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Experimental Investigation of Mechanical Propertiesof Al-6061 Metal Matrix Composites

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ABSTRACT

Metal Matrix Composite materials are widely used in a variety of applications such as aerospace, automotive and structural components resulting in savings of material and energy. Particulate reinforced Aluminium metal matrix composite materials which are having desirable properties such as high specific stiffness, high specific strength, high coefficient of thermal expansion, increased fatigue resistance, and superior dimensional stability compared to unreinforced alloys. The main objective of our project is to make a material consisting of aluminum with a grade of 6061(Al6061), silicon carbide (Sic), and graphite powder by the stir casting manufacturing method. And evaluated fabricated composite material also the determined microhardness,wear resistance, and tensile strength.

KEYWORDS:Al 6061,Sic,Gr powder,Stir casting,Metal matrix

1. INTRODUCTION

I.COMPOSITES:

Composites are manmade materials consisting of one or more discontinuous phases having intimate contact with each other, with the cognizable interface between them. These are multifunctional materials systems that provide characteristics not obtainable from individual phases. Further, composites are tailor-made to be cost-effective, property effective, and application-oriented [1].

In general, the discontinuous phase is harder and stronger than the continuous phase and is called the 'reinforcement whereasthe continuous phase is termed the 'matrix'. The matrix holds reinforcement to form the desired shape and bears the major portion of an applied load, while the reinforcement improves the overall mechanical properties of the matrix. Reinforcement increase the strength, stiffener-resistanttemperaturetant agent resistance capacity, and lowerdensity.

CLASSIFICATION OF COMPOSITES:

In general, composites are classified according to the type of matrix material and then the nature of reinforcement at two distinct levels.

1. Polymer Matrix Composites.
2. Ceramic Matrix Composites.
3. Metal Matrix Composites.

These are the three types of composites.

PROCESSING OF COMPOSITES

Depending upon the application in service, a variety of composites with different combinations of matrix materials and reinforcements are being produced through different fabrication methods, various systems, and processing route Proper mixing methods can minimize the agglomeration of thereinforcementandsettlingoftheparticlescan be minimizedbythequickpouring and employing chill casting technique. Secondary processing like rolling, forging, and extrusion gives better distribution of reinforcements.

Though there are many applications with MMCs; fabrication, secondary processing compatibility between thematrixareinforcement and characterization are still the major problems in the manufacturing of these composites. Sic in various forms has been the most widely used reinforcement, in aluminum alloy. Other reinforcements are $A12O_3$, SiO_2, TiC, TiO_2, ZrO_2, TiB_2, borate whiskers, quartz, diamond, graphite, fly ash, etc. Among the various metal matrix composites (MMC), aluminum alloy metal matrix composites have successfully demonstrated their potential for even high-volume applications.[2]

2.EXPERIMENTAL PROCEDURE:

I.STIR CASTING

Stir casting is a type of casting process in which a mechanical stirrer is introduced to form a vortex to mix reinforcement in the matrix material. It is a suitable process for the r production of metal matrix composites due to its cost-effectiveness, applicability to mass production, simplicity, almost shaping and easier control of the composite structure stircasting.

Stir casting up consists of a furnace, reinforcement feeder, and mechanical stirrer. The furnace is used to heat and melting of the materials. The bottom pouring furnace is more suitable for the stir casting as after stirring the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom of the crucible. The mechanical stirrer is used to form the vortex which leads to the mixing of the reinforcement material which is introduced in the melee stirrer-consists sists of the stirring rod and the impeller blade. The impeller blade may be of various geometry and ad a various number of blades. A flat blade with three numbersis preferred as it leads to an axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, and the rotation speed of the stirrer is controlled by the regulator attack with the motor. Further, the feeder is attached to with furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold, or a lost-wax mold can be used for pouring the mixed slurry.

Figure 1: STIR CASTING SETUP

Various steps involved in the stir casting process in this process, the matrix materialsare kept in the bottom pouring furnace for melting. Simultaneously, reinforcements are preheated in a different furnace at a certain temperature to remove moisture,impurities, etc. After melting the matrix material and ata certain temperature the mechanical stirring is started for the man vortex for a certaiperiodod then reinforcements particles are poured by the feeder provided in the setup at ca constant feed rate at the center of the vortex, and the stirring process is continued focertainaaperiod after complete feeding of reinforcements particles. The molten mixture is then poured into the instead mold and kept for natural cooling and solidification. Further, a post-casting process such as heat treatment, machining, testing, inspection, etc. has been done. There is various impeller blade geometry is available. Melting of the matrix material is the very first step that has been done during this process [3].

PROCESS OF STIR CASTING

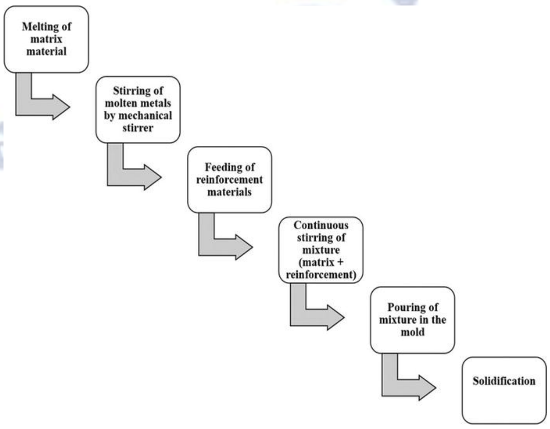

Figure 2:.Melting of Matrix Materials

Out of various furnaces, the bottom pouring furnace is suitable the for fabrication of metal matrix compositesstir casting route, this type of furnconsistssist of automatic bottom pouring technique which provides instant pouring of the melt mix (matrix and reinforcement).

Figure 3: Stirring process

Bottom pouring is mainly used in the investment casting industry. In this technique, a hole is created in the base of the melting crucible to provide bottom pouring and was shielded by a cylinder-shaped shell of metals [15]. In the stir casting process, the matrix material is melted and maintained at a certain temperature for 2–3 h in this furnace. Simultaneously, reinforcements are preheated in a different furnace. After melting the matrix material, the stirring process started to form the vortex[4].

4. **MATERIALS AND MEASUREMENTS:**

1Aluminium6061:

6061 aluminum alloy is aluminum with copper as the primary alloying element. It is strong, with strength comparable to many sheets of steel, and has good fatigue strength andmachinabilityinability. It has lower resistance to corrosion than many other aluminum alloys but has significantly better corrosion resistance than the 2000 alloys. Its relatively high cost limits its use.6061 aluminum alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are ais2025-0, 2025-T6, 2025

Aluminum alloy 6061 has a density of 2.78 gram/cm^3 electrical conductivity of 30%, Young'smodulus of 73 GPA across all temperatures, and begins to melt 500 ^o c.

Figure 4: AL6061 Material

2. Silicon carbide and Graphite Powder:

Commercial Silicon carbide is produced by urban grey metallic structure, in an electric arc furnace. Sic does not melt congruently, therefore the liquid in contact with the silicon carbide does not have the same composition as the solid. This means that the liquid must be solidified at a rate so that the liquid and solid equilibrium.

The material which is in a molten state becomes increasingly rich in silicon, therefore when the liquid solidifies its composition is one of Silicon carbide and graphite [5].

Figure 5: Sic and Gr Powder

5. COMPOSITION OF MATERIAL:

Figure 6: Die to prepare specimen

The fabrication process is carried out in two stages one is composite and hybrid composite. The composite measurements are carried out in the iven table for both composites. The al6061 – Sic alloy which is used forms metal matrix composition and where the al6061 is mixed with Sic in the ratio of(2 %, 4 %, 6 %) and for the hybrid composite composition mixed with SIC in the ratio of (94-3%,91-6%,88-%,85-12%,) to form composition's these alloys are mixed thoroughly in the ball mill for 30 minutes to form the fine mixture (or) mixing in pestle motor thoroughly and the compositions are prepared. In this particular aluminium6061 as matrix and**SIC**as reinforcement for composite increases the mechanical properties of aluminium6061.in the same way for aluminum 6061 ass matrix and both Sic and graphite as reinforcement for hybrid composite. Many types of research were done through powder metallurgy by incorporating ceramic particles as reinforcements on pure aluminium6061 whereas, in this work, a novel idea of reinforcing ceramic particles in aluminium6061 alloy is attempted. Powders of aluminium6061 were generated through ball milling for this work. This paper focuses on further enhancement of the properties of aluminium6061 alloy through powder metallurgy process by incorporating SIC hybrid reinforcement cement[6].

Table 1: Composite of the composite

6. TESTINGRESULTS:

1. **Hardness Test:**

Hardness is a measure of how much a material resists changes in shape. The ability of a material to resist wear, tear, scratching, and abrasion Cutting is called hardness. Harder materials are more difficult to cut and shape than softer ones. They are also usually more brittle which means they do not bend much but can shatter[7].

Table 2: Experimental Results

S.no	composition	Trail 1			Trail 2			MVHN
		D1	D2	VHN	D1	D2	VHN	
1	Al 6061+2% Sic+2%Gr	67	74	114	75	65	120	117
2	Al 6061+4% Sic+2%Gr	87	78	127	76	78	129	128
3	Al 6061+6% Sic+2%Gr	76	67	134	68	89	136	135

Graph for hardness test:

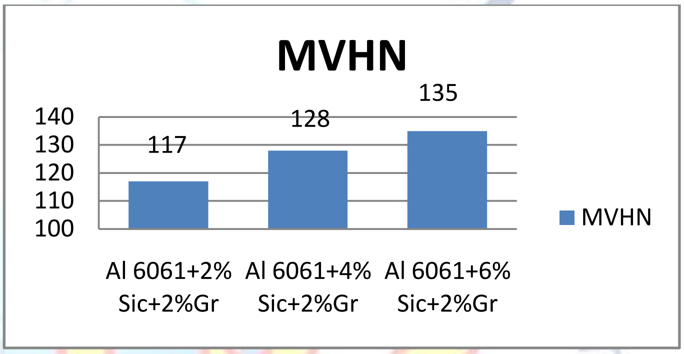

Figure 7:Hardness of prepared samples

2. Tensile Test:

Tensile testing, also known as tension testing, is a fundamental material science and engineering test in which a sample is subjected to a controlled tension until failure. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials [8].

Tensile tests help determine the effectiveness and behavior of a material when a stretching force acts on it. These tests are done under optimum temperature and pressure conditions and determine the maximum strength or load that the material can

Al-6061(%)	SIC(%)	Graphite
96	**2**	**2**
94	**4**	**2**
92	**6**	**2**

withstand.

A tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is and how much it can elongate.

Figure 8:Tensile Test Specimens

Table 3: Mechanical Testing Results

S.no	composition	Initial weight	Final weight	Loss of weight
1	Al 6061+2% Sic+2%Gr	10.78	9.872	0.908
2	Al 6061+4% Sic+2%Gr	10.97	10.083	0.887
3	Al 6061+6% Sic+2%Gr	9.96	9.184	0.776

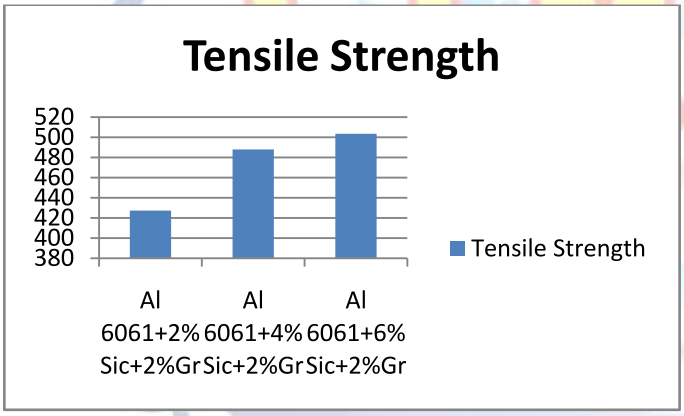

Figure 9:Tensile Test Results

1. **Wear Resistance Test:**

Wear resistance is defined as the ability of the stone to resist comprehensive external forces such as abrasion, edge cutting,and impactduring service [9].

The wear tests were conducted on aluminum (AL6061) alloy and aluminum (AL6061) + nano SIC MMCs as per ASTM G99-95 standard at room temperature using a computerized pin on the disk wear test rig shown in the figure 4.12. The sliding wear test samples were machined of 8 mm nominal diameter and a gauge length of 30 mm was The sliding wear test was conducted Pin-on-disc wear testing machine with da an acquisition system, which was used to evaluate the wear behaviorof the aluminum AL6061) alloy and aluminum (AL6061) + nano SIC MMCs against the toughened steel disc (En-32) with a hardness of 60 HRC and surface roughness (Ra) 0.5 pm. The sliding when test samples were slid over a rotating disc. The disc is coupled to a 1000 rpm capacity DC motor and the disc of 120mm in diameter. Theload can be applied bysimply adding the deadweight up to 200N through steel wire and a pulley arrangement.

Figure 10: Wear Test Machine

Table 4: Wear at 1kg load 200mts

composition	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
Al 6061+2% Sic+2%Gr	427.4	307	19.6
Al 6061+4% Sic+2%Gr	487.8	357	17.8
Al 6061+6% Sic+2%Gr	503.4	398	16.2

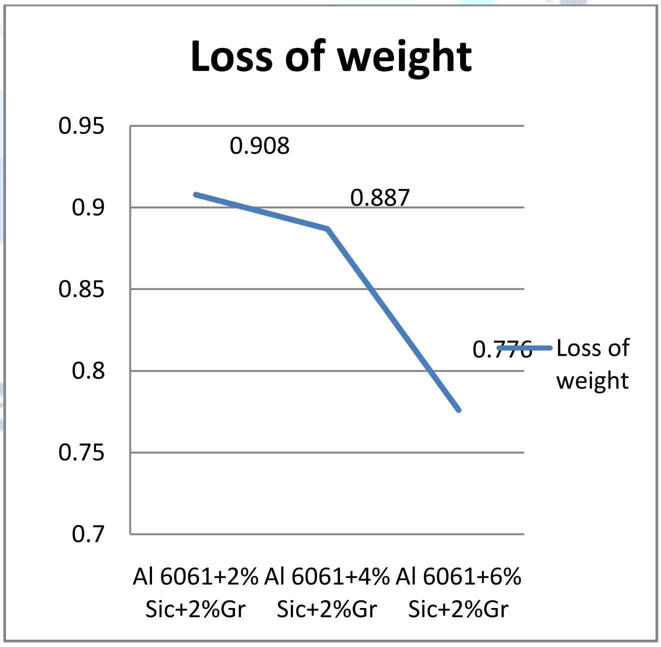

Figure 11: Wear Test ResultsModel 1

Table 5: Wear at 1kg load 400mts

S.no	composition	Initial weight	Final weight	Loss of weight
1	Al 6061+2% Sic+2%Gr	9.872	9.065	0.807
2	Al 6061+4% Sic+2%Gr	10.083	9.294	0.789
3	Al 6061+6% Sic+2%Gr	9.184	8.477	0.707

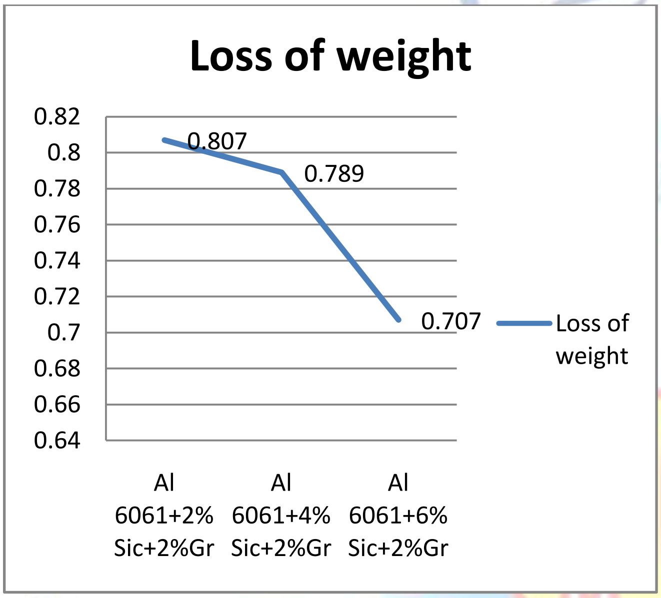

Figure 12: Wear Test Results Model 2

TABLE 6: Wear at 1kg load 600 mts:

S.no	composition	Initial weight	Final weight	Loss of weight
1	Al 6061+2% Sic+2%Gr	9.065	8.387	0.678
2	Al 6061+4% Sic+2%Gr	9.294	8.787	0.507
3	Al 6061+6% Sic+2%Gr	8.477	8.068	0.409

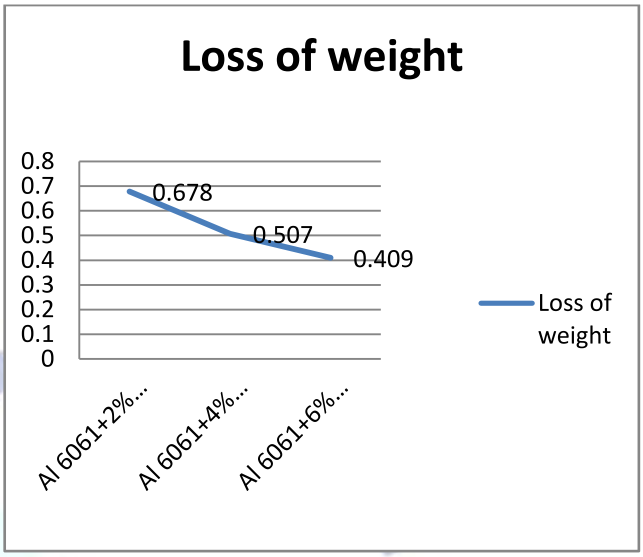

Figure 13: Wear test Results Model 3

Table 7: Corrosion Test:

S.no	composition	Initial weight	Final weight	Loss of weight
1	Al 6061+2% Sic+2%Gr	2.986	2.908	0.078
2	Al 6061+4% Sic+2%Gr	2.876	2.812	0.064
3	Al 6061+6% Sic+2%Gr	2.654	2.094	0.56

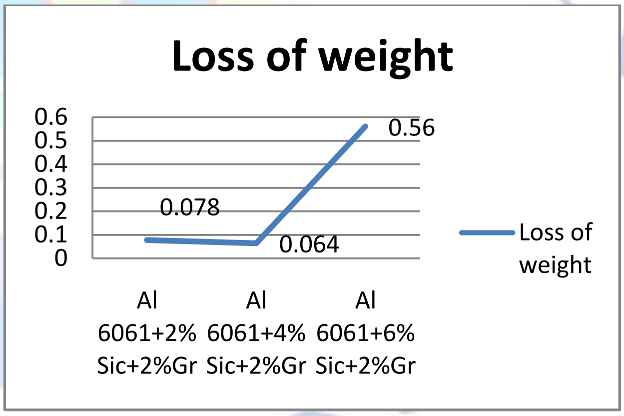

Figure 14: Corrosion Test Results

7. CONCLUSION:

The conclusions of the research work undertaken are;

- The AL6061-SIC -GR nano metal matrix composite materials have been fabricated by stir casting method followed by extrusion process.
- The nano SIC particulates are evenly dispersed in the matrix alloy. The microhardness ofAL6061-SIC -GR nano metal matrix composite material is superior

to the matrix material. The microhardness increases by 12.2% by the addition of 2 wt.%of SIC nano particulates in aluminum (AL6061) matrix alloy.

- The inclusion of SIC nano particulates in the AL6061 matrix alloy significantly enhanced the ultimate tensile strength and yield strength of the AL6061-SIC -GR 2 nano metal matrix composite materials. The 4% of SIC reinforced aluminum (AL6061)-SIC nanocomposite shows a 54.11% increase in the ultimate tensile strength as compared to the ultimate tensile strength of LM 13alloy
- The ductility of AL6061-SIC -GR nano metal matrix composite material decreases as compared to matrix alloy. The ductility decreases by 32.72% with the inducing of 2 wt.% of SIC_{nano} particulates in aluminum (AL6061) matrix alloy.
- The compression strength increases as the fraction of resin enhance the matrix material. The 8 wt.% of SIC reinforced as-cast aluminum (AL6061)-SIC nanocomposite.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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