Study on Mechanical Properties of Al 7075 based Metal Matrix Composites

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***Abstract*: Aluminium is soft and ductile material. There are many series in Aluminium alloys and we have selected Aluminium 7075 which has good corrosion resistance. The aim of our study is to investigate the mechanical behavior and microstructure of the Silicon Carbide particles reinforced with Aluminium 7075.**

In our study we used three different fractions of SiC and the weight fractions are 1%, 2% and 3%. Composites were processed by stir casting method and the specimens were prepared according to ASTM E8 M-09 standards. All the specimens were subjected to different tests like Hardness test, Ultimate Tensile Strength and Wear test and the results were analysed. Microstructure analysis is done to analyse the distribution of reinforcement particles. We observed that with 3% SiC the mechanical properties were the best.

I. INTRODUCTION

A composite material is defined as a structural material created synthetically or artificially by combining two or more materials having dissimilar characteristics. The constituents are combined at macroscopic level and are not soluble 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 characteristics. Reinforcing phase:fibers, flakes, particulates, whiskers etc Matrix phase : continuous phase.

The constituents are combined at microscopic level and are not soluble in each other. Generally, a composite material is composed of reinforcement (fibers, particles/ particulates, flakes and/or fillers) embedded in a matrix (metals, polymers). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material. The most primitive man-made composite materials are straw and mud combined to form bricks for building construction. Example: Concrete, Boron fiber reinforced polymer, Glass Fiber reinforced polymer, Epoxy resin reinforced with graphite fiber.

Classification of composites is done based on both geometry of reinforcing material and the type of matrix material.

Metal matrix composites (MMCs), like all composites consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases. For example Aluminium Oxide fiber is reinforced in a copper matrix for superconducting magnets and silicon carbide (SiC) particle reinforced with in the Al matrix composites used in aerospace, automotive and thermal management applications. For many researches the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering , especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminium crank cases with strengthened cylinder surfaces as well as particle strengthened brake disks. These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application.

Aluminium alloys are alloys in which Al is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. There are two principal classifications, namely cast alloys and wrought alloys.The International Alloy Designation System is the most widely accepted naming scheme for wrought alloys. Each alloy is given a four-digit number, where the first digit indicates the major alloying elements. 1000 series is essentially pure aluminium with a minimum 99% aluminium content by weight and can be work hardened. 2000 series is alloyed with copper, can be precipitation hardened to strengths comparable to steel. Formerly referred to as duralumin, they were once the most common aerospace alloys, but were susceptible to stress corrosion cracking and are increasingly replaced by 7000 series in new designs. 3000 series is alloyed with manganese, and can be work-hardened.4000 series is alloyed with silicon. They are also known as silumin. 5000 series is alloyed with magnesium. 6000 series is alloyed with magnesium and silicon, are easy to machine, and can be precipitation hardened, but not to the high strengths that 2000 and 7000 can reach. 7000 series is alloyed with zinc, and can

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be precipitation hardened to the highest strengths of any aluminium alloy.

II. EXPERIMENTAL DETAILS

Aluminium alloy 7075 was used as matrix in the synthesis of composite. Aluminium alloy was taken from the FENFE METALLURGICALS, in the form of ingots or rods and then cut into smaller pieces with the help of hacksaw in order to keep the alloy inside the crucible properly. In this Zinc is the primary element. Composition of matrix alloy was analyzed and the chemical composition of the matrix alloy.

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the material. All of the different particulates/ fibers used in composites have different properties and so affect the properties of the composite in different ways. The desirable properties of the reinforcements include:

- High strength
- Ease of fabrication and low cost
- Good chemical stability
- Density and distribution

Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Silicon carbide powder has been produced for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates and in bullet proof vests. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic.

A stir casting setup as shown in Figure1, Consisted of a Electrical resistance Furnace and a stirrer assembly which was used to synthesize the composite. The stirrer assembly consisted of a graphite stirrer, which was connected to a variable speed vertical drilling machine with range of 80 to 890 rpm by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size manually.

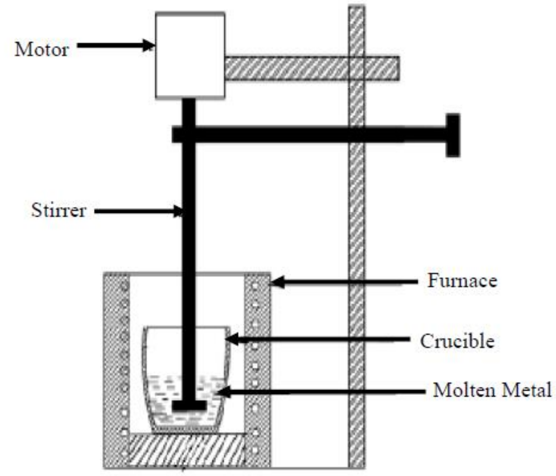

Figure 1: Stir casting

The stirrer consisted of four blades at an angle of 90° apart. Clay graphite crucible of was placed inside the furnace. The graphical representation of stir casting was shown in Figure4.The capacity of the electrical resistance furnace used was upto 1000°C. Figure 8 shows the Pre heating the mould so that it matches the temperature and while pouring the molten metal the mould material will not mix up with that and it also helps in easy removal of the casted part.

III. RESULTS AND DISCUSSIONS

A.Microstructural Observation

Microstructure was visualized with the help of optical microscope. For the specimen preparation, first of all specimen were cut down into small cuboids shapes after that the different samples were grinded on different grit size papers sequentially by 100, 220, 400, 600 and 1000. After grinding, the specimens were mechanically polished by alumina paste and then etched by kellars reagent to obtain better contrast. The specimens were visualized on different magnifications (100X and 200X) to show the presence of reinforcement and its distribution on the metal matrix. Different elements/ compounds which were present in the SiC are difficult to distinguish by optical micrography. In any composites as the reinforcement increases the grain size of the base metal decreases because of the accumulation of reinforcement particles.

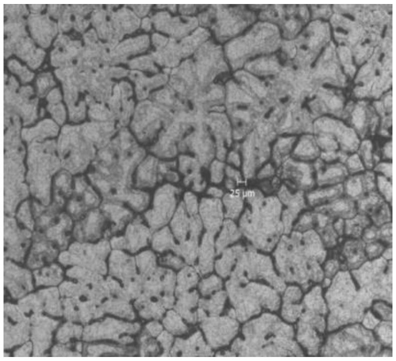

Figure 2: shows the micro structure of the pure aluminium alloy 7075 + 1% SiC

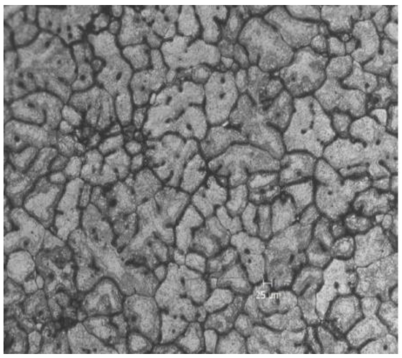

Figure 3: shows the micro structure of the pure aluminium alloy 7075 + 2% SiC

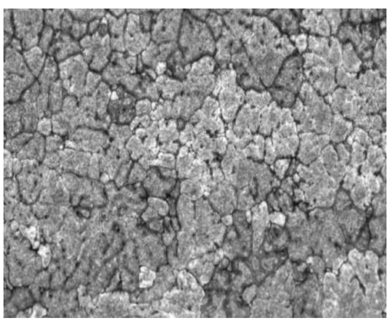

Figure 4 shows the micro structure of the pure aluminium alloy 7075 + 3% SiC

B. Hardness Measurement

A Hardness tester MVH-1is used for the Hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100, 220, 400, 600 and 1000 grit size emery paper. Load used on Brinell Hardness tester was 10kgf with dwell time 10 seconds for each sample.
The results of Brinell Hardness test for alloy 7075 with reinforcement of wt% variation of SiC in Al alloy 7075 MMCs.

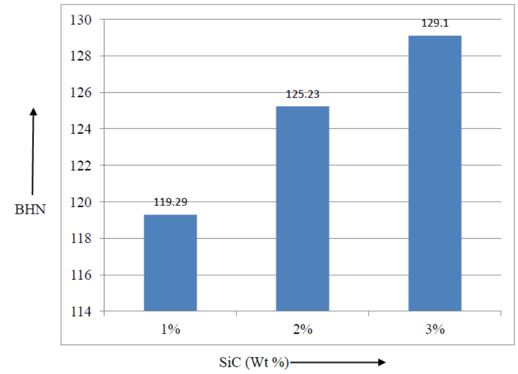

Figure 5: Comparison of Hardness of alloy and MMCs

Figure 5 shows the Hardness of Al alloy and Al based MMCs reinforced with SiC. Hardness of composite depends on the hardness of the reinforcement and the matrix. As the Coefficient of thermal expansion (CTE) of ceramic particles (SiC: 4.03µm/m°C) is less than that of aluminium alloy 7075 (24.3µm/m°C), an enormous amount of dislocations are generated at the particle–matrix interface during solidification process, which further increases the matrix hardness. The higher the amount of particle–matrix interface, the more is the hardening due to dislocations. Hence, the hardness of the composite increases with the decrease in particle size and increase the volume fraction of the reinforcement. From the graph it is clear that as the reinforcement percentage increases the Hardness also increases.

C. Tensile Testing Results

Although tensile testing is not recommended in examining the fracture behavior of SiC reinforced aluminium composite, tensile tests were performed to find out ultimate tensile strength values. But unfortunately, specimens fractured in the early stages of tensile tests and lower strength values were obtained. The main reason is the silicon carbide particulates make notch effect during the testing. From the graph shown in figure 6 we can see that has the percentage of SiC increases the Ultimate Tensile Strength (UTS) also increased.

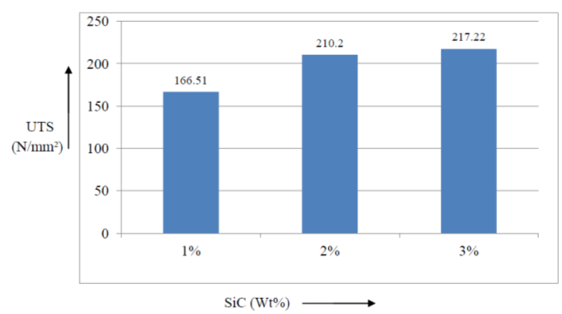

Figure 6: Tensile strengths of different specimens

IV.CONCLUSIONS

The objective of this study is to investigate the fracture behavior of silicon carbide reinforced aluminium matrix composite. Microstructure, hardness tests, tensile tests and wear tests were performed to complete this project.

- Aluminium based metal matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of Silicon carbide particulates.
- The Microstructure images revealed that SiC particulates are fairly distributed in Aluminium alloy Matrix.
- The results confirmed that stir formed Al alloy 7075 with SiC reinforced composites is clearly superior to base Al alloy7075 in the comparison of hardness i.e. the hardness increases after addition of SiC particles in the matrix.
- In Ultimate Tensile Test, as the silicon carbide percentage increases the UTS also increases.
- Finally, we conclude that results obtained at 3% SiC were the best.

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