PHYSICAL AND MECHANICAL BEHAVIOR OF MARBLE ($CaCO_3$) FILLED C93200 ALLOY COMPOSITES FOR BEARING APPLICATION

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Abstract— In our present study the fabrication of marble ($CaCO_3$) filled copper based alloy C93200 composites is focused with the aid of liquid metal stir casting techniques at different weight percentages (0wt%, 1.5wt%, 3wt%, 4.5 wt% and 6wt% of marble).unreinforced C93200 matrix alloy sample is also prepared to compare with fabricated composites. The microhardness, tension test and 3 point bending test followed by void fraction of fabricated composites are also evaluated and compared with unreinforced C93200 base matrix alloy. During the experiment it is observed that tensile strength, flexural strength and hardness of C93200-Marble composites increases (but the toughness of composites was adversely affected) as weight % of Marble particles increases up to certain limit then decreases. Also it is seen that the void fraction of fabricated composites decreases from 0.785% to 0.497% for 0wt% to 4.5wt% of marble ($CaCO_3$). Similarly the hardness value of marble filled C93200 copper based alloy composites initially increases from 115.49 Hv to 128.97 Hv for 0wt% to 4.5wt% of marble but on further addition of marble particulates (6wt%) the hardness value decreases to 121.51 Hv.

Keywords— Bearing Material**,** C93200, Marble, MMCs, Stir Casting, Mechanical Properties.

I. INTRODUCTION

For the last several decades, there has been conspicuous interest in the fabrication and use of copper based metal matrix composites. However very limited literatures exist on copper based metal matrix composites for bearing applications. The most common materials used for bearing are Brass, Bronze and white metal, in addition to these bearing material aluminium and zinc based alloy are also used as a bearing material. The materials which are used for bearing should have high compressive strength, good fatigue strength, good corrosion resistance, minimum coefficient of friction, minimum thermal expansion, and excellent in thermal conductivity. In addition to these properties bearing materials should also have enough hard. One of the most important property is high strength to weight ratio that should posses the bearing materials and this glamorous property may be achieve by developing the MMCs.

Tin bronze (SnBr) based alloys are generally used for main spindle bearing, machine tool bearing, bearing for cranes, roll neck bearing, roll mill bearing, thrust washer, pump, bushing etc. Generally rolling element bearings are used in high precision machine parts in rotational machine for different area of application [1]. To support the spindle and shaft rolling element bearings are preferred for the conversion of load on an application via rotational motion. Basically rolling element bearings are employed in industries and it generally fails due to malfunction or calamitous failures of machineries which results in machine breakdown [2]. Also rolling element bearings are employed in grinding machine, wind turbine, gear box, gas turbine and lathe machine [3].In many tribological fields Bronze based Cu-Sn has been used because of self lubricating, higher strength and good corrosion resistant properties [5-10]. These types of copper based alloy (Bronzes) have been used in chemical industry, navigation, pivots, spring in electro technology, corrosion resistant gear and crank pivot bearing [10-12]. During fabrication of metal matrix composites the probability of particle segregation, undesirable brittleness phase formation, casting defects, and inconsistent distributions are some common issues. So to overcome these issues powder metallurgy route is preferred [13-15]. According to Gangwar et al. [16] hardness of SiBr composites increases as wt% of CaO increases and void content decreases as wt% of CaO increases up to certain limit. Authors Yih et al. [17] developed the brass metal matrix composites reinforced with silicon carbide whiskers with the aid of powder metallurgy route and they concluded that hardness and compressive yield strength of composites were improved and thermal expansion of composites was reduced as compared to base alloy. Authors Zhou et al. [18] developed the $MgAl_2O_4$ spinel whiskers reinforced Aluminium MMCs with the aid of powder metallurgy techniques and there results showed that hardness of composites was increased as amount of $MgAl_2o_4$ whiskers increases as compared to unreinforced aluminium base alloy.

The main motive of metal matrix composites is to combine the desirable properties of base metal alloy and reinforcing materials. Some common ceramic material like SiC, Al2O3, MgO, Whiskers and fibre have generally used as reinforcement material to enhance the properties of MMCs [19-22]. The major task in developing the metal matrix composites is the insertion of reinforcing particulate or materials into the base alloy. The desired strength of composites is greatly influenced by interfacial bonding strength between matrix alloy and reinforcing particles.

Generally powder metallurgy process have been used to fabricate the MMCs since the many years and reason to prefer powder metallurgy is to minimize the difficulty of wetting ceramic or carbide particle with molten or liquid metal of base matrix alloy [23]. Copper based alloy are most widely used material for bearing application because of excellent in thermal and electrical conductivity, self lubricating property, good corrosion and wear resistance [24, 25].

In this present study the copper based (SnBr) alloy C93200 as matrix material and marble slurry or particles (CaCO3) as a reinforcing material are used to fabricate composites by the process of liquid metal stir casting. Effects of marble (CaCO3) content on mechanical properties of composite like microhardness, tensile strength, 3 point bending test followed by void fraction is investigated

II. MATERIALS AND METHODS

2.1 fabrications of composites

Copper based alloy C93200 which is commonly known as leaded tin bronze was used as matrix materials, chemical composition of C93200 alloy is shown on table 1. The marble (which major constituents are CaCO3, mgO, Silica) powder of size 50 micron is used as reinforcing materials. The total number of samples of composites are five, in which the weight % of marble particles varied from 0% to 6%. The composites are fabricated in a rectangular shape (100 mm length, 65 mm width and 10 mm thickness) by process of liquid metal stir casting. The following steps are used to prepare the composites.

Table 1 Chemical composition of (SnBr) C93200 alloy

Elements	Cu	Sn	Pb	Zn	Ni	Fe
Weight %	84	7.0	6	2	1	0.5

C93200 was melted in an induction furnace at around 1100 °C and preheated marble particles (at around 160°C) were slowly added. To ensure the complete mixing of marble particle a stirring arrangement was there which was operated at constant speed (300 rmp.) for 10 minutes. Then the mixture of base alloy and preheated marble particle were poured into the graphite mould. Then C93200 matrix composites were allowed to cool in air for about 15 minute. Thus five different weigh fractions of marble particulate composites are prepared.

Figure 1: Induction furnace with stirrer arrangement.

Figure 2 Casted Marble filled composites

2.2 Mechanical testing

The micro hardness of fabricated composites and unreinforced matrix alloy is measured by Vickers hardness tester (Innovatest Europe BV) at the load of 100gf for dwell time 5 second. The hardness values of matrix alloy and each fabricated composites were recorded at five equivalent locations. The tensile test and 3 point bending test of unreinforced matrix alloy and each fabricated composites is conducted with the aid of universal testing machine (INSTRON-5967). The samples size for all the test was prepared according to ASTM E8 standard. The tensile test of each sample (25 mm gauge length, 6 mm width, 4 mm thickness, 100 mm overall length) has carried out at strain rate of 10 mm/min at room temperature. 3 point bending test (of sample 100 mm length, 10 mm width and 4mm thickness) has performed and during this test 70mm span length and 1mm/min strain rate were maintained.

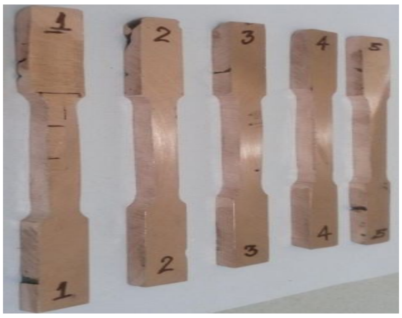

Figure 3 Specimens for Tensile test

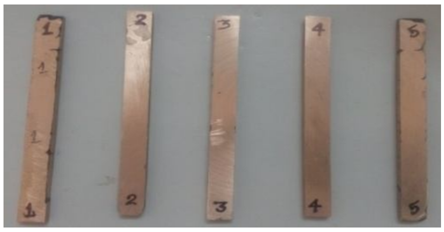

Figure 4 Specimen for 3 point bending test

2.3 void content

The density of C93200 composites has evaluated from formula of rule of mixture [4] and Archimedes method as shown on table 2. From table it is clear that both theoretical and measured densities of C93200 composites are closes to each other but theoretical density (which is obtained by rule of mixture) is slightly greater than measured density. The reason behind this may be due to porosity presents in casted composites [26] and lower density of marble. The theoretical density of C93200 composites is calculated by following formula [27].

$$\rho_{th}=\rho_m v_m+ \rho_{m1} v_{m1} \quad (1)$$

Where ρ_m & ρ_{m1} represents the density of base matrix alloy and density of marble and v_m & v_{m1} represents volume fraction of base matrix alloy and marble respectively.

Void fraction of fabricated composited can be calculate as follows

$$Void\ fraction\ = \frac{\rho_{th}-\rho_{exp}}{\rho_{th}} \quad (2)$$

Table 2 Theoretical and Experimental density

Composition (Weight %)	Theoretical density (g/cm³)	Measured density (g/cm³)	Void fraction
0wt% Marble	8.91	8.84	0.785
1.5wt.% Marble	8.61	8.55	0.696
3wt.% Marble	8.31	8.26	0.601
4.5wt.% Marble	8.04	8.0	0.497
6wt.% Marble	7.75	7.63	1.548

III. RESULT AND DISCUSSION

3.1 Effect of marble ($CaCO_3$) on void content

Theoretically calculated and experimentally measured density of marble filled copper based C93200 Alloy composites are shown in the Table 2 and Figure 5.The void content of these marble filled fabricated composites decreases with increase in marble wt% i.e. void content decreases from 0.785% to 0.497% up to 4.5wt% of marble ($CaCO_3$) but beyond 4.5wt% of marble void content increases to 1.548% for 6wt% of marble. The reason of subsidence in void content may be due to increase in wettability and low density of marble particulate and the increase in void content may be due to improper mixture of filler material i.e. segregation of filler material during the casting process.

3.2 Effect of marble ($CaCO_3$) on hardness.

As weight % of marble particles increases the hardness of C93200 composites also increases. Since the reinforced particles are harder than base alloy it may leads to increasing hardness of composites. It can be observed (from table 3 and figure 6) that when we increased the weight% of marble particles from 0% to 4.5wt% the hardness of composites increases from 115.49 Hv to 128.97 HV. Further when we increase the weight% of marble particle (6wt%) beyond the 4.5wt% hardness value decreases from 128.97 Hv to 120.94 Hv. An increase in the hardness indicates that there is good physical bonding between matrix alloy and reinforced particles interface. As weight% of marble particles increases, there is too much possibility of clustering of marble particles and reduces the surface area of marble particles which results in decreasing hardness value of composites. Thus from above discussion we can conclude that as weight% of marble particles increases the hardness value of each composite also increases as compared to unreinforced base alloy but the maximum hardness value is achieved at 4.5 weight% of marble particles.

3.3 Effect of marble ($CaCO_3$) on Tensile Strength

The variations of tensile strength of marble filled metal matrix composites are shown in the Table 3 and Figure 8. From figure it can be seen that as wt% of marble increases tensile strength of composites also increases. From table 3 also it can be seen that maximum value of tensile strength is 278.99 MPa which is obtained at 4.5wt% of marble. The reason behind this enhancement of tensile strength of composites is the incorporation of hard particulate and when load is applied on the matrix ,the applied load gets transferred to the embedded hard particle which improves the load bearing capacity of fabricated composites. But as we increases the filler (marble) content more than 4.5wt% tensile strength decreases. There may be two reasons for decreasing tensile strength, first one is segregation of particulates and second reason may be increasing brittleness which reduces the ductility of composites.

3.4 Effect of marble ($CaCO_3$) on flexural strength

The test result (from Table 3 and figure 9) shows that, flexural strength of composites increases as weight % of marble particulates increases and maximum value of flexural strength obtained at 4.5 wt% of marble but on further increase in marble weight% flexural strength decreases.

Table 3 Mechanical Properties of composites.

Composition (Weight %)	Hardness (Hv)	Tensile Strength (MPa)	Flexural Strength (MPa)
0 %	115.49	240.71	301.02
1.5%	116.73	245.67	326.60
3%	121.51	259.73	406.03
4.5%	128.97	278.99	413.34
6%	120.94	228.97	402.44

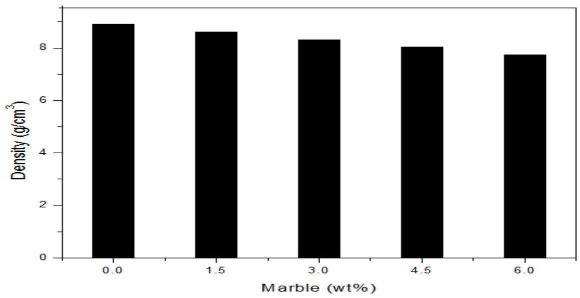

Figure 5 Variation of density with Marble content

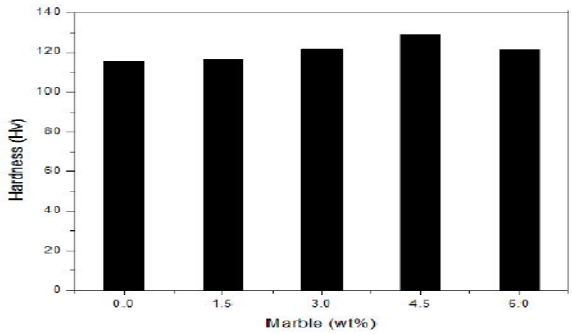

Figure 6 Variation of Hardness with Marble content.

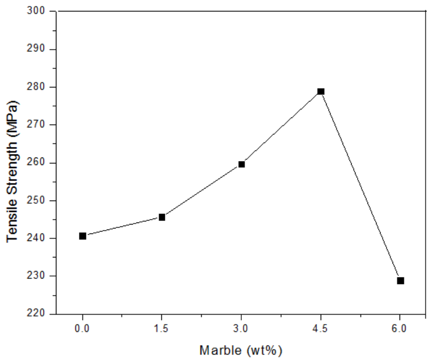

Figure 7 Variation of Tensile strength with Marble content

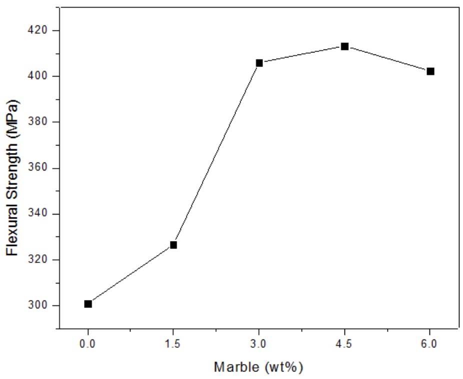

Figure 8 Variation of Flexural strength with Marble content

CONCLUSIONS

Marble ($CaCO_3$) filled copper based C93200 alloy composite has fabricated successfully by using liquid metal stir casting techniques. Voids content, Hardness, tensile strength and flexural strength of fabricated composites has investigated, thus following conclusions are drawn.

1. The void content decreases from 0.785 % to 0.497 % up to 4.5 wt% of marble particle and when wt% of filler increases more than 4.5 % void content increases to 1.54 %.
2. As wt% of marble particle increases hardness of composites also increases and maximum hardness value (128.97 Hv) is recorded at 4.5 wt% of marble particle.
3. Tensile strength of composites increases with increase in marble wt% up to 278.99 MPa and this maximum value of tensile strength recorded at 4.5 wt% filler content.
4. Similarly as filler wt% increases flexural strength of composites also increases up to 413.340 MPa for 4.5 wt% of marble particle.

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