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Mechanical Properties Of AA 6061/ Sic/ Graphene Hybrid Composites

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The present study is concerned with the mechanical characterisation and microstructure of hybrid composites Al/SiC/Graphene based on AA 6061 with varying weight percentages of SiC and Graphene that were produced via powder metallurgy.. To comprehend how dopant particles affected the microstructure and mechanical qualities of the manufactured specimens, a variety of responses, such as mechanical properties, hardness, etc., were assessed. The generated hybrid composite specimens showed a homogeneous dispersal of SiC and graphene particles according to Scanning Electron Microscopy (SEM). The addition of more graphene particles to the hybrid composite improved its mechanical characteristics.

Keyword: Hybrid composite, Mechanical Properties and Powder Metallurgy.

1. Introduction

Since its exceptional strength, exceptional resistance to corrosion, affordability, and ease of fabrication, aluminum and its alloys are widely utilized for many different engineering purposes. Aluminum and its alloys are widely used in many engineering sectors due to their affordability and ease of manufacture.[1-3]. The degree of hardness stiffness, compression strength, and strong tensile capacity are some of the desired characteristics of aluminum alloy hybrid nano composites (AAHNCs). These materials exhibit greater abrasion resistance when compared to pure alloys. These materials are employed in numerous structural applications across multiple industries, such as automotive, aircraft, and marine. Heavy-duty structural uses for AA 6061 can be found in truck frames, locomotive coaches, buildings, towers, army and industrial bridges, aerospace utilization, and shipbuilder activities.Due to its excellent electrical conductivity, lack of density, high strength, and higher resistance to corrosion, as well as greater the ability to be machine. AA 6061 is the most frequently used matrix material [1, 4-5]. Metal matrix composites (MMCs) have garnered an abundance of focus recently because of their superior mechanical qualities, which have resistant to wear as well as mechanical strength. Space structures, sliding electrical contacts, common applications include automobile pistons around cylinders barriers, rings for pistons, linking rods, and blower impellers. [4]. Aluminium matrix composites can withstand compressive and tensile forces with remarkable strength. Research has been conducted by attempting to incorporate various materials for reinforcing into the aluminium matrix. MMC components must be finished to the necessary dimensions and tolerances and formed into an appropriate shape [6-9]. Common MMC reinforcements include alumina-silica, boron carbide alumina, and silicon carbide. Numerous varieties of reinforcements are being used to improve the tribological qualities, including wear resistance, corrosion resistance, ductility, and workability. The incorporation of reinforcements such as carbide, oxides, and Graphene so forth can enhance the hardness of metal matrix composites [10].

Metal matrix composites are fabricated using various techniques, including stir casting, diffusion bonding, powder metallurgy, infiltration, and deposition methods. The behaviour of the material is affected by the choice of fabrication technique used to create the composite. To fabricate MMCs, stir casting is the most commonly employed method. A relatively inexpensive method to produce metal in large quantities, along with alloy matrix composites is powder metallurgy (PM). This is because of their capacity to blend the uniform dispersion of reinforcement with the intense refining of starting powders [16-17]. The goal is to create a new material with enhance properties by adding the various qualities of two or more existing materials. To increase bonding strength of the interphase the manufacturing process which is somewhat as well as properties of matric particles such as size, shape, and volume percentage should be controlled. Inspite of these difficulties the PM method offers several significant advantages, including enhanced control over the distribution of reinforcement and the development of a more homogeneous matrix microstructure.Inexpensive and has good wettability, high hardness, high compressive strength, thermal conductivity, and superior chemical inertness with minimal particles made of SiC showed expansion due to heat in spite of having a low density. SiC particles have been added by numerous researchers as reinforcement to the Al metal matrix [18-20].

Composites made of aluminium alloy 6061 with silicon carbide nanoparticles have better self-lubricating properties, toughness, and machinability. The low cost, higher wear resistance and elastic modulus of SiC nanoparticles make them highly promising. These microparticles typically neither form undesired phases nor react with the matrix materials, and they have excellent mechanical and oxidation resistance [21]. Recently, there has been a lot of interest in graphene, a two-dimensional, hybridized single-atom layers structure of graphite, due to its unique mechanical, electrical, and thermal properties. [22]. It can be made in a number of ways that rely on the chemical or thermal reduction of graphene oxide (GO), Due to graphene's mechanical characteristics, there is a lot of interest in combining these nano-platelets with metal matrices to create nanocomposites. .AA 6061/SiC composites were made by varying the weight percentage of SiC (0, 5, 10, and 15) and the length of the sintering process. Under ideal process conditions, they reported that the composite's toughness and hardness increased from 3.2 J/m^3 to 5.2 J/m^3 and from 73 to 81 HRB, respectively [23].

Silicon carbide (SiC) is used as a reinforcing agent in the fabrication of aluminium alloy composites. The stir casting method was utilized in the fabrication of this composite sample.

They observed that the addition of SiC particle significantly increased the hardness and impact strength [24]. Friction stir processing (FSP) was used to manufacture Al−SiC−graphene nanoplatelets (GNP) and Al−SiC−multi walled carbon nanotubes (CNT) hybrid composites. Tribological analysis shows that, in comparison to the as-received AA 6061 alloy, the specific wear rate of the Al−SiC−GNP hybrid composite decreased by approximately 56%, while it increased by approximately 122% in the Al−SiC−CNT hybrid composite [26]. By changing the GNP levels from 0 weight percent to 1 weight percent, several Al-GNP composites were created. Ball-milling-based powder metallurgy technique. Comparing the Al-0.5 weight percent GNP to the pure Al samples, the Al-0.25 weight percent GNP showed 135% tensile strength and ~70% compressive strength and 73% hardness [27].

A few composites researchers have assessed the material's density, hardness, and tensile testing of the manufactured specimen to look into its mechanical characteristics. The objective of this study is to use powder metallurgy to create an Al/SiC-Graphene composite. This study article's main goal is to examine the created composite's mechanical characteristics in order to determine whether or not it is suitable for usage in the automotive, aerospace, and industrial sectors.

2. Experimental Procedure:

Various weight percentage of SiC and Graphene added with AA 6061 by the ball milling process.

Sample 1 (AA 6061), Sample 2 (1 wt% SiC and 1.5 wt% Graphene), Sample 3 (2 wt% SiC and 2.5 wt% Graphene) and Sample 4 (3 wt% SiC and 3.5 wt% Graphene) processed through powder metallurgy method. The Hybrid Composites various wt% of AA6061/SiC/Graphene were obtained in the form of a rod of diameter 1.5cm and a length 3cm. AA6061 with as a matrix alloy and reinforced by different percentage of SiC and Graphene. To ensure a homogeneous distribution, the reinforcement particles were added gradually throughout the experiment. The mixtures were sintered for one hour at 200^{O}C and compressed at 400 MPa. Ultimately, the composite materials formed into shaped metal blocks by extruding them at the same temperature using a hydraulic extrusion mould that had been heated inadvance. Following extrusion, Heat treatment was applied to the composite materials. The composite materials were dissolved for one hour at 500^{O}C, and they were promptly cooled in water. After cooling, the samples are heated to 180 °C for 8 hours, with a heating speed of 10 °C per minute.

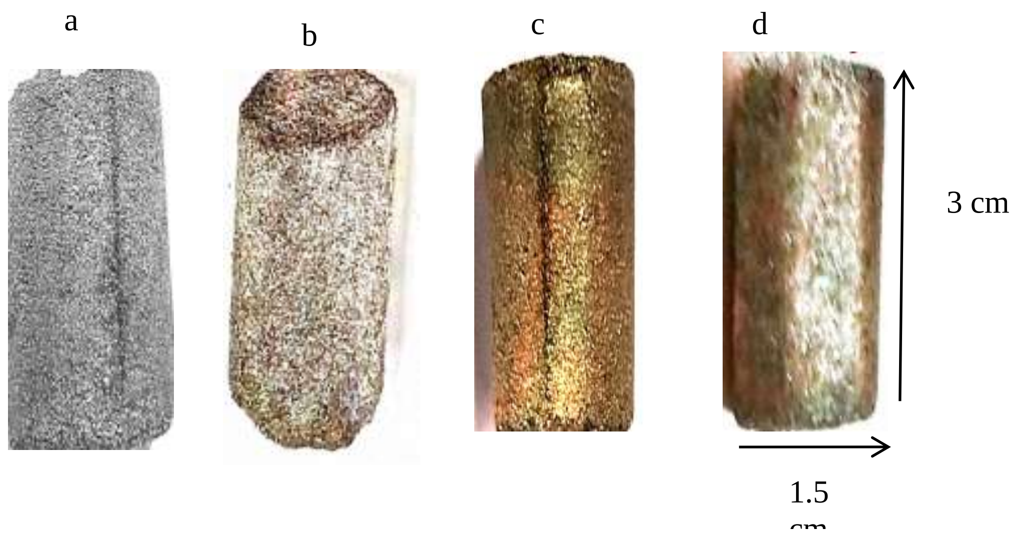

Fig 1.Samples (a)1 (b) 2 (c) 3 and (d) 4.

3.Result and Discussions

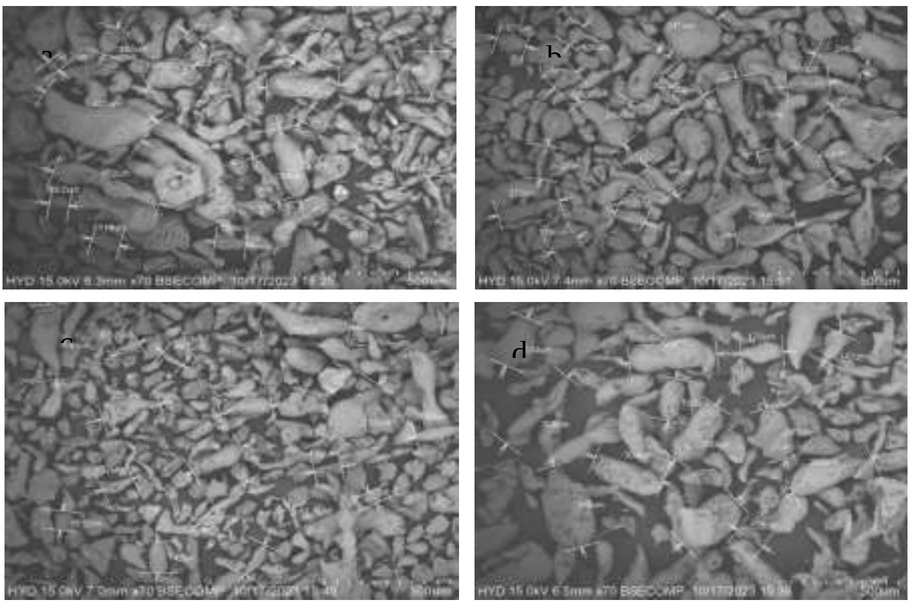

Fig 2. SEM images of samples (a)1 (b) 2 (c) 3 and (d) 4.

Investigations into the microstructure of the composites were conducted at different magnifications using an electron gun scanning electron microscope (SEM) and a microanalysis system (EDS).The AA6061 alloy, as received, has elongated grains; Fig.2 illustrates the SiC/Graphene reinforced surface composites, with an average grain size of roughly 3µm. Reduced grain size and particle distribution were used to optimize the process parameters. Consequently, the chosen process parameters. With these process parameters, the microstructure is almost uniform regardless of the volume fraction of SiC and graphene. In Fig 2 (a) given sample 1 the microstructure of pure AA 6061.SiC/graphene adding the size of particles decreased in Fig 2(b). Increased dopant percentage SiC/graphene the size of microstructure decreased again see in Fig 2 (c). Further increasing dopant percentage the microstructure increased size and have some broken [Fig (d)]. Corresponding AA/SiC-grapheme nanocomposite samples EDS analysis given in Fig 3.

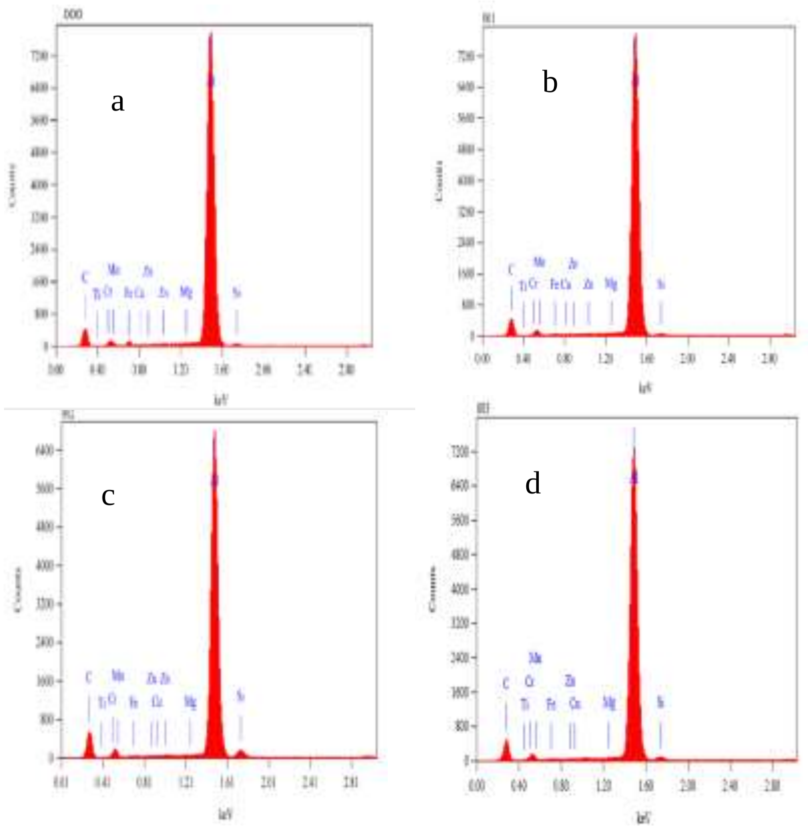

Fig 3. EDS of samples (a)1 (b) 2 (c) 3 and (d) 4.

The compositions pure AA 6061 and SiC, graphene based samples EDS spectra given in Fig 3.
The compositions of samples given in Table1 that indicates all samples are good compositions of metals.

Samples	Cu	Cr	Fe	Mg	Mn	Si	Ti	Zn	C	Al
Sample1	0.25	0.1	0.4	0.9	0.05	0.6	0.1	0.15	ND	Remains
Sample2	0.520	ND	0.16	ND	0.14	0.32	0.03	ND	12.50	Remains
Sample3	0.08	0.19	ND	ND	0.13	1.65	0.17	0.09	17.10	Remains
Sample4	0.20	0.02	0.45	ND	ND	0.72	ND	ND	14.27	Remains

Table.1. Mass of compositions in samples.

Note: ND means not detected.

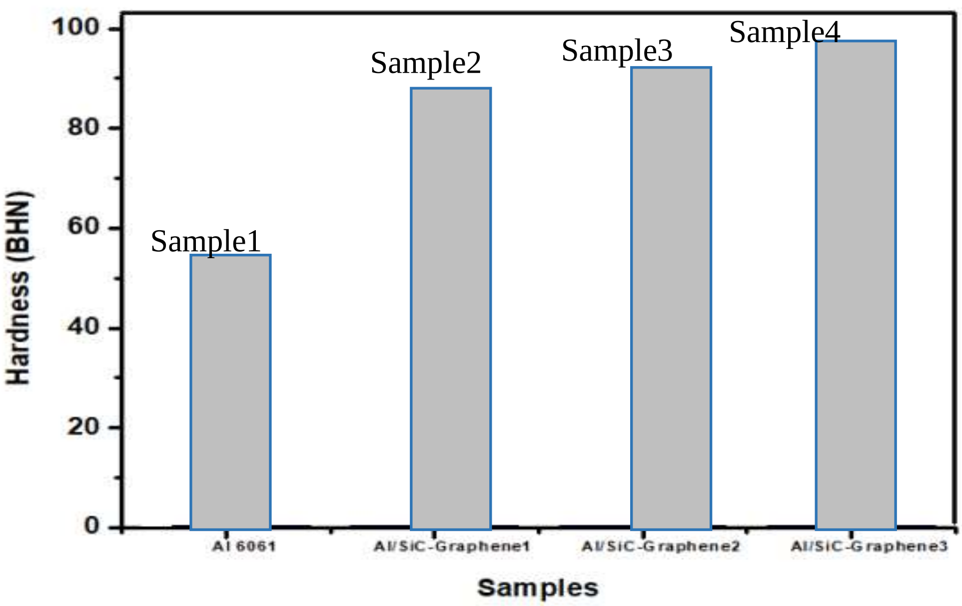

Fig 4. Hardness of samples (a)1 (b) 2 (c) 3 and (d) 4.

AA6061 based hybrid composite hardness as indicated in Table 2. It has been found that adding dopant improves the matrix's hardness. Fig 4 illustrates how the weight percentage of SiC and graphene in the AA6061 alloy affects hardness variation. It has been observed that as the weight percentage of SiC and graphene in the matrix increased, so did the matrix's hardness. For the sample 4 (AA/SiC-Graphene3), a hardness of 95 is noted. Previous studies [28–29] also noted that base materials' hardness was enhanced by reinforcements.
The compression strength of AA6061 alloy and AA6061 combination with varying weight percentages of SiC and graphene composites is displayed in Table 2. It can be inferred from that the compression strength of AA/SiC-Graphene increases with the amount SiC-Graphene particles present in the base AA6061 alloy. Because SiC-Graphene is so excellent, the compression strength determines the framework's strength. Particle strength is consistently very high, and this high strength of compression helps to increase the base Al material's crushing strength [30-31]. In a different study, Sharma et al. [30] synthesized AA 6061 + SiC + graphene and AA 6061 + SiC + carbon nanotube and assessed the mechanical and

microstructural characteristics of the surface composites. According to their report, AA + SiC + graphene demonstrated comparatively higher microstructure, micro hardness, wear resistance, and strength than AA 6061 + SiC + carbon nanotubes. Graphene ends that have been squeezed out form a layer that offers resistance to wear and applied load. Here, present work compression strength varies on SiC and graphene wt%. excessive addition of SiC and graphene will make the grain size coarser and produce cracks. It leads to the deterioration of the compressibility of the material. For that reason sample 4 has decreased compression strength compare to other samples [32].

Table 2. Mechanical properties of samples.

Sample	Compression Strength (MPa)	Hardness (Shore A)	Coefficient of Friction	Salt Spray Corrosion
Sample1	4.90	55	0.58	The given samples are subjected to salt spray corrosion test for 24 hours, found free from red rust formation
Sample2	4.93	90	0.47	The given samples are subjected to salt spray corrosion test for 24 hours, found free from red rust formation.
Sample3	4.83	88	0.41	The given samples are subjected to salt spray corrosion test for 24 hours, found free from Al/SiC-Graphne2red rust formation.
Sample4	3.94	92	0.43	The given samples are subjected to salt spray corrosion test for 24 hours, found free from Al/SiC-Graphene 3 red rust formation.

In order to investigate the impact of precipitate generation on tool-workpiece friction, a tribology system friction test was performed on all heat-treated samples after they had been polished. The sample on the table moved at a speed of 10 mm/s along the X-axis during the friction test. The X-axis was fifteen millimetres long. A 7 mm-diameter steel ball served as the friction tool. The Z-axis loads and friction time were 5 N and 8 min, respectively. The heat-treated AA/SiC-Graphne1 samples produced particles on their surface that reduced surface quality and raised the friction coefficient, which is one explanation for this. As a result, when machining AA/SiC-Graphne2 alloys, the production of particles from SiC-Graphne1 plays a significant role in determining the tool-workpiece friction coefficient. This has an impact on the newly created surface as well, which has an impact on the final surface quality [32]. It could observe SEM images of samples. AA6061/SiC-Graphne2 sample has good surface quality than AA/SiC-Graphne1 sample. The decrease in friction coefficient with increase of SiC and graphene wt%. for AA/SiC-Graphne3. For the Al 6061 alloy to the AMC with 15% vol% of SiC, the reported friction coefficient decreased[34].

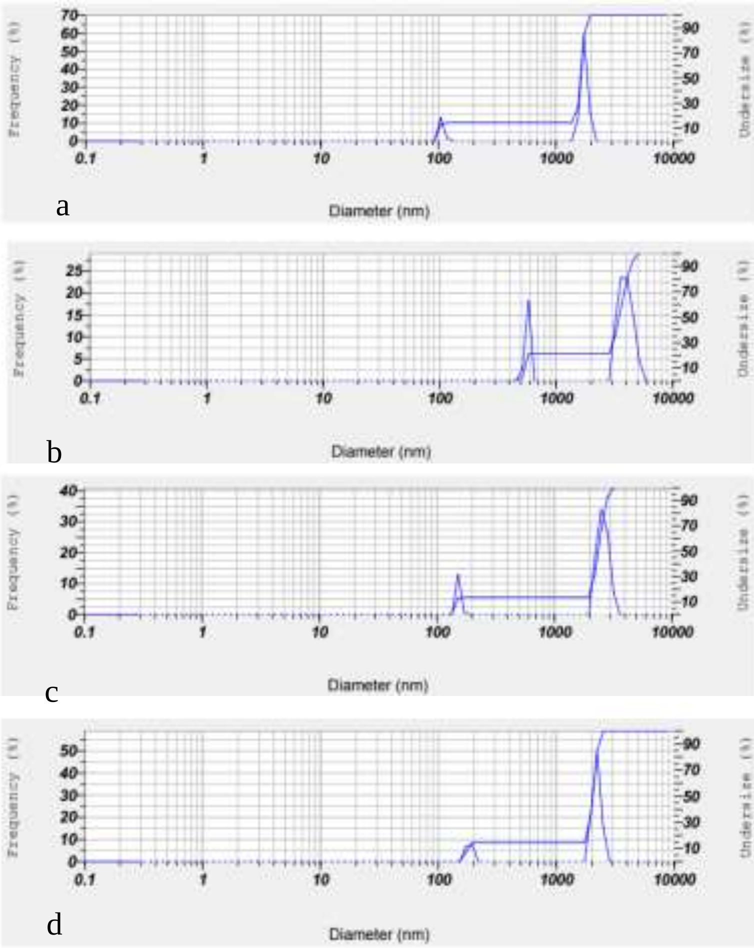

Fig 5. Particle distribution of samples (a)1 (b) 2 (c) 3 and (d) 4.

Fig 5 displays the particle size distribution of pure AA 6061, Al/SiC-Graphen1, AA/SiC-Graphene 2 and AA/SiC-Graphen3. It is evident that following, the distribution's frequency changed, and the graph's curves somewhat moved in the direction of smaller particle sizes. The average particle sizes of the samples (sample1, sample2, sample3 and sample4) that were received were found to be 3.4,2.3 and 2.0 µm, respectively. Moreover, the matching standard deviations are 1.3, 0.8 and 0.6 µm. Table 4 displays the distributions of sizes.It is found that the particle distributions with tiny mean diameter are rather narrow. Furthermore, the distributions become wider as the mean size increases [35]. The best mechanical properties of the composites can be achieved by selecting a critical size for the reinforcement particles. The sample 4 composites in this investigation show higher mechanical property results.

Table 3. Particle size of samples

S.NO	Sample	Mean	Standard deviation	Mode
1	Sample1	1425.1	556.1	1644.1
2	Sample2	3055.8	1379.2	3495.9
3	Sample3	2133.2	829.1	2393.5
4	Sample4	1805.0	685.8	2074.3

4. Conclusions:

AA6061 based hybrid composites were successfully prepared by the by the powder metallurgy method.Using good densification and better hardness were achieved for composites containing 2.5 wt. % graphene. However, composites containing 1.5 wt. % graphene had poor hardness. Therefore, 2 wt% SiC and 2.5 wt% Graphene is an optimum content for obtaining highly dense and hard AA6061 hybrid composites. Numerous research has shown that increasing the amount of graphene for the best rates of graphene increases the strength of composites with metal matrix. Overall research results indicate that AA606/SiC/graphene has better mechanical characteristics.

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