American Journal of Sciences and Engineering Research

E-ISSN– 2348–703X, Volume 8, Issue 5, 2025

Investigation on Mechanical Properties of Aluminium Hybrid Composites Reinforced with Silicon Carbide and Graphite

P. Senthilkumar[1], R. Suresh[2], G. Nallaiya[3], J. Prakash[4],

[1,4]*Lecturer, Department of Mechanical Engineering, Valivalam Desikar Polytechnic College, Nagapattinam, Tamilnadu, India.*

[2]*Lecturer(Sl.Gr), Department of Mechanical Engineering, Valivalam Desikar Polytechnic College, Nagapattinam, Tamilnadu, India.*

[3]*Lecturer, Department of Tool and Die Making, Murugappa Polytechnic College, Chennai, Tamilnadu, India.*

Corresponding Author: P. Senthilkumar.

ABSTRACT*: This research investigates the mechanical properties of aluminium hybrid composites. Al6061 has been chosen as the matrix material. Silicon carbide was used as reinforcement at weight percentages of 0%, 1.5%, 3%, and 4.5%, and graphite was used as an additional reinforcement at weight percentages of 0%, 1.5%, 3%, and 4.5%. The stir-casting method was used to prepare the Al 6061-based aluminium hybrid composites. The mechanical properties (i.e., tensile strength, percentage elongation, and hardness) of the prepared composites were investigated. The test results revealed that the increase in the weight percentage of the reinforcement materials caused an increase in the tensile strength and hardness of the aluminium hybrid composite, whereas the percentage elongation decreases with the increase in reinforcements.*

Keywords: *hybrid composites, Al 6061, silicon carbide, graphite, mechanical properties.*

I. INTRODUCTION

Aluminium alloys are an important engineering material. Aluminium alloys are mostly used in transportation (automotive, aerospace, and marine), construction, electrical and electronics, and consumer goods. A composite material is a combination of two materials with different physical and chemical properties. A composite material is made up of a matrix and a reinforcement phase. Aluminium matrix is mostly used in composites compared to the other matrices such as copper, titanium, etc. Ceramic particulates are added to the aluminium base matrix as a reinforcement to fabricate aluminium metal-matrix composites. Figure-1 represents several reinforcements that can be utilized for the development of MMCs. Aluminium metal-matrix composites have significantly better properties compared to unreinforced alloys. Aluminium metal-matrix composites are extensively used due to their desirable properties like low weight, low cost, high strength-to-weight ratio, good corrosion resistance, good thermal conductivity, and high stiffness. The main required characteristics of materials for present engineering applications are lightweight, high strength, high stiffness, and low cost. Such types of requirements cannot be achieved completely by single reinforced metal-matrix composites. Hybrid metal-matrix composites can be prepared by reinforcing two or more reinforcing materials into a metal matrix. In recent years, hybrid metal-matrix composites have been the focus of attention for researchers due to their enhanced mechanical performance when compared to single reinforced MMCs and

 Received-18-08-2025, Accepted- 29-08-2025

monolithic alloy. Figure-2 shows a variety of aluminium metal-matrix composites applications in engineering, transportation, and recreation.

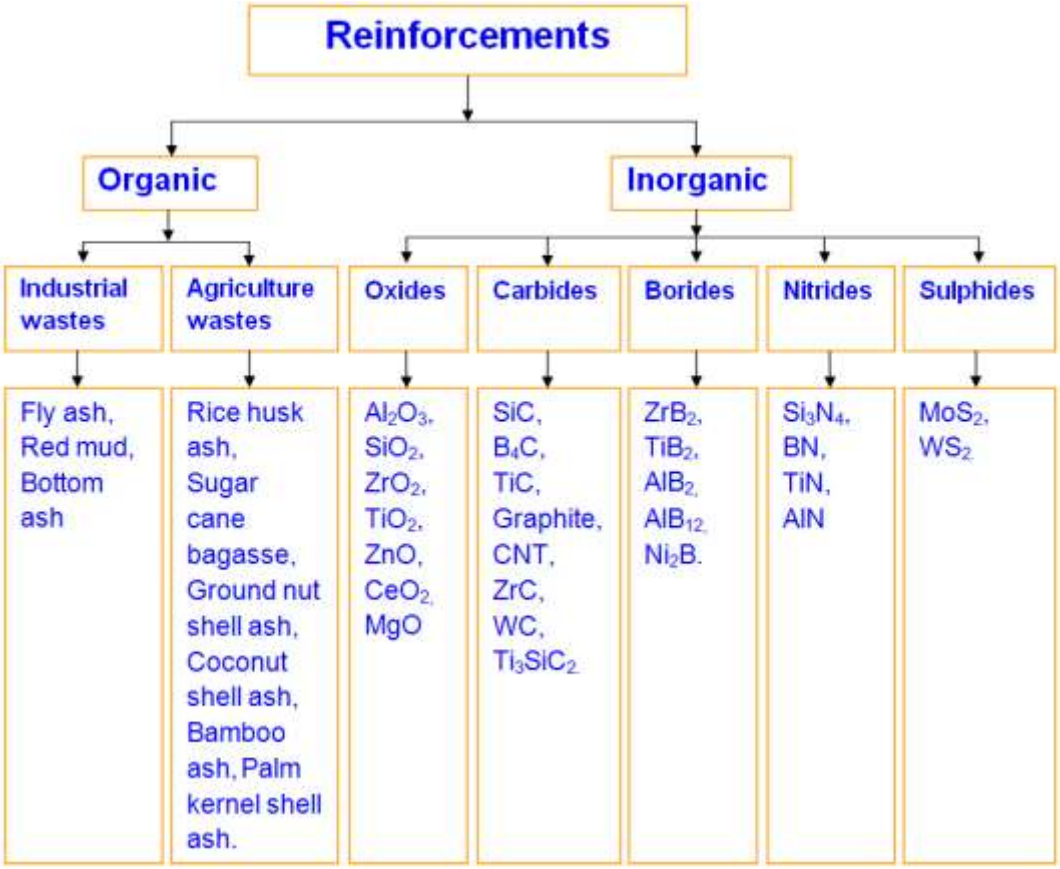

Figure -1: Several reinforcements used for the development of MMCs

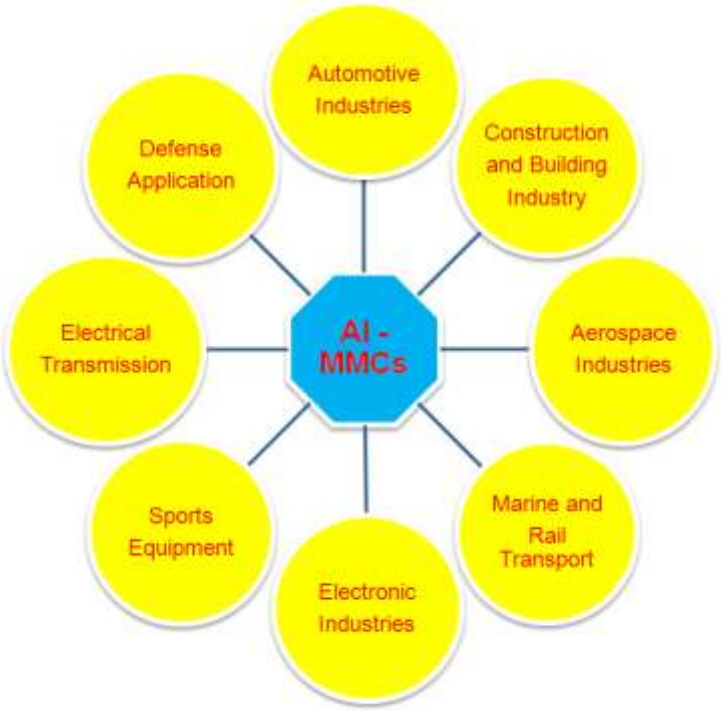

Figure -2: Applications of aluminium metal-matrix composites

II. LITERATURE REVIEW

V. Mohanavel et al [1] fabricated aluminium 6351 - graphite composite by stir casting method and studied its mechanical properties. Percentage of graphite was varied from 0 to 12wt% in steps of 4wt%. The result of this test showed that the tensile strength and hardness of the composite decrease with increase in the mass fraction of graphite particle content, this may be due to poor interfacial bonding between the reinforcement and the matrix.

Ananthakrishna Somayaji et al [2] have used aluminium 6082 as the matrix material and graphite with weight percentage (0, 2, 4 & 6wt %) as the reinforcement to produce the composite by stir casting. Mechanical properties of the fabricated aluminium matrix composites are investigated. The researchers observed that the tensile strength and percentage elongation increased with the increase in percentage of reinforcement in the matrix alloy, while the hardness found to be decreased.

Pawan Kumar et al [3] prepared a hybrid metal matrix composite using an Al6063 alloy as a matrix and graphite and boron carbide as reinforcement materials with the help of a stir-casting process. The wt% of boron carbide is varied as 3, 6, 9, and 12 and a constant 4 wt% of graphite is used to prepare the composites. The mechanical properties of aluminum based composites were investigated. The findings obtained from AA6063 hybrid composites revealed that the microhardness and UTS were enhanced with the addition of Gr and B_4C particles. The highest UTS of 152.3 MPa was found in the AA6063 hybrid composite with 4 wt% of Gr and 9 wt% of B_4C. Whereas a maximum hardness of 79.2 HV was found in the AA6063 hybrid composite with 4 wt% of Gr and 12 wt% of B_4C.

Madeva Nagaral et al [4] investigated the influence of Al_2O_3 and graphite on the microstructure and mechanical behavior of Al6061- Al_2O_3 and Al6061-Graphite composites. The Al6061- Al_2O_3 and Al6061-Graphite composites were fabricated separately by introducing 9 wt. % of Al_2O_3 and graphite particulates by two stage melt stirring process. Mechanical properties of the fabricated aluminium matrix composites are investigated. Results revealed that the hardness of Al6061-Graphite composite has decreased after the addition of graphite particulates into aluminium matrix. Also, the tensile strength and percentage elongation of Al6061-9 wt. % of graphite composites is more compared to base alloy.

Niranjan K N et al [5] have manufactured Al 6061 matrix reinforced with 6wt% SiC constant and varying steps of graphite by 3wt%, 6wt%, and 9wt%. Mechanical properties of the fabricated aluminium matrix composites are investigated. They stated that the hardness decreases with the increase in the percentage of graphite, tensile strength and compression strength increases with the increase in graphite particulates with the influence of SiC particulates.

In this work, an attempt has been made to prepare Al6061 alloy composites by adding silicon carbide and graphite reinforcement particles into the matrix by using a stir casting methodology. The silicon carbide and graphite were added in 0%, 3%, 6%, and 9% by weight (equal proportion) to the molten metal. The objective of the present investigation is to determine the mechanical properties of the aluminum hybrid composites by adding reinforcement particles into the aluminum alloy.

III. MATERIAL AND METHODS

Aluminium alloy (Al6061) as a matrix material and SiC and graphite as reinforcement were used in the present work. Al6061 alloy is chosen as the matrix material in metal matrix composites due to its excellent combination of properties, including good strength, lightweight, and corrosion resistance. The chemical composition of aluminium alloy (Al6061) is shown in table-1. SiC was chosen as one of the reinforcing particles because it provides high strength, high hardness, light weight and good wear resistance to the developed composite. Graphite is often chosen as reinforcement in aluminium matrix composites due to its lightweight, wear resistance, and thermal and electrical properties. A composition of composite specimens is shown in table-2.

Table-1: Chemical composition of Al6061

Element	Weight %	
	Minimum	Maximum
Mg	0.8	1.2
Si	0.4	0.8
Fe	0.0	0.7
Cu	0.15	0.40
Cr	0.04	0.35
Zn	0.0	0.25
Ti	0.0	0.25
Mn	0.0	0.15
Al	95.85	98.56

Table-2: Compositions of composite specimens

Weight % Of Al6061	Weight % of SiC	Weight % of Graphite	Weight % of reinforcement
100	0	0	0
97	1.5	1.5	3
94	3.0	3.0	6
91	4.5	4.5	9

Preparation of hybrid composites

The stir casting method is used for the manufacturing of metal matrix composites. This method helps to achieve a uniform distribution of reinforcement in the matrix material. The Al6061 is the base material, and SiC and graphite are used as the reinforcement particles. Initially, pure aluminium alloy was cut into small pieces to minimize the melting time and maximize the effective melting. The silicon carbide and graphite particles were initially preheated separately at a temperature of 400-450°C to remove moisture and to help even distribution within the Al6061 alloy. The aluminum alloy was charged into the graphite crucible and heated to 750°C till the entire metal in the crucible was melted. The preheated SiC particles were added to the molten metal at a constant rate during the stirring. Stirring continued for another 10 minutes even after the completion of particle feeding. Then preheated graphite particulates were added at a constant rate, and the stirring continued for 20 min. After 20 minutes of stirring, the complete mixture of reinforcement materials with aluminium alloy 6061 metal matrix was made. The mixture was poured into the mold, which was also preheated to 500°C for 20 min to obtain uniform solidification. After solidification, the composite can be cut into different shapes and sizes as per requirements.

Mechanical test

The aluminum alloy 6061 and hybrid composites specimens are further subjected to mechanical tests like tensile and hardness.

IV. RESULTS AND DISCUSSION

The mechanical properties of the composite specimens are presented in table-3.

Table-3: Mechanical properties of matrix and hybrid composites.

Weight % of reinforcement	Tensile Strength (MPa)	Percentage Elongation	Hardness (BHN)
0	124.0	5.9	58
3	147.8	4.7	65
6	163.6	4.1	70
9	179.2	3.9	73

Tensile strength

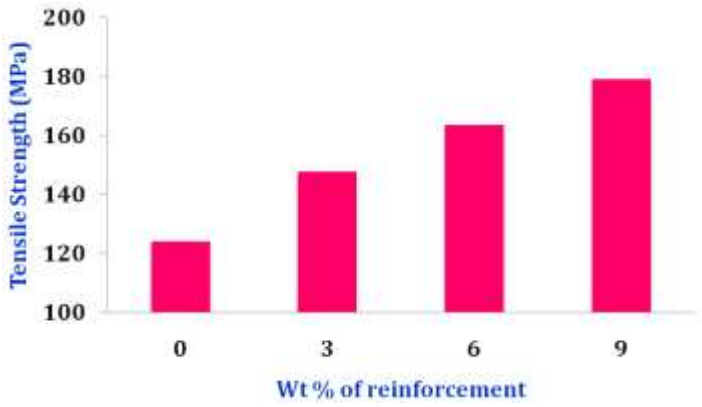

Figure-3: Tensile strength of composites

The tensile strength of aluminum hybrid composites is shown in figure-3. It was noticed that the tensile strength of the Al6061 alloy increased with the addition of wt% of silicon carbide and graphite particles in the Al6061 alloy. This is due to the interfacial bonding between the matrix and reinforcement. Also, the addition of silicon carbide particles enhanced the strength of the base alloy. These factors increase the strength of the composite materials. A maximum tensile strength of 179.2 MPa was noticed for the matrix that had 4.5 wt% of silicon carbide particles with 4.5 wt% of graphite reinforcements. It is about a 44.5% enhancement in tensile strength when compared to the Al6061 alloy. M Girikonda et al [6] have manufactured Al 7075 matrix reinforced with 4% B_4C constant and varying Al_2O_3 weight fractions of 2%, 4%, 6%, 8% and 10%. The test samples were prepared as per ASTM standards to investigate mechanical properties. Results indicated that the increase in weight percentage of reinforcement particles has increased the tensile strength of the Aluminum hybrid composites. Palanisamy Pugalenthi et al [7] fabricated an Al7075 composite reinforced with various weight percentages of silicon carbide particulates and a constant weight percentage of Al_2O_3 by stir casting. Four specimens were produced with different compositions comprising SiC (3, 5, 7 and 9 wt %) and Al_2O_3 2wt% in all the combinations. Mechanical properties like ultimate tensile strength, yield strength, percentage of elongation and hardness were examined. The test results revealed that the increase in the wt% fractions of the reinforcement materials caused an increase in the tensile strength of the aluminium composite.

Percentage elongation

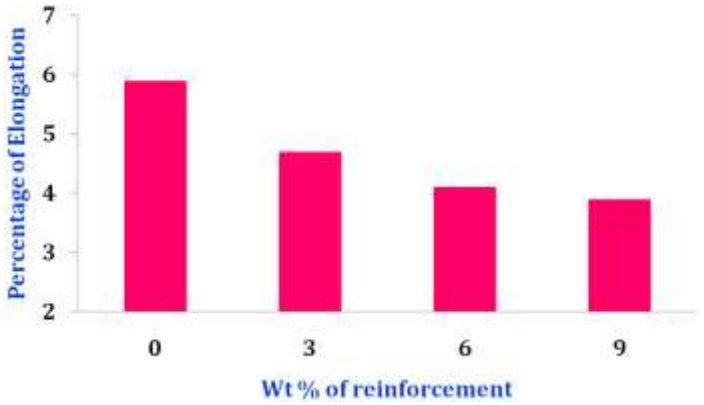

Figure-4: Percentage elongation of composites

The percentage elongation of the pure and Al 6061-based aluminium hybrid composite specimens is shown in Figure-4. It can be observed from the table that the percentage elongation has decreased significantly from 5.9% to 3.9%. It can be noticed from the investigation that there is a considerable depletion in the percentage elongation of composites, with an increase in the wt% of reinforcement material. This depletion in the properties of the composite compared to the base alloy can be majorly attributed to the dispersion hardening taking place in the composite material. Dora Siva Prasad et al [8] prepared a hybrid metal matrix composite using an A356.2 Alloy as a matrix and RHA and SiC as reinforcement materials with the help of a double stir casting process. Tensile and hardness tests were conducted. They observed that the composite with the composition of 8% RHA and 8% SiC exhibits less percentage elongation and they concluded that the percentage elongation of the composite decreases with the increase in RHA and SiC content. Jasmina Petrovic et al[9] developed a hybrid aluminum alloy EN AW 6061 MMC reinforced with 5% Al_2O_3 and varying wt% (1, 2 and 3%) walnut shell ash. Mechanical properties of the fabricated aluminium matrix composites are investigated. The results showed that the elongation decreases with an increase in the weight fraction of ash in the composites.

Hardness

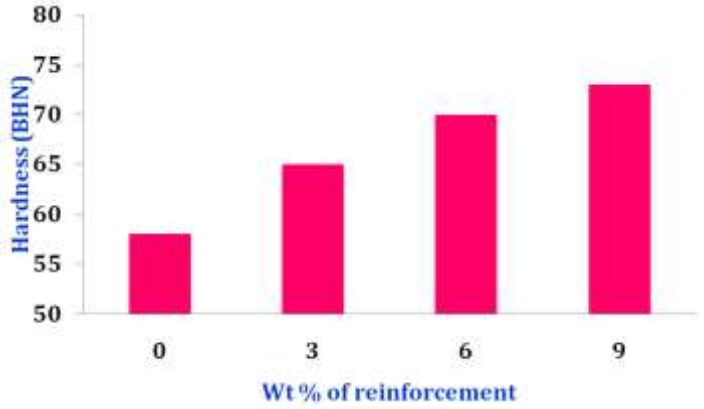

Figure-5: Hardness of composites

The variation in hardness of silicon carbide-graphite reinforced aluminium hybrid composites is presented in Figure-5. The observations of the hardness values indicate that there is an increase in hardness with the addition of reinforcement particles. This is due to the addition of hard reinforcement materials to the Al6061 alloy. The maximum hardness is obtained at 4.5 wt% of silicon carbide and 4.5 wt% of graphite reinforcements. It shows an improvement of up to 25.86% when compared to the Al6061 alloy. R. Girimurugan et al [10] deals

with the preparation and mechanical characterization of aluminium 6061 metal matrix reinforced with silicon carbide and eggshell. Silicon carbide and eggshell can be considered in different percentages like (2+1), (4+2), (6+3), (8+4). The Al 6061-based hybrid aluminium metal matrix composite was characterized by various mechanical tests. The researchers observed that the hardness of the composite increased with an increase in weight percent of reinforcements in the matrix. Arun Kumar Rajamanickam et al [11] prepared a hybrid metal matrix composite using an aluminium LM13 alloy as a matrix and boron carbide and titanium diboride as reinforcement materials with the help of a stir-casting process. The wt% of titanium diboride is varied as 0, 3, 6, 9, 12, 15 and a constant 3 wt% of boron carbide is used to prepare the composites. The mechanical properties of aluminum based composites were investigated. Results indicated that the hardness of the composite is higher than the base matrix. Also, the hardness of the composite increased with increase in weight percent of TiB_2 in the matrix.

V. CONCLUSIONS

The experimental investigations were carried out on the pure and Al 6061-based aluminium hybrid composites. In this research work, the Al 6061 composite was prepared by varying the weight percentage of silicon carbide and graphite particles. The four different compositions of materials were prepared. The various properties, such as tensile strength, percentage elongation, and hardness of developed specimens were investigated. Based on experimental results, the following conclusions can be drawn:

- Stir casting is an effective technique for producing aluminium hybrid composites.
- The tensile strength of the silicon carbide and graphite-filled Al6061 alloy composites was found to increase with an increase in the reinforcements.
- The hardness of the silicon carbide and graphite-filled Al6061 alloy composites was found to increase with an increase in the reinforcements.
- The hard nature of the included silicon carbide particles improves the tensile strength and hardness of the hybrid composites.
- The percentage elongation of the hybrid composites decreases with the increase in the percentage of reinforcements.

VI. REFERENCES

1. V. Mohanavel, K. Rajan, S. Suresh Kumar, G. Vijayan and M. S. Vijayanand. (2018). “Study on mechanical properties of graphite particulates reinforced aluminium matrix composite fabricated by stir casting technique,” *Materials Today: Proceedings,* 5, 2945–2950.
2. Ananthakrishna Somayaji, Madeva Nagaral,Chandrashekar Anjinappa, Meshel Q. Alkahtani, Ravikiran Kamath Billady, Nithin Kumar, Virupaxi Auradi, Saiful Islam,J. Ranga Raya Chowdary,Abdul Razak,Mohammad Amir Khan, and Channa Keshava Naik. (2023). “Influence of Graphite Particles on the Mechanical and Wear Characterization of Al6082 Alloy Composites,” *ACS Omega*, 8, 26828-26836.
3. Pawan Kumar and Ramesh Kumar Garg. (2025), “Microstructural and mechanical properties of boron carbide and graphite particles based AA6063 hybrid composite,” *Journal of Adhesion Science and Technology*, 39(13),2027-2040.
4. Madeva Nagaral, Shivananda B K, V Auradi, K I Parashivamurthy and S A Kori. (2017). “Mechanical Behavior of Al6061-Al_2O_3 and Al6061-Graphite Composites,” Materials Today: Proceedings, 4, 10978–10986.
5. Niranjan K N, Shivaraj B N, Sunil kumar M and Deepak a R. (Jan -2017). “Study of mechanical properties on Al6061 hybrid composite by stir casting method,” *International Research Journal of Engineering and Technology (IRJET)*, 04(1), 1036-1040.
6. M Girikonda, E Sai Baba, M Vinitha and D V V Krishna Prasad. (2020). “Mechanical Characterization of Stir Cast Al-7075/Al_2O_3/B_4C Hybrid Metal Matrix Composites”, *International Research Journal of Engineering and Technology (IRJET)*, 07(11), 1068-1071.

7. Palanisamy Pugalenthi, Murugesan Jayaraman and Venkatajalapathy Subburam.(2019). "Study of the Microstructures and Mechanical Properties of Aluminium Hybrid Composites with SiC and Al_2O_3", *Materials and technology*, 53(1), 49–55.
8. Dora Siva Prasad, ChintadaShoba and NalluRamanaiah. (2 0 1 4). "Investigations on mechanical properties of aluminum hybrid composites," *Journal of Materials Research and Technology*, 3(1), 79–85.
9. Jasmina Petrovic, Srba Mladenovic, Ivana Markovic and Silvana Dimitrijevic.(2022). "Characterization of Hybrid Aluminum Composites Reinforced with Al_2O_3 Particles and Walnut Shell Ash," *Materials and technology*, 56(2), 115–122.
10. R. Girimurugan, R. Pugazhenthi, T. Suresh, Pon. Maheskumar, M. Vairavel, "Prediction of mechanical properties of hybrid aluminium composites," *Materials Today: Proceedings*, https://doi.org/10.1016/j.matpr.2020.09.302.
11. Arun Kumar Rajamanickamand Uvaraja VC, "Assessment of mechanical properties of LM13 aluminum alloy hybrid metal matrix composites," *Materials Research Express*, 9 (2022) 075001.