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MECHANICAL PROPERTIES OF MMC'S- AN EXPERIMENTAL INVESTIGATION

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ABSTRACT

This paper reports an investigation of Mechanical properties of ascast aluminum alloy composite reinforcing with SiCp and graphite particles. The result reveals that as the reinforcement content increases the mechanical properties such as ultimate tensile strength, yield strength, hardness and compressive strength of the composite increases predominantly but the density of the composite will decrease. The increased strength of aluminium 2024/SiCp-Gr composite is attributed to synergistic influence of the dislocation density generated due the differences in coefficient of thermal expansion between the constituents of the composite.

Key words: Aluminum alloy, SiCp, Graphite, MMC, Mechanical properties.

1. INTRODUCTION:

The need for lightweight, high performance, structural materials made them attractive candidate for Aerospace, Automotive and Consumer related industries, provided the necessary impetus for the development and emergence of Metal Matrix Composites. These materials have emerged as the important class of advanced materials giving engineers the opportunity to tailor the material properties according to their needs[1]. Essentially these materials differ from the conventional engineering materials from the viewpoint of homogeneity. In composites controlled distribution of one or more reinforcement materials in continuous second metal matrix phase is possible. Large majority of these composite materials are metallic materials reinforced with high strength, high modulus and brittle ceramic phases which can be either continuous in the form of fiber, discontinuous in the form of whisker, platelets or particulate reinforcements embedded in a ductile metallic matrix. The reinforcement metal matrix offer potential for improvement in efficiency, mechanical performance and reliability over the new generation alloys[2,3]. Earlier study on MMCs addressed the behavior of continuous fiber reinforcement composite based on aluminum, zinc and titanium alloys matrices and the reinforcements used was Alumina fibers,[4] carbon fiber[5] etc. The extensive use of these composites is restricted by high manufacturing cost of composite fiber and composite, but the family of MMCs that include both particulate and whiskers have attracted the considerable attention than fiber reinforced MMCs, because of their low cost and considerable ease of manufacturing. These particulates are roughly divided into two broad groups, on the basis of hardness as soft particles[6,7] with a hardness below 2 GPa, like talc, graphite and hard particles [8-10] with hardness in the range of 4-40 GPa, such as SiC, Al_2O_3, TiC_2 etc. In recent years ceramic reinforcement aluminum alloy matrix composites (AMCs) are receiving increasing attention because of their improvements in elastic modulus, strength, structural rigidity,[8-12] wear resistance,[13,14] dimensional stability and control of physical properties such as density and coefficient of thermal expansion.[15,16] These properties are important in Automobile and

Aerospace applications because of the potential for large reduction in weight, 20-40% increase in strength, 30-50% increase in stiffness, increase in wear resistance, etc. [8-17]

2. EXPERIMENTAL PROCEDURE

2.1 Material

The discontinuous reinforced metal matrix composite material selected for present investigation was based on the Al-Cu-Mg matrix alloy, designated by the aluminium association as AA2024. This matrix alloy was chosen since it provides excellent combination of strength and damage tolerance at elevated temperatures. The nominal chemical composition (in wt. %) of the matrix alloy is given in the table1. The reinforcement was silicon carbide particles of size 100 μm and Graphite powder of size 100-150 μm were used as the dispersoid. Liquid metallurgy method was used for processing of the composite.

2.2 Preparation of the composite:

In the present investigation large ingots of matrix material weighing approximately 10 kgs was cut into small pieces for accommodating into the crucible. Graphite crushed manually and sieved to particles of 100-150 microns. The percentage of graphite is kept constant at 2 percent by weight and SiCp was varied from 0 to 6 by weight percentage. The Liquid metallurgy technique was used to prepare composite specimens.[18, 19] This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al-2024) was first superheated above its melting temperature. The temperature is lowered gradually below the liquidus temperature to keep the matrix alloy in the semisolid state. At this temperature, the preheated blended mixtures of SiCp and graphite particles were introduced into the slurry and mixed manually. Manual mixing was used because, it is very difficult to mix using automatic device when the alloy is in the semi liquid state. After sufficient manual mixing, the composite slurry temperature was increased to fully liquid state and stirring was continued to about five minutes at an average speed of 300-350 rpm. The melt was then superheated above liquidus temperature and finally poured into the cast iron permanent mould of 15mm diameter and 200mm height.

2.2 Testing of composites

The Tensile test was conducted in accordance with ASTM E8-95 standards at room temperature using a universal testing machine. The tensile test specimens of nominal diameter 12.5 mm and gauge length of 62.5 mm was machined from cast composites with the gauge length of the specimen parallel to the longitudinal axis of the casting. Final surface preparation was achieved by mechanically polishing the specimen by fine grid size emery paper for each composite specimen. The compression test was conducted as per ASTM-E9-95. The specimen size of nominal diameter 13 mm and gauge length of 25 mm was machined from cast composites. In these tests, the compressive load was applied gradually and corresponding strain was measured until the failure of the specimen occurred. The hardness test was conducted in accordance with ASTM-E-10 standards. A Brinnel hardness tester was used which has a ball indenter diameter of 2.5 mm, minor load of 10 kg and a major load of 62.5 kg. The load was applied for 15 seconds. The hardness readings were taken for each specimen at different locations to circumvent the possible effects of particles segregation. Four specimens were tested for each test, the difference in readings is very marginal and the average reading was taken.

3 RESULTS AND DISCUSSION

3.1. Microstructure

The micrograph illustrating the microstructure of the metal matrix composites was used in this investigation. Samples for the microscopic examination were prepared by standard metallographic procedures etched with killer's agent and examined under optical microscope. The optical microstructure of ascast Al2024 alloy and Al2024/SiCp-Gr composite are shown in Fig 1(a) and (b). Micrograph indicates the nearly uniform distribution of the SiCp and Graphite particles in the Al2024/6%SiCp/2%Gr composite.

3.2 Tensile properties

The table 2, shows the effect of SiCp and Graphite reinforcement content on the Ultimate Tensile Strength, Yield strength, Hardness, compressive strength and ductility of the composites. The Tensile properties of the Al2024/SiCp/Gr MMCs for three different volume fractions at ambient temperature reveals an increase in Ultimate Tensile Strength, Yield strength with increase in reinforcement content in the aluminium alloy matrix. The ductility of the composite decreases as the percentage of the reinforcement content increases in the composite.

The Fig 2 reveals that the Ultimate Tensile Strength of the composite increases about 50percent with the addition of 6 percent of SiCp and 2 percent Graphite. The Fig3 shows the increase in yield strength of the composite about 40 percent by the addition of the reinforcement. The ductility of the composite is decreased by 80 percent, which is illustrated in Fig 4. These results are inline with the other researchers. [6,9,10,12,20,21] The several strengthening mechanisms have been proposed, either independently or in synergism are considered responsible for the improved strength of discontinuous reinforced metal matrix composites. Srivastan [22] attributed the increase of mechanical properties are due to large differences in coefficient of thermal expansion between the aluminium alloy and the reinforcements.

This resulting in misfit strain due to the differential thermal contraction at the interface between the matrix and the reinforcements. The misfit strain and resultant misfit stress, generates dislocations. The increased dislocation density, generated to accommodate the misfit strain provides a significant contribution to strengthening of metal matrix. G.Ranganath et. al, explained the reasons for the improvement in strength have been attributed to the concurrent and mutually interactive influences of the intrinsic behaviors in thermal expansion coefficient between the constituents of the composites and to the constrained plastic flow and triaxiality in the soft and ductile alloy matrix as a consequence of the presence of the hard and brittle particle reinforcement. [23] The increase in UTS may be due to the SiC particles acting as barriers to dislocations in the microstructure. This dislocation increases the dislocation density, which provides a positive contribution to strength of the Al2024/SiCp/Gr composite. There is decrease in the interparticle distance between the reinforcement particles, which causes increased resistance to dislocation motion as the particulate content is increased. During the deformation either the matrix material has to push the hard particulate further or it has to bypass the particles for deformation, during the process the dislocation piles up. This restriction in the plastic flow in the matrix provides enhanced strength in the composite. Fig 4 shows the effect of reinforcement on the ductility of the composite containing different percentage of SiC and graphite particles. It is seen that as the percentage of SiC and Graphite particles increases, the ductility of the composite material decreases monotonically by significant amounts if other parameters are kept constant. Quantitatively as the SiCp content is increased from 0 to 6 weight percent along with two weight percent of graphite at the interval of 2 weight percent shows the reduction in the ductility. There is also an imbrittlement effect due to hard SiC and Graphite particles resist the passage of dislocation either by creating stress fields in the matrix or by inducing large difference in the plastic behavior between the matrix and the particulate. [23]

3.2. Compressive properties

The graph shown in the figure 5, illustrates the effect of Silicon carbide particulate and graphite reinforcement content on the compression strength of the composite. It is observed that the compressive strength of the composite is increased by about 5 percent as the reinforcement content increases from 0 to 2 weight percent.

As the reinforcement content increases further, the compression strength of the composite increases from 5 to 41 percent. The results obtained in this study are inline with the other researchers.[20,21] This increase in the compression strength is because of the presence of hard particles, which imparts high strength to the composite.[22] This may be due to very small amounts of particulates at different orientations, which can make tremendous difference in stress-strain behavior. The rigidity and crushing strength of particles is much higher than that of matrix material hence the strength increases.

3.3. Hardness

Hardness, which is described as resistance to surface indentation of the material, which is shown in the Fig 6. This graph explains the effect of particulate reinforcement on the Brinnel Hardness Number (BHN). The hardness of the composite increases about 80 percent as the reinforcement content of the silicon carbide and graphite is increased from 0 to 2 percent. The hardness of the composite specimen is increased with increase in the percentage of particulate reinforcement.This increase in hardness is expected since SiC particles being a very hard dispersoid contribute positively to the hardness of the composite. The increased hardness is also attributable to the hard SiC particles acting as barriers to the movement of dislocations within the matrix. The dispersoid strengthening effect is expected to be retained even at elevated temperature[10] and for expected time period, because the particles are not reactive with the matrix phase.[13,21]

4. CONCLUSIONS

The results of the investigation on the effect of SiCp and graphite reinforcement content on mechanical properties of the Al2024 aluminium alloy composite, provides the following observations.
It is possible to produce metal matrix composites having relatively improving mechanical properties, by dispersing SiC and Graphite particles in to the molten aluminium alloy using modified liquid metallurgy method.
Inclusion of SiC and Graphite particulate reinforcement content improves the mechanical properties of the composite material like tensile strength, hardness, and compression strength at the cost of ductility.

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TABLES

Table-1: Composition of Al2024 (weight %)

Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
93.5	Max 0.1	3.8-4.9	Max 0.5	1.2-1.8	0.3-0.9	Max 0.5	Max 0.5	Max 0.5

Table2. Mechanical properties of MMCs containing various amounts reinforcement content.

%of SiC	%Gr	UTS (Mpa)	Brinell Hardness (HB)	Yield Strength (MPa)	Ductility (% elongation)	Ultimate compressive strength (MPa)
0	0	118	62	60	4	748
2	2	124	112	66	2	821
4	2	167	135	74	1	902
6	2	185	159	84	0.6	1050

FIGURES

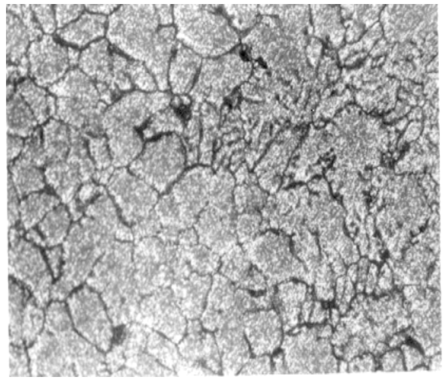

Fig.1 (a) Micrograph of Al2024.

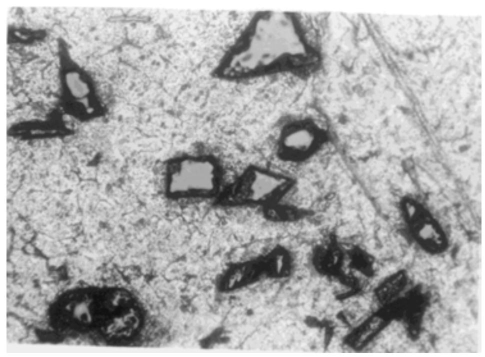

Fig 1(b) Micrograph of Al2024-6%SiCp-2%Graphite.

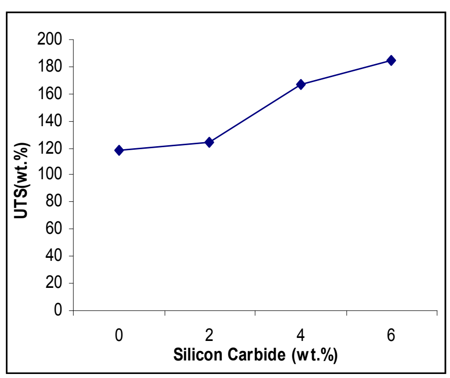

Fig.2. Effect of Silicon Carbide on ultimate tensile strength of the 2% Gr Al2024 composites.

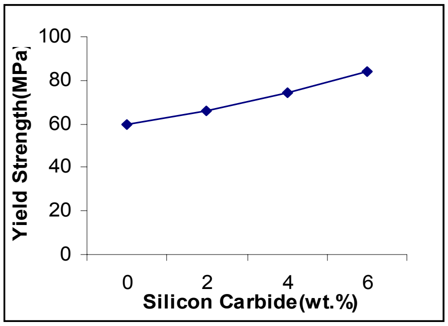

Fig.3. Effect of Silicon Carbide on Yield strength of the 2% Gr Al2024 composites.

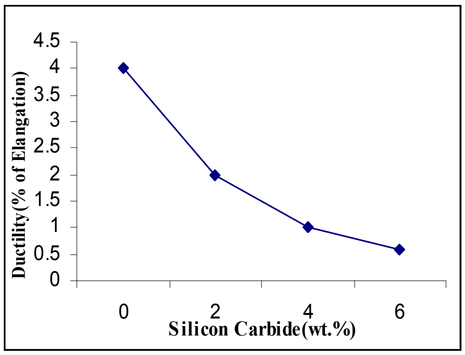

Fig.4. Effect of Silicon Carbide on Ductility of the 2% Gr Al2024 composites.

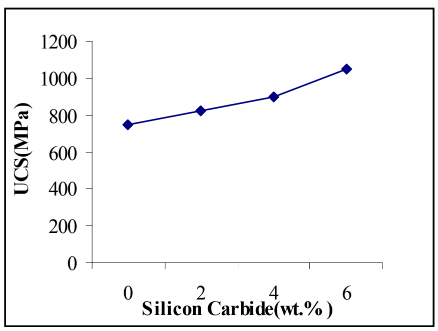

Fig 5. Effect of Silicon Carbide on UCS of the 2% Gr Al2024 composites.

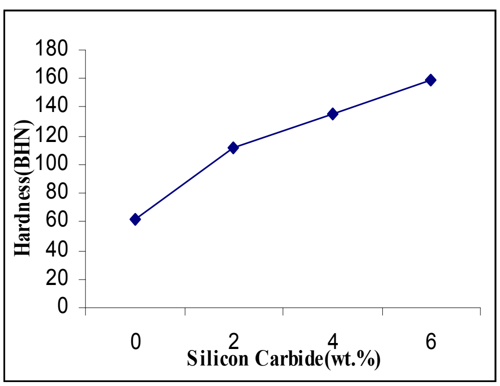

Fig.6. Effect of Silicon Carbide on Hardness of the 2% Gr Al2024 composites.