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Experimental Investigation of Mechanical Properties of Hybrid Aluminium Metal Matrix Composites

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ABSTRACT: Many studies in the field of material science have uncovered the existence of composite materials outperform conventional materials due to their superior mechanical characteristics. Aluminium-based Composite materials are increasingly being employed in a number of applications. applications such as automotive, aircraft, military, and others. Among the numerous aluminum alloys, the strongest alloy with the highest strength to weight ratio is aluminum alloy 6061 (AL6061) from the 6XXX family. The primary goal of the research is to create a Hybrid metal matrix composite [HMMC] using aluminum 6061 as the metal matrix and silicon carbide and graphite as reinforcement. Graphite at 3% constant and different amounts of silicon carbide at 0%, 2%, and 4% by weight are added, and the specimens are manufactured by stir casting and machined according to ASTM standards. Mechanical tests such as tensile, compression, and microstructure investigation are then performed on the samples. The resulting results are compared to those obtained in the as cast condition, and conclusions are reached. Tensile and compression strength enhanced with 3% graphite constant and silicon carbide concentration increasing. Microstructure analysis revealed that silicon carbide particles were dispersed in the matrix

KEYWORDS: Aluminium metal matrix, Silicon Carbide, Graphite

I. INTRODUCTION

Aluminium is durable metal with light weight and has silver like appearance when cut. It is easily machinable and is good conductor of heat and electricity. It is extracted from bauxite ore and purified by several processes. Additionally, it found in several mineral rocks being 15 combined with compounds namely silicon (Si) and oxygen (O₂) and is also called alumina silicates. There are many alloys of aluminium which are designed by series 1XXX to 8XXX depending upon major alloying element they contain. These alloys have favourable such as low weight, high thermal, and electrical conductivity, high corrosion 75 resistance, high ductility and excellent machining properties. They are utilized in because of these qualities. several fields. Among the various alloys available, aluminium alloy 6061 (AL6061) belonging to 6XXX series is the strongest alloy. The capability of this alloy is comparable to 3 steel and is found to have high strength to weight ratio. Due to this reason this is majorly used in field of aerospace and also in industries like military, marine and structural equipment where high strength and low weight is required. In the recent trends, Composites made of aluminum are utilized for their enhanced properties and found to have replaced via means of conventional materials in the several of the industries and is specially used in aerospace industry due to their reduced size and weight. Considering the major application, aluminium is combined with silicon carbide. This combination is used to make structural aerospace components as they exhibit high strength. Numerous research projects are carried out on various materials to establish their qualities for use in engineering sectors. Many materials, including composites, have outstanding characteristics and hence find employment in a number of industries. Nowadays, most materials are chosen for applications such as maritime, military, and structural equipment based on a high strength to weight ratio, high level of durability, and so on. Because it is difficult for a monolithic alloy to have they're all needed qualities, composite materials come into play. Composites are described as the synthesis of one or more (hybrid) elements that differ in physical and chemical composition, with one acting as the base and the others as reinforcement materials to achieve the necessary qualities for their specific usage. When a single reinforcing material is added to an alloy, its qualities become excess, and so more than one (hybrid) material is added to counteract the disadvantage of single metal matrix composites.

The hybrid metal matrix as a result concept was born. The goal of this effort is to create an aluminum-based hybrid composite [HMMC]. The basic matrices are aluminum 6061, while the reinforcement elements are silicon carbide and graphite. In light of the combined features of these materials, such as reduced weight, high stiffness, durability, and so on, the consolidation of aluminum, graphite, and silicon carbide plays a crucial part in the aerospace sector. Aluminium is a non-ferrous metal derived from bauxite ore through multiple refining processes. Among the different types of Al alloy series, Al6061 has good thermal and electrical conductivity, is easily machinable, has a high strength to weight fraction, and is light in weight when in comparison to engineering metals such as steel. In light of their improved qualities, particularly reduced size and weight, aluminum-based composites are widely employed in aerospace, automobiles, and missiles in today's competitive world. With this in mind, aluminium base metal is combined with silicon carbide and graphite. Silicon carbide is made up of two key elements: silicon (Si) and carbon (C). Moissanite is an uncommon mineral that contains crystalline silicon carbide. Pure sic has the physical attribute of being a transparent and colorless crystal. When impurities such as aluminum are added, the hue changes to greenish or light blue based on the proportion of contaminant added. Silicon carbide is made up of a total of four carbon atoms covalently bound to a single silicon atom in the center. owing to its strong refractoriness (high melting temperature and minimal thermal expansion), sic is utilized as a refractory lining material in high temperature applications. In addition to the foregoing features, sic is the hardest substance after boron carbide and diamond; this obvious property distinguishes sic. However, it possesses superior features to aluminium, such as high strength, high melting point, and stiffness, and when combined, it improves the basic properties of aluminium. Furthermore, the combined ceramic and semiconductor capabilities of sic are used in the manufacture of high voltage and high temperature devices. Increased sic hardness, on the other hand, increases cutting tool wear rate, which has a negative influence on Al alloy machinability. Milling, turning, and drilling of Al/SiC composites use hard nitride coated tools and diamond to generate desired shaped. The project's main goal is to create an Al hybrid composite [HMMC] in which aluminum 6061 is the base metal and graphite and silicon carbide are encapsulated as reinforcement. The proportionate amount of base metal graphite, 3%, and silicon carbide particles, changing in weight percent of 0%, 2%, and 4%, are added, and composites are made. The raw materials are stir cast and manufactured in accordance with ASTM standards. These samples are subjected to evaluation of tensile and compression strength, microstructure examination. The obtained samples are in comparison to reinforced alloy and conclusions are made. A literature review is conducted on base metal, particulates, 33 composite materials, mechanical and microstructure tests.

II. RELATED WORK

Anthony Xavier et al, [1] Hybrid composites' machinability was investigated, and moreover the result of feed rate, depth of cut, and cutting speed on cutting force and surface roughness of hybrid MMC. And he concluded that surface roughness is mostly determined by feed rate, with lower feed rates having less surface roughness. MMC's presence of graphite promotes surface finish. in contrast to CNT-based composites, graphite-based MMC requires higher cutting force. Nagendra kumar mayur et al, [2] Aluminum 6061 alloy mechanical characteristics enhanced with Sic were investigated, with an emphasis on the Sic distribution in Al alloy. According to the findings, he concluded that while the density composed of Al-sic compound increases, and moreover the installation of sic in Al alloy improves both tensile strength and hardness when in contrast to Al 6061 alloy alone. Palani kumar K et al,[3] He researched the thrust force, and moreover hybrid surface finish MMC and arrived at a conclusion that increasing Feeding frequency and other cutting parameters increases thrust force. This is because at higher feeds, The cutting instrument is becoming more stressed., which further raises thrust force. Based on his findings, it is apparent that as spindle speeds increase, thrust force decreases, further improving surface smoothness. He came to the conclusion that a lower feed rate and greater spindle speed values and moreover a smaller drill bit dia increase surface finish in a hybrid MMC. The existence of graphite in MMC lessens composite hardness, which is beneficial to composite machinability. Sivananthan S [4] The hardness, tensile property, and compression strength composite Al-Sic have been improved in their properties by diffusing increased weight percentage of Sic reinforcement material with Al6061 alloy, in accordance with findings of his experiments. Because of this this, Al-Silicon carbide composites are widely employed as excellent composites, particularly in the nuclear and missile industries. **Nagaral M** [5] Mechanical properties of al-Sic and Al-graphite composites were investigated. His findings show that adding 9 wt% Sic to Al alloy increases the density of Al-Sic. The density of an Al-Graphite composite decreases with the graphite inclusion as a result of manufacture voids or pores in addition to the low density of graphite. While increasing the graphite content to 9wt% reduces the toughness of the Al-graphite composite. As a result, Sic and Graphite composites are widely employed in the marine and vehicle industries.

III. METHODOLOGY

Aluminium, silicon carbide and graphite materials are thought to be the best. most promising ones based on their qualities, traits, and applications, particularly in the creation of aerospace and automotive components. As a result, these three materials were selected. to prepare the study's specimens. Utilizing the stir casting technique, three work samples with different weight percentages are created. The furnace consists of heating coils that are looped around a crucible that is positioned in the middle. When melting raw materials, a stirrer with an impeller that is electrically operated is put inside the crucible. The crucible is cleaned and positioned in the middle of the furnace before the operation begins. Al6061 ingots of the requisite weight are weighed in a weighing scale before being dropped into a crucible. Turn on the furnace and adjust the temperature to between 750 and 800 oC. Al6061 must have the necessary weight percentages of reinforcement materials (0%Wt of Sic and 3%Wt of Gr) added before it can be placed in a crucible to melt. To ensure uniform distribution of reinforcement, an electrically powered stirrer covered in ceramic or graphite is subsequently used inside the crucible. Stir casting set-up is shown in fig 1.1

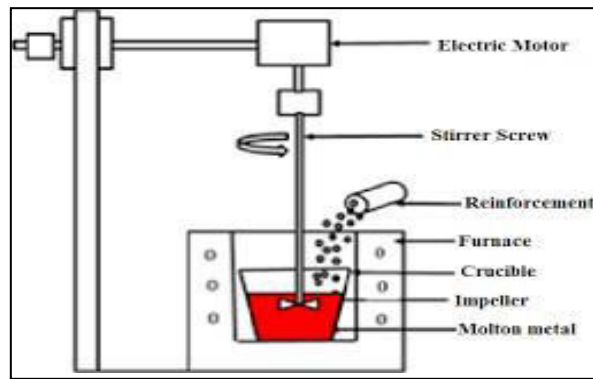


Figure 1.1: STIR CASTING SET-UP.

When the molten material reaches pouring temperature, the crucible is taken out of the furnace and the molten hot material is poured into heated metallic molds that are the right size. The cast is taken out of the mould box once it has solidified and allowed to cool to room temperature. For the remaining two samples of varying weight fractions, the same process is used. Sic and Gr compositions

Table 1.1 Composition of Reinforcement Materials.

Reinforcement fillers	HMMC-A	HMMC-B	HMMC-C
<u>Sic</u>	0%	2%	4%
<u>Gr</u>	3%	3%	3%



Figure 1.2: HMMC-A

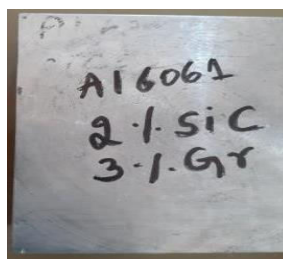


Figure 1.3 HMMC-B

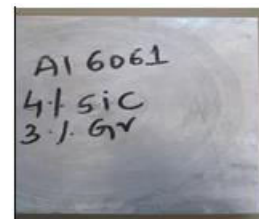


Figure 1.4 HMMC-C

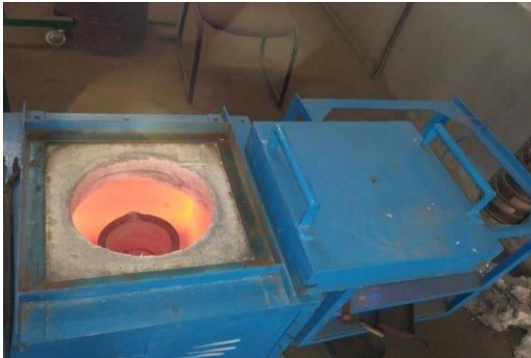


FIGURE 1.5: MELTING FURNACE



Figure 1.6: MOLDED SAMPLES.

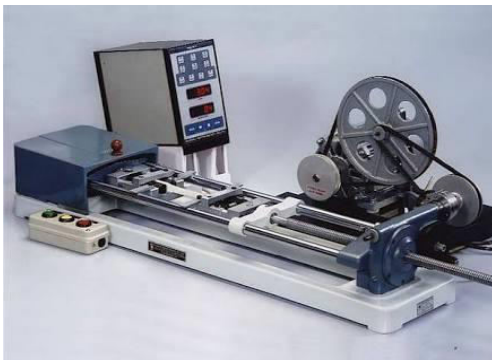


Figure 1.7: BENCH TENSOMETER.



Figure 1.8: TENSILE SAMPLE.



Figure 1.9: UTM MACHINE.

IV. EXPERIMENTAL RESULTS

Aluminium, Siliconcarbide 0%, Graphite 3%.

Compression test

Sample	Area mm ²	Compression Load KN	Compression Strength MPa
01	113.11	56.36	498.32

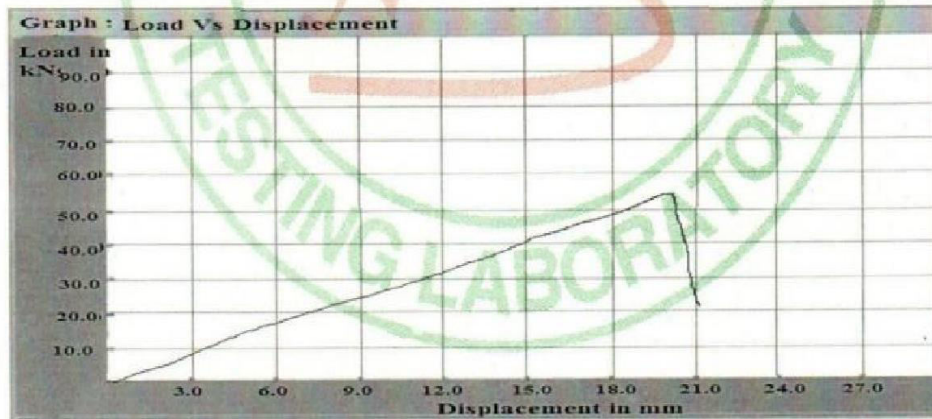


Figure 2.1: load v/s displacement graph for pure Al6061+3%Gr+0%Si.

Hardness test

Test method: ASTM E384

Sample	Result-1	Result-2	Result-3	Average
01	77.3	78.6	78.1	78.0

Tensile test

Test method: ASTM E8M-15a

TEST	RESULT
Initial Area mm ²	64.32
Initial gauge Length mm	45.00
Final gauge Length mm	50.36
Yield strength MPa	177.69
Ultimate Tensile Load KN	13.93
Ultimate Tensile strength MPa	216.7
% Elongation	11.97

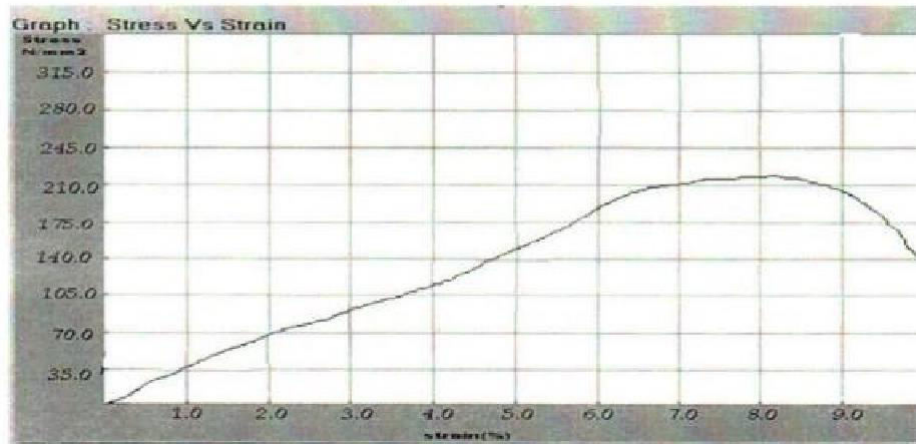


Figure 2.2: Strain vs Stress graph for pure Al6061+3%Gr+0%SiC.

Aluminium, Siliconcarbide 2%, Graphite 3%.

Compression test

Sample	Area mm ²	Compression Load KN	Compression Strength MPa
02	113.11	67.87	560.52



Figure 2.3: Load v/s Displacement graph for pure Al6061+3%Gr+2%SiC.

Hardness test

Test method: ASTM E384

Sample	Result-1	Result-2	Result-3	Average
02	83.0	82.0	83.0	83.0



Tensile test

Test method: ASTM E8M-15a

TEST	RESULT
Initial Area mm ²	65.81
Initial gauge Length mm	45.00
Final gauge Length mm	50.21
Yield strength MPa	198.4
Ultimate Tensile Load KN	15.22
Ultimate Tensile strength MPa	231.4
% Elongation	11.57

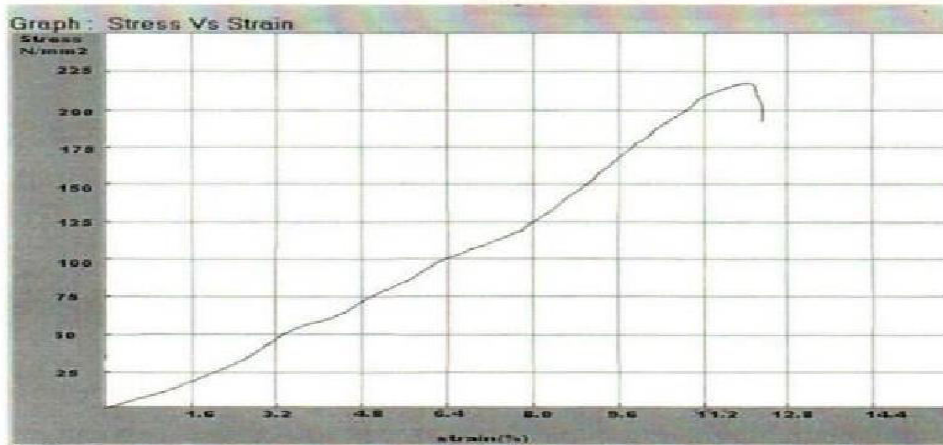


Figure 2.4: Strain vs Stress graph for pure Al6061+3%Gr+2%SiC.

Aluminium, Siliconcarbide 4%, Graphite 3%.

Compression test

Sample	Area mm ²	Compression Load KN	Compression Strength MPa
03	113.11	69.97	618.62

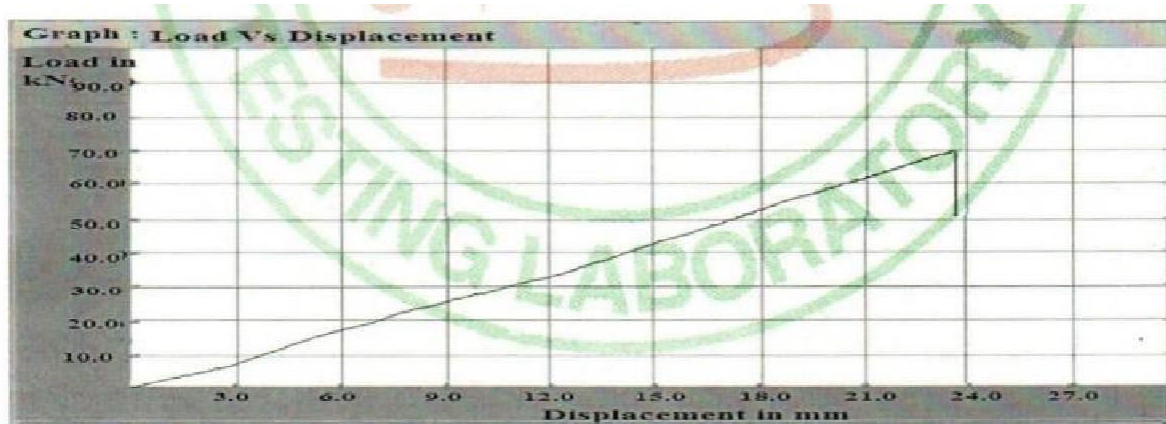


Figure 2.5: Load v/s Displacement graph for pure Al6061+3%Gr+4%SiC.

Hardness test

Test method: ASTM E384

Sample	Result-1	Result-2	Result-3	Average
03	89.8	90.1	89.2	89.7

Tensile test

Test method: ASTM E8M-15a

TEST	RESULTS
Initial Area mm ²	62.74
Initial gauge Length mm	45.00
Final gauge Length mm	48.98
Yield Load KN	13.63
Yield strength MPa	217.41
Ultimate Tensile Load KN	17.48
Ultimate Tensile strength MPa	278.7
% Elongation	8.84

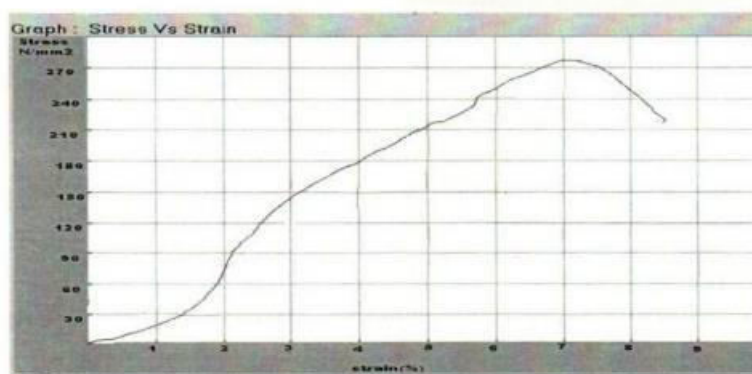


Figure 2.6: Strain vs Stress graph for pure Al6061+3%Gr+2%SiC.

V. CONCLUSION

1. Stir casting process: The Following that, the analyzed samples were exposed to stir casting to prepare the composite and unreinforced cast samples. The obtained cast products were free of porosity and blow holes to the maximum extent.
2. Machining: The casted samples were machined by lathe machine with specification as per ASTM standards to be able to test for mechanical properties and microstructure study.
3. Tensile test: The machined samples were put through tensile test according to the ASTM E8 standard and were carried out using PC2000 Bench horizontal extensometer. Tensile strength was discovered. increased as the content on silicon carbide increased and thus there was 31% increase in the composite sample in comparison to unreinforced alloy.
4. Compression test: The A compression test was performed. on hot extruded 6016 Al alloy base material and all Al/graphite composites. The compressive stress-strain curves were determined and the test results were extracted and plotted.

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