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Fabrication and Effect of Molybdenum disulfide and Boron Carbide filled Copper Metal Matrix Composite

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ABSTRACT

A composite having base metal as pure copper ingrained with Molybdenum disulfide (MoS_2) and Boron Carbide (B_4C) is made by stir casting method. The reinforcements MoS_2 and B_4C were taken in particulate form and having the particle size of 20 microns. Generally, the metal matrix composites are known for their higher strength to weight ratio, lower density good tribological properties etc. In this work, the idea is to figure out the density as well as void content and the toughness of composite by varying the filler ceramics particles in different amounts, the MoS_2 varies from 1 to 3 weight percentage and the B_4C varies from 1.5 to 4.5 weight percentage.

Keywords: Boron Carbide, Density, Molybdenum disulfide, Stir Casting, Toughness.

I. INTRODUCTION

In the past few decades, there has been much interest in copper based metal matrix composites (MMCs) because of its higher electrical and thermal conductivity, but for many applications the pure copper does not fit suitable because of its lower strength. So the improvement in the strength to weight ratio of copper is necessary for widen up its application in industries [1]. The need of suitable material for specified purpose draw our attention towards composites because composites provides a variety of different mechanical, physical as well as chemical properties. Composites have higher strength to weight ratio, good surface properties like hardness, wear resistance, corrosion resistance etc. [2].Although composites are best suited materials for industrial applications but there is a limitation in using the composites and that is cost, the composites are costlier than monolithic material. Cost of composite is a very big challenge among the engineers and that is why we are selecting the cheapest method for MMC production i.e. stir casting technique.In general, the manufacturing processes used for making metal matrix composites are powder metallurgy, squeeze casting, stir casting, spray casting technique etc. among all techniques, Stir casting is ancient but successful technique [3]; it allows the reinforcements to mix uniformly in molten metal. Uniform mixing and good bonding between matrix and reinforcement will certainly result in better mechanical properties [4].

MoS_2 is a solid lubricant and it has good ability to make a self-lubricating composite however the B_4C is the third known hardest material after diamond and cubic boron nitride (CBN) [5] so the proposed composite can be used in those applications where self-lubricating, scratch resistance, higher thermal and electrical conductivity is needed i.e. it can be used in the electrical appliances in which variable resistance is required like rheostat, current regulators etc. This paper is the result of investigation of MoS_2 and B_4C micro particles (20μm) filled copper metal matrix composite for density and toughness. Density is directly related to the degree of compactness of atoms, and toughness is the ability of material to withstand against the shock/impact load in other words it is the measurement of degree of brittleness. More brittle material will have the less ability to store the shock energy and vice-versa [6].

II. COMPOSITE FABRICATION

Preparation of composites were done by "Stir Casting" technique. Stir casting is a liquid state composite fabrication technique[7], in which pure copper, Molybdenum disulfide (20-micron particle size) and Boron Carbide (20-micron particle size) were taken as raw materials. In this fabrication technique the small pieces of pure copper were placed into a crucible made of graphite and then an automatic temperature controlled electric furnace was used to melt the copper, the melting temperature of copper is 1085 ^{o} C. After melting copper, the reinforcement particles were added to the melt (as given below in table-1) and a motor equipped stirrer of graphite was used for stirring, the stirring was done at 100-200 rpm for 10 minutes, and then the melted slurry was poured into a mould cavity. After solidifying the composite taken out from the cavity.

Table 1: Composition of Composite

Composite designation	Pure Copper wt.%	B_4C wt.%	MoS_2 wt.%	Combined wt.% of filler
CBMo – 0	100	0	0	0
CBMo – 1	97.5	1	1.5	2.5
CBMo – 2	95.0	2	3	5
CBMo – 3	92.5	3	4.5	7.5

III. RESULT AND DISCUSSION

3.1 Density and void content: Archimedes' principle was used for determination of the density of composite experimentally, and the rule of mixture was used for obtaining the theoretical density [8].

$$Theoretical\ Density = \frac{1}{\sum \frac{wt\ (r)}{\rho\ (r)} + \frac{wt\ (m)}{\rho\ (m)}} \quad \dots\dots\dots\dots (1)$$

$$Void\ Content = \frac{Theoretical\ Density - Experimental\ Density}{Theoretical\ density} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where, wt (r) = Weight percent of reinforcement,

ρ (r) = Density of reinforcement,

wt (m) = Weight percent of matrix,

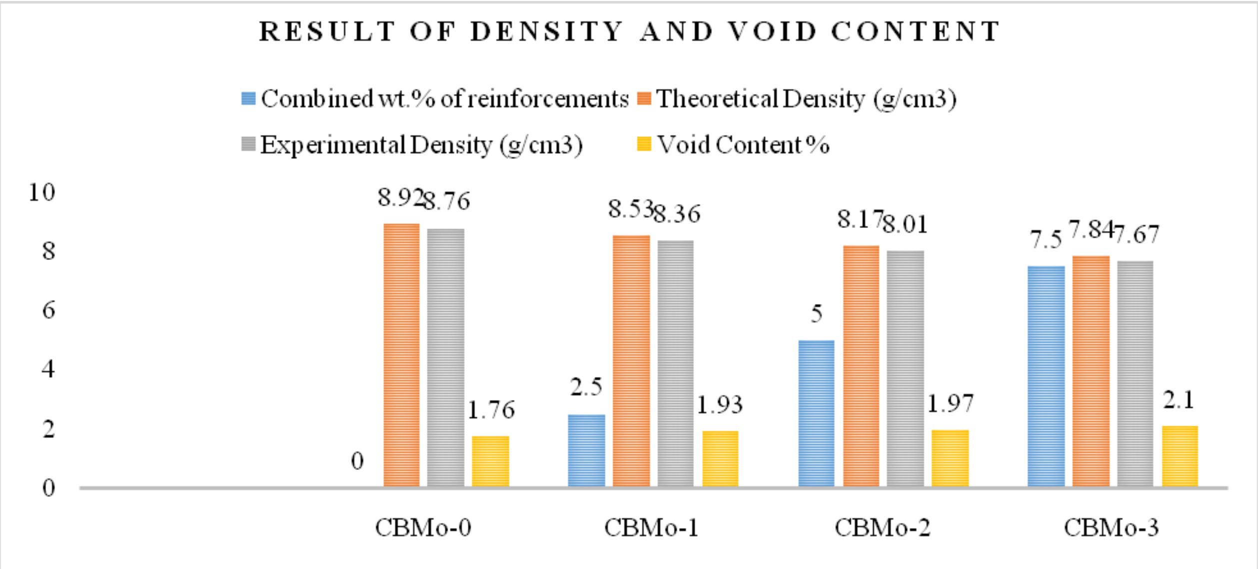
ρ (m) = Density of matrix

To determine the density experimentally, firstly the mass of the sample was observed on electronic balance machine and then the sample was dipped into a measuring cylinder filled with water, the raise in the level of water will be equal to the volume of dipped sample [8]. Thus the experimental density was found by formula:

$$Experimental\ density = \frac{Mass\ of\ the\ Sample}{Volume\ of\ the\ Sample} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Table 2: Result of density and void content

Composite Designation	Combined wt.% of reinforcements	Theoretical Density (g/cm^3)	Experimental Density (g/cm^3)	Void Content %
CBMo-0	0.0	8.92	8.76	1.76
CBMo-1	2.5	8.53	8.36	1.93
CBMo-2	5.0	8.17	8.01	1.97
CBMo-3	7.5	7.84	7.67	2.10

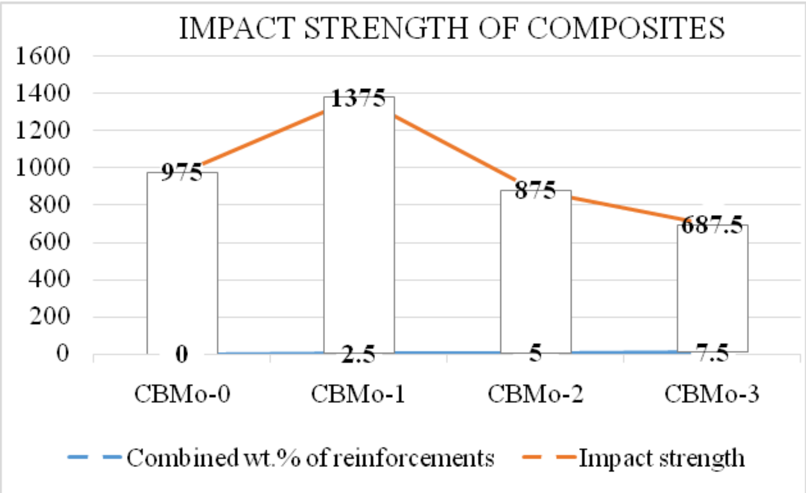


Composite Designation	Combined wt.% of reinforcements	Impact strength (K-Joule/m^2)
CBMo-0	0.0	975.0
CBMo-1	2.5	1375.0
CBMo-2	5.0	875.0
CBMo-3	7.5	687.5

The above result shows that on increasing the amount of reinforcement the density decreases continuously as well as the void content increases.

3.2 Toughness Test:

Table 3: Impact Strength of composites



Under the condition of impact load, the maximum amount of energy absorbed by the material is known as toughness. The toughness test of composite was carried out by Charpy impact test. In Charpy impact test the sample of 55x10x10 mm^3dimension was placed as simply supported. A V-shaped notch of 45^o was made in the middle of the sample. A pendulum hammer was used to strike the sample in opposite direction of notch, and the sample breaks and the hammer still swing. The difference between maximum potential energy of pendulum before strike and maximum potential energy after strike is known as rupture energy [9].

The toughness test result is showing that rupture energy for CBMo-1 (2.5%) is highest among all four compositions of composite and after 2.5% reinforcement the toughness value started decreasing. So in future we should not mix the reinforcement (MoS_2+B_4C) more than 2.5% into copper.

IV. CONCLUSION

The experiment investigated on B_4C and MoS_2 particulate filled metal matrix composites has led to the following conclusions:

(1) Copper based metal matrix composite reinforced with boron carbide and molybdenum disulfide was successfully fabricated through stir casting technique

(2) Density of composite material decreases with the addition of the reinforcements. The values of Experimental density and theoretical density are close to each other. Hence void content is not much higher that means casting of composite material is fairly good.

(3) Impact strength of composite increases rapidly when boron carbide and molybdenum disulfide particulate increase up to 2.5% but after that the impact strength started decreasing.

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