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Studies on Al8081-B_4C Metal Matrix Composites Fabricated by Stir Casting Method

Kumar Lingaraj Patil[1], Mousil Ali[2], Madeva Nagaral[3]
[1]PG Student, Gousia College of Engineering, Ramanagar-562159
[2]Department of Mechanical Engineering, Gousia College of Engineering, Ramanagar-562159
[3]Design Engineer, ARDC, HAL-Bangalore-560037

Abstract: *Aluminium MMCs are preferred in the fields of aerospace, military, automotive, marine and in many other domestic applications. In the present work, an attempt has been made to develop and study the, Mechanical properties of Al-8081/B_4C reinforced aluminium metal matrix composites. The composite was prepared by using Liquid Metallurgy Route (Stir Casting Technique). Liquid state has some important advantages such as better matrix particle bonding, easier control of matrix structure, simplicity, low cost of processing, nearer to net shape and wide selection of material. Al-8081 alloy was taken as the base matrix to which B_4C particulates are used as reinforcements. Al8081-B_4C composites were prepared by varying weight percentage of B4C i.e 0 to 6 %, in steps of two. The objective is to study the effect of B_4C particulates on mechanical properties such as ultimate tensile strength, yield strength and hardness of Al8081 alloy composites. The results of this study revealed that, as the B_4C content was increased, there were significant increases in the ultimate tensile strength, yield strength and hardness in the composites as compared to the base matrix.*

Key words: *Al-8081Alloy, B_4C, Stir Casting, Mechanical Properties, Metal Matrix Composites.*

I. Introduction

A composite material is a 'material system' composed of a combination of two or more micro or macro constituents that differ in form, chemical composition and which are essentially insoluble in each other. One constituent is called as Matrix Phase and the other is called reinforcing phase. Reinforcing phase is embedded in the matrix to give the desired characteristic [1].

Metal Matrix Composites (MMCs) have emerged as an important class of materials and are increasingly utilized in various engineering applications, such as aerospace, marine, automobile and turbine compressor engineering, which require materials offering a combination of light weight with considerably accelerated mechanical and physical properties such as strength, toughness, stiffness and resistance to high temperature [2-4].

Particle reinforced metal matrix composite represent a group of materials where the hardness, resistance of the reinforcements is combined with the ductility and toughness of matrix materials [5]. Aluminium is the most frequently use matrix material due to its low density. Because of its extreme hardness and temperature resistant properties, SiC, Al_2O_3 ceramic particles are often used as reinforcement within the aluminium matrix. This type of composite is more frequently used in the automotive industry today, particularly in various engine components as well as brakes and rotors [6-7].

The combined attributes of metal matrix composites, together with the costs of fabrication, vary widely with the nature of the material, the processing quality of the product. In engineering, the type of composite used and its application vary significantly, as do the attributes that drive the choice of metal matrix composites in design. For example, high specific modulus, low cost, and high weld ability of extruded aluminium oxide particle-reinforced aluminium are the properties desirable for bicycle frames. High wear resistance, low weight, low cost, improved high temperature properties, and the possibility for incorporation in a large part of unreinforced aluminium are the considerations for design engine pistons [8-9].

Many researchers exploited the different reinforcement particles with different form to fabricate the aluminum composites and used different fabrication routes to achieve required properties. B_4C are the suitable reinforcement materials to improve tribological properties of a matrix material [10].

As revealed in the so far performed research, the particulate B_4C increases wear resistance and also contribute to improvement of mechanical properties, also at elevated temperatures. The presence of B_4C could effectively prevent the matrix deformation, to carry the load and lock the micro cracks that often develop along the friction direction.

Investigation of mechanical behaviour of aluminium alloys reinforced by micro hard particles such as B_4C is an interesting area of research. Therefore, the aim of this study is to investigate the effect of B_4C content on the hardness and tensile strength behaviour of Al8081 – B_4C composites, made by stir casting method.

II. Experimental Details

2.1 Materials

Metal matrix composites containing 2, 4 and 6 weight percentages of B_4C particles were produced by liquid metallurgy route. For the production of MMCs, an Al8081 alloy was used as the matrix material while B_4C particles with an average size of 80-90µm were used as the reinforcements. Al8081 alloy having chemical composition as per the ASTM ingot specification is given in Table 1 [11].

Table 1: Chemical composition of Al8081 alloy

Si	Fe	Sn	Cu	Mn	Zn	Al
0.7	0.7	18-22	0.7-1.3	0.1	0.05	Bal

2.2 Preparation of composites

In stir casting method before the casting reinforcements, stirrer, permanent mould preheated to 300^{o}C to remove moisture and gases from the surface of the reinforcements, and equipments before casting. Now the required amount of Al8081 is weighed and placed in the graphite crucible and heated to 730^{o}C using resistance furnace then the degassing tablet is added to minimize the coating film defects by expelling the volatile components present in the melt during casting. The tablet helps in the removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. Then the matrix Al8081 is reinforced with B_4C particulates with different weight percentages (2, 4&6). The micro particle of $B_4C$was added at the temperature of 710^{o}C and a constant rigorous stirring was done for 15mins until a clear vortex is formed.

Before the addition of reinforcements the cover flux and magnesium were added to decrease the surface tension and viscosity of the melt. At the pouring temperature of 710^{0}C the molten mixture was poured into the cast iron mould and allowed to solidify for few minutes.

2.3 Testing of Composites

All tests were conducted in accordance with ASTM standards. Tensile tests were conducted at room temperature using a universal testing machine (UTM) in accordance with ASTM standard E8-M82. The tensile test specimens of diameter 9mm and gauge length 45mm were machined from the cast composites with the gauge length of the specimens parallel to the longitudinal axis of the castings. For each composite, three tensile test specimens were tested and the average values of the ultimate tensile strength and yield strength were measured. The Micro-Vickers hardness values of the samples were measured on the polished samples using diamond cone indentor with a load of 100gms and 10 seconds as a holding time. Hardness value reported is the average value of 100 readings taken at different locations on the polished specimen. For tensile results, test was repeated three times to obtain a precise average value.

III. Results And Discussions

3.1 Hardness Measurement

The Vickers micro-hardness of cast Al8081 and Al8081- B_4C composites are evaluated using diamond indenter at an applied load of 100grms at 50X optical zoom with dwell time 10 secs for each sample at different locations. The plot of Vickers Hardness Number (VHN) with a variation in B_4C wt percentages in metal matrix composite has been presented in figure 1 and Table 2. The measured mean values of VHN were plotted as a function of weight percentage of B_4C. From the study it can be observed that as the reinforcement content was increased, there was an increase in the hardness. The increase in the hardness is probably attributed to the fact that the hard B4C particulates acts as barrier to the movement of the dislocations within the matrix. Various other researchers have also reported that the addition of hard ceramic particulates to metal alloys could lead to improved strength, wear resistance and hardness. A similar effect was observed by Serajul et al. [12] for SiC reinforced aluminium alloy MMCs. They found that the hardness linearly increases with increasing volume percentage of SiC. Boron Carbide, being hard exhibit a greater resistance to indentation by the hardness tester and hence enhanced hardness.

Table 2: Micro-Hardness Test Results of Different Composition.

SL NO	Composition Material	Mean Micro Hardness No (VHN)
1	Al8081 Alloy	64.1
2	Al8081- 2 wt% B_4C	76.4
3	Al8081- 4 wt% B_4C	89.6
4	Al8081- 6 wt% B_4C	108.3

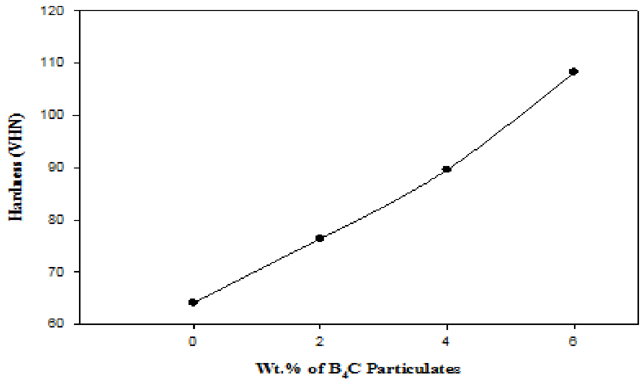

Figure 1: Micro-Hardness Test Results for Different Composition.

3.2 Evaluation of Tensile Strength

The graph of Ultimate Tensile Strength (UTS) and yield strength with a variation of B4C in metal matrix composite has been presented in figure 2 and 3 respectively. The measured mean values of UTS and yield strength were plotted as a function of weight percentage of B_4C particulates. From the study it can be observed that within the scope of this investigation as the B_4C content was increased, there was an increase in the UTS and yield strength. The increase in ultimate tensile strength is attributed to the presence of hard B4C particles, which imparts strength to the matrix alloy, thereby providing enhanced tensile strength.

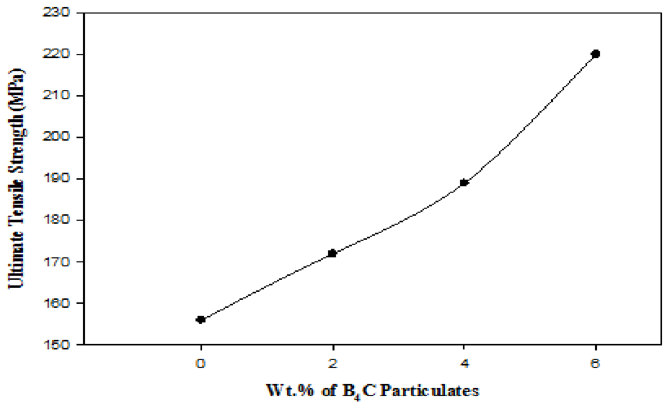

Figure 2: Tensile Test Results of Different Specimens

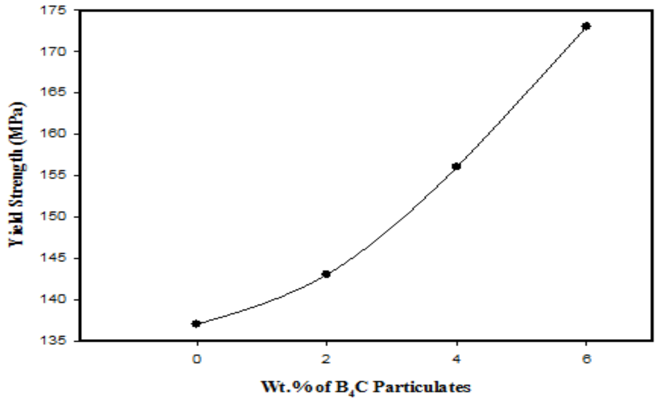

Figure 3: Tensile Test Results of Different Specimens

IV. Conclusions

The present work on processing of Al8081 reinforced with 2, 4 and 6wt% of B4C particulate composite via melt stirring method has lead to the following conclusions.

1. Al8081 alloy reinforced with B4C particulate composites were successfully produced by melt stirring method.
2. The addition of B4C particulate to the Al8081 alloy has led to improved hardness when compared to the matrix alone.
3. The addition of B4C reinforcement to the Al matrix has improved mechanical properties like ultimate tensile strength and yield strength. The extent of improvements obtained in Yield Stress and Ultimate Tensile Stress were respectively.

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