Fabrication and Testing of Aluminium 6061 Alloy & Silicon Carbide Metal Matrix Composites

Miss. Laxmi[1], Mr. Sunil Kumar[2]

[1]PG student, Dept. of Mechanical Engineering, OITM, Juglan, Hisar, Haryana, India.
[2]Assistant Professor, Dept. of Mechanical Engineering, OITM, Juglan, Hisar, Haryana, India.

Abstract – *The composite materials have advantages over other conventional materials due to their higher specific properties such as tensile, flexural and impact strengths, stiffness and fatigue properties, which enable the structural design to be more versatile. Due to their many advantages they are widely used in aerospace industry, mechanical engineering applications (internal combustion engines, thermal control and machine components), electronic packaging, automobile, and aircraft structures and mechanical components. The problem is associated with the study of mechanical properties of aluminium- Silicon carbide metal matrix composites (MMCs) of aluminium alloy of grade 6061 with the addition of 10% 15% and 20%by weight composition of Silicon carbide (SiC) by stir casting technique. The changes in physical and mechanical properties will be taken into consideration. For the achievement on the above, an experimental setup will be prepared to facilitate the preparation of required MMCs. The experiment has to be carried out by preparing the sample of 10% ,15% and 20%composition of Silicon carbide by stir casing process and then study the mechanical properties i.e. hardness. A brief analysis of microstructure has to be conducted on scanning electron microscope (SEM) to verify the dispersion of reinforcement in the matrix.*

***Key Words*: Aluminium, Silicon Carbide, stir casting, etc.**

1. INTRODUCTION

Over the last thirty years, composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated nice applications.

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years.

Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance fiber reinforced polymer can now be found in such diverse applications as composite armors designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc.

Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity.

1.1 Metal Matrix Composite

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. A metal matrix composite consists of two chemically and physically distinct phases, suitably distributed to provide properties that cannot be obtained with either of the individual phases.

Generally, there are two phases either a fibrous or particulate phases in a metallic matrix. Sustainably progress in the development of the light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. Especially in the automotive industry, MMCs have been commercially in fiber reinforced pistons and aluminium crank cases with strengthened cylinder surface as well as particle strengthened brake disk. 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. For example, Al2O3 fiber reinforced in a copper matrix for superconducting magnets and SiC particles reinforced with in the aluminium matrix composites are used in aerospace, automotive and thermal management applications.

Objectives of Metal Matrix Composites

The fabrication of MMCs is done to achieve the following objectives:

1. To increase yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness.
2. To increase creep resistance at higher temperature compared to that of conventional alloys increase in fatigue strength especially at higher temperature.
3. To improve thermal shock resistance.
4. To improve corrosion resistance.
5. To increase Young's modulus.

1.2 Aluminium-SiC Metal Matrix Composite

Aluminium is the most abundant material in the Earth's crust and the third most abundant element after oxygen and silicon. It makes up about 8% by weight of Earth's solid surface. The chief source of aluminium is bauxite ore. Its Atomic number is 13. Aluminium is soft, light weight, durable, ductile and malleable metal with appearance ranges from slivery to dull grey, dependent on the surface roughness. Aluminium is non-magnetic and non-sparking. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal exposed to air, effectively preventing further oxidation.

Presents works utilizes Al-6061 as the matrix material which has numerous applications in Aircraft fittings, camera lens mounts, couplings, marines fittings and hardware, electrical fittings and connectors, decorative or misc. hardware, hinge pins, magneto parts, brake pistons, hydraulic pistons, appliance fittings, valves and valve parts; bike frame, doors, window frames, shop fitting, architected applications, extrusions etc.

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metal working techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling.

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 mass-produced since 1893 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 in bulletproof 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.

2. METHODOLOGY

Different Method used to Manufacture Particulate Reinforced MMCs. MMCs manufacturing can be broken into three types: solid, liquid and vapor. Present works utilizes the stir casting techniques for fabrication of MMCs. The details of stir casting are as follows:

Stir casting

Stir casting set-up mainly consists a furnace and a stirring assembly shown in figure 1. In general, the solidification synthesis of metal matrix composites involves a melt of selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispersions under selected condition to obtain the desired distribution of dispersed phase in the cast matrix.

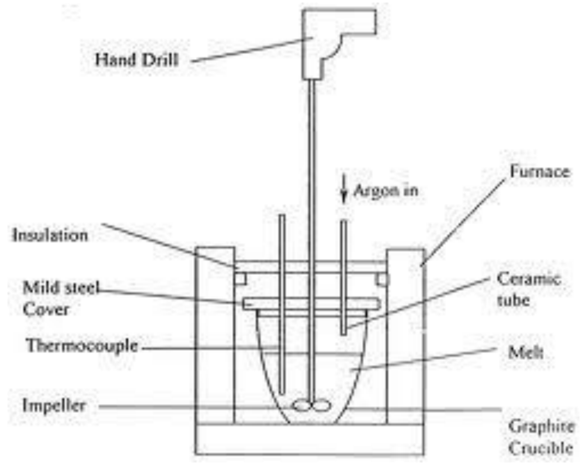

Fig-1: Stir casting

In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention include:

1. The difficulty in achieving a uniform distribution of the reinforcement material.
2. Wettability between the two main substances.
3. Porosity in the cast metal matrix composites.
4. Chemical reaction between the reinforcement material and the matrix alloy.

In order to achieve the optimum properties of metal matrix composites, the distribution of reinforcement material in the matrix alloy must be uniform and the wettability or bonding between these substances should be optimized. The porosity levels needs to be minimized.

Steps involved for fabrication of metal matrix composites (Al-6061/SiC) are as follows:

1. Firstly, silicon carbide particles are preheated in the induction resistance furnace at 11000 c for 1 to 3 hours to make their surfaces oxidized.
2. Aluminum alloy (circular rod) is heated to the temperature of 950 (above the liquidus temperature of alloy) for 30 minutes.
3. The furnace temperature was first raised above the liquidus to melt the alloy scraps completely and was then cooled down just below the liquidus to keep the slurry in a semi-solid state. At this stage the preheated SiC particles were added and mixed manually.
4. After sufficient manual mixing is done, the composite slurry is reheated to a fully liquid state and then automatic mechanical mixing is carried out for about 10 minutes at a normal stirring rate of 600 rpm.
5. In the final mixing process, the furnace temperature was controlled within 760±10^{o}C. Pouring of the composite slurry has been carried out in the sand mould prepared according to the specifications for hardness, impact and normalized displacement test.

Table 1 shows the designation of composites formed by stir casting method.

Table-1: Designation of composites

Composites	Compositions
S1	Aluminium (90wt %) + Silicon Carbide (10wt%)
S2	Aluminium (85wt %) + Silicon Carbide (15wt%)
S3	Aluminium (80wt %) + Silicon Carbide (20wt%)

3. RESULTS

3.1 Effect of reinforcement on hardness of composites

Surface hardness of the composites is considered as one of the most important factor that governs the wear resistance of the composites. Figure 2 shows the effect of reinforcement on hardness of composites. The test results show that with the increase of reinforcement from 10% to 15%, hardness of the composites is improved. On further increase of reinforcement up to 20%, result as decrease in hardness. The effect of reinforcement with 15wt% reinforcement shows better hardness value as compared to 20wt%. The increase in hardness value is may be due to the incorporation brittle SiC particulates in the aluminium.

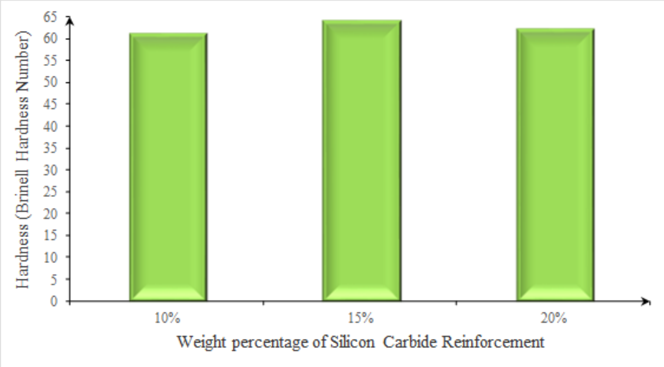

Fig - 2: Effect of reinforcement on hardness of composites

3.3 Surface Morphology

A SEM micrograph (magnified view) of the tensile fracture surface of 10%, 15% and 20 % of Silicon Carbide reinforced Aluminium matrix composite is shown in Figure 3, 4 and 5. The Scanning Electron Microscope (SEM) is used for observation of specimen surfaces. When the specimen is irradiated with a fine electron beam (called an electron probe), secondary electrons are emitted from the specimen surface. Topography of the surface can be observed by two-dimensional scanning of the electron probe over the surface and acquisition of an image from the detected secondary electrons.

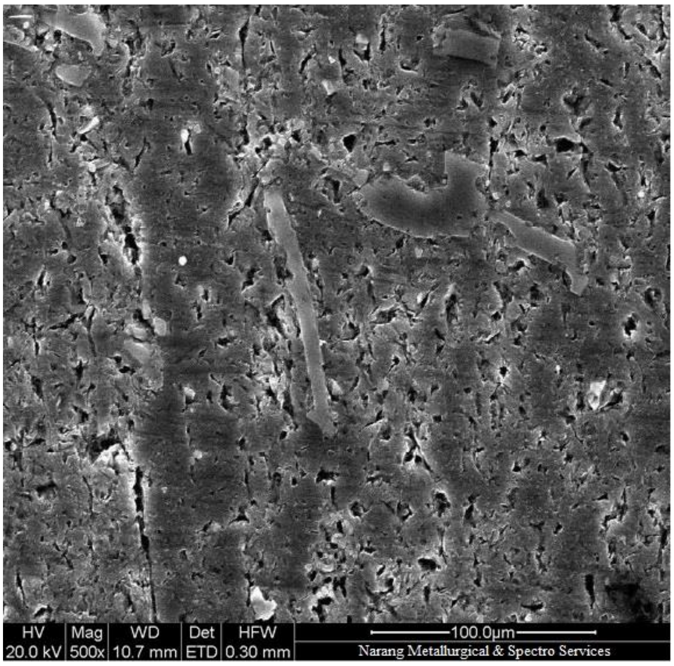

Fig-3: Scanning electron microscopy image of SiC (10 wt%) reinforced Aluminium matrix composite specimen subjected to tensile test

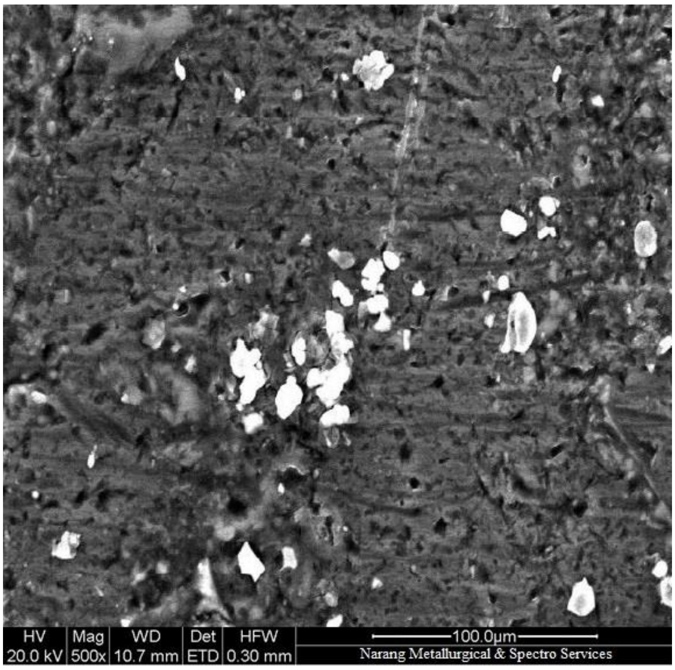

Fig-4: Scanning electron microscopy image of SiC (15 wt%) reinforced Aluminium matrix composite specimen subjected to tensile test

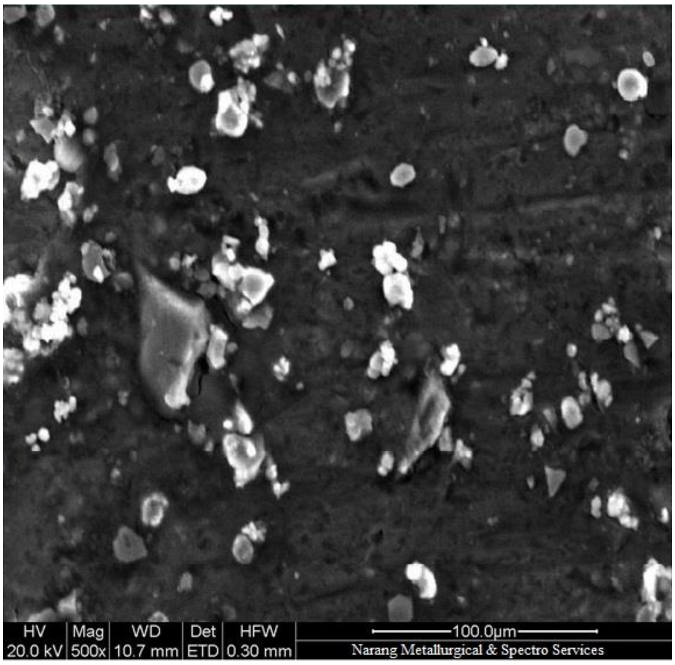

Fig-5: Scanning electron microscopy image of SiC (20 wt%) reinforced Aluminium matrix composite specimen subjected to tensile test

4. CONCLUSIONS

The experimental investigation on the mechanical behaviour of SiC reinforced Aluminium matrix composites lead to the following conclusions:

1. Successful fabrication of SiC reinforced Aluminium matrix composite by Stir-casting method.
2. The results of study suggest that with increase in composition of SiC, an increase in hardness have been observed.
3. The test results show that with the increase of reinforcement from 10% to 15%, hardness of the composites is improved. On further increase of reinforcement up to 20%, result as decrease in hardness. Out of all these specimens, the hardness is more for 15% SiC with Al specimen (64BHN).
4. Scanning Electron Microscopy images of all the specimens, subjected to tensile strength is examined.

REFERENCES

[1]. Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, *Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite,* Journal of Minerals & Materials Characterization & Engineering, vol.8, 2009, 455-467.

[2]. Manoj Singla, Lakhvir Singh, Vikas Chawla, *Study of Wear Properties of Al-SiC Composites,* Journal of Minerals & Materials Characterization & Engineering, Vol. 8, 2009, 813-819.

[3]. A. Chennakesava Reddy, *Tensile Properties and Fracture Behavior of 6063/SiC Metal Matrix Composites Fabricated by Investment Casting Process,* International Journal of Mechanical Engineering and Materials Sciences, 2010, 73-78.

[4]. S. Das, R.Behera, A. Datta, G.Majumdar, B. Oraon, G. Sutradhar, *Experimental Investigation on the Effect of Reinforcement Paricles on the Forgeability and the Mechanical Properties of Aluminium Metal Matrix Composites,* Materials Sciences and Applications, 2010, 310-316.

[5]. G.B. Veeresh Kumar, C.S.P. Rao, N. Selvaraj, M.S. Bhagyashekar, *Studies on Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites,* Journal of Minerals & Materials Characterization & Engineering, vol. 9, 2010, 43-55.

[6]. G.B. Veeresh Kumar, C.S.P. Rao N. Selvaraj, *Mechanical and Tribological Behavior of Particulate Reinforced Aluminium Metal Matrix Composites – A review,* Journal of Minerals & Materials Characterization & Engineering, Vol. 10, 2011, 59-91.

[7]. Rabindra Behera, S. Das, D. Chatterjee, G. Sutradhar, *Forgeability and Machinability of Stir Cast Aluminium Alloy Metal Matrix Composites,* Journal of Minerals & Materials Characterization & Engineering, Vol. 10, 2011, 923-939.

[8]. K.K. Alaneme and M. O. Bodunrin, *Corrosion Behaviour of Alumina Reinforced Aluminium (6063) Metal Matrix Composites,* Journal of Minerals & Materials Characterization & Engineering, Vol. 10, 2011, 1153-1165.

[9]. Avdesh, *Corrosion Behaviour of Aluminium based Metal Matrix Composites Reinforced with SiC and Zircon Sand,* Thesis submitted in Thapar University, 2011.

[10]. Z. Hasan, R. K. Pandey, D. K. Sehgal, *Wear Characteristics in Al-SiC Particulate Composites and the Al-Si Piston Alloy,* Journal of Minerals & Materials Characterization & Engineering, vol.10, 2011, 1329-1335.

[11]. Rajaneesh N. Marigoudar, Kanakuppi Sadashivappa, *Dry Sliding Wear Behaviour of SiC Particles Reinforced Zinc-Aluminium (ZA43) Alloy Metal Matrix Composites,* Journal of Minerals & Materials Characterization & Engineering, vol. 10, 2011, 419-425.

[12]. G.G. Sozhamannan, S. Balasivanandha Prabu, V. S. K. Venkatagalapathy, *Effect of Processing Parameters on Metal Matrix Composites: Stir Casting Process,* Journal of Surface Engineered Materials and Advanced Technology, 2012, 11-15.

[13]. David Raja Selvam, Robinson Smart, D.S. Dinaharan, *Synthesis and characterization of Al6061-Fly Ashp-SiCp composites by stir casting and compocasting methods*, Eco-Energy and Materials Science and Engineering Elsevier, 34 (2013) 637-646.

[14]. Moustafa M. M. Mohammed, Omayma A. Elkady, *Effect of Alumina Particles Addition on Physico-Mechanical Properties of Al-Matrix Composites*, Open Journal of Metal, 2013, 72-79.

[15]. Jayashree P.K., Gowri Shankar M. C, Achutha Kini, *Review on Effect of Silicon Carbide (SiC) on Stir Cast Aluminium Metal Matrix Composites*, International Journal of Current Engineering and Technology, 2013, 1061-1071.