Characterization of Mechanical Properties of Silicon Carbide Reinforced Aluminum Matrix Composites

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Abstract: Aluminum matrix composites (AMCs) is used in manufacturing of different parts because they have higher strength to weight ratio, High wear resistance, Good dimensional stability, Higher cyclic fatigue characteristics. AMCs are very useful in aerospace, marine and automotive applications. In present experimental investigation aluminum alloy 6061 is used as a metal matrix and SiC particles are used as reinforcement. The AMCs are fabricated using electromagnetic stir casting process by varying SiC (0%, 3%, 6% and 9% wt.) percentage. The tensile strength, flexural strength and hardness test were carried out. There was increase in tensile strength, flexural strength and hardness with increase in percentage of SiC in composite**.**

***Index Terms* - Aluminum, SiC, Electromagnetic stir casting, Mechanical Properties.**

I. INTRODUCTION

Composites: Composite materials are combination/mixing of two or more different materials together, which create superior and unique material. Metal matrix composites are being increasingly used in aerospace and automobile industries owing to their enhanced properties such as high strength to weight ratio, hardness, higher fatigue resistance, higher thermal conductivity, electrical conductivity and wear resistance over unreinforced alloys [1-4].The constituents remains separate at macroscopic level within the final structure, in order to attain properties that the individual materials by themselves cannot attain. The composites are consists of two different types of materials one is matrix material and another is reinforcement. The discrete constituent is known as reinforcement and the continuous phase is called matrix.

Metal Matrix Composites (MMCs): In Metal Matrix Composites (MMCs) metal or its alloys are used and it is combined with reinforcement. MMCs are found to have significant characteristics as compared with PMCs, CMCs and CCCs. MMCs are operated in higher temperature range and have better electrical and thermal conductivity as compared to PMCs. CMCs are found to have lower fracture toughness than MMCs. Also, MMCs are priced at a lower cost and are having higher shear strength than CCCs. The different metallic alloys such as aluminum (Al), copper (Cu), magnesium (Mg), nickel (Ni), and titanium (Ti) are used in MMCs [5].

Aluminum Matrix Composite (AMCs): In MMCs generally Al and its alloys are widely used because of Al and its alloy have low density, high strength, corrosion resistance and toughness, least costly, light in weight etc. However, the Al and its alloy has limitations because of poor wear resistance and endurance of temperature. Addition of reinforcement with Al and its alloys this limitations gets eliminate. The Al and its alloy are cheaper than Mg. Also Mg has explosive nature so it is difficult to handle.They find applications as cylinder blocks, pistons, piston insert rings, brake disks and calipers [6-8].

Reinforcement: There are various types of reinforcement materials available in different sizes and shapes. In MMCs individual or multiple reinforcements can be used. The performance of AMCs is highly depending on selection of right amount of reinforcement. The reinforcements being used are fibers, whiskers and particulates [9].As a reinforcement ceramics, industrial wastes and agro waste can be used. Carbides, oxides and nitrides are generally used as ceramics reinforcements. Some of them are SiC, B4C, tungsten carbide (WC), TiB_2, Al_2O_3, BN, TiC, Si_3N_4 etc. Industrial waste materials like fly-ash and red mud are used as reinforcement. And as agro wastes rice husk ash (RHA), bamboo leaf ash, corn cob ash etc. can be used.

FABRICATION PROCESSES FOR AMCs:

The fabrication methods for AMCs are classified in two different way: Solid state processes and liquid state processes.

1) Solid state processes:
   a. Powder blending (PM Processing)
   b. Physical vapor deposition (PVD)
   c. Diffusion bonding (DB)
2) Liquid state processes:
   a. Stir casting process
   b. Spray deposition process
   c. Infiltration process
   d. In-situ processing (Reactive processing)

STIR CASTING PROCESS*:*

In stir casting process molten metal is vigorously stirred and vortex is formed. The vortex can be formed by means of mechanical stirrer or electromagnetic stirrer. The particles are added from side of the vortex and mixture of molten matrix material and reinforcement are vigorously stirred.

In present investigation fabrication of AMCs are done by electromagnetic stir casting (EMS) process. The Schematic view of EMS is shown in figure 1

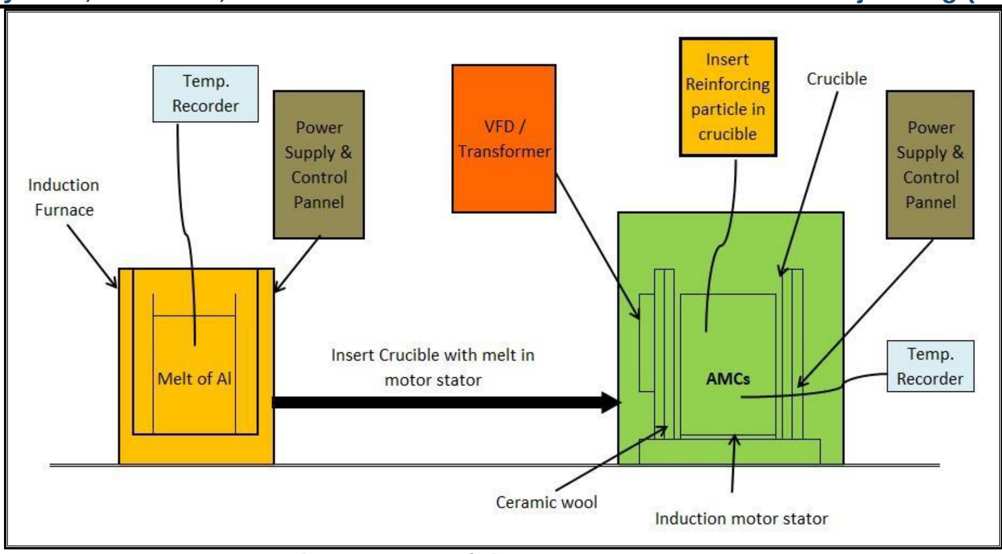

Figure 1: Schematic view of electromagnetic stir casting setup

Al matrix material is melted into furnace by applying temperature above its melting point. Liquid molten metal is then put into EMS set up, where it is vigorously stirred by applying electromagnetic field and the pre-treated reinforcement is apply during electromagnetic stirring. By varying current of induction motor speed of stirring can be controlled.

II. Materials And Methodology

2.1 Materials used in experiment:

In the present experimental research Al alloy used as a metal matrix and SiC ceramics powder used as a reinforcement.

AA 6061 METAL MATRIXL: In present experiment investigation AA6061 is used as metal matrix material. AA6061 alloy is one of the alloy from series of wrought alloys. Mg and Si are primary constituents in AA6061 alloy.AA 6061 has some handsome properties such as good workability, mechanical properties, and medium to high strength, good surface finish and high corrosion resistance. 6061 Al alloys are used in various different application like automotive parts, bicycle frames, airplane parts and aerospace components as due to its high mechanical properties and good corrosion resistance properties.

SiC REINFORCEMENT: Silicon carbide used as the reinforcement material. Silicon carbide is approximately twotimes stiffer than steel and doubles the density of steel.SiC particles are available easily and also they are cheap and commonly used as abrasive, ceramics, refractory and chemical purposes. By adding reinforcements in AMCs increases mechanical properties and increases wear resistance properties. However, vigilant selection of amount of reinforcement must be required. Because if increased to certain limit, then it led to severe consequences as increase in amount of reinforcement makes composites that are difficult to machine and brittle nature of casted AMCs are increased. Hardness of SiC particles are very high. Hence, SiC reinforcements are used in place of aluminum oxide particulate reinforcement due to high wear and creep resistance capability and also they are not affected by alkalis or acids. At elevated temperature SiC generates the layer of its oxide and which prevents it from reaction with aluminum matrix material. SiC ceramics particles maintain their strength at higher temperature. The size of the silicon carbide particle is upto 150µm. The following are the characteristics of silicon carbide Hard and wear-resistant, good thermal conductivity, high strength and stiffness and excellent size and shape capability.

2.2 Electromagnetic Stir Casting Method

The steps followed for AMCs development using EMS process are:

- Take aluminum in the crucible and put it in the electric Furness and wait until the aluminum melt. Aluminum 6061 melt at the 750ºC. Die heated on the hot plate up to 300ºC.
- After melting aluminum at 750ºC, take outside crucible from Furness and place in the motor. The inner part of the induction motor cover by the ceramic wool which prevents the heat transfer from the crucible to the motor winding.
- When voltage supply to the motor magnetic field produces inside the motor. This magnetic field cut the flux produced in the motor. Hence aluminum rotates inside the crucible.
- Pre-heated silicon carbide added in the crucible during the rotation of the aluminum.
- Stir the matrix and reinforcement in the crucible for 5 minutes.
- After stirring, pour the AMCs in preheated die

2.3 Tensile, Flexural and Hardness Test

The mechanical properties are very important for any material with the application of load, which determine the usefulness of a material in a specific product application [10]. Resistance against deformation is the modulus (elastic modulus), while flexural strength can be calculated from the maximum load before fracture under flexural loading. The hardness is known as the resistance to plastic deformation, generally by indentation, cutting, or abrasion [11, 12]. The mechanical properties of AMCs are extensively governed by the properties of matrix, reinforcement, and reinforcement/metal interface [13].Tensile test results also provide a great deal of information relative to the fundamental mechanisms of deformation that occurs in the specimen [14]. Tensile test of AMCs has been conducted as per ASTM E08 – 09. The structure and properties of the reinforcements control the mechanical properties of the composites. Increase in strength of the composites are reasoned to the strong interface that transfers and distributes the load from the matrix to the reinforcement [15].Three Specimens each of 0%, 3%, 6% and 9% were subjected to three point bending flexural test. The testing was carried out using a Tensile testing machine (TTM), L-Series H50KL. A crosshead speed of 5 mm/min selected during flexural testing. In this work hardness of Aluminum metal matrix composite measured by Rockwell hardness tester. Average readings were calculated using readings obtained from testing of 4 specimens of each type of composition of AMC.

III. Result And Discussion

The value of maximum strength exerted on the specimen before breaking is measured. From the data we can say that with the increase in percentage of reinforcement particles the value of tensile strength is also increased. The value of maximum strength exerted on the specimen before cracking under bending force. It is observed that the flexural strength is surge with the increase in the percentage of SiC. The result according to percentage of SiC is shown below. The hardness is increased with SiC %

The below figures shows the relation between tensile strength, flexural strength and hardness with the percentage.By comparing different regression like, Linear, Polynomial (Order 2), Polynomial (Order 3) and Exponential, for tensile properties the value of (Coefficient of Correlation) $R^2 = 1$ in 3rd Order Polynomial type regression. So, the Graph 1, 2 and 3 were drawn using 3rd Order Polynomial regression.

The relationship for tensile strength (T.S.) and SiC percentage (x) is expressed as:

$$T.S. = -0.0926x^3 + 1.5556x^2 - 1.5x + 94 \qquad (1)$$

The relationship for Flexural strength (F.S.) and SiC percentage (x) is expressed as:

$$F.S. = -0.0926x^3 + 0.9444x^2 + 3x + 246 \qquad (2)$$

The relationship for Hardness (HR) and SiC percentage (x) is expressed as:

$$HR = --0.0838x^3 + 0.9356x^2 + 2.4144x + 66.6 \qquad (3)$$

Table 1 Results of Test

Sr. No.	% SiC	TENSILE STRENGTH (T. S.) in MPa	(% increase in T.S. by comparing with 0% SiC)	FLEXURAL STRENGTH (MPa)	(% increase in F.S. by comparing with 0% SiC)	HARDNESS (HR)	(% increase in HR by comparing with 0% SiC)
1	0	94	-	246	-	66.6	-
2	3	101	7	261	6	80	20
3	6	121	29	278	13	96.66	45
4	9	139	48	282	14.6	103	54.6

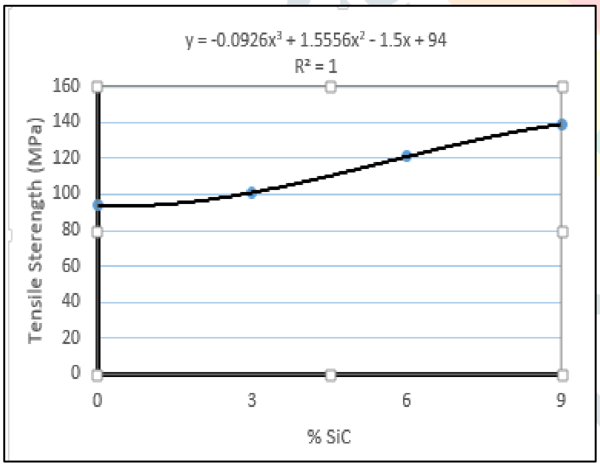

Figure 2: Tensile Strength V/S % SiC

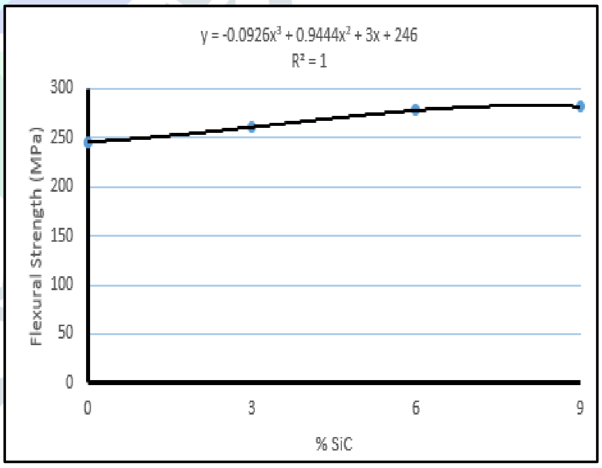

Figure 3: Flexural Strength V/S % SiC

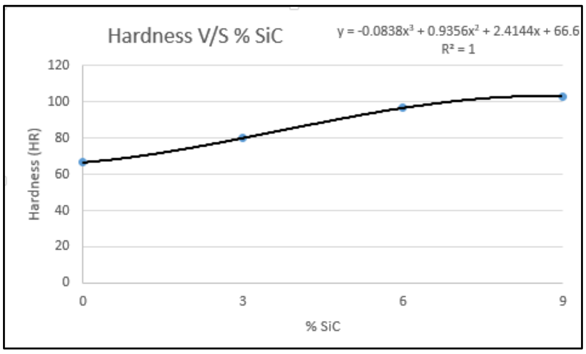

Figure 4: Hardness V/S % SiC

IV. Conclusion

On the basis of present experiment work following conclusions can be derived.

1. Electromagnetic stirring is successfully used to fabricate AMCs with 0%, 3%, 6% wt. SiC and 9% wt. SiC.
2. As reinforcement percentage increase in AMCs, the tensile strength, flexural strength and hardness of AMCs is increased.

3. Tensile strength of 0% SiC was 94 MPa, but at 9% SiC was 139 MPa. The tensile strength of 9% SiC reinforced AMC is increased upto 48% compared to pure AA 6061. Similarly, theflexural strengthof 9% SiC reinforced AMC is increased upto 14.5% compared to pure AA 6061 and hardness is increased by 54% respectively having 9% SiC.
4. The mathematical equations are derived from the experimental values of tensile strength, flexural strength and hardness.
5. From those equations, it was revealed that the tensile strength, flexural strength and hardness follows polynomial cubic relation with percentage of SiC reinforcement present in AA 6061 matrix.

REFERENCES

[1] R. Dwivedi, “Performance of MMC Rotors in Dynamometer Testing”, SAE Technical Paper Series, 940848, Warrendale, PA, USA.
[2] B. Neitzel, M. Barth, M. Matic, “Weight Reduction of Discs Brake Systems with the Utilization of New Aluminum Material”, SAE Technical Paper Series, 940335, Warrendale, PA, USA.
[3] T. Zeuner, P. Stojanov, P.R. Saham, H. Ruppert, A. Engels, “Developing trends in disc brake technology for rail application”, Mater. Sci. Technol. 14 (1998) 857–863.
[4] R. Dwivedi, “Development of Advanced Reinforced Aluminum Brake Rotors”, SAE Technical Paper Series, 950264, Warrendale, PA, USA, 1995, 8 p.
[5] Davim J. Machining of metal matrix composites. London, UK: Springer, 2012.
[6] Davim JP. Tribology of composite materials. New York, NY: Nova Science Publishers, 2012.
[7] Anoop S, Natarajan S and Kumaresh Babu SP. Analysis of factors influencing dry sliding wear behaviour of Al/SiCp–brake pad tribosystem. Mater Des 2009; 30: 3831–3838.
[8] L. Ceschini, C. Bosi, A. Casagrande, G.L. Garagnani, “Effect of thermal treatment and recycling on the tribological behaviour of an AlSiMg–SiCp composite”, Wear 251 (2001) 1377–1385.
[9] T. Miyajima, Y. Iwai; “Effects of reinforcements on sliding wear behavior of aluminum matrix composites”, Wear 255 (2003) 606–616.
[10] Chung DD, Composite Materials: Science and Applications, Springer Science & Business Media: New York, NY, 2010.
[11] Dowling NE. Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture, and Fatigue, Prentice Hall: Upper Saddle River, NJ, 1993.
[12] Ashby MF, Jones DRH, Engineering Materials 1: An Introduction to Their Properties and Applications, Butterworth-Heinemann: Oxford, 1996.
[13] Taheri-Nassai E, Kobashi M, Choh T. Scr. Metall. Mater. 1995, 32, 1923-1929.
[14] Characterization of Tensile Properties of Short Randomly Oriented Glass Fiber reinforced Nylon 6 composite.
[15] Rang Chen, Akira lwabuchi Tomoharu Shimizu, Hyung Seop Shin, Hidenobu Mifune, “The sliding wear resistance behavior of NiAI and SiC particles reinforced aluminium alloy matrix composites”, Wear 213 (1997) 175-184