FABRICATION AND CHARACTERIZATION OF AL6063-AL_2O_3- SIC COMPOSITES BY STIR CASTING

Ashish Sharma
M.tech, Department of Mechanical Engineering
Candigarh Engineering Collage
Landran(Mohali), India
ashishsharma261192@gmail.com

Sachin Mohal
Associate Professor, Department of Mechanical Engineering
Chandigarh Engineering College
Landran (Mohali), India
sachinmohal13@gmail.com

Narender Panwar
Assistant Professor, Department of Mechanical Engineering
NIT Srinagar
Srinagar, India
narender.16k@gmail.com

Rajwinder Singh
Assistant Professor, Department of Mechanical Engineering
Chandigarh Engineering College
Landran (Mohali), India
rajgill4u@gmail.com

***Abstract*— The present work is based on Aluminium metal matrix composites reinforced with SiC-Al_2O_3. The change in mechanical properties of Al_2O_3 and SiC reinforced into Al-6063 has been studied. The composite has been fabricated by stir casting. Aluminium Alloy 6063-Al_2O_3-SiC composites have been successfully prepared by stir casting technique. It has been concluded that grain size of the fabricated composite increases with increase in reinforcement content. Micro-hardness of aluminium matrix composite increases for 6% alumina reinforcement but decreased for 9% alumina reinforcement. Rockwell Hardness of composite increases with increase in silicon carbide content in composite. Tensile strength and percentage elongation has been decreased, with increase in weight fraction and increases again with further increase in alumina percentage.**

Keywords—Aluminum matrix composite; Alumina, Silicon carbide; Stir casting

I. INTRODUCTION

Metal matrix composites (MMC) are types of engineering materials that are combined by reinforcement of two or more than two types of materials, such that we can get advantages from all of constituent materials. The most commonly used matrix materials are Aluminum, Titanium & Magnesium, whereas the reinforcements are SiC, Al_2O_3 B_4C etc. [1-2]. Among them, Aluminium based MMC's are widely used due to their remarkable mechanical properties They have low density, high elastic modulus , great strength, and good wear resistance, which make them attractive for applications in the construction, aerospace, defence and automobile industries[3-4]. For the improvements in properties of an aluminum alloy, reinforcement are added to create an aluminum matrix composite. Remarkable increase in stiffness and strength has been observed even with the addition of small amount of reinforcements [5]. Generally, aluminum is reinforced with ceramic's such as B_4C, TiC, AlN, TiB2, TiO2, SiC (silicon carbide), Al_2O_3 (alumina) particulates. Hard metals such as titanium and tungsten were also found to be used [6]. In spite of the improvement in properties, the properties of aluminum composites are still not proven to be recouped with any of the aluminum products [7]. Techniques such as squeeze or stir casting, spray co-deposition and powder metallurgy has been used to fabricate metal matrix composites [8]. The cluster, uneven distribution and poor mutability are the main problems associated with fabrication of these composites [9]. Stir casting is accepted as the most reliable and broadly used technique for the manufacturing of metal matrix composites [10-13]. Al_2O_3 is known to have unique properties such as high wear resistance , high melting point, higher corrosion resistance at very low cost. It have great advantage when used for high speed machining as compared to traditional high speed steel and other cutting tools[14-15]. But due to poor damage tolerance and brittleness it have limited application [14]. It has also been found that when both SiC (silicon carbide), Al_2O_3 (alumina) particulates are fabricated together they tends to retain superior strength and toughness at higher temperature as well as room temperature [16].

The manufacturing cost of these metal matrix composites (MMCs) when produced using above spray co-deposition and powder metallurgy is found to be high due to the expensive equipment's and complicated processing routes used which results in limited use of these materials. In order to resolve the above mentioned issues, the authors have recently utilized SiC and Al_2O_3 (alumina) as the reinforcement for Aluminium 6063 alloy. Good formability characteristics and suitability in bulk strength enhancement through heat treatment makes aluminium alloy 6063 a popular choice as a matrix material for the processing of metal-matrix composites.materials

A. Matrix Material

In this study, Al 6063 alloy has been used as a matrix material. It was purchased in the form of rod from J.V. Mill & Hardware Store, Industrial Area Phase II, Chandigarh

B. *Reinforcement Material*

Aluminium oxide or alumina (Al_2O_3) manufactured by Avantor Performance Materials India ltd. and Silicon Carbide (SiC) has been used as reinforcement material for development of the composites. Aluminium oxide and Silicon carbide is purchased from J.V. Mill & Hardware Store, Industrial Area Phase II, Chandigarh.

Alumina has been varied in 3%, 6% and 9% whereas silicon carbide is used in constant composition 6 % of total composite mass by weighing in accordance to total composition of material to be manufactured. The scanning electron microscopy (SEM) technique has been used to determine elemental composition of alumina and silicon in aluminium 6063 when reinforced.

II. METHODS

A. *Fabrication of samples*

Stir casting method have been used for fabrication of Samples. Muffle furnace has been used for preparing/melting of alloys etc. The matrix material has been placed in crucible for heating and left until it melts completely. Preheated reinforcement particles are then added into crucible having molten matrix material. The alloy melts and the reinforcement particles have been mixed by mechanical stirrer mounted on muffle furnace. The molten mixture has been superheated in muffle furnace which leads to increase in fluidity of alloy for pouring. Then the molten material is poured into various molds that are cylindrical in shape with different dimensions.

B. *Mechanical Testing*

As fabricated samples have been machined and polished metallographically according to ASTM International standards in order to investigate their mechanical properties. For this purpose, an Inverted Metallurgical Microscope (50x-1600x) and a test method ASTM E112:13 at a Temperature of 25±3ºC and Rel. Humidity of 40-60 % has been used for testing grain size of samples. A universal testing machine (Model: UTE100) with capacity of 1000kN and resolution 0.05kN and a test method IS: 1608:2005 at a Temperature of 25±3ºC and Rel. Humidity of 40-60 % has been used for tensile testing and percentage (%) elongation of samples. Vicker Hardness Tester (Model: VM-50) by Fuel Instruments & Engineers Pvt. Ltd. and a test method IS: 1501:2002 at a Temperature of 25±3ºC and Rel. Humidity of 40-60 %. has been used for hardness testing of samples.

III. RESULTS AND DISCUSSION

A. *Microscopic analysis*

The microscopic analysis has been performed to analyse the variation in grain size and to check the uniform distribution of reinforcements in the matrix. It has been found that the grain size tends to increase with increase in % of alumina as reinforcement in the composite as shown in Table I. This might have happened due to constant increase in amount of alumina as a reinforcement [17].

TABLE I. GRAIN SIZE OF Al6063/Al_2O_3/ SiC COMPOSITES

S. No.	Grain Size of Al6063/Al_2O_3/ SiC composites	
	Sample Type	***Grain Size***
1	Al 6063 + 3% Al_2O_3 + 6% SiC	6
2	Al 6063 + 6% Al_2O_3 + 6% SiC	7
3	Al 6063 + 9% Al_2O_3 + 6% SiC	8

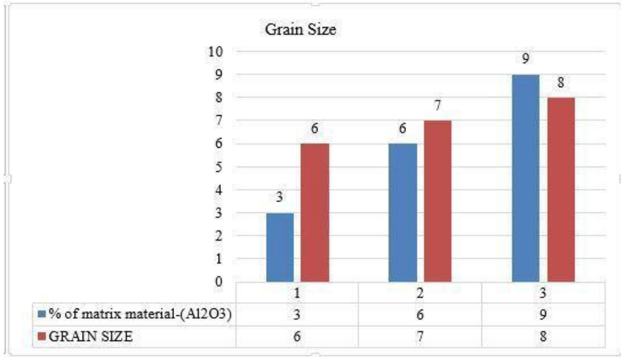

Fig. 1 . *Variation in grain size of composites*

B. *Tensile Strength*

The tensile strength of composites are shown in Table II whereas Fig. 2 represents the variation of tensile strength with respect to change in Al_2O_3 percentage. It has been noticed that the tensile strength has been decreased, with increase in weight fraction of alumina initially and increases again with further increase in alumina percentage.

As amount of reinforcement increases, material deforms plastically, more number of dislocations are generated and hinder the further movement of the composites during testing. Strong reinforcement-matrix interaction effectively transfers tensile stress from matrix to reinforcement leads to improvement of tensile strength [16]. Decrease in particle size increases in interfacial action leading to material become more brittle hence reduced tensile strength.

TABLE II. TENSILE STRENGTH OF Al6063/Al_2O_3/ SiC COMPOSITES

S. No.	Tensile strength of Al6063/Al_2O_3/ SiC composites	
	Sample Type	***Tensile strength (N/mm^2)***
1	Al 6063 + 3% Al_2O_3 + 6% SiC	94
2	Al 6063 + 6% Al_2O_3 + 6% SiC	83
3	Al 6063 + 9% Al_2O_3 + 6% SiC	108

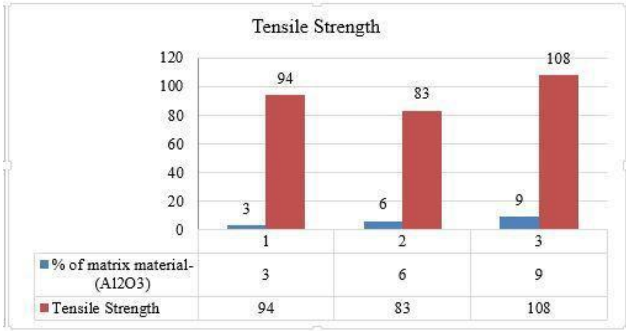

Fig. 2 . *Variation in Tensile Strength of composites*

C. Percent Elongation

The percentage elongation of Al6063/Al_2O_3/SiC composite is shown in Table III. It has been observed that the percentage elongation of Al6063/Al_2O_3/SiC composite first decreased considerably and then slightly increases with increase in alumina percentage as shown in fig.3. The decrease in elongation of composite may be due to increase in brittleness of composite due to addition of harder alumina particles.

TABLE III. PERCENT ELONGATION OF Al6063/Al_2O_3/ SiC COMPOSITES

S. No.	Elongation of Al6063/Al_2O_3/ SiC composites	
	Sample Type	*Elongation (%)*
1	Al 6063 + 3% Al_2O_3 + 6% SiC	9.3
2	Al 6063 + 6% Al_2O_3 + 6% SiC	7.4
3	Al 6063 + 9% Al_2O_3 + 6% SiC	8

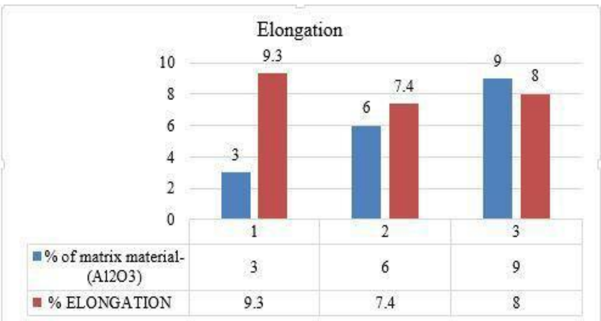

Fig. 3 . *Variation of percent Elongation of composites*.

D. Micro Hardness

Table IV shows that the micro-hardness of Al6063/Al_2O_3/ SiC composites. The Micro hardness of fabricated composite increases with increase in percentage of alumina in the matrix but further increase in alumina percentage decreases the hardness of the composite (ref. Fig. 4). The increase in hardness may due to increase in addition of harder alumina particles. But further increase in value of alumina reinforcement reduces the hardness this may be arisen from the presence of more porosity in composites with higher reinforcement and also may be due to clustering of reinforcement particles at percentage.

TABLE IV. MICRO-HARDNESS OF Al6063/Al_2O_3/ SiC COMPOSITES

S. No.	Micro-hardness of Al6063/Al_2O_3/ SiC composites	
	Sample Type	*Micro-hardness (HV)*
1	Al 6063 + 3% Al_2O_3 + 6% SiC	40
2	Al 6063 + 6% Al_2O_3 + 6% SiC	49
3	Al 6063 + 9% Al_2O_3 + 6% SiC	47

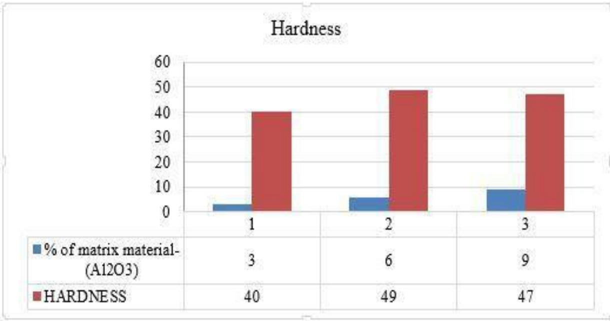

Fig. 4 . *Variation of Micro- Hardness of composites*

IV. Conclusions

The following important conclusions of the present investigation are:-

- Al6063/Al_2O_3/SiC composites have been successfully prepared by stir casting technique.
- Grain size of the fabricated composite increases with increases in reinforcement content.
- It has been noticed that the tensile strength has been decreased, with increase in weight fraction of alumina initially and increases again with further increase in alumina percentage.
- It has been observed that the percentage elongation of Al6063/Al_2O_3/SiC composite first decreased considerably and then slightly increases with increase in alumina percentage. This mainly occurs due to increase in brittleness of composite due to addition of harder alumina particles.
- It has been concluded that the micro-hardness of 49 HV is achieved for Al6063/6%Al_2O_3/6%SiC composite. Moreover, it has been noticed that micro-hardness decreases with increase in Al_2O_3%.

References

[1] A. Ahmadi, M. R. Toroghinejad, A. Najafizadeh, " evolution of microstructure and mechanical proprties of Al/Al_2O_3/SiC hybrid composite fabricated by accumulative roll bonding process" Mater. Des., Vol. 53, pp 13–19, 2014.

[2] A. K. Mishra, V. Kumar, R. K. Srivastava, "Optimization of Tribological Performance of Al-6061T6-15% SiC_p-15% Al_2O_3 Hybrid Metal Matrix Composites Using Taguchi Method & Grey Relational Analysis", J. Miner. Mater. Charact. Eng., Vol. 2, pp 351-361, 2014.

[3] R. Zheng, H. Yang, T. Liu, K. Ameyama, C. Ma, "Microstructure and mechanical properties of aluminum alloy matrix composites reinforced with Fe-based metallic glass particles" Mater. Des., Vol. 53, pp 512-518, 2014.

[4] M Haghshenas, Reference Module in Materials Science and Materials Engineering, 2015

[5] M. Ramachandra, K. Radhakrishna, "Effect of reinforcement of flyash on sliding wear, slurry erosive wear and corrosive behavior of aluminium matrix composite" ,Wear, Vol. 262, pp 1450–1462, 2007.

[6] P. S. Sahu, R. Banchhor, "Fabrication methods used to prepare Al metal matrix composites- A review "Inter. Res. J. Eng. Technol., Vol. 03, Issue 10, 2016

[7] Jason S. H. Lo, "Achieving multi-functional properties via squeeze cast hybrid metal matrix composites 16th International Conference on composite materials

[8] N. Panwar and A. Chauhan, "Development of Aluminum Composites using Red Mud as Reinforcement"Proceedings of 2014 RAECS UIET Panjab University Chandigarh (2014) 1-4.

[9] D.W. Lee, B.K. Kim, "Nanostructured Cu–Al_2O_3 composite produced by thermochmical process for electrode application", Mat. Letters, Vol. 58, pp 378– 383, 2004

[10] J. Hashim, L. Looney, M.S.J. Hashmi, "Metal matrix composites: production by the stir casting method" J. Mater. Proc. Technol., Vol. 92-93, pp1-7, 1999.

[11] N. Panwar and A. Chauhan, "Fabrication methods of particulate reinforced Aluminium metal matrix composite- A review "Materials Today: Proceedings 5 (2018) 5933–5939.

[12] N. Panwar, R.P. Poonia, G. Singh, R. Dabral, A. Chauhan, "Effect of Lubrication on Sliding Wear Effect of Lubrication on Sliding Wear of Red Mud Particulate Reinforced Aluminium Alloy 6061"Tribology in industry, Vol. 39, issue 3, pp 307-318,2017.

[13] R. Dabral, N. Panwar , R. Dang , R.P. Poonia, A. Chauhan, "Wear Response of Aluminium 6061 Composite Reinforced with Red Mud at Elevated Temperature"Tribologi in industry Vol. 39, issue 3, pp 391-399, 2017.

[14] Z. Yin, C. Huang, B. Zou, H. Liu, H. Zhu and J. Wang "High temperature mechanical properties of Al_2O_3/TiC micro–nano composite ceramic tool materials" Ceramics International, vol. 39, pp 8877-8883, 2017.

[15] L.Xuefei, L. Hanlian, H. Chuanzhen, Z. Bin and Z. Longwei "High temperature mechanical properties of Al2O3-based ceramic tool material toughened by SiC whiskers and nanoparticles" Ceramics International, Vol. 43, pp 1160-1165, 2017

[16] G.S.Thompson, M.P. Harmer,"Nanoscale Ceramic Composites "Encyclopedia of Materials: Science and Technology" (Second Edition) 2001,Pages5927–5930.

[17] M. Rahimian , N. Parvin and N. Ehsani, "The effect of production parameters on microstructure and wear resistance of powder metallurgy Al–Al_2O_3 composite, Materials and Design, Vol. 32, Issue 2, 2011, pp 1031-38