International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
National Conference on Advances in Engineering and Technology
(AET- 29th March 2014)

RESEARCH ARTICLE OPEN ACCESS

Comparative Investigation of Mechanical Properties of Aluminium Based Hybrid Metal Matrix Composites

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ABSTRACT
Aluminium alloys are widely used in automobile industries and aerospace applications due to their great mechanical properties, low density, low coefficient of thermal expansion, better corrosion resistance and wear as compared with conventional metals and alloys. The low production cost and better mechanical properties of composites makes them very useful for various applications in many areas from technological point of view. The aim involved in designing aluminium based metal matrix composite by combining different percentage of particulates in the mixture. Present study is focused on the fabrication of two aluminium 6063 based metal matrix composites. One reinforced with silicon carbide, graphite and second reinforced with silicon carbide, boron carbide by stir casting technique. The percentage of each reinforcement particulate is kept 10% in two composites. The various mechanical tests like tensile strength test, ultimate tensile strength test, flexural test & hardness test performed on the samples obtained by stir casting technique for comparison purpose. The result indicated that the developed method is quite successful and there is an increase in the value of tensile strength, ultimate tensile strength, hardness value and flexural strength of newly developed composite having SiC and B4C particulates in comparison to the SiC, graphite reinforced composite.

***Keywords* -** Aluminium 6063, SiC, B_4C, Graphite, Metal matrix composite, stir casting.

I. INTRODUCTION

The challenge and demand for developing metal matrix composites for use in high performance structural and functional applications including aerospace industries, automobile sector, defence etc. have significantly increased in the recent times [1]. The need to develop new materials with combinations of low density, improved stiffness and high strength in order to overcome the limitations of existing high-strength aluminum alloys and titanium alloys improved the design procedures and has resulted to achieve improvements in overall efficiency, reliability and performance by reducing either absolute weight or increases in strength-to-weight ratio. For this purpose the materials of high ultimate tensile strength, high stiffness, yield strength and low density is required.

Metal-matrix composites consist of at least two components. Among two components one is matrix phase usually a continuous phase like aluminium, magnesium & second component is discontinuous phase like fibers, whiskers or particles called reinforcement. The objective of developing metal matrix composite materials is to combine the desirable properties of metal and particulates. The matrix holds the reinforcement to form the desired shape & reinforcement improves most of the mechanical properties of composite. Aluminium metal matrix composites are preferred over other materials due to its properties like greater strength, improved stiffness, reduced density, improved temperature properties, controlled thermal expansion and improved wear resistance.

Based on the literature survey it has been observed that the application scope for aluminium based metal matrix composite is expanding. For the fabrication of AMCs on an industrial scale the technique used can be either solid state processing or liquid state processing. The liquid state processing technique especially stir casting is a promising method for the production of AMCs because of their simplicity and ease of manufacture [5]. The aim involving of this study are the fabrication of two hybrid composites and then investigating the comparative mechanical properties like tensile strength, ultimate tensile strength, hardness, flexural strength. Some of the authors have carried out the research work on different composites and their mechanical properties.

An experiment to investigate the mechanical behavior of aluminium 6063 reinforced with Al_2O_3 alumina fabricated by stir casting method is performed [3]. The reinforcement volume percentage was taken as 0%, 6%, 9%, 15% and 18% in the metal matrix composites. The results revealed that the mechanical properties like tensile strength, yield strength, hardness values of composites increased with increase in alumina volume percentage while the fracture toughness was found to be decreased. Further the porosity level less than 3.6% was found in AL6063/Al_2O_3 metal matrix composites.

In [4], authors fabricate the aluminium based metal matrix composite by stir casting technique & further investigated the mechanical properties of composites. In this experiment aluminium 6063 was taken as base metal & aluminium oxide Al_2O_3 as reinforcement. The results showed that aluminium composite was superior to the base alloy AL6063. Further with increase in weight percentage of reinforcement particles in composite the mechanical properties like tensile strength, impact strength, hardness & yield strength improved and elongation decreased which confirms that alumina addition increases brittleness. A fairly distribution of reinforcement particles were found in the composite.

In [2], authors performed an experiment for the fabrication of aluminium-boron carbide metal matrix composite with stir casting technique & further investigated the mechanical properties. In this experiment aluminium LM6 alloy was taken as base metal & different percentage (0%, 2.5%, 5%, and 7.5%) of boron carbide as reinforcement. The results revealed that with increase in weight percentage of reinforcement particles in MMC, the ultimate compressive strength, hardness increased and density decreased.The scanning electron microscopy indicated the uniform distribution of reinforcement particles in the metal matrix composites.

II. MATERIALS USED

2.1 Metal Matrix Material: In the present experimental investigation the matrix material used is an aluminium alloy (6063) whose chemical composition (in weight %) is listed in Table 1. Al6063 is precipitation hardening aluminium alloy, containing Magnesium and Si as its major alloying elements. It has good mechanical properties. The melting point of aluminium 6063 is low (710°C).

Table 1: Chemical composition of AL 6063 Alloy

Constituents	%age
Si	0.45
Fe	0.22
Cu	0.02
Mn	0.03
Mg	0.50
Zn	0.02
Cr	0.03
Ti	0.02
Balance	Al

2.2 Reinforcement Material: The role of the reinforcement in a composite material is fundamentally to increase the mechanical properties of composite. The reinforcements used in the experimental investigation are:

Silicon Carbide: It is originally produced by a high temperature electro-chemical reaction of sand and carbon. The property of Silicon Carbide includes good mechanical properties with low density, high temperature strength and thermal shock resistance, highly wear resistant. Silicon carbide is a compound of silicon and carbon with chemical formula SiC. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products. Today the material has been developed into a high quality technical grade ceramics. It is used in abrasives, refractories, ceramics, and other high-performance applications

Boron Carbide: The boron carbide is one of the hardest material [8]. It is produced by reacting carbon with B_2O_3 in an electric arc furnace. For commercial use the boron carbide powers are milled and then purified to remove the metallic impurities. The density of B_4C is 2.52 g/cm^3, melting point is very high up to 2445^{o}C and hardness is 2900-3500.

Graphite: It is the most stable form of carbon under standard condition. Carbon exists in two crystalline allotropic forms one is diamond and second is graphite. The properties of graphite are listed in table 2.

Table 2: Properties of Graphite used as reinforcement

Properties	Porosity (%)	Bulk density (g/cm)	Flexural strength (mpa)
values	0.7-53	1.3-1.9	6.9-100

III. EXPERIMENTAL METHODOLOGY

The fabrication of metal matrix composite used in the present study is carried out by stir casting method. A stir casting setup consists of a resistance muffle furnace and a stainless steel stirrer which is connected to a variable speed vertical motor arrangement with range of 80 to 890 rpm by means of a steel shaft as shown in figure 1. Stir casting is the simplest and the most economical method for the fabrication of metal matrix composite [7]. In this present experimental method the molten aluminium matrix metal AL6063 is melted at a definite temperature nearby 710^{o}C in the muffle furnace and then a preheated reinforcement material with a (wt %

of 10% each of SiC and Gr for first sample and SiC and B4C for second sample) is mixed with molten alloy & then stirrer is used to mix the mixture. In order to achieve the uniform properties of the composite, the distribution of the reinforcement material in the matrix alloy must be maintained.

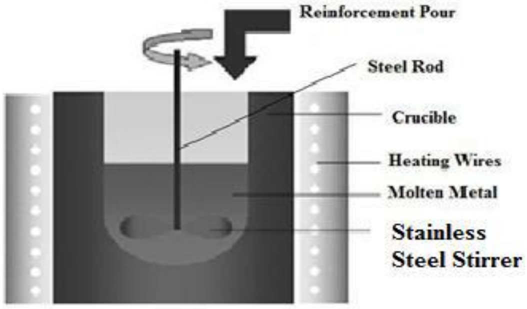

Fig.1: Stir Casting Technique

The inert gas (nitrogen) is used to prevent the oxidation of mixture. The mixed molten MMC is then poured into a mould & is then allowed for the solidification for some time. The schematic diagram shows various parts of stir casting machine as well as process.

IV. RESULT & DISCUSSION

For the nomenclature of samples the sample having composition Al6063/10% SiC/10% Gr is names as specimen A and the sample having composition Al6063/10% SiC/10% B_4C is names as specimen B

4.1 Tensile strength

The tensile testing was done on FIE make universal testing machine UTE-100 in Industrial Development Cum Facility Centre CITCO Chandigarh. For the identification purpose of two samples of composite materials the sample having AL6063/10%SiC/10%Gr composition is named as specimen A and sample having AL6063/10%SiC/10%B_4C composition is named as Specimen B. The tensile testing results are shown in the table 3 and figure 2.

Table 3: Tensile Testing Results of Two Composite Samples

Sr. No.	Samples	Tensile Strength (N/mm^2)	Percentage Elongation (%age)
1	Specimen A	10.4	31.250
2	Specimen B	11.8	12.500

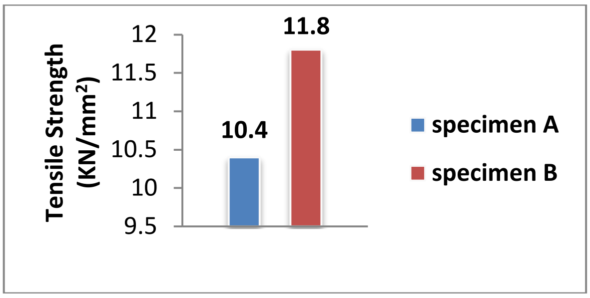

Fig 2: Comparison of Tensile Strength

4.2 Ultimate Tensile Strength

The ultimate tensile strength is the maximum engineering stress level in tensile test or it is the ability of material to withstand before fracture. The maximum load taken by the test specimen is measured in terms of its ultimate tensile strength against fracture. In stress-strain diagram the ultimate tensile strength is the highest point where curve line is flat and shown at the end of elastic portion or very close to the elastic limit. In case of ductile materials the stress hardening occurs and stress continue to increase until breaking of specimen but stress- strain curve may show decline in stress level before fracture. This is due to the reason that engineering stress is based on the original cross section and it commonly not accounts the fracture occurs in the specimen. For the design of components UTS is an important parameter [9]. It is easy to determine and is quiet reproducible. The ultimate tensile strength is useful for the specification and quality control of the components and parts in design problems. The ultimate tensile testing results are shown in table 4 and figure 3.

Table 4: Ultimate tensile strength results of two composites

Sr. No.	Nomenclature of samples	Maximum Force (KN)
1	Specimen A	22.450
2	Specimen B	28.250

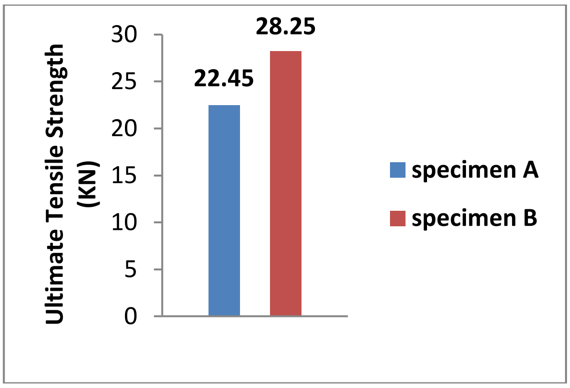

Fig 3: Comparison of Ultimate Tensile Strength

4.3 Hardness Measurement

Hardness test was carried out at room temperature using Vickers hardness tester with at least three indentations of each sample and then the average values were utilized to calculate hardness number [6]. Load used on Rockwell's hardness tester 150 Kg at dwell time of 20 sec. for each sample. The hardness of MMCs of specimen B increases with addition of SiC and B_4C of particulate in the matrix. The added amount of SiC & B_4C particles enhances hardness, as these particles are harder than Al alloy, which render their inherent property of hardness to soft matrix as shown in Table 5 and Figure 4.

Table 5: Hardness Test Results of Two composites

Sr. No	Samples	HV 1	HV 2	HV 3	Average HV
1	Specimen A	41.2	40.5	41.5	41.0
2	Specimen B	49.5	48.9	49.2	49.2

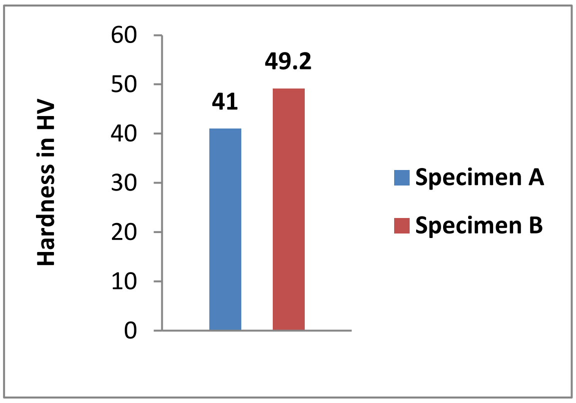

Fig 4: Comparison in terms of Hardness

4.4 Three Point Bending Test

In order to observe the fracture behavior of aluminium based metal matrix composites of different composition of reinforcement particulates the three point bending test or flexural test is performed. This method is also called transverse beam test for materials subjected to simple beam loading.

Table 6: Flexural Strength Test Results of two composites

Samples	Area of specimen mm^2	Max. Force KN	Flexural Strength KN/mm^2
Specimen A	160.14	22.450 KN	0.017
Specimen B	226.65	28.250 KN	0.030

The Flexural test measures the force required to bend the specimen under three point loading conditions as shown in Table 6 and Figure 5. The data is used to select those materials that will support loads without flexing. The specimen deflection is measured by crosshead position and results can also be plotted on stress-strain curve. This test includes flexural strength and flexural modulus. Flexural modulus is used as an indication of a material's stiffness when it is flexed.

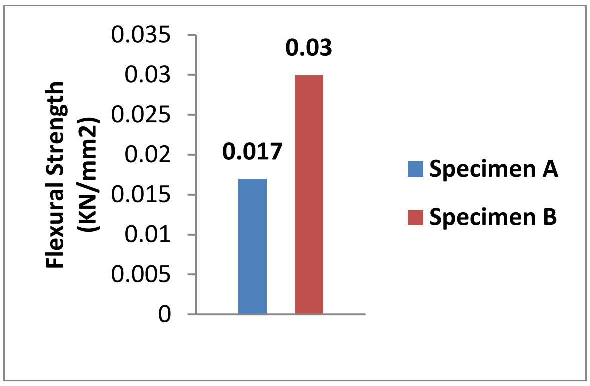

Fig 5: Comparison in terms of Flexural Strength

V. CONCLUSION

Aluminium based metal matrix composites are successfully fabricated by stir casting technique with fairly uniform distribution of Silicon Carbide, graphite in specimen A and silicon carbide, boron carbide in specimen B.

The tensile strength of specimen B is much greater than specimen A which revealed that specimen B is much stronger than specimen A

The ultimate tensile strength of specimen B is found to be more than the specimen A. it means that the load required to break the specimen having composition of silicon carbide, boron carbide is more than the specimen having composition of silicon carbide, graphite.

The hardness of specimen B is more than the specimen A. So the specimen B can be used where material hardness is an essential parameter.

The flexural strength of specimen B is more than that of specimen A. This indicated that specimen B can withstand against heavy loads conditions.

Applications of Aluminium MMCs: The composites can be used in automobiles parts of cars, trucks etc in the internal parts of engine. Also they can be used in turbines, aerospace industries, submarines in defence, tanks etc where high strength to weight ratio is an essential requirement.

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