THE EFFECT OF PARTICLE HYBRIDIZATION ON MICRO STRUCTURE ANALYSIS AND MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES: AN EXPERIMENTAL APPROACH

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Mechanical and physical performance of alumina and boron carbide particulate filled reinforcement with Al7075 matrix prepared by stir casting techniques were investigated experimentally. The composite comprises of the base matrix Al7075 with various concentration of two particle reinforcements named alumina (Al_2O_3) and boron carbide (B_4C). In that one of the particle reinforcement alumina has various altitude of 2,4,6,8 and 10 wt% and other one boron carbide has 5 wt% kept as constant for all specimens. The specimens were prepared by stir casting techniques to preserve the perfect dispersion of particulate reinforcement in final fabricated composites.The influence of alumina and boron carbide particulate in final composites were analyzed by examining the mechanical properties such as tensile behavior and hardness of composites. To study the micro structure and dispersion of particle reinforcements, the alumina and boron carbide particulate dispersion was evidently exposed by scanning electronmicroscopy (SEM) techniques and XRD techniques. The result shows addition of particulates directly increases the hardness and density of composites. In the same way result exposes mechanical behavior of tensile property also increased with addition of filler reinforcements.

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1. Introduction

Metal Matrix Composites (MMC) has acknowledged increasing attention at present era researchers, because of their favorable mechanical and physical properties over monolithic metals. In that aluminium matrix composite plays a vital role in all over automobile and aerospace applications. The challenges and opportunities of aluminium matrix composites are viable for further processing in various applications [1]. The MMC briefly summarized for continuous fiber, discontinuous fiber and particle reinforced fiber for a different automobile, military, aerospace and sports applications [2].The suitability of MMC and their technical issues like material design and development methodologies, characterization and control of interfacial properties are clearly studied for developing second generation of MMC [3]. Various attempts has been made to review the different combination of reinforcing materials used in the processing of hybrid aluminium matrix composites and how it affects the mechanical, corrosion and wear performance of the materials [4,5]. The reinforcement of short fiber and particle in aluminium matrix composites has made strong interfacial bonding so that the wear properties and fracture toughness were influenced in positive manner [6].The most commonly used reinforcements are Sic, B_4C, Al_2O_3, WC,

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graphite, fly ash, mica, talc, coconut shell . Hybrid metal matrix composites are current generation composites where more than one reinforcement of different shape and size are used to attain improved properties [7, 9].

In general, manufacture of composites are classified into two broad categories namely solid phase and liquid phase fabrication methods. From all the processing routes, liquid metallurgy method is the most sought due to its several advantages such as cost-effective, mass production, near net shaped components can be produced. It is found that the stir cast method offers better matrix particle binding due to stirring action of particles into the melts. In part of that the stir casting techniques was evaluated for silicon carbide aluminium matrix MMC [8]. It was reported that by controlling the processing variables such as holding temperature, stirring speed, size of the impeller and the amount of reinforcement, it is possible to manufacture a composite by stir casting with a broad range of mechanical properties. The researchers revealed that uniform distribution of reinforcements was observed in the stir cast composites [10-13]. The addition of Particulates like silicon carbide, boron carbide, aluminium oxide to aluminum alloy significantly improves the density, micro hardness, thermal stability, tensile strength, and wear of the base alloy. In the same way increase of particulates decreases the impact toughness of the composites. In addition to that the microstructural analysis has employed to evince the existence of particle reinforcements and its influences in results. The SEM micrograph noticeably depicts the uniform distribution of reinforcements and also elucidate the homogeneity of cast composites[14-16].

Moreover this present work makes an attempt to analyse the influence of alumina and boron carbide particulate in base Al7075 matrix composites by examining the mechanical properties like tensile behavior and hardness of composites. The reinforcement used was alumina and boron carbide with different volume of fractions. Micro structure and dispersion of particle reinforcements is evidently exposed by scanning electron microscopy (SEM), the XRD techniques was used to ensure the presence of chemical compositions of base matrix and particle reinforcements.

2. Material and methods

Materials

The metal matrix chosen for the current investigation is AL7075 which was purchased from Perfect metal works, Bangalore. The chemical composition for the alloy is show in table 1. alumina and boron carbide particulates are used to fabricate the composite with an average particle size of 37 microns which were supplied by Speed fam Chennai.

Table 1. Chemical Composition of Al 7075 in weight percentage

Chemical Composition	Si	Fe	Cu	Mn	Mg
% of comp	0.4	0.5	1.6	0.3	2.5
Chemical Composition	Cr	Zn	Ti	Al	-
% of comp	0.15	5.5	0.2	Bal	-

Material fabrication:

In the present study, the base matrix Al 7075 was reinforced with 2,4,6,8 and 10 wt% AL_2O_3 and 5% of B_4C about average particle size of 37 μm. The actual chemical composition of Al 7075 alloy is given in table 1. In order to increase the wettability magnesium of 2.52% [9] in weight was added during production of the hybrid composites

Preparation of hybrid composites

A liquid metallurgy route has been adopted to prepare the hybrid composites. In this technique, the calculated amount of AL7075 was melted in an open electrical resistance furnace at a temperature of about 700°c. The temperature of the furnace was maintained at an accuracy of ±50°c using a digital thermo couple. Degassing process was carried out to force out all the absorbed gases and to reduce the porosity. The ceramic particles are preheated in a muffle furnace to around 1000°C for 2 hours for oxidizing the surfaces. To obtain homogeneous distribution of reinforcement in the composites proper stirring is mandatory. The base metal was stirred with the assistance of a mechanical stirrer with a speed of about 525 rpm to form a fine vortex for 10 minutes. Magnesium of about 2.52 wt % was also added to enhance the wettability property of the composites. The pre heated reinforcements and magnesium were added at a constant feed rate into vortex formed in the melt. For the proper mixage of the reinforcement the Stirring was continued for about 10min even after the completion of reinforcement addition. The stir casting setup is shown in Fig. 1

Fig.1Stir Casting Setup

The melt with reinforcement particles was poured into a cylindrical permanent metallic mold with a diameter of 15 mm and 120 mm length. The manufactured composite was allowed to solidify in atmospheric air and was taken out from the mould after solidification. The same procedure was used to manufacture with different weight percentage (2, 4, 6, 8 and 10 wt. %) of alumina and 5 wt % of boron carbide powder. For the comparison study purpose, unreinforced aluminium alloy was also cast under similar cast conditions

Density measurement

Density measurements were carried out on the base alloy and particulate reinforced samples using the Archimedes principle. Mass of the specimen was determined by measuring the weight of the specimen using an electronic weighing machine having accuracy up to 0.001 mg. The density was measured by weighing the composites in air and in another liquid of known density. According to Archimedes principle the density can be measured using the Eqn.1

$$\rho_{mmc} = \frac{m}{m - m_1} \rho_w \tag{1}$$

Where

m is the mass of the cast composite in air

m_1 is the mass of the same composite sample in distilled water

ρ_w is the density of the distilled water (998 kg/m^3 at 20°c)

Hardness test

The hardness tests were carried out to find the effect reinforcements in the base alloy. A Brinell hardness tester (AKB-3000(M)) was employed to determine the values as per ASTM E10-07 standards. A load of 500 kg was applied on the specimen with a 10mm steel ball indenter for 30 seconds at room temperature. An optical microscope was deployed to measure the indentation diameter. The hardness was calculated using the Eqn.2.The hardness was measured at five different places of the specimen and mean value was calculated

$$BHN = \frac{2P}{\pi D(D - \sqrt{(D^2 - d^2)})} \tag{2}$$

Where

P is the applied force in N
D is the diameter of indenter in mm
d is the diameter of indentation mm

Tensile test:

The Aluminium alloy and the particulate reinforced composites were machined and subjected to micro tensile test as per the ASTM E8 standard shown in Fig. 2.

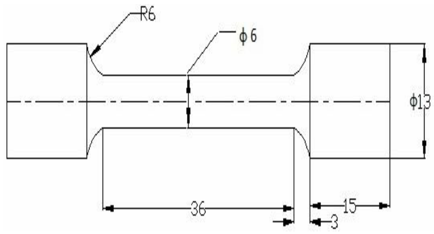

Fig.2Tensile specimen size

A universal testing machine loaded with 20kN was used to conduct the experiment. The test was repeated thrice for each melt. The mean values obtained were considered to calculate the tensile strength of the composites.

Micro structural Analysis

The microstructure of the hybrid composites was examined using a scanning electron microscope (JSM-6360). The specimens for microstructure test were polished metallographically. The Polished surface of the specimen was then etched with 10% of NaOH Solution and examined for the uniformity in distribution of reinforcements in aluminium hybrid composites. The XRD technique was used to evidently ensure the presence of base matrix and its particle reinforcement dispersion.

3.Result and discussions

Microstrucutrual characterization

An analysis for the distribution of alumina and boron carbide particles reinforced with aluminium matrix composites was done after completion of fabrication. It is visibly shown that the dispersion of the boron carbide and alumina reinforcements and particles are embedded inside the base aluminium matrix. The Fig.3 shows the SEM micrograph of the hybrid composites, as it can be seen that distribution of the alumina and boron carbide median size of the particles in the aluminum matrix are uniformly distributed over the fabricated composites.

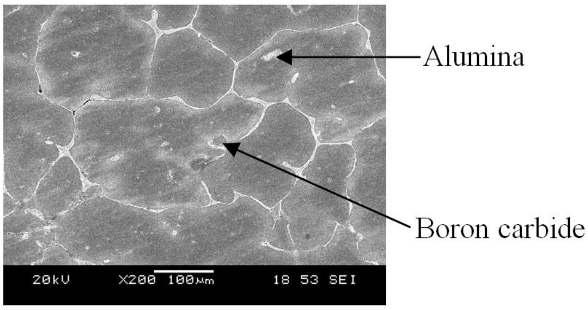

Fig 3 SEM image of hybrid composite

In general the strength and stiffness of the composites based on their reinforcement inter locking with base matrix of the composites. However, the testing of chemical composition is also one of the guaranteed techniques to ensure the homogeneous dispersion of reinforcements and matrix. For that the XRD techniques was carried to show cast the various chemical composition present in composites, Fig.4 shows the presence of aluminium, boron carbide and alumina.

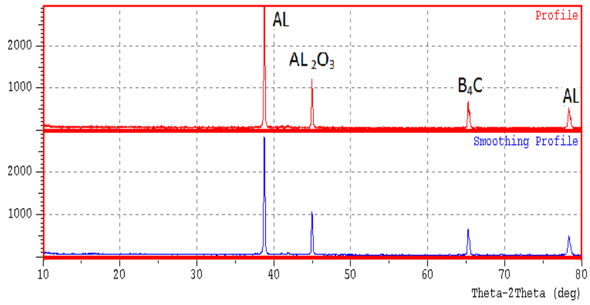

Fig 4. XRD Analysis of the hybrid composites

In that the dispersion of reinforcements plays vital role to decide the strength and stiffness of the composites. The Fig.3 SEM micrograph provides a clear schematic view about the perfect dispersion of reinforcements.

Density Measurements

The density of composites was influenced by the addition volume fraction of reinforcement particles. The theoretical and experimental density value of fabricated composites are shown in table 2.The comparison of theoretical and experimental density obtained by Archimedes principle is shown in Fig 5. From the results it is evident that the density of hybrid composites is higher than the base material. The density increases with the addition of the reinforcements.

Table 2 Theoretical and Experimental density of composites

Sample.No.	Samples	Theoretical Density(g/cc)	Experimental density(g/cc)
01	Base alloy	2.81	2.79
02	2% Al_2O_3 , 5% B_4C	2.82	2.81
03	4% Al_2O_3 , 5% B_4C	2.84	2.83
04	6% Al_2O_3 , 5% B_4C	2.86	2.84
05	8% Al_2O_3 , 5% B_4C	2.88	2.86
06	10%Al_2O_3 , 5%B_4C	2.91	2.88

The figure 5 shows the theoretical and experimental density of various samples. It is clear that the density of composites increased by increasing the volume fraction of reinforcements, also it can be concluded that the reinforcement particles not melted with base aluminium matrix.

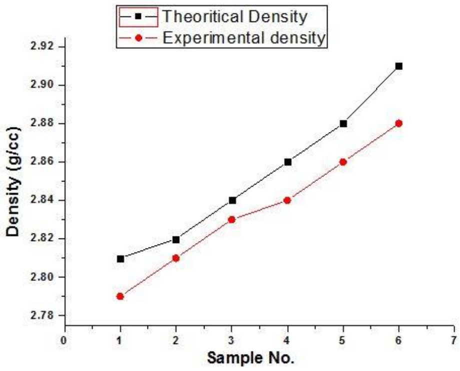

Fig. 5 Theoretical and Experimental density values of composites

Hardness Measurements

The hardness of the fabricated composites was influenced by the variation of particle reinforcements. From the Brinell hardness test it was evident that the hardness of the composite is greater than that of its cast matrix alloy. Due to the increase of ceramic phase in the hybrid composites the hardness value increases linearly with the increase in volume fraction of particle reinforcements. The addition of alumina and boron carbide particulates in matrix has improved the hardness by acting as a barrier for the motion of dislocation of the matrix lattice. The table 3 and Fig. 6 evidently expose the improvement of hardness of fabricated composites.

Table 3 Hardness values of composites

Sample. No	Samples	Hardness value(BHN)
01	Base alloy	65
02	2% Al_2O_3 , 5% B_4C	82
03	4% Al_2O_3 , 5% B_4C	98
04	6% Al_2O_3 , 5% B_4C	112
05	8% Al_2O_3 , 5% B_4C	125
06	10% Al_2O_3 , 5% B_4C	137

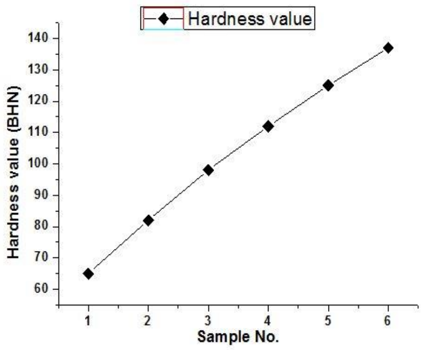

Fig. 6 Brinell values of hybrid composites

Tensile Strength

Variation in ultimate tensile strength of hybrid metal matrix composites reinforced with alumina and boron carbide of different volume of fractions is shown in table 4. The Ultimate Tensile strength was increased with an increase of alumina particulates in the composites. This may be credited to the reality that addition of Alumina and boron carbide leads to an increase in tensile strength and decrease in ductility. The particle reinforcement used in this aluminium matrix notifies that the binding ability between matrix and reinforcement highly increased with adding of particles. It was Evident from Fig7 that the tensile strength value keeps on increasing with addition of particle reinforcement.

Table 4Tensile strength values of composites

Sample. No	Samples	Tensile Strength(Mpa)
01	Base alloy	198
02	2% Al_2O_3 , 5% B_4C	230
03	4% Al_2O_3 , 5% B_4C	248
04	6% Al_2O_3 , 5% B_4C	265
05	8% Al_2O_3 , 5% B_4C	287
06	10% Al_2O_3 , 5% B_4C	305

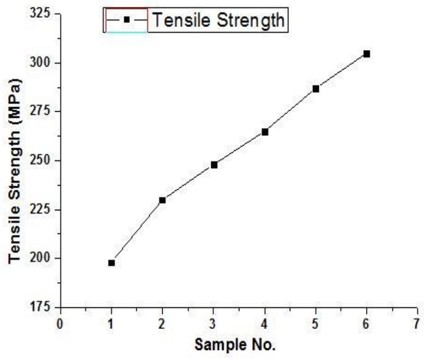

Fig. 6 Tensile strength values of hybrid composites

In this part of work increasing tensile properties of composites was increased with the particle reinforcements, it is clear that binding ability between base matrix and particle reinforcements was good in nature. Also the particle reinforcements of alumina and boron carbides are predominantly plays a vital role to transfer the stress induced in the composites.

4. Conclusions

The major conclusions of the current investigations are summarised below.

a) The liquid metallurgy route was found to be suitable method to fabricate the aluminium hybrid composites matrix composites.

b) The micro-structural studies of SEM and XRD techniques revealed the homogeneous distribution of the particulates in the hybrid composites

c) The density of the composites are found to be increased than the base alloy

d) Weight percentage of reinforcements showed a direct relation with hardness, tensile strength. Increase in addition of alumina and boron carbide restricts the deformation of the aluminium alloy, resulting in increased hardness, tensile strength

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