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Substantial Review of the Mechanical Conditions of Hybrid Metal MATRIX Composites AL 6063, Sic, & Gr.

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Abstract

Aluminium 6063 is heat-treated extruded alloy that is used in a variety of engineering and structural components, such as aircraft wings and fuselages, railings, window frames, drive shafts, valves, and so on. Because of its great features, such as medium-to-high strength, excellent environmental resistance, low density, high elongation at break, and superior machinability, Al-6063 is widely used among the 6000 series of aluminum. An overview of the mechanical, tribological, and microstructural characteristics of stir-cast Al-6063 metal/matrix composites (MMCs) is provided in this paper. The purpose of this review article is to demonstrate how various reinforcements affect the metallurgical behavior of Al-6063 MMC. Particulate reinforcements such as Sic, Al2O3, Gr, B4C, Tic, fly ash, bagas ash, and red mud were stir-cast with Al-6063 alloy as single, dual, and triple reinforcements. Key findings describe the overall properties of Al-6063 MMC, providing researchers with a methodical methodology for selecting optimal parameters for the manufacturing of aluminium-based MMC with single, dual, and triple reinforcements. The overall properties of Al-6063 MMC are summarised, together with relevant findings, to provide researchers with a methodical strategy for selecting optimal parameters for aluminium-based MMC manufacturing.

Keywords: Stir Casting & MMC, Sic and Gr Reinforcements, Al6063 Alloy

Introduction

Al-6000 alloys, also known as Mg/Si alloys, are wrought alloys with heat retained due to the presence of magnesium silicate (Mg_2Si) [1]. Al-6000 alloys are widely used in welding and structural components due to their excellent corrosion resistance, medium strength, and good formability [2]. Commercial alloys from the Al-6000 series used in the development of aluminum-based metal/matrix composites (MMC) are Al-6061, Al-6063, Al-6026, and Al-6082, with Al-6061 reinforced the most with particulate reinforcements via stir casting [3-4]. The most versatile alloy, Al-6063, is used in marine fittings, yachts, chassis, bearings, and scuba tanks, as well as shipbuilding, transportation, aircraft structure, and automobile components [3]. Al-6063 alloy combines excellent properties such as high temperature strength, high stiffness to weight ratio, superior, and ca stability [6-4]. Al-6063 alloy is widely used in engineering and structural applications because its strength can be increased through liquid heat treatment and age-hardening techniques [5]. Despite having a good combination of physical and mechanical properties, aluminum alloys have failed to perform in a variety of high-performance and high-temperature applications. Aluminum particulate metal/matrix composite has emerged as the most valuable alternatives for researchers working in these areas [6]. Though are used for more than just structural and functional applications, these composite materials have shown great promise as multi-functional materials in the aerospace, marine, defence, and automobile industries [7-3]. The harder reinforcement (non-metallic material) is dispersed into the softer matrix (metallic alloy) to achieve a homogeneous distribution of reinforcing and matrix phases in particulate metal/matrix composites [8]. The goal of PMMC is to achieve the required mechanical strength and hardness while also improving physical and biological properties. A major area of research in recent years has been the unique combination of ceramic and agro-industrial waste in the form of hybrid metal/matrix composites (HMMC). Particulate ceramic reinforcements commonly used include Sic, B4C, Al2O3, Gr, and agro-industrial reinforcements such as Agassi ash (BA), bamboo leaf ash (BLA), fly ash (FA), red mud (RM), and rice husk ash (RNA). [9-10] A systematic case study on the mechanical, biological, micro structural, and physical characterization of stir-cast Al-6063 MMC is presented in this review article. The impact of single, dual, and triple reinforcements on overall properties has been discussed. Comparative studies of the Al-6063 alloy and the Al-6063 MMC were also conducted, with the results presented in tabular form, bar charts, optical microscopy (OM), and scanning electron microscopy (SEM) graphs. Finally, key findings summarize the experimental results of various characterizations. This article is unique in that no previous research has been conducted to demonstrate the overall metallurgical properties of stir-cast Al-6063 MMC with optimized process parameters. This review article will assist academic researchers in the future in selecting the best permutation and combination of reinforcements, as well as optimizing process parameters, to synthesize other aluminum-based alloys with the best metallurgical and functional properties.

Composite Material

The basic structure of a review article is depicted. Composites are generally made up of two or more metals, or metals mixed with non-metals, that are joined together in any proportion. Ceramics, industrial waste, and agricultural waste are more frequently used to make these composites. Metal matrix composites (MMCs) play a larger role in the fabrication of composites for a variety of applications because they are produced and used more frequently than their peers, ceramic matrix composites and polymer matrix composites. [10] [11] reviewed the overall reinforcement philosophies, mechanical, corrosion, and biological properties of aluminum hybrid metal matrix composites. Their findings are as follows: Aluminum hybrid composites are a new generation of metal matrix composites that have the potential to meet the most recent advanced engineering applications. [10] Metals and their alloys are the primary constituents of metal matrix composites. Aluminum, one of the most abundant materials in the Earth's crust, has been used in a variety of forms, shapes, and sizes for a long time. It is traditionally an unavoidable metal that contributes to every industrial manufacturing industry. It is commonly referred to as a "researcher's delight" because its alloys and composites account for more than half of all research conducted worldwide. Aluminum matrix composites (AMC's) are widely used in a variety of fields due to their appealing properties such as low cost, light weight, high strength-to-weight ratio, high hardness, and excellent corrosion and wear resistance. This paper examines the effect of hybrid reinforcement on the mechanical behavior of aluminum matrix composites. The paper discusses the fabrication of aluminum-based hybrid metal matrix composites as well as their mechanical properties such as hardness, toughness, and tensile strength. [3] In general, more research is being conducted in paradigms such as the effect of process parameters in casting AMC's and their optimization, the experimental investigation of mechanical properties in AMC's, the study of corrosion resistance and biological behavior in AMC's, and so on. Stir casting is used to make metal matrix composites. Stir casting is primarily used in the production of particulate-reinforced metal matrix composites (PMMC). Casting is one of the most cost-effective methods of producing aluminum alloy-based casting composites. [12] attempted to improve the mechanical properties of AMC's, such as tensile strength and hardness, by reinforcing the 6063-Al matrix. Using the stir casting method [13]

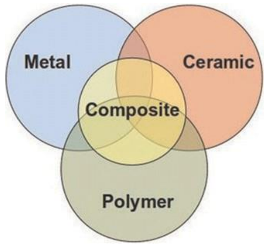

Figure.1 The family of composites among metals/ceramics/polymers

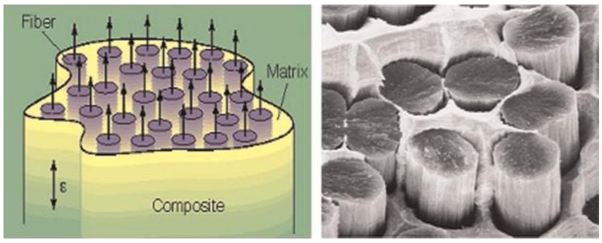

Figure 2 Schematic and actual illustration of matrix and reinforcement within a composite structure, Kainer (2006)

Table 1. Potential and realistic technical applications

Composite	Components	Advantages
Aluminum–silicon carbide (particle)	Piston Brake rotor, calliper, liner Propeller shaft	Reduced weight, high strength and wear resistance High placed on resistance, reduced weight Reduced weight, excessive particular stiffness
Aluminum–silicon carbide (whiskers)	Connecting rod Sprockets, pulleys, and covers	Reduced reciprocating mass, high specific strength and stiffness, low coefficient of thermal expansion Reduced weight, excessive electricity and stiffness
Aluminum–aluminum oxide (short fibers)	Piston ring Piston crown (combustion bowl)	Reduced reciprocating mass, excessive creep and fatigue resistance
Aluminum–aluminum oxide (extended fibers)	Connecting rod	Reduced reciprocating mass, advanced strength and stiffness
Copper–graphite	Electrical contact strips, electronics packaging, bearings	Low friction and wear, low coefficient of thermal expansion
Aluminum–graphite	Cylinder, liner bearings	Call resistance, decreased friction, put on and weight
Aluminum–titanium carbide (particle)	Piston, connecting rod	Reduced weight and wear
Aluminum–fiber flax	Piston	Reduced weight and wear
Aluminum–aluminum oxide fibers	Engine block	Reduced weight, stepped forward power and put on resistance
Super alloy-based composite (Ni– Ni3Nb)	Turbine blades	Fatigue resistance, impact strength, temperature resistance

Stir casting

The liquid metallurgical mode (stir casting) was identified as one of the best and most widely used techniques among all primary production methods in a review of the literature on the fabrication routes of aluminum-based composites [14]. Stir casting has a number of advantages over other traditional methods, including low processing costs, good particulate homogeneity, lower moisture absorptions, mass production capability, and adaptability to a wide range of shapes, sizes, and volume fractions. Between the matrix and reinforcing phase, agglomeration, and porosity are the main limitations of this process [15]. The stir casting procedure's most significant advantage is its ability to fabricate materials in conventional ways, such as gravity casting using a bottom pouring furnace, which makes this process much simpler than other processes; however, the manufacturing cost savings through this process are also one-third to one-tenth of other processes. [16] Figure 3 depicts a basic stir casting setup with systematic stir casting components. Various process parameters influenced the overall properties of stir-cast MMC, as well as the distribution of reinforcing particles within a molten matrix. The proper selection of these parameters has a significant impact on the overall performance of composite materials in terms of improved mechanical, biological, and micro structural properties [13-14]. The mechanical properties of as-cast Al-6061 MMC were discussed and compared to those of Al-6061 alloy, including ultimate tensile strength (UTS),, yield strength (IS), percentage elongation, ultimate compressive strength (UCS), and impact strength. The mechanical characterization specifications are written in accordance with the standards of the American Society for Testing and Materials (ASTM). [13] The UTS, YS percentage elongation, and UCS of fabricated composites were determined using a universal testing machine (UTM). A Rockwell and hardness tester was used to determine the macro hardness of cast specimens, and a Vickers hardness tester was used to determine the test.

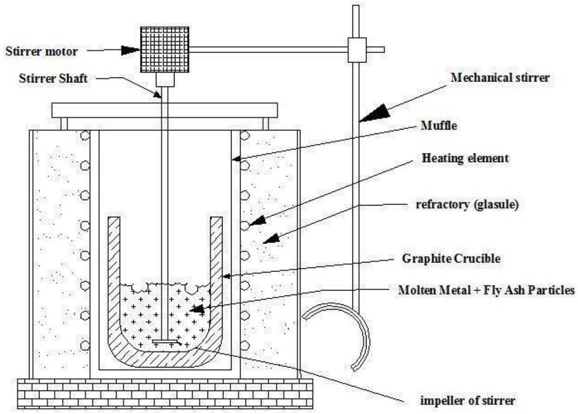

Figure. 3 Stir casting setup

Alloy to improve reinforcement distribution [24-25]. Reinforcement is forcefully added into the molten stage of aluminum, and achieving homogeneity during solidification of the fabricated composite is dependent on the following factors.

- Stirring speed and time
- Stirring blade angle
- Pouring temperature and solidification rate
- Size, percentage, and relative density of reinforcement

Recently, there have been significant changes in the stir casting process. Researchers created a two-step electromagnetic assisted stir casting process to improve the mechanical properties of fabricated composites.

Process Parameter

The mechanical properties of as-cast Al-6063 MMC were discussed and compared to those of the Al-6063 alloy, including ultimate tensile strength (UTS), yield strength (YS), percentage elongation, ultimate compressive strength (UCS), and impact strength. The mechanical properties of Al-6063 MMC with various sample compositions were determined. The mechanical characterization specifications are written in accordance with the standards of the American Society for Testing and Materials. The specific parameters and processing conditions used during the stir casting process will be determined by the composite material being manufactured and the desired final product properties. For example, during the mixing process, the temperature and rate of stirring can be adjusted to achieve a homogeneous mixture, and the cooling rate during casting can be adjusted to control the microstructure of the material

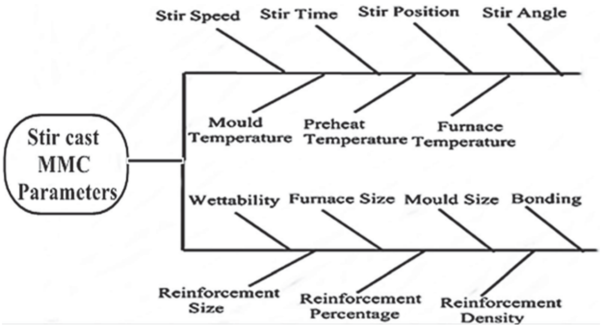

Figure. 4 Fish bone diagram Stir cast MMC process parameters.

Literature Review

Maurya et al. et al. [15] created an AA-6061-SiC MMC to investigate the effect of Sic particulates on the mechanical properties of manufactured composites. Electromagnetic stirring was used to reinforce the composite with 2, 4, 6, and 8 WTA Sic of 30 km particle size. Mechanical results show that gradually increasing the weight percent Sic (2/ 8 WTA) raises composite hardness and tensile strength from 40 to 51 HRB and 276 to 298 MPA, respectively.

Prashant et al. [41] investigated the differences between GR-reinforced AA-6061 MMC; AA-6061 MMC. The composite was made with 125 km size and equal amounts of 6, 9, and 12 WTA Gr and Sic using a stir casting method. The experimental results show that adding Sic particulates increases from 98 to 151 VHN, while adding Gr particulates decreases from 98 to 76 VHN. The effects of 3 weight percent Sic and 3, 6, and 9 weight percent ionosphere particulates on the mechanical properties of reinforced composites were investigated.

Ashoka et al. [18] Mechanical mixing was done for 2.5 minutes at 700 RPM. The incorporation of ionosphere with Sic reinforcements increases the young modulus and hardness of HMMC from 61 to 68 GPA and 63 to 70 VHN, respectively, as demonstrated by the test results.

Ramesh et al. [13] investigated the mechanical properties of HMMC made of AA-6061, Sic, and ZrO2. The composite was made using a conventional stir casting method with a composition of 5 WTA Sic and 2:3 WTA Sic: ZrO2. When comparing 2 WTA Sic/3 WTA ZrO2/AA-6061 to 5 WTA Sic/AA-6061, significant improvements in UTS and hardness were observed. The fatigue strength of the AA-6061/Sic/ZrO2 HMMC was found to be higher than that of the single-reinforced composite.

Dwivedi [2] which matrix material is to be heated above its melting point until it reaches a liquid state, after which the molten metal is cooled to the semisolid stage [26]. Particles that have been preheated are added and mixed using a stirring mechanism. The resulting slurry is heated again until it reaches the liquid state. Many authors created Palms with various reinforcements using the stir casting method and tested their mechanical properties.

Thomas et al [19] created an aluminum alloy reinforced with 15% Sic stirred by hand, using an existing stir casting mechanism and a modified mechanism that included a stirrer with two blade assemblies and holes in the feeder, as well as feeder rotation at 800 rpm. The existing mechanism's experiment results were compared to the modified mechanism's results. According to the findings, the percentage elongation has increased by 34%, the buckling load has increased by 5.45%, and the BHN value has increased by 5.45%.

Prabu et al. [20] [21] investigate the effect of the stirring process on the fabrication of an Al/105 Sic composite. Observations show that the microstructure of the composite changes with stirring speed and time, as well as the hardness of the fabricated composite. The results also show that particle agglomeration was greater when the stirring speed was low and the stirring time was short.

Prasad et al. [12] used a double stir casting process to create hybrid metal matrix composites with 8% rice husk ash and Sic particles. The uniform distribution of rice husk ash (RNA) and Sic in the matrix phase was reported by the authors. It was also discovered that as the percentage of reinforcement increases, so do the porosity and hardness. Further investigation revealed that the yield strength and ultimate tensile strength increase with increasing RNA and Sic content.

Kumar et al. [22] used the stir casting method to create Al6061 composites with fly ash. Fly ash with particle sizes of 75-100, 45-50, and 4-25 mm was used to introduce it into the molten phase. Each set includes three types of samples reinforced with weight fractions of 10, 15, and 20%. According to research, the size of fly ash particles affects the compressive strength, hardness, and tensile strength of Al6061. It was also discovered that as the weight fraction of the fly ash particles increased, the ductility of the composite decreased. On the other hand, increases in ultimate tensile strength, compressive strength, and hardness values Through SEM analysis, no voids were discovered.

K. Raja et al. [13] investigated three stir casting techniques on a fly ash-reinforced Arsing alloy composite. These studies investigated the liquid metal stir casting, compo-casting, and modified compo-casting routes, followed by squeeze casting. Modified compo casting produces a composite with no porosity and proper particle distribution.

Jayaseelan et al. [23] compared the extrusion properties of Alaric produced by two methods: powder metallurgy and stir casting. The microstructures of stir-cast specimens were finer, and the hardness was higher than that of powder-metallurgy specimens. They are also stronger.

Keshavamurthy et al. [24]: To fabricate an Al7075-TiB2 composite in situ. The, yield strength, and ultimate tensile strength of the Al7075-TiB2 composite were significantly higher than those of a reinforced alloy. The Al7075-TiB2 composite had significantly higher micro hardness, yield strength, and ultimate tensile strength than a reinforced alloy.

Keshavamurthy et al. [24]: In situ fabrication of an Al7075-TiB2 composite. The Al7075-TiB2 composite had significantly higher, yield strength, and ultimate tensile strength than a reinforced alloy.

Rao et al. [17] looked into the effect of applied pressure on the biological behavior of aluminum. Overall, the results showed that adding 10% Sick to the base alloy increased seizure resistance by 33%, and adding 25% Sick increased seizure resistance by 50%. Wear rates in all samples increase marginally with applied load prior to reaching the transition load. The wear surface in a seizure condition is distinguished by the formation of parallel lips and the destruction of MML (wave-like material flow) along the sliding direction.

S. CEM Humus et al. [25] created through liquid-phase particle mixing (melt stirring) and squeeze casting. The thermal expansion and thermal conductivity of hybrid composites with varying graphite contents (5.0, 7.5, and 10 wt. %) and silicon carbide particle sizes (45 mm and 53 mm) were investigated. The results showed that increasing the graphite content improved dimensional stability, and there was no discernible difference in thermal expansion behaviours between the silicon carbide-reinforced composites of 45 mm and 53 mm. When the graphite component of hybrid composites was enriched, the thermal conductivity decreased.

M. Vamsi Krishna et al. [26] Because of their low density, high strength, and good structural rigidity, they have gained widespread acceptance for automobile, industrial, and aerospace applications. We attempt to prepare and compare the mechanical properties of Al6061-SiC and Al6061-SiC/Graphite hybrid composites in this paper. The composites were made using the stir casting method, with the amount of reinforcement varying from 5-15% in 5-wt% steps. Micro structural studies and were used to characterize the prepared composites, and their mechanical properties were evaluated in accordance with the standards.

Atla Sridhar et al. [27] investigated the effect of graphite on the mechanical and biological properties of hybrid metal matrix composites made of Al 7075-SiC-graphite. The mechanical properties of an aluminum metal matrix composite reinforced with silicon carbide (Sic) ceramic material are excellent. According to the research, incorporating graphite into the composite for wear reduction is effective. It was investigated whether the material Al 7075 (aluminum alloy 7075) could be reinforced.

Jaswinder Singh et al. [28], improving surface properties and retaining bulk properties are critical requirements. This paper describes the properties of Al/Sic/Gr hybrid composites that can be used in a variety of biological applications. Gr particles are used to assist in the formation of a thick and extensive bricklayer on the wear surface. Under certain conditions, this layer reduces the rate of wear by reducing direct contact between the rubbing surfaces. According to morphological analysis of worn surfaces, hybrid composites outperform pure aluminum alloy and ceramic-reinforced composites in terms of wear.

Das et al.[29] In their study, they found that aluminum matrix composites (AMC's) impregnated with hard ceramic particulates are replacing conventional materials in automobile, aerospace, marine, and military applications for their significant properties, like high temperature resistance, high stiffness, and a high strength-to-weight ratio.

Mishra et al. [30] developed a silicon carbide (Sic) particulate-impregnated Al 7075 matrix composite that was then heated to T6 temperature. To compare machining performance, it was machined with multiple layers of Red-coated tungsten carbide (WC) inserts in a dry environment and a pollution-free spray impingement cooling (SIC) environment. In terms of cutting tool temperature (T), average roughness of the machined surface (Ra), and tool flank wear, the Sic environment performed better (BBC). The experimental data was used to create quadratic response surface models.

Satya Kumar Dewangan et al. [31, 32]. The importance of research on metal matrix composites based on aluminum has increased recently. The final section of the work focuses on the analysis of the mechanical behavior of composites made of the aluminum alloy 6063 and reinforced with silicon carbide (Sic) and graphite particles with total metal matrix reinforcement. In this hybrid reinforcement, the hardness, tensile strength, thermal conductivity, and microstructure of the composites were investigated. The variations of Sic and graphite (2+2%), (4+2%), and (6+2%) were taken into consideration.

Devaraju Atari et al. [33] investigation, tool rotational speed has an impact on the wear and mechanical characteristics of surface hybrid composites made from aluminum alloys using friction stir processing (FSP). The surface hybrid composites' reinforcement particle dispersion was examined using an optical microscope. The Sic, Gr, and Al2O3 reinforcement particles are uniformly distributed throughout the nugget zone, as demonstrated by the microstructures of all the surface hybrid composites. The presence and pining effect of hard Sic and Al2O3 particles caused them to decrease when the rotational speed was increased, and it showed a higher value in the Alaric/Al2O3 surface hybrid composite. Mechanical and biological behavior of particulate-reinforced aluminum metal matrix composites was investigated.

B. Veeresh Kumar et al. [34]. The results include a review of the wear performance of hard ceramic-reinforced aluminum matrix composites with a focus on mechanical and physical parameters, as well as material considerations and the effects of lubrication, work hardening, mechanical mixed layering, heat treatment, etc.

S.V. Prasad and R. Astana [35] argues that particulates will lighten vehicles and improve engine performance, resulting in lower fuel usage and emissions. To overcome Al's poor adhesion and seizure resistance, Sic, Al2O3, or graphite particles must be dispersed in Al in order to replace cast iron engine components with lightweight alloys. Wear and friction are greatly decreased as a result of using these particulates. Al MMCs can also withstand high mechanical and thermal loads and reduce heat losses by allowing for a closer fit because of their lower thermal expansion coefficient. As a result, higher cylinder pressures (and consequently higher engine performance) are made possible.

Judith Jiang [36] there has been research on the mechanical behavior of semisolid 7075 aluminum matrix composites reinforced with canonized Sic particles. The microstructure of the 7075 AMC's reinforced with hand-sized Sic particles prior to semisolid compression is composed of tiny, spheroid solid grains encased in liquid phase. Semisolid compression causes non-uniform plastic deformation of solid grains.

Subhranshu Chatterjee [37] looked into the effects on microstructure and residual stresses. Microstructure and residual stresses have a significant influence on the wear and tensile properties of 6061-Al/Al2O3 and 6061-Al/Sic composite samples' wear and tensile properties. Because of the higher residual stress, the wear tracks of 6061-Al/Sic composite showed more debris than those of 6061-Al/Al2O3 composite, this is also supported by the formers higher wear rate.

P.K. Jayashree [38] conducted a review of the literature and concluded that more research was needed to compare the properties of welded joints in heat-treated and unheated conditions in order to improve welded joint quality. Microstructural examination was used to determine how sic particles behaved in metal matrix composites during welding as well as how these properties improved after the precipitation hardening process.

Dunia Abdul Saheb [39] parameters are held constant while varying the weight fractions of Sic, graphite, and alumina (5%, 10%, 15%, 20%, 25%, and 30%), while graphite weight fractions of 2%, 4%, 6%, 8%, and 10% are studied. The results showed that the matrix was quite successful in achieving uniform reinforcement dispersion in the matrix. The hardness of ceramic materials has been observed to increase with increasing weight percentage. The best results (maximum hardness) were obtained at 25% Sic weight fraction and 4% graphite weight fraction.

Ramnath, Vijaya [40] In comparison to conventional engineering materials, the addition of reinforcements to the metallic matrix improves the stiffness, specific strength, wear, creep, and fatigue properties. This paper summarises the effects of addition on various reinforcements in an aluminium alloy, highlighting the benefits and drawbacks of each. It is also thoroughly discussed how different reinforcements on AMCs affect mechanical properties like tensile strength, strain, hardness, wear, and fatigue.

A. Baradeswaran et al. [41] investigated the effect of graphite on the wear behaviour of an Al 7075/Al2O3/5 weight percent graphite hybrid composite. The study demonstrates the effectiveness of incorporating graphite into the composite for wear reduction. Al 7075 (the aluminium alloy 7075) reinforced with Al2O3-graphite was studied. The composites were created using the liquid metallurgy method. Ceramic particles and solid lubricating materials were mixed into an aluminium alloy matrix to reduce wear resistance and the coefficient of friction.

S. Venkat Prasat et al. [42] investigate the use of fly ash and graphite particles as low-cost reinforcing materials for hybrid composites to improve wear resistance, mechanical properties, and density. Methodology/design/approach - The stir casting method was used to create the AlSi10Mg/fly ash/graphite (Al/FA/Gr) hybrid composite. The dry sliding wear and friction behaviour of hybrid composites were investigated using a pin-on-disc machine while varying parameters such as load and fly ash weight fraction and compared to base metal alloys and aluminum-graphite composites. The tests were carried out at a constant sliding speed of 2 m/s over a distance of 2,400 m.

S. Kumar et al. [43] investigated aluminum-based composites machined using wire electrical discharge machining. They optimised parameters like peak current, pulse on time, wire feed rate, and reinforcement weight percentage in their work, which affect responses like kerfs width and surface roughness. They discovered that incorporating reinforcement particles into the composite increased the machined area's surface roughness.

Table 2: Authors reported work

Author	Route	Matrix/reinforcement	Remarks	ef
Balasivanandaprabu et al.	Stir casting	Al with 10% Sic	Better distribution of particles	20]
Rajan et al.	compo casting	Al-Si-Mg alloy with Fly ash.	Uniformly distributed and porosity free composites	13]
Jayaseelan et al.	stir casting	Al- Sic	Finer microstructure high Hardness	44]
Kalaiselvan et. al	stir casting	AlAA6063 12wt.% B4C	Hardness achieve 80.8 Hand tensile strength 215 MPA	45]
Prasad et al.	Stir casting	Al/Rice hush ash	Increase in Hardness	12]
Sourav Kayal et.al.	Stir casting	Al LM-6/Sic p	Hardness increases	46]
Anil Kumar et al.	Stir casting	Al6061 with Fly ash	Reduced compressive strength, tensile Strength and hardness.	20]
Verma et al.	Stir casting	Al6063/Fly Ash	Increase in hardness but reduction in fatigue strength.	47]
Atuanya et al.	Stir casting	Al-Si-Fe alloy/ bread fruit seed hull ash	Impact strength decreases	48]
Sharanabasappa et al.	Stir casting	Al LM25/ Fly Ash and Alumina	Tensile strength camp; hardness increases	49]
Keshavamurthy et al.	Stir casting	Al7075-TiB2	Micro hardness and Yield strength increases	50]
Selvam. et al.	Stir casting	Al6061/Sic + Fly Ash	Macro hardness and tensile strength increases	51]
Alaneme et al.	Double stir cast	Rice husk ash(RNA)-Alumina/ Al	Hardness, tensile strength increases	50]
Mathiazhagan et al.	Stir casting	Al/Cu/Sic	Tensile strength increases	52]
Prasad et al.	Double stir casting process	Hybrid MMC with Sic, 8% rice husk ash.	Increased Yield strength and ultimate tensile strength	12]
Thomas et al.	Stir casting	Al LM6/Sic	Increase in buckling load	19]
Dwivedi et. al	Electromagnetic stir	A356 15wt.sic	Stirring at 210 rpm for7 min. Hardness achieved 104.66 BHN and tensile strength 309.83MPa	2]
Singh et al.	Stir Casting	Al6063/Groundnut shell	Increase Ultimate tensile strength, compressive strength	53]

Discussion:

Metal matrix composites (MMCs) have received significant attention in the field of materials science due to their unique mechanical properties, such as high strength, stiffness, and wear resistance. In recent years, researchers have focused on developing hybrid MMCs by incorporating multiple reinforcement materials, such as aluminum (Al), silicon carbide (Sic), and graphite (Gr), to create a composite material that can provide superior mechanical properties compared to individual materials.

This compressive review investigates the mechanical properties of Al, Sic, and Gr hybrid MMCs. The review summarizes the recent research on the mechanical properties of these materials, including their compressive strength, modulus of elasticity, and strain rate sensitivity.

Al/Sic/Gr hybrid MMCs have been shown to exhibit high compressive strength and modulus of elasticity. The addition of Sic and Gr to Al improves the mechanical properties of the material by enhancing its stiffness and strength. Several studies have shown that the compressive strength of Al/Sic/Gr hybrid MMCs increases with increasing Sic and Gr content.

The strain rate sensitivity of Al/Sic/Gr hybrid MMCs has also been investigated in several studies. The results show that the strain rate sensitivity of the material is influenced by the composition and microstructure of the MMC. An increase in Sic and Gr content has been found to improve the strain rate sensitivity of the material.

In addition, the microstructure of the MMC, such as the size and distribution of the reinforcement materials, has a significant impact on the mechanical properties of the material. A study found that the addition of Gr to Al/Sic hybrid MMCs improved the microstructure of the material, resulting in a more uniform distribution of Sic particles and a higher compressive strength.

Overall, the investigation of the mechanical properties of Al/Sic/Gr hybrid MMCs has shown promising results, indicating that these materials have the potential to be used in various engineering applications where high strength and stiffness are required. Further research is needed to optimize the composition and microstructure of these materials to achieve even higher mechanical properties.

One of the research papers that investigated the mechanical properties of Al/Sic/Gr hybrid metal matrix composites is "Mechanical Properties of Aluminum Hybrid Metal Matrix Composite Reinforced with Silicon Carbide and Graphite Particles" by K. et al. (2018). The authors focused on investigating the effect of Sic and Gr particles on the mechanical properties of the composite material, specifically in terms of compressive strength, hardness, and wear resistance.

In this study, the Al/Sic/Gr hybrid composites were prepared using the stir casting method, where the reinforcement particles were added to molten aluminum and stirred for a specific time to ensure a uniform distribution of the particles. The composites were fabricated with different Sic and Gr weight percentages, ranging from 2% to 10%.

The results of the study showed that the compressive strength of the Al/Sic/Gr hybrid composites increased with increasing Sic and Gr content, reaching a maximum value of 244 MPA for the composite with 6% Sic and 4% Gr weight percentage. The addition of Sic and Gr particles also increased the hardness and wear resistance of the composite material. The wear resistance was tested using a pin-on-disk apparatus, and the results showed that the wear rate of the composites decreased with increasing Sic and Gr content.

Furthermore, the study investigated the microstructure of the composite material using scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. The results showed a uniform distribution of the reinforcement particles in the Al matrix, and the XRD analysis confirmed the formation of a new phase in the composite material.

The study also investigated the strain rate sensitivity of the Al/Sic/Gr hybrid composites. The results showed that the strain rate sensitivity increased with increasing Sic and Gr content. The authors attributed this to the strengthening effect of the reinforcement particles, which improved the material's ability to resist deformation under high strain rates.

Overall, this study demonstrated that the addition of Sic and Gr particles can significantly improve the mechanical properties of Al-based metal matrix composites. The results suggest that these materials have great potential for use in applications where high strength and wear resistance are required. Another research paper that investigated the mechanical properties of Al/Sic/Gr hybrid metal matrix composites is "Mechanical Properties and Microstructure of Hybrid Composites .This study aimed to investigate the effect of varying Sic and Gr content on the mechanical properties and microstructure of the composite material, particularly in terms of compressive strength and modulus of elasticity.

In this study, the Al/Sic/Gr hybrid composites were fabricated using the powder metallurgy method. The Sic and Gr particles were mixed with aluminum powder, and the mixture was compacted using a press and sintered in a furnace at a high temperature. The composites were prepared with different weight percentages of Sic and Gr, ranging from 5% to 15%. The results of the study showed that the compressive strength and modulus of elasticity of the Al/Sic/Gr hybrid composites increased with increasing Sic and Gr content. The maximum compressive strength and modulus of elasticity were observed for the composite with 15% Sic and 15% Gr weight percentage, which were 165 MPA and 43 GPA, respectively.

The authors attributed this improvement in mechanical properties to the strengthening effect of the reinforcement particles and the homogeneous dispersion of the particles in the aluminum matrix. In addition, the study investigated the microstructure of the composite material using SEM and XRD analysis. The results showed a homogeneous distribution of the Sic and Gr particles in the Al matrix, with no significant agglomeration or clustering of the particles. The XRD analysis also confirmed the formation of new phases in the composite material. The study also investigated the strain rate sensitivity of the Al/Sic/Gr hybrid composites. The results showed that the strain rate sensitivity increased with increasing Sic and Gr content. The authors attributed this to the strengthening effect of the reinforcement particles, which improved the material's ability to resist deformation under high strain rates.

The composites were fabricated using the powder metallurgy method, where Al 6063 powder was mixed with Sic and graphite particles and the mixture was compacted using a uniaxial press and sintered in a furnace at a high temperature. The composites were prepared with different weight percentages of Sic and graphite, ranging from 2.5% to 10%.

The results of the study showed that the addition of Sic and graphite particles significantly improved the mechanical properties of the Al 6063 matrix. The maximum compressive strength was observed for the composite with 7.5% Sic and 2.5% graphite weight percentage, which was 296 MPa. The micro hardness of the composite material also increased with increasing Sic and graphite content.

The study also investigated the microstructure of the composite material using SEM and XRD analysis. The results showed a uniform distribution of the Sic and graphite particles in the Al 6063 matrix, with no significant agglomeration or clustering of the particles. The XRD analysis also confirmed the formation of new phases in the composite material.

Furthermore, the study investigated the fracture behavior of the Al 6063/Sic/graphite hybrid composites using the acoustic emission technique. The results showed that the addition of Sic and graphite particles improved the fracture toughness and ductility of the composite material.

Overall, this study demonstrated that the addition of Sic and graphite particles to Al 6063 matrix can significantly improve the mechanical properties of the composite material, particularly in terms of compressive strength and micro hardness. The authors suggest that these materials have potential for use in various engineering applications where high strength and stiffness are required. Overall, this study demonstrated that the Al/Sic/Gr hybrid composites prepared using the powder metallurgy method exhibited improved mechanical properties compared to the pure Al matrix. The results suggest that these materials have potential for use in applications where high strength and stiffness are required." An investigation of the mechanical properties of Al 6063, Sic, and graphite hybrid metal matrix composites" is a research paper that investigates the mechanical properties of Al 6063/Sic/graphite hybrid metal matrix composites. The authors aimed to investigate the effect of varying weight percentages of Sic and graphite on the mechanical properties of the composite material, particularly in terms of compressive strength.

The composites were fabricated using the powder metallurgy method, where Al 6063 powder was mixed with Sic and graphite particles and the mixture was compacted using a press and sintered in a furnace at a high temperature. The composites were prepared with different weight percentages of Sic and graphite, ranging from 2.5% to 10%. The results of the study showed that the addition of Sic and graphite particles significantly improved the mechanical properties of the Al 6063 matrix. The maximum compressive strength was observed for the composite with 7.5% Sic and 2.5% graphite weight percentage, which was 296 MPA.

The composite material also increased with increasing Sic and graphite content. The study also investigated the microstructure of the composite material using SEM and XRD analysis. The results showed a uniform distribution of the Sic and graphite particles in the Al 6063 matrix, with no significant agglomeration or clustering of the particles. The XRD analysis also confirmed the formation of new phases in the composite material.

Furthermore, the study investigated the fracture behavior of the Al 6063/Sic/graphite hybrid composites using the acoustic emission technique. The results showed that the addition of Sic and graphite particles improved the fracture toughness and ductility of the composite material. Overall, this study demonstrated that the addition of Sic and graphite particles to Al 6063 matrix can significantly improve the mechanical properties of the composite material, particularly in terms of compressive strength and . The authors suggest that these materials have potential for use in various engineering applications where high strength and stiffness are required.

Conclusion

After reviewing the available literature on the mechanical properties of Al 6063, Sic, and graphite hybrid metal matrix composites (HMMCs), the following conclusions can be drawn

- ❖ Most studies concluded that adding reinforcement such as Sic, Al_2O_3, TiB_2, B_4C, Tic, and others increased the hardness and strength of composites. Gr has greater hardness and strength than other materials.
- ❖ Composite powders of Alice and Gr composites reinforced with stir cast composite powders
- ❖ MMC engineering applications are expanding rapidly in fields such as automotive, defence, and aerospace. Marine and sports utilities as a result, the study concentrated on recent studies on cost.
- ❖ The various manufacturing techniques, particularly the impact of proper selection of stir casting process parameters, used by many investigators in the fabrication of AMC's, have been thoroughly discussed. According to the literature, choosing the optimal level of process parameters in stir casting technique, such as stirring temperature (700-770 C), stirring speed (600-700 rpm), stirring time (10-15 min), reinforcement preheating time (2-4 hrs), and preheating temperature (200-250 C)
- ❖ The quality of cast samples, such as strength, stiffness, hardness, grain size, and interfacial bonding, can be improved with the proper selection of the matrix and percentage weight of reinforcements, the addition of a degassing agent, and the proper pouring temperature.-effective and optimized methods for manufacturing MMCs.

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