze, Cobalt, Stir Casting, Proof Strength, Strain Energy Density, Modulus of Toughness, Compressive strength, Shear strength.

I. INTRODUCTION

Bearings are used to keep pieces from rubbing together during relative motion. Rolling part bearings and hydrodynamic journal bearings are the two types of bearings. A bearing's primary purpose is to hold a rotor and casing together with as little wear as possible. From your wristwatch to the car you drive, this bearing duty may be seen in almost every facet of everyday life. Journal bearings are increasingly being used in production for both low and high-speed rotating machinery. Cu alloys have long been utilized for bearings due to their combination of high strength, chemical reaction resistance, and auto-lubrication qualities. [1] Bronzes are a copper alloy that has been widely utilized for bearings, shafts, and other uses [2].

The addition of alumina to an aluminum bronze composites [3] improved the hardens and tribological characteristics of the material. The wear rate of Cu–Sn bronze [4] has been improved by adding alumina. The addition of nano SiC particles to a bronze matrix [5] increased microhardness and improved sliding wear performance. The addition of Ag and Cr [6] to a bronze composite improved its lubricating qualities and wear resistance. In bronze composites, the inclusion of SiC, SiO_2, and graphite [7] improved corrosion resistance under acid rain. There is limited analysis of the mechanical properties of bronze-based composites. Available cobalt-reinforced bronze-based composites also lack the properties. The researchers did not focus on failing tribological properties, such as compression and shear checking.

Most of the researchers did not focus on compression estimation or crushing power. Most bearings frequent failure is due to crushing that is very frequent in bearings. But due to compression the researcher has completely ignored the loss. Therefore, the results of the research carried out by the several investigations are very conservative. Therefore, cobalt metal powders were added to bronze composite with proportions of 2, 4, 6 & 8 weight percent and their mechanical characteristics under tension, compression and shear were evaluated in this investigation.

II. MATERIALS AND PROCEDURES

A. Materials

A The present work bronze ingots made of compositions 90% copper and 10% tin were used as matrix material and cobalt metal powder of 40µm size were used as reinforcement material.

B. Experimental Work

In an electrical resistance furnace, bronze ingots were melted at a temperature of 950°C. Degassing was performed using tablets containing hexachloroethane (C_2Cl_6). The proper amount of cobalt metal powder was then carefully introduced to the liquid bronze (2 percent of the weight of bronze).To extract the moisture (if any) in it, the cobalt metal powder applied to the liquid bronze was pre-heated to 300^0C. At the same time, the molten metal composite was vigorously stirred with a stirrer, at a steady speed of 300rpm. The high-temperature liquid metal composite was poured into warmed (300^0C) cast iron moulds to create the required specimens. The weight percentages of 4%, 6% and 8% were calculated using the same method.

C. Testing

It was proposed to test the manufactured specimens for mechanical characteristics under tension, compression and shear. It was proposed to do the Scanning electron microscopy and the Energy dispersive X-Ray analysis to know the dispersion of the metal matrix reinforcement.

*C.*1 *Tensile Test*

Circular cross tensile specimens-section with a 9mm diameter & 36mm length (ASTM E – 8 M) were machined. Three specimens were prepared for each composition. The experiments were performed using a servo-universal hydraulic testing system. All tests were conducted at a rate of 0.1mm / min in displacement control mode. The load and the resulting displacement were recorded.

C.2 *Compressive Test*

Compression specimens were machined with a diameter of 13mm and a length of 25mm (ASTM E-9). Three Specimens were prepared for each composition. The experiments were carried out using a servo-universal hydraulic control system. The load and the corresponding displacement were recorded.

C.3 *Shear Test*

Shear strength refers to a material's capacity to endure pressures that cause it to slide against itself. The Indian IS5242 standard was used to conduct the direct shear test. A 12mm diameter, 60mm long cylindrical specimen is inserted via circular holes into three hardened steel blocks, the centre of which is dragged (or pushed) between the other two to shear the specimen on two planes. The experiments were carried out using a servo-universal hydraulic control system. The load and the corresponding displacement were recorded.

III. RESULTS & DISCUSSIONS

A. Microstructure Characterization

The characteristics of particulate composites are heavily influenced by the form, density, size, and distribution of reinforcing particles. Microstructural characterization of the experimental composites was done on ground and polished samples using a JEOL JSMT320 scanning electron microscope (SEM). To produce an image in the as-polished samples, SEM examination was performed utilising a large-area backscattered electron detector. Furthermore, the Energy dispersive X-Ray investigation validated the dispersion of reinforcement in composites.

Fig. 1 (a – e) represent the microstructures of Bronze, Bronze - 2wt. % Co, Bronze - 4wt. % Co, Bronze - 6wt. % Co and Bronze - 8wt. % Co composites respectively. Cobalt reinforced bronze based composites microstructures have changed their shape and inter-metallic phase distributions also occurred. The addition of cobalt affects the bronze structure, it limits the motions between the atoms; thus, the composites structural stability improved. The performance of the composites improves as the porosity of the composites decreases; as a result, tensile strength, hardness and wear rate increases.

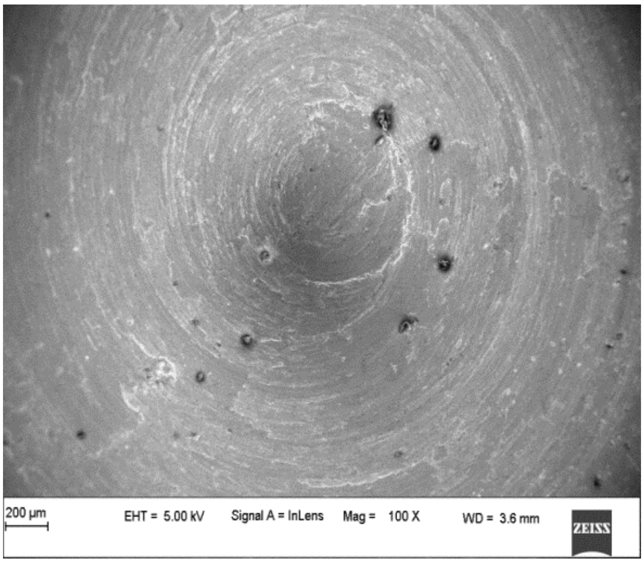
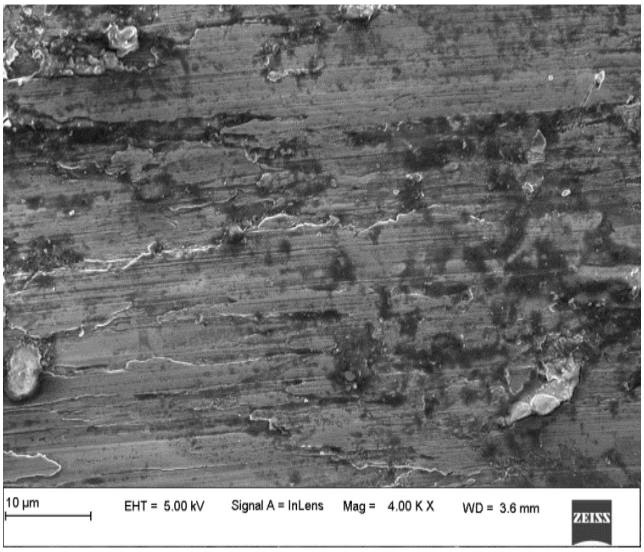


Figure.1 a



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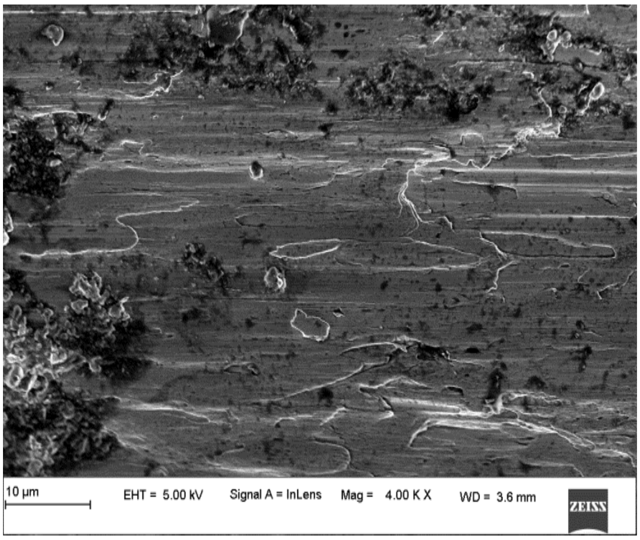

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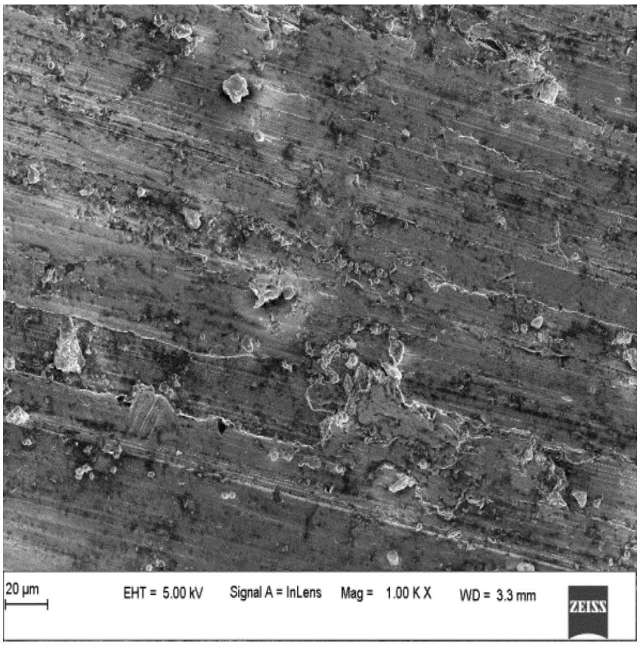

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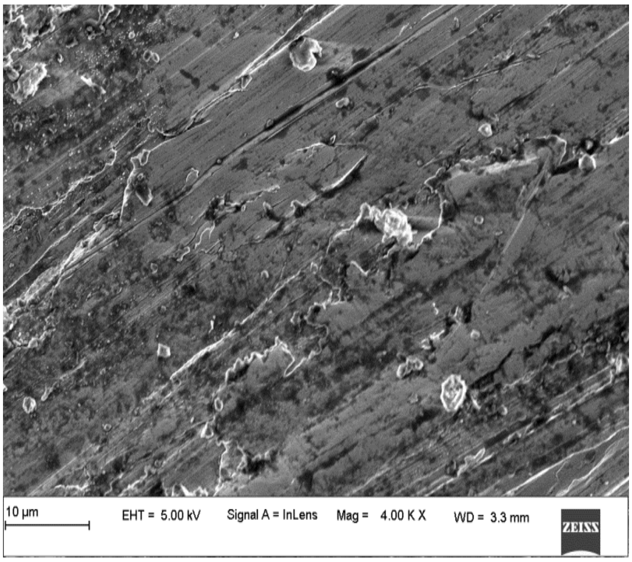


Figure.1 e

Fig. 1. The SEM micrographs of (a) Bronze, (b) Bronze - 2wt. % Co, (c) Bronze - 4wt. % Co, (d) Bronze - 6wt. % Co and(e) Bronze - 8wt. % Co composites.

Fig. 2 (a) represent the diffraction diagram of the Bronze alloy. The peaks on the diffraction map correspond to the Cu-rich and Sn-rich phases of the binary Cu–Sn system. Diffraction diagrams of Bronze - 2wt. percent Co, Bronze - 4wt. percent Co, Bronze - 6wt. percent Co, and Bronze - 8wt. percent Co composites are shown in Fig. 2 (b–e). The diffraction diagrams of these compositions were different small peaks which did not correspond to any equilibrium phase of Cu–Sn system.

The above result suggested that adding cobalt to the bronze alloy altered the alloy's base structure and caused microstructure to degenerate. Each element was in the form of pure state. However, the microstructures typically have a large number of casting defects in these modified compositions; particularly the porosity resulting from the casting of gravity.

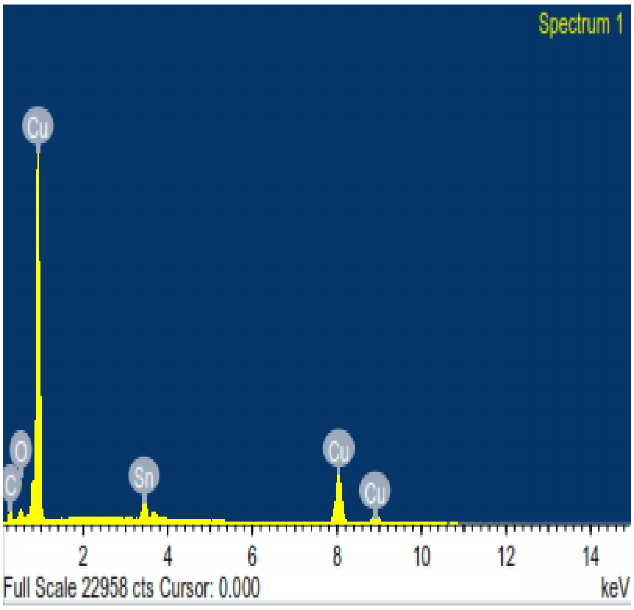
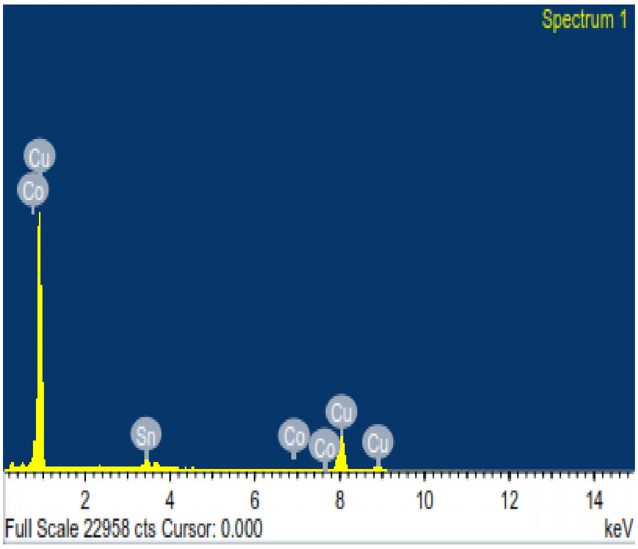


Figure.2 a



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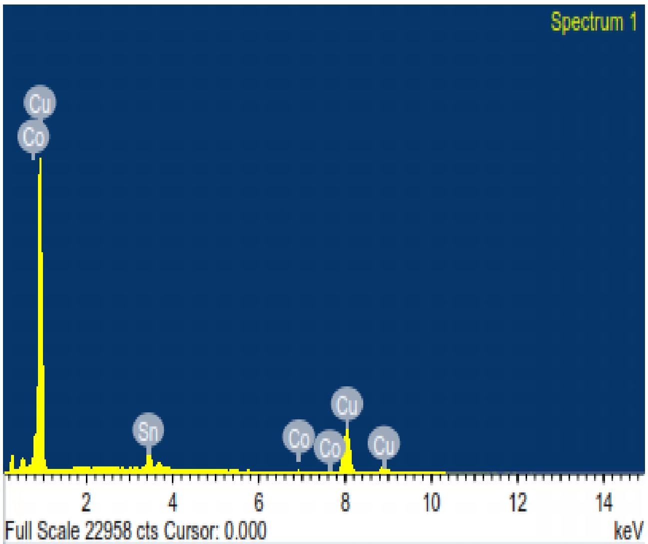

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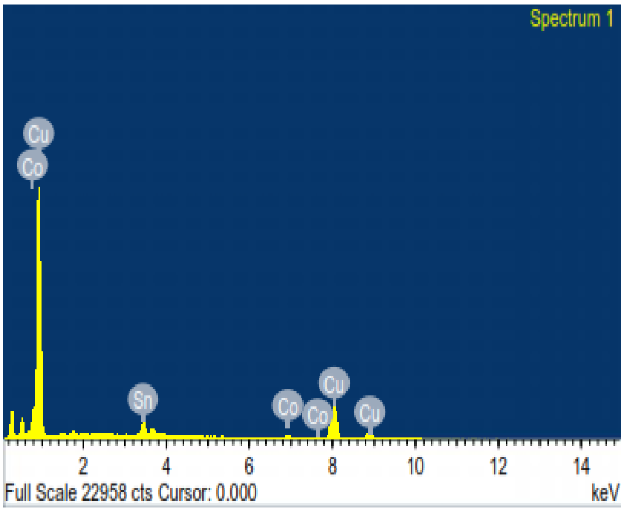

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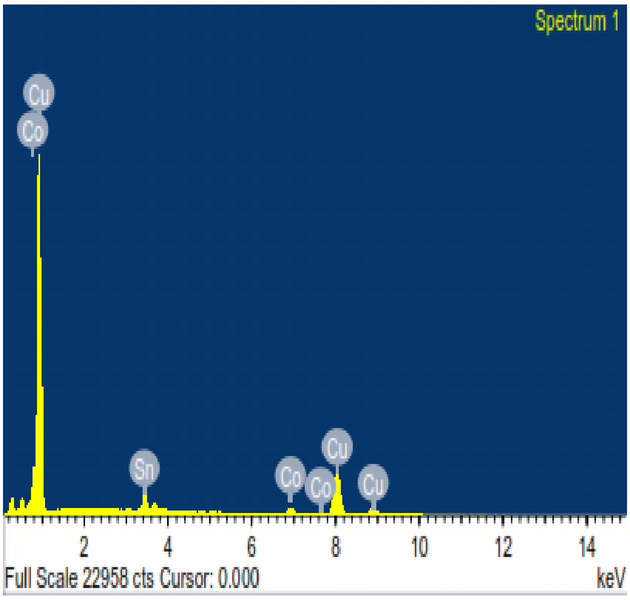


Figure.2 e

Fig. 2. EDAX Patterns of (a) Bronze, (b) Bronze - 2wt. % Co, (c) Bronze - 4wt. % Co, (d) Bronze - 6wt. % Co and (e) Bronze - 8wt. % Co composites.

B. Tensile Characteristics

Tensile stress – strain curves for bronze and its modified compositions shown in Fig. 3. Reveal that the tensile strength increased steadily by an increase in weight reinforcement percentage applied to the metal matrix. Compared to the unreinforced bronze alloy shown in Table 1, the highest tensile strength was measured at 6% cobalt reinforced bronze-based composite. When the reinforcements are applied, the particulate reinforcements form nuclei tends to further formation of grains, it restricts the movements. [8-9]. Similar findings on mechanical and tribological properties were reported by Dyachkova et al [4] on the sintered Cu– Sn bronze with alumina additive. They reported reduction of the friction coefficient and wear rate with the addition of the correct percentage of alumina. The fracture surfaces were visually inspected after each tensile test was completed. For all of the specimens the fracture surfaces were smooth. Specimens had fractured primarily under conditions of plane strain; fracture was found to have occurred without necking in any of the samples, which indicates a brittle failure.

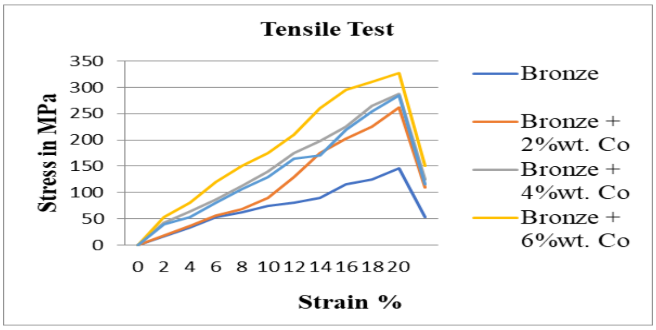


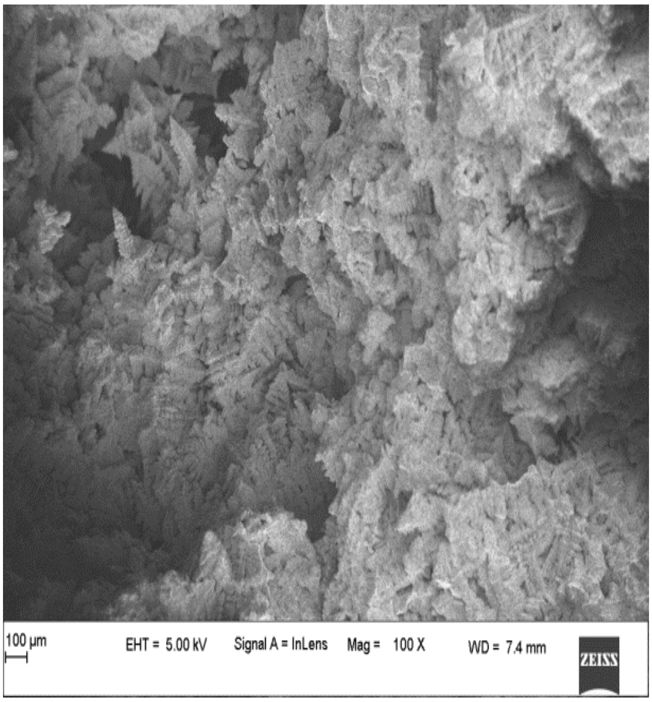
Figure. 3. Tensile stress – strain curves for bronze and its modified compositions

Table 1 Tensile properties of bronze and its modified compositions

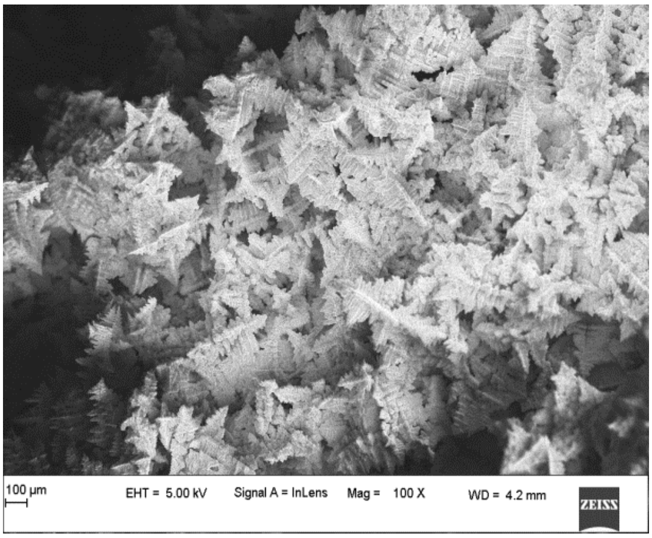
Composition	Modulus of Elasticity E in GPa	Proof Strength (0.2% offset yield) in MPa	Compressive Strength in MPa	Strain Energy Density in Nmm/mm^3	Modulus of Toughness in Nmm/mm^3	Fracture Strain
Bronze (90% Cu +10% Sn)	100	56.84	145.814	3.296	28.433	0.03111
Bronze + 2wt.% Co	145	215.1	262	12.906	51.352	0.041
Bronze + 4wt.% Co	154	240.3	288	14.177	56.736	0.042
Bronze + 6wt.% Co	156	243.9	327	14.634	64.419	0.058
Bronze + 8wt.% Co	143	242.1	285	14.283	56.145	0.039

C. Fractographic Analysis

The mechanical characteristics of metallic alloys for solidification are heavily dependent upon a microstructure. The mechanical characteristics with microstructure parameters are very useful in preparing the solidification conditions in order to achieve a desired degree of final characteristics. The broken +surfaces of tensile were inspected closely by the electron microscope. Fig. 4 (a – b) reflect SEM images of 6% cobalt content bronze based composite tensile fracture surfaces. A lot of small dents and a handful of broken particles make up the fault surfaces. It can be inferred that the broken particles contain intermetallic cobalt. During the test of tensile these particles were broken and became sources of crack. Some particles were destroyed, and some gas cavities pulled out. Even the fractographs show a lack of deep dents reflecting brittle failure as dark and smooth surfaces.



(a)



(b)

Fig. 4. SEM of tensile fracture surfaces of 6% Cobalt content Bronze based composite

D. *Compressive Characteristics*

Compressive stress- strain curves for bronze and altered compositions shown in Fig. 5. Reveal that the compressive force steadily increased with the increase of weight reinforcement percentage applied to metal matrix. Compared to the unreinforced bronze alloy shown in Table 2, the highest compressive strength was measured at 6%cobalt reinforced bronze based composite. The load on the matrix is transmitted to the reinforcing components when hard particles are present, increasing the load bearing capacity of the composites. The nature of failure is almost brittle. Similar finding on mechanical and corrosion properties was reported by Venkatesan et al [10] on bronze with TiB_2 additive. They reported that addition of reinforcement improves the mechanical characteristics of the bronze composite samples and suggested slight marginal improvement in the corrosion properties.[11-19]

Table 2 Compressive properties of bronze and its modified compositions

Composition	Modulus of Elasticity E in GPa	Proof Strength (0.2% offset yield) in MPa	Compressive Strength in MPa	Strain Energy Density in Nmm/mm^3	Modulus of Toughness in Nmm/mm^3	Fracture Strain
Bronze (90% Cu +10% Sn)	267	300	962.695	41.4	500.601	0.48
Bronze + 2wt.% Co	275	410	1153.546	48.38	636.757	0.488
Bronze + 4wt.% Co	291	435	1246.012	51.33	642.942	0.492
Bronze + 6wt.% Co	309	466	1273.014	64.30	661.967	0.496
Bronze + 8wt.% Co	300	425	1032.793	50.15	524.65	0.484

Table 3 Shear properties of bronze and its modified compositions

Composition	Modulus of Rigidity G in GPa	Proof Strength (0.2% offset yield) in MPa	Shear Strength in MPa	Strain Energy Density in Nmm/mm^3	Modulus of Toughness in Nmm/mm^3	Fracture Strain
Bronze (90% Cu +10% Sn)	37	135	335.9938	16.605	159.877	0.475
Bronze + 2wt.% Co	54	143	362.5197	19.019	177.6346	0.49
Bronze + 4wt.% Co	57	154	371.3616	23.1	194.6553	0.524
Bronze + 6wt.% Co	58	160	397.8874	24.32	209.2224	0.525
Bronze + 8wt.% Co	53	153	371.3616	22.797	188.775	0.508

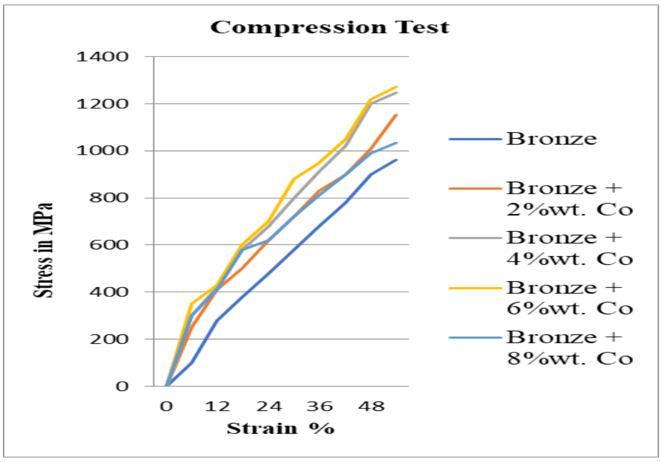


Figure. 5. Compressive stress – strain curves for bronze and its modified compositions

E. Shear Characteristics

Shear stress-strain curves for bronze and altered compositions shown in Fig. 6. Reveal that, with the rise in weight the shear intensity steadily increased reinforcement percentage applied to metal matrix. Compared to the unreinforced bronze alloy shown in Table 3, the highest shear strength was measured at 6% cobalt reinforced bronze based composite. The microstructures of cobalt reinforced bronze-based composites have been shape shift and inter-metallic phase distributions have occurred. The addition of cobalt changes the bronze

structure, it limits the transverse motions between the atoms; thus the composites' shear stability improved.

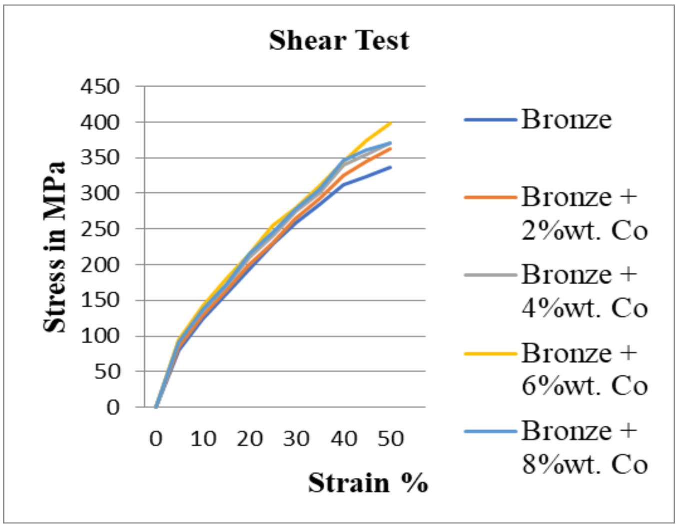


Figure. 6. Shear stress – strain curves for bronze and its modified compositions

IV. CONCLUSIONS

Stir casting was used to create the Bronze – Cobalt reinforced 2 percent, 4 percent, 6 percent and 8 percent particle composites. The mechanical characteristics of the sample were examined and compared to those of base metal. The following are the findings of the investigation.

1. Bronze – Cobalt reinforced particulate composites were successfully fabricated by stir casting technique.
2. The tensile strength of 6wt.% Cobalt reinforced Bronze based composites was found to be maximum.
3. The compressive strength of 6wt.% Cobalt reinforced Bronze based composites was found to be maximum.
4. The shear strength of 6wt.% Cobalt reinforced Bronze based composites was found to be maximum.
5. SEM micrographs showed the distribution of cobalt particles in the bronze matrix was fine.
6. Analysis EDAX revealed the presence of cobalt particles with homogenous dispersion in the bronze matrix.

V. CONFLICT OF INTEREST

The authors declare no conflict of interest

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