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Experimental Investigation on Mechanical Properties of Hybrid Metal Matrix Composite Reinforced With Alumina, Graphite and Silicon Carbide

Nagisetti Dileep Kumar[1], Dr. B. Amar Nagendram[2]
[1] *Post Graduate Student, Department of Mechanical Engineering (M.Tech, Machine design), DMSSVH College of Engineering, Machilipatnam, India*
[2]*Professor, Department of Mechanical Engineering, DMSSVH College of Engineering, Machilipatnam, India*

ABSTRACT : *In the present investigation, the study on mechanical properties of Aluminum Hybrid Matrix Composites (AMCs) reinforced with alumina (Al_2O_3), silicon carbide (Sic) and graphite (Gr) particles. Al6063 alloy is used as the matrix material with varying the reinforcement of alumina at fixed quantity of 5 wt% SiC and 5 wt% of graphite. The composites were fabricated by stir casting equipment methodology with controlled speed and feed parameters. Hardness is measured by using Brinell hardness equipment and tensile properties were measured by using universal testing machine and it is compared with aluminum alloy. There was a great advancement in hardness and tensile properties by changing the compositions. The Sic and Al2O3 resulted in improving the hardness and density of their respective composites. Further, the changing the compositions of these reinforcements contributed in increased hardness and density of the composites.*

Keywords: *Graphite, Hardness test, Hybrid metal matrix composites silicon carbide, Tensile strength*

I. INTRODUCTION

Aluminum is used as a matrix material due of its effective physical characteristics and most widely available material. This leads for the improvement of new material. Most of research work on Metal matrix Composites (MMC) was carried out on Silicon (Sic), Aluminum oxide (Al_2O_3) and Graphite (Gr) particle reinforcements and few worked on mixture of reinforcements (hybrid composites). Modern composite materials are typically optimized to accomplish a proper balance of properties for a given range of applications. Given the widespread range of materials that may be considered as composites and the broad range of uses for which the composite materials may be designed, it is difficult to concur upon a single, logical and practical definition. However, as a widespread practical definition, composite materials may here three variations of inlet valves are used, be limited to focus those materials that contain a continuous matrix constituent that binds together and provides to a succession of a stronger, stiffer reinforcement constituent. The resulting composite material has a balance of structural properties that is superior to other constituent material alone. Local varying internal tension due to the thermal expansion behavior of the two phases in a hybrid metal matrix composites is an additional influencing factor. The reinforcement is very noteworthy because it is accountable for the estimation and optimization of mechanical properties, cost and performance of a given composite. In particular, many of the considerations arising due to fabrication, processing and service performance of composites are associated exclusively to the metallurgical aspects that take place in the interfacial region between matrix and reinforcement.

Mukesh Kumar et.al [1] is investigated Enhancement of Mechanical Properties of Aluminum (6063) based Metal Matrix Composite Reinforced Silicon Carbide .In his experiments three specimens were prepared having 5%, 7%, and 9% composition of silicon carbide. It was detected that the best optimum results were obtained at 9% which gives Density 2.42 g/cc, Tensile strength 83.69 N/mm2, Hardness 38.1 BHN. V. Daniel Jebin et.al [2] presented Wear behaviour of AL6063-Alumina Metal Matrix Composite. In his thesis he conducted experiments taking Al 6063 alloy matrix composites reinforced with Alumina particles can be successfully synthesized by the stir casting method. MS Raviraj, CM sharanprabhu, G.C.Mohankumar [3] in his research entitled “Experimental analysis on processing and properties of al6061-TiC metal matrix composites”. Stir casting is used for fabrication Al6061-TiC metal matrix composites. Hardness and Ductility increases by increasing particle reinforcement. GauravMahajan, Nikhil Karve, UdayPatil, P. Kuppan and K. Venkatesan [4] in his research on Analysis of Microstructure, Hardness and Wear of Al6061-SiC-TiB_2 Hybrid Metal Matrix Composite. Microstructure and mechanical properties such as micro hardness and wear are studied for various compositions of reinforcements, 10% Sic and 2.5%, 5% and 10% TiB_2. The results indicate that the hardness value increases while the wear resistance increases up to certain amount and reduces drastically when crossed the transition load.

In this paper the Hybrid Metal-matrix composite of Al6063 alloy reinforced with graphite (Gr), aluminium oxide (Al2o3) and silicon carbide (Sic) are fabricated successfully by using stir casting method. The Tensile strength of metal matrix composites are done successfully and observed that composition of Al+5% Sic+5%Al2o3+5%Graphite is having higher tensile strength of 133MPa. Hardness test on composites are performed successfully and also concluded that the material composition of Al+5% Sic+5%Al2o3+5%Graphite is having higher hardness of 49.6 HBW compared to the other compositions.

II. EXPERIMENTATION

In this research work, Al 6063 is selected as the matrix alloy and the reinforcements are alumina Silicon Carbide and Graphite. Table 1 illustrates the percentage compositions of the samples considered for the research work.

Table 1: Percentage compositions of the hybrid metal matrix composites

Particulars	Weight fraction with reinforcements
Al 6063	200gm , No reinforcements
Al 6063 +5%Sic+5% Graphite	5% Silicon Carbide(10gm) and 5%(10gm) Graphite
Al6063+5%Al2o3+5%Graphite	170g of Al,5%(10g) of Al2o3,5%(10gm) of graphite
Al 6063 +5% Sic+5%Al2o3	170gm of Al,5%(10gm) of Sic,5%(10g) of Al2o3
Al 6063+5% Sic+5%Al2o3+5%Graphite	170gm of Al, 5%(10gm) of Sic, 5%(10g) of Al2o3 and 5%(10gm) of Graphite

Here we are fabricated 10 samples for calculating the tensile strength and hardness.

- 5 samples for tensile test.
- 5 samples for hardness.

2.1 Fabrication process

The most widely available method of fabricating metal matrix composites is so called stir casting procedure. The procedure which is used for quick production of composites widely used in industries is the vortex or stir casting technique. Stir casting generally consist of prolonged liquid reinforcement contact, which can cause considerable interface reaction. In this research we are aiming to study, the effect of aluminum oxide, Silicon Carbide and Graphite on stir cast Aluminum Metal Matrix Composites. 1.5 kg of Al 6063 alloy pieces in the electric arc furnace is heated and allows the same to melt at 7500C and care has been taken to achieve complete melting. The initial equipment of electric arc furnace is shown below in “Fig “1.The alloy pieces are kept in the crucible and preheat the mould at the required temperature 7500C - 8000C. The “Fig 2” shows the fabrication process using a mould box. Preheat the reinforcements Silicon Carbide and Graphite at the equal temperature range. Slag has been removed using scum powder to escape poor quality casting and maintained at the same temperature for about 25 minutes to remove the moisture casting. Approximately 7.5% weight of solid dry hexachloro-ethane tablets are used to remove the oxide layers of the molten metal at temperature 7500C. Figures 3 and 4 show the scum powder and degassing tablet used for the fabrication of composites. Stirring process of the molten metal to create vortex by means of stir casting process and the temperature of molten metal has been maintained around 7500C.

The stirring of the mixture has been carried out to confirm uniform distribution of reinforcements in the matrix material. Continuous stirring has been accomplished at the range 250 to 300 rpm to a time of about 15 minutes having the material feed rate at 30gm/minute. After smooth solidification process, preheat the mould to avoid shrinkage of casting metal for about 3 hours to complete the process. Figures 5 and 6 show the mould box and accessories used to prepare the samples based on stir casting process.

Figure 1: Stir casting equipment with electric arc furnace

Figure2: Stirring method of composites

Figure 3: Determination of stirrer speed with tachometer

Figure 4: Dimmer start for variable speed to stirrer

Figure 5: Mould preparation for Metal matrix composites

Figure 6: Fabricated hybrid metal matrix composites

III. RESULTS

3.1 Tensile Strength on hybrid metal matrix composites

The hybrid metal matrix composites were fabricated for measuring the tensile strength at different compositions. The tensile strength is measured by using universal testing machine, it is observed that when the tensile strength of Al alloy6063 is 128.54N/mm^2 is compared to the other compositions the tensile strength is increased when the composition is changed.

3.1.1 Sample no1: Al alloy6063

Table 2: Input and output data of Al alloy6063

Input Data	
Specimen shape	Solid round
Specimen diameter	12.5mm
Initial gauge length	50mm
Pre load value	0 KN
Maximum load	600 KN
Maximum elongation	250mm
Specimen cross section area	130.7mm^2
Final gauge length	56mm
Output data	
Load at yield	12.5KN
Yield stress	96.54N/mm^2
Load at peak	16.62KN
Tensile strength	128.54N/mm^2
% of elongation	21.34%

It is observed that the tensile strength is not greater than the 130MPa which is very low when compared with the initial value of241MPa of Al6063 alloy and minimum percentage elongation is greater than 18% i.e. having a value of 21.34%.

3.1.2 Sample no2: Al+5%Sic+5%Graphite

Table 3: Input and output data of Al+5%Sic+5%Graphite

Input Data	
Specimen shape	Solid round
Material type	Al+SIC+Gr
Specimen diameter	12.5mm
Initial gauge length	50mm
Pre load value	0 KN
Maximum Elongation	200mm
Specimen cross section area	121.15mm^2
Final gauge length	56mm
Output data	
Load at yield	10.54KN
Yield stress	87.264N/mm^2
Load at peak	14.514KN
Tensile strength	109.623N/mm^2
% of elongation	19.34%

3.1.3 Sample no3: Al+5%Al2o3+5%Graphite

Table 4: Input and output data of Al+5%Al2o3+5%Graphite

Input Data	
Specimen shape	Solid round
Material type	Al+Alumina+Gr
Specimen diameter	12.5mm
Initial gauge length	50mm
Pre load value	0 KN
Maximum Elongation	200mm
Specimen cross section area	121.15mm^2
Final gauge length	56mm
Output data	
Load at yield	9.95KN
Yield stress	80.524N/mm^2
Load at peak	12.340KN
Tensile strength	103.202N/mm^2
% of elongation	3.14%

It is observed that the Al6063-5%Al2o3 with this combination we can clearly observe that upon increasing the percentage of alumina, tensile strength and yield strength of the material increases.

3.1.4 Sample no4: Al+5%Sic+5%Al_2O_3

Table 5: Input and output data of Al+5%Sic+5%Al_2O_3

Input Data	
Specimen shape	Al+Sic+ Alumina
Material type	12.5mm
Specimen diameter	
Initial gauge length	50mm
Pre load value	0 KN
Maximum Load	650KN
Maximum Elongation	250mm
Specimen cross section area	121.74mm^2
Final gauge length	56mm
Output data	
Load at yield	10.89KN
Yield stress	89.758N/mm^2
Load at peak	14.250KN
Tensile strength	119.084N/mm^2
% of elongation	14.82%

3.1.5 Sample no5: Al+5%Sic+5%Al_2O_3+5%Graphite

Table 6: Input and output data of Al+5%Sic+5%Al_2O_3+5%Gr

Input Data	
Specimen shape	Solid round
Material type	Al+Sic+Alumina+Gr
Specimen diameter	12.5mm
Initial gauge length	50mm
Pre load value	0 KN
Maximum Load	650KN
Maximum Elongation	250mm
Specimen cross section area	109.17mm^2
Final gauge length	56mm
Output data	
Load at yield	11.19KN
Yield stress	102.497N/mm^2
Load at peak	14.520KN
Tensile strength	132.854N/mm^2
% of elongation	10.68%

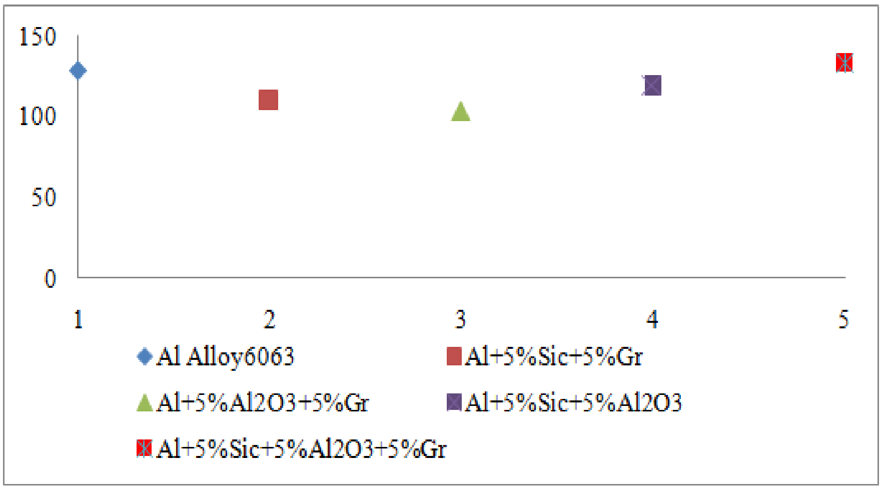

Figure 7: Over all comparison of tensile results

The above graph shows the overall comparison of tensile strengths and it can clearly observe that the tensile strength is increased to 133MPa which is higher than all the above tested samples. So we can infer that if we have taken this particular composition we can certainly increase the ultimate tensile strength of the material.

3.2 Hardness test on hybrid metal matrix composites

The hardness is measured by using Brinell hardness equipment. Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Hardness is depends on ductility, elastic stiffness, plasticity, strain, strength, toughness. Hardness test is measured by using Brinell hardness equipment.

Figure 8: Computerized Brinell hardness equipment

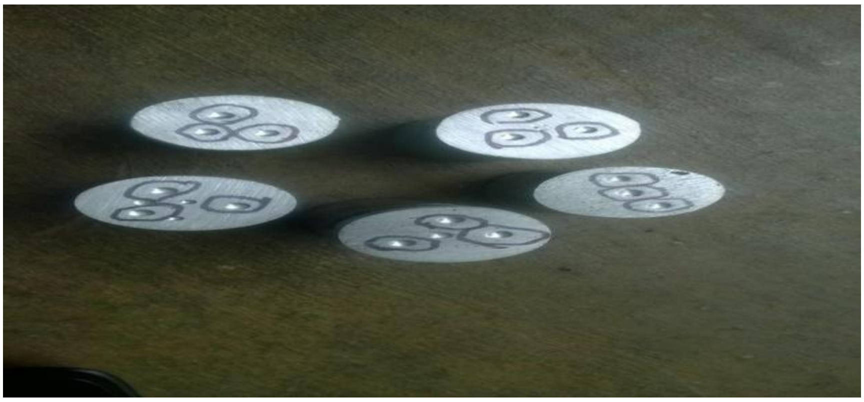

Figure 9: Dents formed during hardness method

Table 7: Hardness results

Material Type	Ball diameter	Test load	Hardness result
Al6063	5.0mm	250kg	46.5HBW
Al+5%Sic+5%Graphite	5.0mm	250kg	46.5HBW
Al+5%Al2o3+5%Graphite	5.0mm	250kg	44.7HBW
Al+5% Sic+5%Al2o3	5.0mm	250kg	47.5HBW
Al+5% Sic+5%Al2o3+5%Graphite	5.0mm	250kg	49.6HBW

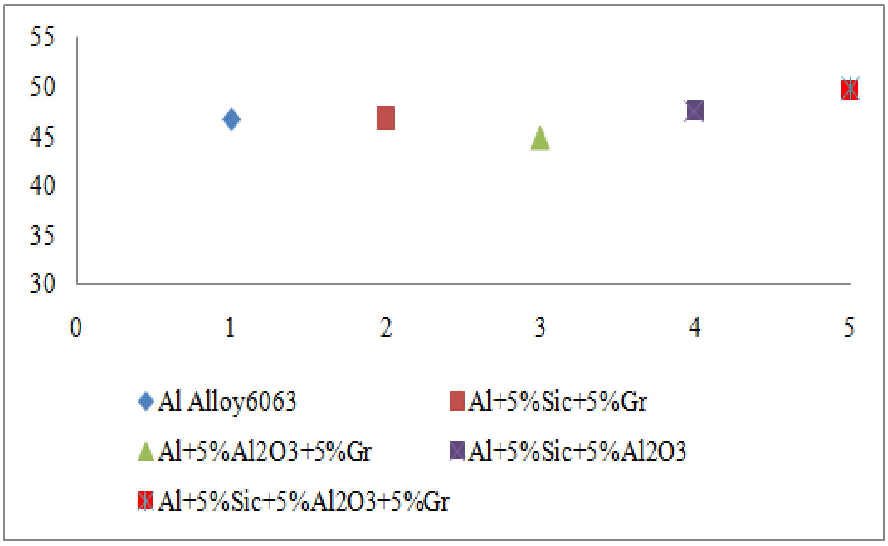

Figure 10: Over all comparison of hardness results

IV. CONCLUSIONS

Hybrid Metal-matrix composite of Al6063 alloy reinforced with graphite (Gr),alumina(Al2o3) and silicon carbide (SiC) are fabricated successfully. Tensile strength of fabricated metal matrix composites are done successfully and observed that composition of Al+5% Sic+5%Al2o3+5%Graphite is having higher tensile strength of 133MPa compared to the other compositions. Hardness of the composites are performed successfully and concluded that material composition of Al+5% Sic+5%Al2o3+5%Graphite is having higher hardness of 49.6 HBW compared to the other compositions.

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