ENHANCEMENT OF MECHANICAL, MICROSCOPIC AND TRIBOLOGICAL PROPERTIES OF HYBRID METAL MATRIX COMPOSITE REINFORCED WITH ALUMINA, GRAPHITE AND SILICON CARBIDE

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Abstract: In the present investigation, studies on microstructure and 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 varying from 5 to 10%, SiC from 5 to 10 wt% in steps of 5 wt% and fixed quantity of 5 wt% of graphite. The composites were fabricated by stir casting equipment methodology with controlled speed and feed parameters. The fabricated composites were examined for microstructure to know the particle distribution in the matrix material. Hardness and tensile properties were also studied and compared with the aluminum alloy. There was a great advancement in hardness and tensile properties by increasing the weight percentage of SiC particles. In this paper we also aimed to conduct tribological properties of hybrid metal matrix composites by wear testing equipment according to ASTM standards and the manufactured components are compared with already existable hybrid metal matrix composites.. The SiC and Al2O3 resulted in improving the hardness and density of their respective composites. Further, the increased %'age of these reinforcements contributed in increased hardness and density of the composites.

Keywords: Hybrid metal matrix composites, silicon carbide, tensile strength, hardness

1. Introduction

Aluminium is used as a matrix material due of its effective characteristics and most widely available material. Aluminium alloy alone shows poor mechanical and tribological properties. This leads for the development of new material. Most of research work on MMCs was carried out on SiC, Al2O3, Gr particle reinforcements and few worked on combination 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 varieties 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 an 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 related exclusively to the metallurgical aspects that take place in the interfacial region between matrix and reinforcement.

The composite strength, stiffness and toughness are affected by reinforcement particle size, particle adhesion, particle loading in both micro and macro scale. There is a critical particle size below which the yield strength and compressive strength are greatly enhanced. Alumina as reinforcement with Al-6061was studied which reveals that with increase in temperature the wear reduces. The Mechanical property of the composite like strength and stiffness are found to improve with variation in the reinforcement weight fraction. Density of the composite increases with increase in weight percentage of the reinforcement in case of Al 2024 –Al2O3 material system.

2. LITERATURE REVIEW

Mukesh Kumar et.al investigated Enhancement of Mechanical Properties of Aluminium (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 observed 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 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. Wear behaviour of Al6063 /Al2O3 MMC is tested using Pin-on disk machine and is that found increasing the percentage of Alumina particles will reduce the wear rate.

. Ms Raviraj, CM sharanprabhu, G.C.Mohankumar in his research entitled “Experimental analysis on processing and properties of al6061-TiC metal matrx composites”. Stir casting is used for fabrication Al6061-TiC metal matrix composites. Hardness and Ductility increases by increasing particle reinforcement.

Gaurav Mahajan, Nikhil Karve, Uday Patil, P. Kuppan* and K. Venkatesan 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.

Jayasheel I. Harti et.al studied on Wear Behavior of Al2219-TiC Particulate Metal Matrix Composites TiC particulate reinforced Al2219 alloy metal matrix composites were prepared by stir casting method. Weight fraction of the reinforcement was varied from 0 to 6 wt. % in steps of 2 wt. %(2,4,6%). the wear rate was increased with increase in normal load and sliding speed for all the conditions. Further, wear studies also suggest that wear rate of the Al2219-TiC composites was lesser than that of the Al2219 matrix.

J. Zhang et al. conducted rigorous studies on the effect of Silicon Carbide and Graphite particulates on the resultant damping behavior of 6061 A1 metal matrix composites to develop a high damping material. The micro structural analysis has been performed using scanning electron microscopy, optical microscopy and image analysis. It was shown that the damping capacity of Al 6061 could be significantly improved by the addition of either Silicon Carbide or graphite particulates through spray deposition processing.

3. EXPERIMENTAL PROCEDURE FOR PREPARATION OF HYBRID METAL MATRIX COMPOSITES

In the present research work, Al 6063 is selected as the matrix alloy and the reinforcements are alumina Silicon Carbide and Graphite. Table 3.1 illustrates the percentage compositions of the samples considered for the research work with varying weight fractions.

Particulars	Weight fraction with reinforcements
Al 6063	200 gm , No reinforcements
Al 6063 +10%Sic+5% Graphite	10% Silicon Carbide(20 gm) and 5%(10 gm) Graphite
Al6063+10%Al2o3+5%Graphite	170g of Al,10%(20g) of Al2o3,5%(10gm) of graphite
Al 6063 +5% Sic+5%Al2o3	180gm of Al,5%(10gm) of Sic,5%(10g) of Al2o3
Al 6063+5% Sic+5%Al2o3+5%Graphite	170 gm of Al, 5%(10 gm) of SiC, 5%(10g) of Al2o3 and 5%(10 gm) of Graphite

Table 1: percentage compositions of the hybrid metal matrix composites with varying weight fractions.

Finally we have fabricated 10 samples
5 samples for tensile test
5samples for hardness, microstructure and wear test.

3.1 Preparation of composites:

The most widely available method of producing metal matrix composites is so called stir casting technique. The technique which is used for quick production of composites widely used in industries is the vortex or stir casting technique. Stir casting usually involves prolonged liquid reinforcement contact, which can cause considerable interface reaction. In our research we are aiming to study, the effect of aluminum oxide, Silicon Carbide and Graphite on stir cast Aluminum Metal Matrix Composites has been discussed (1). 1.5 kg of Al 6063 alloy pieces in the electric arc furnace is heated and allows the same to melt at 750^0C 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 750^0C - 800^0C. Fig 2 shows the fabrication process using a mould box. Preheat the reinforcements Silicon Carbide and Graphite at the same temperature range. Slag has been removed using scum powder to avoid 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 750^0C. 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 750^0C. The stirring of the mixture has been carried out to ensure uniform distribution of reinforcements in the matrix material. Continuous stirring has been accomplished at the range 250 – 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.

Fig 1: stir casting equipment with electric arc furnace

Fig 2: stirring method of composites

Fig 3: determination of stirrer speed with tachometer

Fig 4: Dimmer start for variable speed to stirrer

Fig 5: Mould preparation for Metal matrix composites

fig 6: Fabricated hybrid metal matrix composites

4. RESULTS & DISCUSSIONS

4.1 TENSILE STRENGTH:

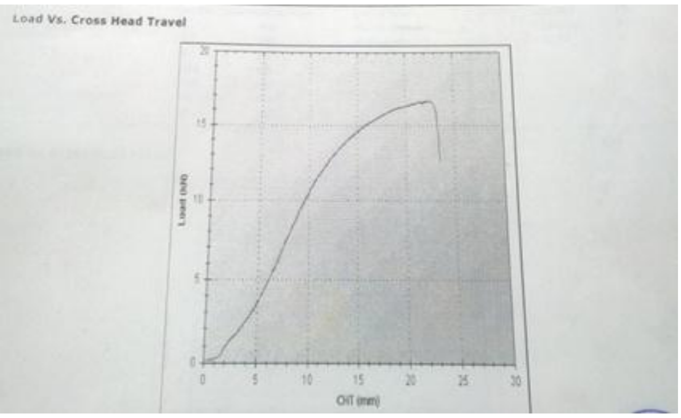
Sample no 1:

Input data

Specimen shape : solid round
Material type : Al alloy6063
Specimen diameter : 12.5mm
Initial gauge length: 50mm
Pre load value : 0KN
Max. Load : 6ooKN
Max .elongation : 250mm
Specimen cross section area: 130.7mm2
Final gauge length : 56mm

Output data

Load at yield : 12.75KN
Yield stress : 97.553N/mm2
Load at peak : 16.620KN
Tensile strength : 127.163N/mm2
% 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 of 241 MPa of Al6063 alloy and minimum percentage elongation is greater than 18% i.e. having a value of 21.34%.(5)

Sample no 2:

Al+10%Sic+5%Graphite

- **Input data**

Specimen shape : solid round
Material type : Al-SIC+Gr
Specimen diameter : 12.5mm

Output data

Load at yield : 10.33KN
Yield stress : 85.264N/mm^2
Load at peak : 13.160KN

Initial gauge length: 50mm | Tensile strength : 108.623N/mm^2

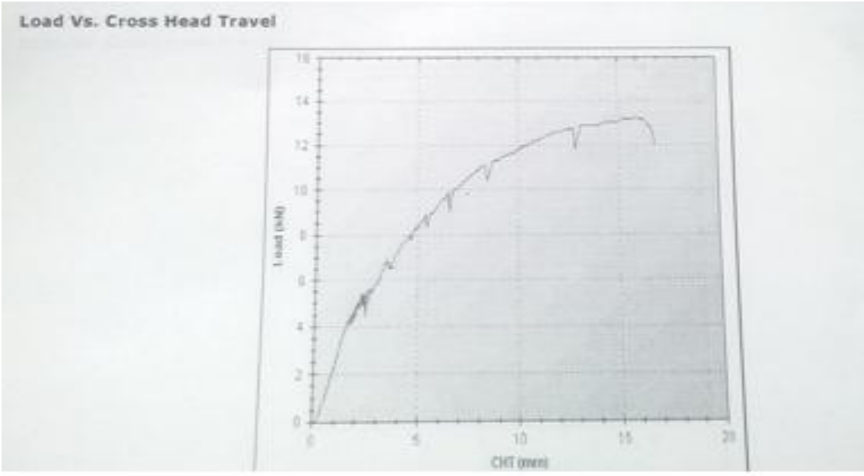
Pre load value : 0KN | % of elongation : 19.34%

Max. Load : 200 KN

Max .elongation : 200 mm

Specimen cross section area: 121.15mm^2

Final gauge length : 56mm



Sample no 3:

Al+10%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 : 0KN

Max. load : 200 KN

Max .elongation : 200mm

Specimen cross section area: 121.15mm^2

Final gauge length : 56mm

Output data

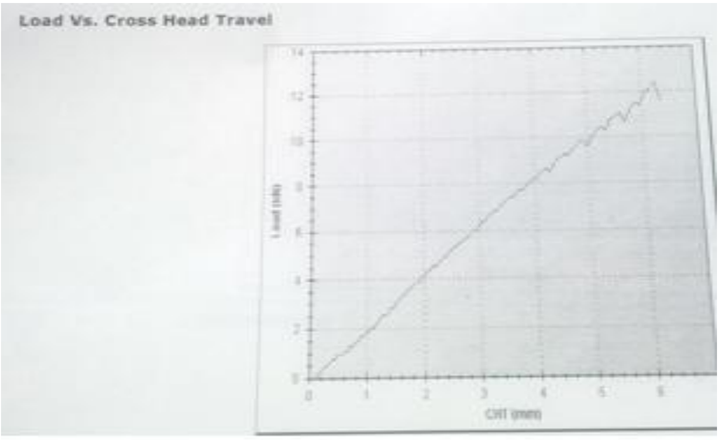
Load at yield : 9.71KN

Yield stress : 79.633N/mm^2

Load at peak : 12.340KN

Tensile strength : 101.202/mm^2

% of elongation : 3.14%



It is observed that the Al6063-6%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)

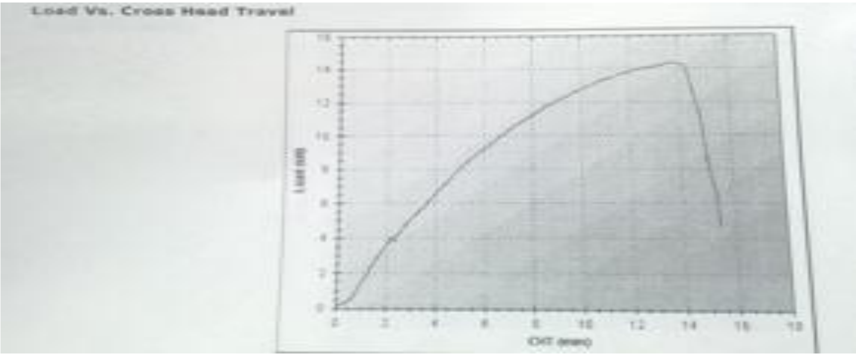
***Sample no 4*:**
Al+5% Sic+5%Al2o3

- **Input data**

Specimen shape : solid round
Material type : Al- Alumina+Sic
Specimen diameter : 12.5mm
Initial gauge length: 50mm
Pre load value : 0KN
Max. Load : 650KN
Max .elongation : 250mm
Specimen cross section area: 121.74mm^2
Final gauge length : 56mm

Output data

Load at yield : 10.89KN
Yield stress : 89.454N/mm2
Load at peak : 14.250KN
Tensile strength : 117.054/mm2
% of elongation : 14.82%



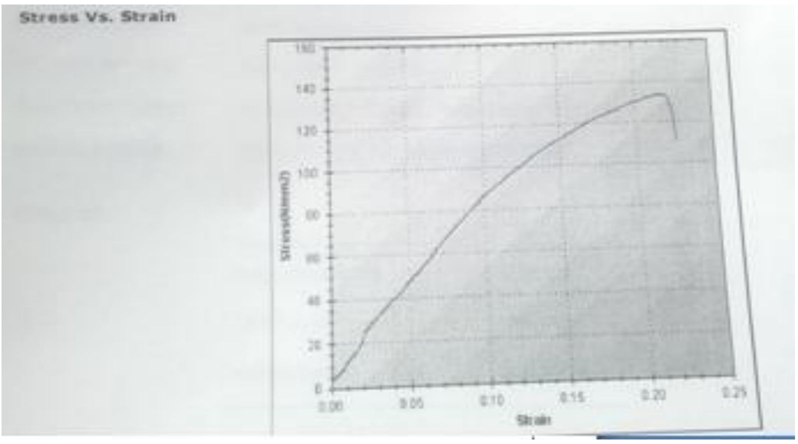
***Sample no 5*:**
Al+5% Sic+5%Al2o3+5%Graphite

- **Input data**

Specimen shape : solid round
Material type : Al-Sic+Alumina+Gr
Specimen diameter : 12.5mm
Initial gauge length: 50mm
Pre load value : 0KN
Max. Load : 650KN
Max .elongation : 250mm
Specimen cross section area: 109.17mm^2
Final gauge length : 56mm

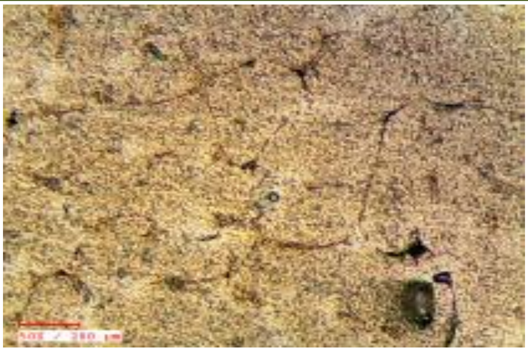
Output data

Load at yield : 11.19KN
Yield stress : 102.497N/mm^2
Load at peak : 14.520KN
Tensile strength : 132.999 N/mm^2
% of elongation : 10.68%



in this graph we can clearly observe that the tensile strength is increased to 133 MPa 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.(4)

4.2: Determination of Microstructure of Hybrid metal matrix composites

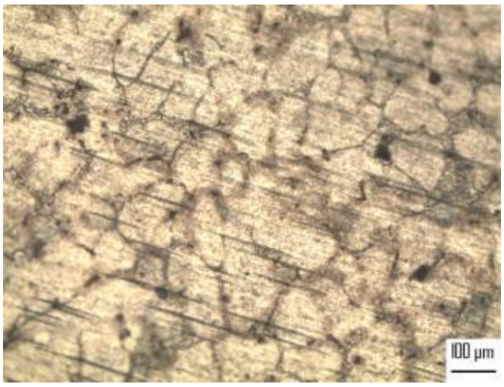


Microstructure of Al 6063 alloy

Microstructure of Al+10%Sic+5%Graphite

Microstructure of Al+10%Sic+5%Graphite

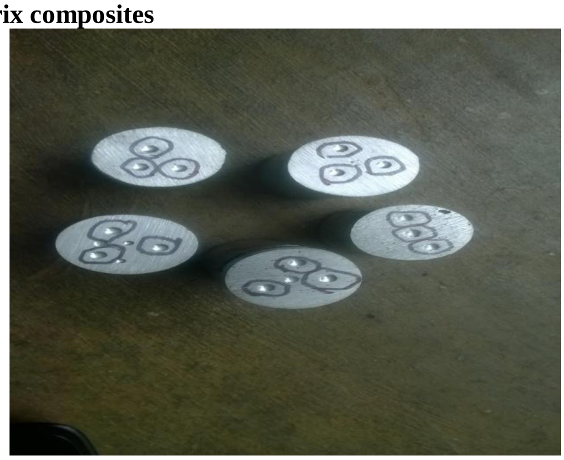
Microstructure of Al+5% Sic+5%Al2o3



Microstructure of Al+5% Sic+5%Al2o3+5%Graphite

4.3: Determination of hardness of hybrid metal matrix composites

computerized Brinell hardness equipment



Dents formed during hardness method

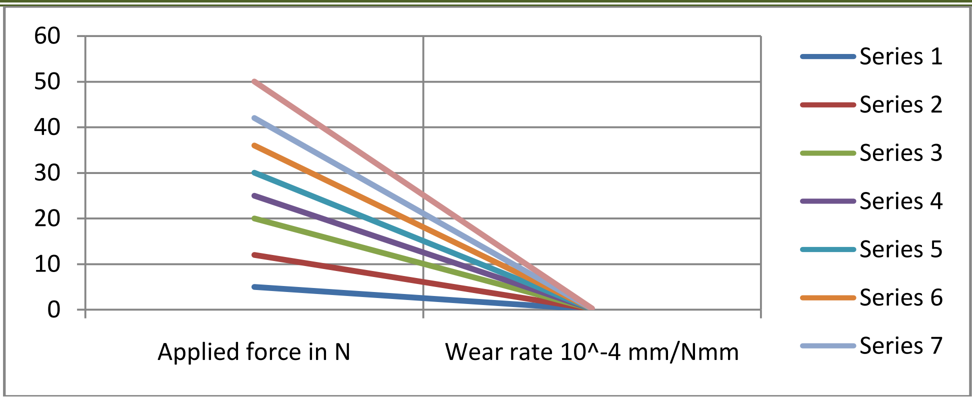
Material	Al6063	Al+10%Sic+5%Graphite	Al+10%Al2o3+5%Graphite	Al+5% Sic+5%Al2o3
Specification	Brinell 25HBW	AA6063/12sic-5Gr- 40HBW	Brinell 25HBW	Brinell 25HBW
Material type	Al alloy	Al –10%Sic+5%G	Al-10%Al2o3+5%Gr	Al-5%Sic+5%Al2o3
Ball diameter	5.0mm	5.0mm	5.0mm	5.0mm
Test load	250kg	250kg	250kg	250kg
Hardness result	47.5HBW	47.5HBW	43.7HBW	47.5HBW

Material	Al+5% Sic+5%Al2o3+5%Graphite
Specification	Brinell 25HBW
Material type	Al-5%Sic+5%Al2o3+5%Gr
Ball diameter	5.0mm
Test load	250kg
Hardness result	49.6HBW

4.4 Determination of coefficient of friction by using Wear test equipment

The measurement of wear of the pin is used to evaluate the volumetric loss, which in turn is used to compute the wear rate of the composites using the following formula:
WR=V/LP(2)
Where, WR is the wear rate in mm3/N-m, V is the volumetric wear loss in mm3, L is the sliding distance in m and P is the normal load in N

Pin material	Al+5% Sic+5%Al2o3+5%Graphite
Disc material	EN 36 steel with a hardness of 75HRC
Pin dimensions	20*20*50 mm^3
Sliding speed (m/sec)	1.5 & 3
Sliding distance(m)	1500
Track diameter (mm)	100
Disc speed(rpm)	257 & 589



The wear is low at lower value of applied loads. So at lower loads the reduced wear is observed. As the applied load is increased, the wear loss also increased. Higher wear is observed for maximum load.

5. Conclusions:

1. Hybrid Metal-matrix composite of Al6063 alloy reinforced with graphite (Gr),alumina(Al_2o_3) and silicon carbide
   (SiC) are fabricated successfully.
2. 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 133 MPa.
3. 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.
4. Microstructure of all the fabricated components are done successfully and observed that material composition of Al+10%Sic+5%Graphite is having more fine grain boundaries
5. It shows improvement in tensile strength, hardness and microstructure graphs values at different compositions.
6. Wear test results shows that for material composition of Al+5% Sic+5%Al2o3+5%Graphite is having less wear than the other fabricated components.

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