Experimental Investigations of Aluminium Metal Matrix Composites

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Abstract

This research paper is focused on one fine casting technique to fabricate a metal matrix composite (MMC).As the results of this investigation of mechanical characteristics of reinforced aluminum alloy (Al 6061) samples produced by the stir casting process are presented in this work. We chose several sets, each with two composite samples, for our investigation. One sample contained 3% silicon carbide content, whereas the second sample had 6% silicon carbide content. Furthermore, both samples had the same amounts of fly ash and graphite—2% and 1%, respectively—in all sets. It has been noted that adding graphite to aluminum composites improves their machinability, elastic modulus, and tensile strength. The solid lubricating properties of the graphite particles are responsible for this enhancement. To enhance the composite characteristics and to increase the properties like tensile strength, the fly ash is added Specifically, the tensile strength rose as the weight fraction of reinforced silicon carbide was raised, up to a maximum of 6% SiC. The primary objective is to manufacture a metal matrix composite (MMC) with enhanced strength, reduced porosity, increased tensile properties, and decreased weight and density.

Keywords: MMC, Al (6061), Sic, Fly ash, Graphite, Tensile, Wear

Introduction

When manufactured and constructed properly, Metal Matrix Composites (MMCs) can have the required properties of both ceramics and metals. Notable properties offered by metal matrix composites (MMCs) include increased strength, decreased weight, and improved resistance to wear and corrosion. Furthermore, the ceramic reinforcement found inside MMCs has exceptional strength and stiffness. The binding effects of both ceramic matrix composites and the metal matrix composites results in increasing of mechanical properties of a fabric made of a ductile ceramic material reinforced with a metal matrix [1]. In order to produce the metal matrix composites (MMCs) with ceramic reinforcement the aluminium alloy is to be solidified and also special casting method is to be employed i.e stir casting method. These include the even dispersion of silicon carbide (SiC), the behavior of SiC and aluminum alloy when they wet, the creation of flawless castings of metal matrix composites (MMCs), and the reactions that take place between SiC reinforcement and the aluminum matrix composite (AMC) at high temperatures [2]. Composite materials employ a variety of reinforcing materials, one of it, fly ash, has attracted the interest of investigators as a notable reinforcement. As the continuous method of casting is responsible for the improved mechanical qualities like density, strength and ductility.

Evolution of Aluminium Matrix Composites (AMC's)

While Aluminum matrix composites, which combine with the advantages of Silicon carbide (SiC) reinforcement and metal matrices to produce improved tribological, mechanical, and thermal expansion capabilities. There was no text provided by the user to alter. Because AMC processing involves the brace being added, it may be divided into discrete matrix steps. Charts are a useful tool for visualizing the broad coalition involved in processing AMCs.

1. Powder blending is a technique frequently used in solid state processing that entails combining powders to get the required composition. Diffusion bonding is another method used, in which solid materials are joined by atoms diffusing over the contact.

2. A variety of techniques, including squeeze casting method, stir casting process, liquid metal infiltration and spray deposition can be used to create the liquid state.

3. A physical vapor discharge can be used to characterize the gas state. Liquid phase procedures are generally more effective than vapor phase and solid phase approaches.

STIR Casting

The stir casting method, often known as the vortex technique, is thought to be the most practical and affordable approach. The vortex method is introducing a molten matrix state which is from pre-treated ceramic particles ad as a result it eds up with the swirl. It is usually possible to include ceramic particles with a maximum size range of 5 to 100 m and an integration rate of around 30% of liquifed aluminum alloys. The process of stir casting is used to create the composite material. This study's matrix alloy is Al 6061; the other constituents are made up of three different types of reinforcing particles: fly ash, graphite, and Sic. By using a mechanical stirrer made of graphite, the stir casting process mixes the reinforcing material and base metal uniformly, producing a homogenous mixture [3]. Stir-casting serves as the main processing method for fabricating the Al/SiC/Graphite/FlyAsh composite. The matrix material is Al 6061 aluminum alloy, whose chemical composition has already been discussed. The reinforced material is a combination of SiC, graphite, and fly ash with a volume fraction of 3% SiC + 1% Graphite + 2% Fly Ash (Sample A) and 6% SiC + 1% Graphite + 2% Fly Ash (Sample B). The Al matrix material is melted with Silicon Carbide crucible within a resistance-heated furnace, and the liquid metal is heated to 835 degrees Celsius to initiate the stir-casting process.

And the required amount of a combination with Sic, graphite, and fly ash particles that have been preheated to 650ºC are introduced to the molten Al material in nitrogen gas flow. At 300 revolutions per minute, a mixer agitates the reinforcement particles. Following the stirring procedure, the mixture is poured into a metallic mould and heated to between 800 and 850 degrees Celsius. The mould and mixture are then quenched in water together [4]. The MMC is then let to cool in the air. Computerized UTM and Pin on disc are used to assess the composites' tensile and wear tests. After both samples were polished and subjected to UTM testing, they were machined into dumbbell shapes in order to undergo tensile testing. Aluminium matrix composites reinforced with iron aluminide intermetallics.is combined with a technique stir casting method.[12] In the aluminium matrix, a uniform distribution of recently generated intermetallics was observed. These stages increased the matrix's difficulty by doubling the value obtained. In this work the physical and mechanical properties of A16063 reinforced with different weight percentages of fly ash is studied with the help of stir casting method. As the reinforcement weight percentages increased, the reinforced composites' porosity, hardness, and tensile strength improved, but their density declined. The suitable casting method for metal matrix reinforcement composites is stir casting method.

According to the tensile test, the proportion of reinforcement increases strength initially before declining. The hybrid composite hardness and pure AL7075-T651 alloy hardness were compared using Rockwell hardness. [10]

Experimentation Matrix Material

From extensive literature survey and thorough evaluation of earlier statistical charts, the proportion of constituents was fixed for preparing the composites and evaluating its characteristics.[11] The compositions of different constituents are as exposed in the table 1 below

SAMPLE	1	2
Al6061	94%	91%
SiC	3%	6%
Fly Ash	2%	2%
Graphite	1%	1%
TOTAL	100%	100%

T1. Proportions of Composites ratio

Experimental Procedure

Wear Testing

The act of removing material from one or both surfaces when two surfaces are moving relative to one another is known as wear [5]. Using a digitalized pin-on-disc device, a wear test was carried out at a constant speed of 380 rpm for 4 minutes and 10 seconds. On a Pin-On-Disc machine, wear resistance testing was conducted at load variations of 10, 20, and 30 N with disc rotating speed of 380 rpm. As seen in Figure 1, a standard cylindrical pin wear testing sample with dimensions of 6 mm in diameter and 20 mm in length was manufactured on the lathe machine. At low velocities, adhesive wear dominates, where material gets ripped off due to strong adhesion between surfaces.[9] As velocity increases, abrasive wear becomes more prominent, where hard asperities on one surface plow grooves into the other. Further increase in velocity might lead to a formation of protective oxide layers or lubrication films, which can decrease wear.

Figure 1. Standard Wear test specimen

Criteria for wear testing

- The wear test was conducted using the following parameters: Load (N): 10, 20, 30, and 380 rpm for the disc rotation speed. 50 mm for the track, 4 minutes, 60 seconds [7-9].[6]
- Table 6 displays the wear test results for Al-SiC /Fly ash/Graphite MMCs on a pin-on-disc configuration under various load conditions (10, 20, 30 N, 4 minutes, 10 seconds, 380 rpm).1 and Al+3% SiC+2% Fly Ash+1% Gr, it raises the frictional force and height loss wear (μ). [10-13].

Tensile Test

The maximum tension stress at which a material changes it shape or subjected to break is known as the material's tensile strength. Using this testing method, toughness, resilience, and Poisson's ratio may also be determined.[8] A 1000KN capacity computerized Universal Testing Machine (UTM) is seen in the figure. The sample is gradually loaded, and the UTM's digital load indicator measures the load extension at regular intervals. A material fails when a specific load extension rises more quickly.[7] After removing it, the extension is calculated using the scale. The specimen is gradually loaded up until it breaks. The tensile test results are displayed as graphs for both specimens in the same manner: load vs. displacement and stress vs. stain revealed in Figure 2.

Figure 2. Experimental setup for tensile strength

Results and Discussion

Wear Test Results:

Track Radius 50 mm Constant which is shown in Table 3

Sample Number	Load(N)	Speed (RPM)	Time(mins:sec)	Height loss wear(µ)	Frictional Force(N)
1	10	380	4:10	40	4.8
	20	380	4:10	65	6.9
	30	380	4:10	90	14.6
2	10	380	4:10	25	3.9
	20	380	4:10	55	7.7
	30	380	4:10	80	12.8

Table 3. Wear Test Results on Material Samples

The table shows wear test results for two samples under different loads (10 N, 20 N, 30 N). Wear loss (amount of material worn away) is measured in micrometers (µm). The Sic and Fly ash particle size is measured as 50 µm

- Sample 1 wear loss increases with load (40 µm at 10 N, 90 µm at 30 N).
- Sample 2 shows a similar trend (25 µm at 10 N, 80 µm at 30 N).

- Sample ID: A unique identifier for each test specimen. This could be a number or a combination of letters and numbers.
- Material: The type of material the wear test specimen is made of.
- Load (N): Force applied during the test (10 N, 20 N, 30 N).
- Speed (RPM): Rotational speed (380 RPM in this case).
- Time (mins:sec): Test duration (4:10 in this case).
- Height Loss (µm): Material worn away (values for different loads on two samples).

Figure 3. Experimental specimen after the wear test sample 1

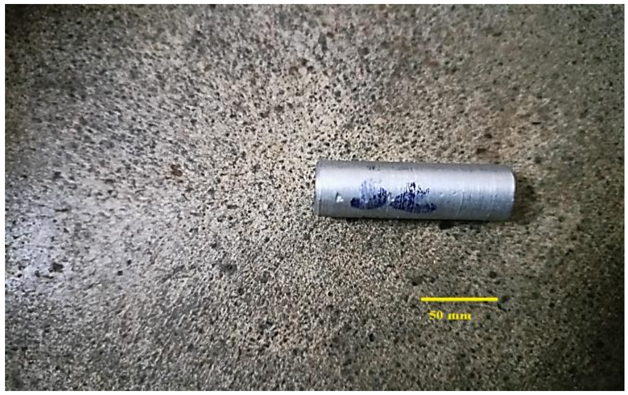


Figure 4. Experimental specimen after the wear test sample 2

Tensile Test Results

The specimen, which is made in accordance with standard E8, is inserted into the UTM in the space between the specimen holders. The assembly is kept clean, and a constant force is applied to the specimen's two ends in opposing directions and of equal length and the results are revealed in Table 2.

S.No	Sample	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
1.	Al+ 3% SiC+ 2% flyash +1% Graphite	119.78	124.31
2.	Al+ 6% SiC+ 2% flyash +1% Graphite	130.458	138.63

Table 2. Tensile Test Results

The table likely shows wear test results on two aluminum-graphite composite samples (material not explicitly mentioned) under different loads (10 N, 20 N, 30 N).[13] It details wear loss (amount of material worn away) in micrometers (μm) for each sample at different loads. The experimental specimen for the tensile test is shown in Figures 5 and 6.

- Sample 1: wear loss increases with load (specific values not shown here).
- Sample 2: similar trend observed (specific values omitted).

Figure 5. Experimental specimen for after tensile test sample 1

Figure 6. Experimental specimen for after tensile test sample 2

Result Graphs

The graph shows wear test results for two aluminum-graphite composite samples (material not shown) under varying loads (vertical axis: wear loss in micrometers, horizontal axis: load in Newton's). Wear loss increases for both samples (Sample 1 and Sample 2) as the load gets higher. This suggests greater wear with increasing force on the materials.

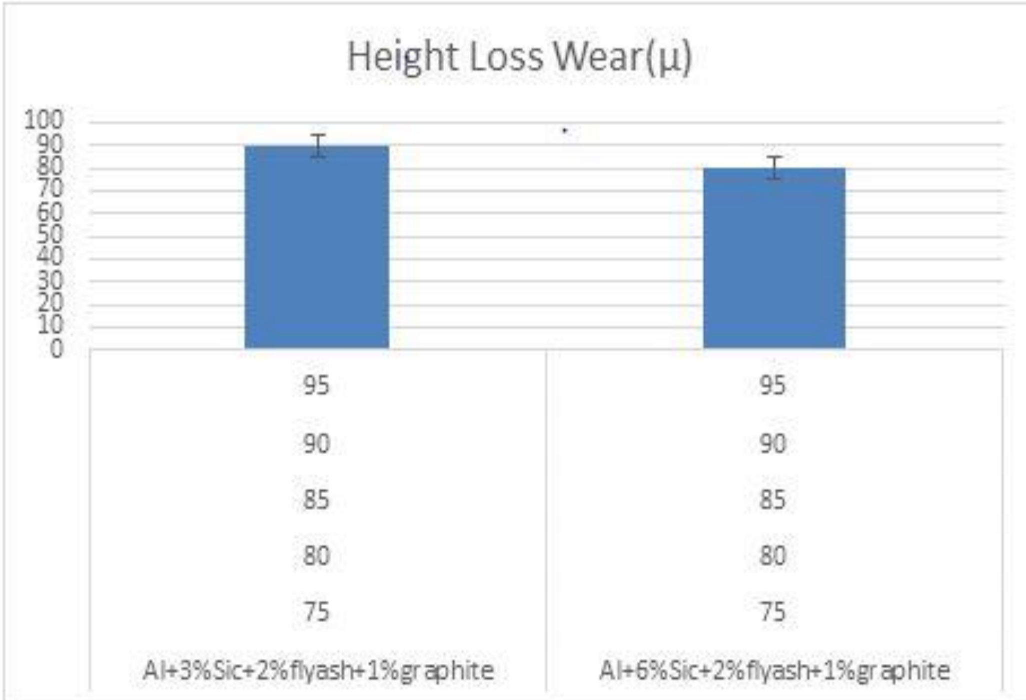


Figure 7. Height loss wear (μ) graph.

The graph shows wear test results for two materials (likely aluminum-graphite composites). Wear loss (y-axis, micrometers) increases for both samples as the load applied (x-axis, Newtons) gets higher. This suggests the materials wear more under greater pressure.

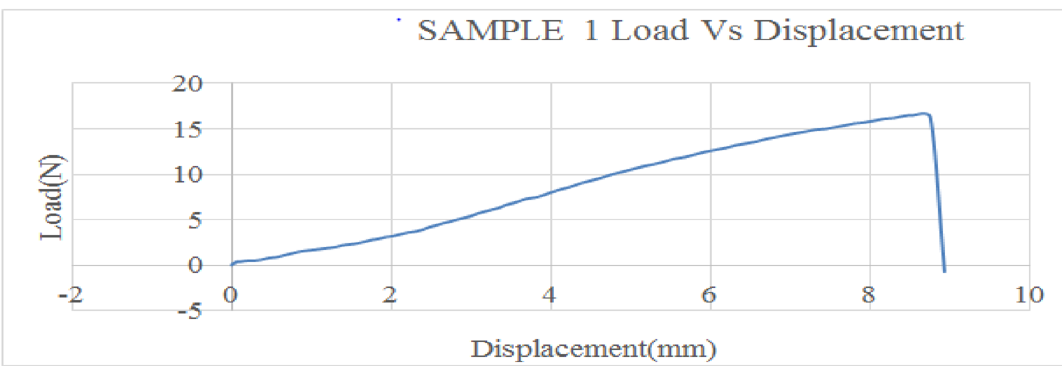


Figure 9. Sample 1 Load vs. Displacement Graph

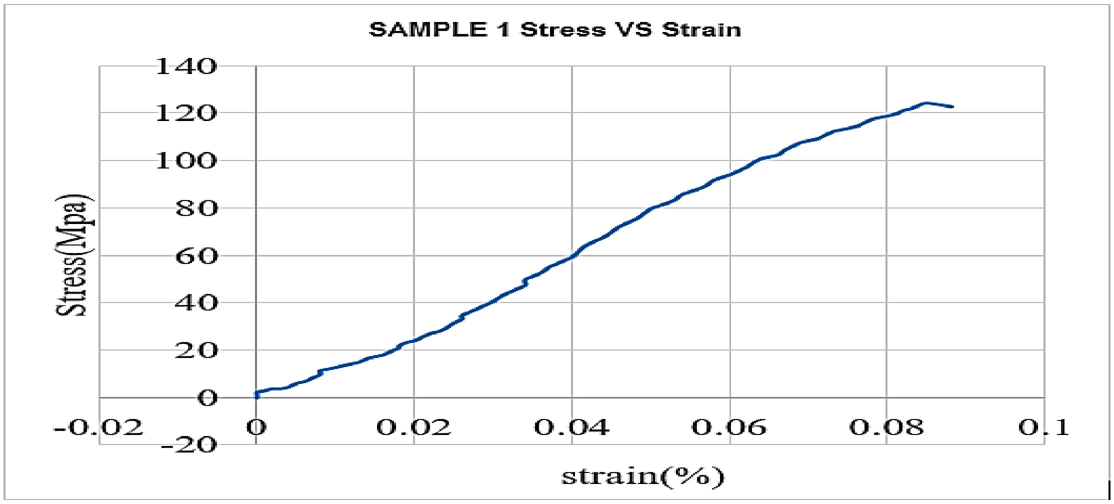


Figure 8. Sample 1 stress vs. strain graph

- The graph shows wear loss (vertical axis, labeled "Height Loss" in micrometers) compared to the load applied (horizontal axis, labeled "Load" in Newtons) during the test.
- Two lines likely represent results from two separate samples (Sample 1 and Sample 2)

The trend suggests that wear loss increases as the load applied to the samples increases. This means the materials wore away more under higher pressure.

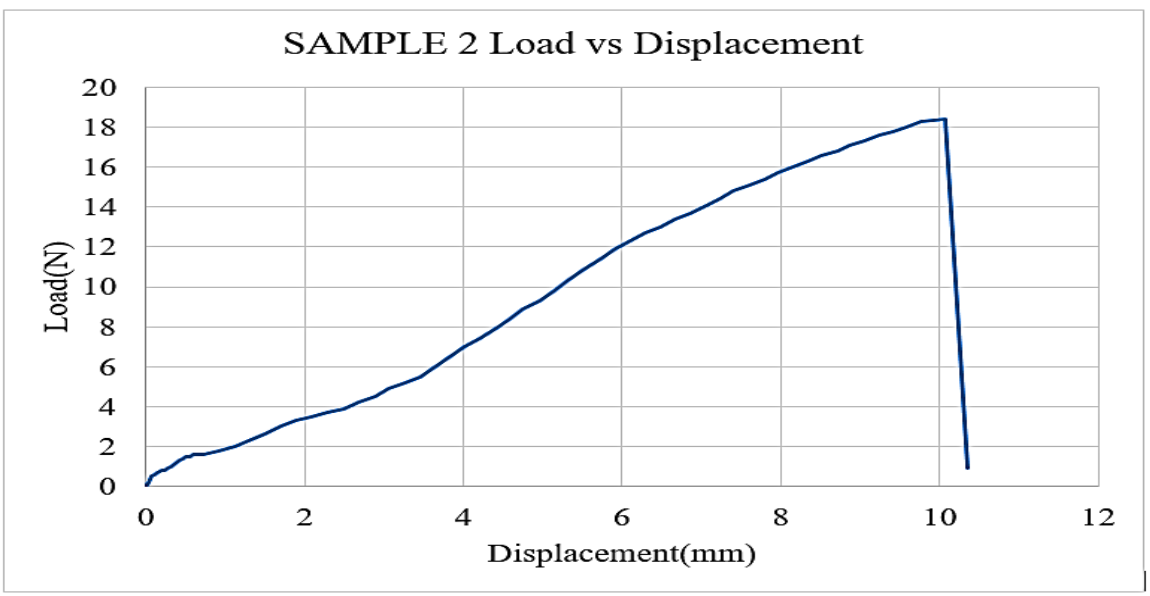
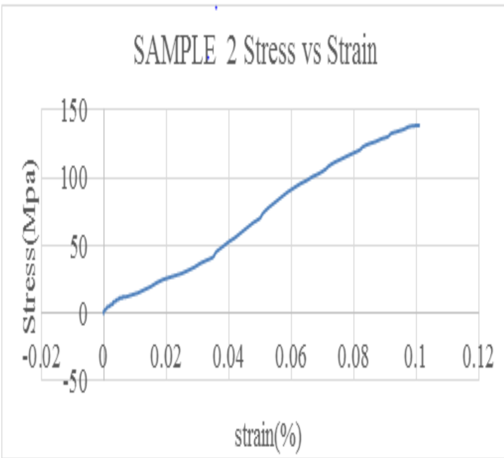


Figure 10. Sample 2 load vs. displacement graph

- The graph shows wear loss (vertical axis, units in micrometers) versus load applied (horizontal axis, units in Newton's).
- Two lines represent results likely from two different samples.
- Wear loss appears to increase for both samples as the load applied increases.

- **Wear increases with load:** The graph shows a positive trend, where wear loss (vertical axis, µm) increases as the load applied (horizontal axis, N) increases.

- **Two samples tested**: Two separate lines likely represent results from two different samples.



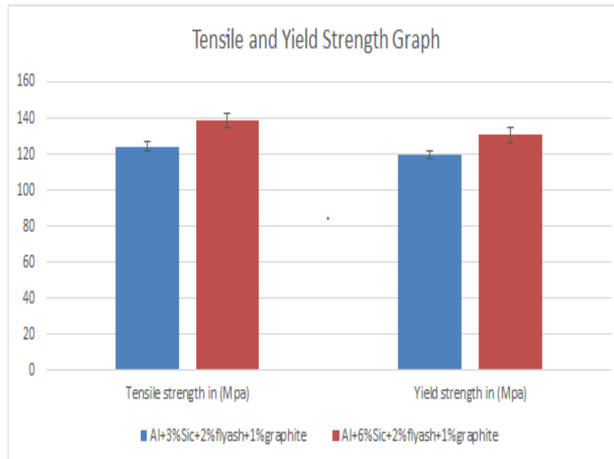


Figure 11. Sample 2 Stress vs Strain graph

Figure 12. Tensile and Yield Strength Graph

It is discovered that when Sic particles make up 6% of the composite, its tensile strength rises and continues to rise. This is because the tensile strength will rise with the addition of Sic and Fly Ash particles since they have a higher hardness than the aluminum matrix.

Conclusions

In wear test at constant RPM and time the load 10, 20, 30 N increases for both samples the height loss wear is reduced and addition of reinforcements it leads to decrease the height loss wear and Frictional force. For sample 1 (Al+3% SiC+2% Fly Ash+1%Gr) it has maximum Height loss wear (μ) is 90 and frictional force is 14.6 N, sample 2 (Al+6% SiC+2% Fly Ash+1%Gr) it has maximum Height loss wear (μ) is 80 and frictional force is 12.8 N, Addition of reinforcement leads to decrease the Frictional force and Height Loss wear. In tensile test addition of SiC of reinforcement has high tensile strength and yield strength it increases linearly. The addition of reinforcement leads to increase the displacement, stress and strain also. Addition of % reinforcement material it leads to increases the tensile strength and yield strength, in wear test sample 1 has high height loss wear and frictional force compare with sample 2. Inorder to increase the ultimate tensile strength fly ash content to be increased. Whereas ductility has decreased with increase in fly ash content. In combination of graphite content with aluminium composites improve the tensile strength, elastic modulus, and machinability due to the solid lubricating property of the graphite particles. The research main novelty is understanding how these three specific reinforcing materials work together to influence properties like tensile strength, machinability, and density. It's not just about the individual effects, but the interplay between them.

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