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Review of Aluminium (AA6061) Metal Matrix Composite (MMC) by Stir Casting Method

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ABSTRACT

Industrial development has boosted the use of aluminium to accommodate high demand. Among the most popular aluminium alloys is the AA6061 of the 6xxx series due to it characteristics. AA6061 is a preferred matrix material for Metal Matrix Composite (MMC) fabrication. This study comprehensively reviews an AA6061 aluminium matrix composite produced through the liquid processing technique-stir casting. This review focuses on process parameters, manufacture of conventional mixtures, range of reinforcement, mechanical and tribology properties of AA6061 composites. Significant findings show that increased reinforcement in AA6061 matrix composites greatly improves the properties, such as strength, hardness, ductility, and wear resistance. Producing AA6061 composites with various reinforcements such as organic, inorganic (carbide, oxides, borides and nitrides), hybrid, and other nanomaterials makes the composites more appropriate for high-stress applications. The AA6061 matrix has effectively included a broad spectrum of reinforcing materials, from micro to nanoscale, showcasing the adaptability and versatility of the stir casting method. Future studies should focus on improving AA6061 composite manufacture using advanced casting processes and comprehensive material characterization. These composites have great potential as advanced materials for several industrial applications due to its remarkable mechanical and tribological properties.

1. Introduction

The combination of a minimum of two different materials in a proportional ratio created a special feature known as Matrix Composite [1-3]. There are three main categories of matrix composite such as polymer matrix composites (PMC), ceramic matrix composites (CMC), and metal matrix composites (MMCs) [2,4]. Metal matrix composites (MMCs) are a type of composite that is the choice of industrial applications compared to PMC and CMC due to their advantages. (MMCs) are advanced materials composed of other ceramic or metallic material which is known as reinforcement [2,4,5]. The metal matrix is a conventional alloy which has excellent characteristics including low weight, high

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strength, high stiffness, strong wear resistance, low density, high ductility, and toughness with electrical and thermal conductivity [1,3,5]. At the same time, reinforcement is a high-strength material that exhibits superior thermal properties as well as remarkable mechanical characteristics including higher strength, hardness, fracture toughness, and better resistance to wear and corrosion [1,6]. These advantageous characteristics led to the increased use of composite materials in industrial applications [2].

Aluminium Metal Matrix Composite (AMMCs) has been an industry favourite since the 1930s due to its widespread application in automotive, defence, transportation, aerospace applications and civil construction [4,7-10] Aluminium Metal Matrix Composite (AMMC) are composite materials that consist of pure aluminium or its alloy as the matrix [2] and ceramic or metallic particles as a reinforcement material [3]. Ceramic, synthetic, industrial, and agro waste that has micro or nano size is effectively blended with matrix to produce AMMCs [2,4,11]. Silicon carbide, boron carbide, titanium boride, zirconium oxide, aluminium oxide, boron nitride, tungsten carbide, titanium carbide etc. are used to reinforce AMMCs with improved quality and mechanical characteristics than pure aluminium [5,10,12]. The best manufacturing techniques have been explored for AMMC which include solid-state processing and liquid-state processing [1,2,4]. Solid-state techniques include friction stir processing and powder metallurgy in which the bonding of a matrix with reinforcement occurs because of the mutual diffusion arising between them in the solid state at a higher level of temperature and pressure [13,14] Liquid state processes include squeeze casting, stir casting, and liquid infiltration [1,14,15], the dispersion of reinforcement in the molten matrix, followed by its solidification through the casting process.

Aluminium Metal Matrix Composites (AMMCs) are mostly produced by the stir-casting technique [2,4]. Stir casting is the most popular method in liquid-state processes. Since mixing occurs in molten conditions, stir casting is economical compared to other manufacturing techniques. It also provides homogenous dispersion of reinforcement in the matrix, better wettability, and reduced porosity [2,4]. Several research studies indicated that the stir-casting method is widely used and suitable for fabricating Aluminium Metal Matrix Composites (AMMCs) with reinforcements such as Silicone Carbide (SiC), Boron Carbide (B_4C), Aluminium Oxide (Al_2O_3) and Titanium Carbide (TiC) as well as other inorganic, organic, hybrid, and nanomaterials [2,4,15]. However, attention should be given to achieving the uniform distribution of reinforcement material.

The main objective of the paper is to review the various possible MMCs fabricated through stir casting with AA6061 as the matrix material. The output model can be used to investigate the influence of other parameters on the AA6061 composite.

2. Matrix Material: Aluminium, AA6061

AA6061 is one of the most prevalent alloys in the 6xxx family, and it is used as a matrix material in numerous AMCs because of its ability to change composite strength with proper heat treatment [2]. Its high thermal conductivity and low density are offset by its low wear resistance [16]. The basic alloy has a tensile strength of 115 MPa, Rockwell hardness of 30 HRB, and elastic modulus of 70-80 MPa [2]. Table 1 shows some key characteristics and properties of Aluminium AA6061. In addition, Aluminium AL60061 is also the material choice to use as a matrix material in metal matrix composites (MMCs). A novel composite based on Aluminium AA6061 with high tensile strength may be created using a range of reinforcing materials.

Table 1
Chemical composition of AA6061 aluminium alloy [2]

Element	Composition (mass percentage)
Al	95.85-98.56
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

3. Fabrication Techniques of MMC

Researchers have used a variety of manufacturing techniques for Metal Matrix Composites. Each process has distinct advantages and impacts on the mechanical and physical characteristics of the composite [1,17]. The processing techniques are divided into solid-state and liquid-state processing [1,17]. The selection of processing techniques depends upon reinforcement material and material properties. Liquid state manufacturing is a commonly used technique to produce Aluminium Metal Matrix Composites (AMMC), which involves the dispersion of reinforcements in the molten matrix, followed by solidification using either the infiltration or casting process [2]. Stir casting, squeeze casting and liquid infiltration are the liquid state manufacturing techniques popular in producing AMMCs. In addition, there are further methods that use a semi-solid condition of the matrix, such compo casting, rheocasting, in situ fabrication, and spray deposition, although they are less common than methods that use solid or liquid states [2,14,15,18].

3.1 Stir Casting Method

Stir casting is a liquid-state processing technique, also known as “vortex technique,” commercially used in producing Metal Matrix Composite (MMC) [11,19,20]. The stir-casting method provides homogenous reinforcement in a matrix, reduces porosity and better wettability [2]. It is a cost-effective, highly flexible, and mass-production method of metal matrix composite (MMC) [2,4,20,21]. The stir-casting technology is widely used in commercial production due to its unique properties. The simplicity and flexibility of the process made it an economical method suitable for large-scale fabrication [2,4,20]. There are several important components in the stirring system like the furnace, stirrer, reinforcement feeder and control system [2,15,22]. Shown in Figure 1. The mechanical stirrer is introduced to form a vortex to mix reinforcement in the matrix material [4], it is connected to the electric motor coupled system and controlled with a multi-speed controller device. The crucible's construction makes it chemically inert to the matrix and reinforcements. Preheating the reinforcements to the point of melting is a standard procedure to improve component mixing [2]. The bottom pouring furnace is a suitable furnace type for the stir-casting process for fabricating metal matrix composites. Its automated bottom-pouring technology allows the melt mix to be poured instantly [23]. The reinforcement in the particulate form up to 30% by weight can be added in molten alloy to achieve a better distribution of the reinforcement [11,24].

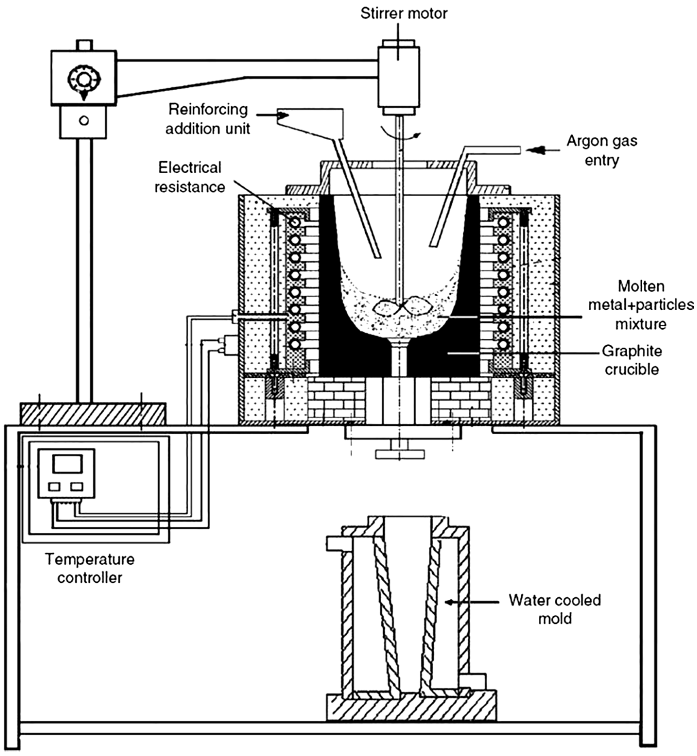


Fig. 1. A schematic showing the stir casting facility [13]

Several parameters have a substantial impact on determining the characteristics of AMMCs. Process parameters such as the reinforcement size, speed of stirrer, stirring time, stirrer blade design, and melt temperatures are found to maximize the impact [23]. Selecting a process variable is of considerable importance since it can easily altered without any additional effort and expense throughout the process [2]. For achieving homogenous mixture through this process, wettability between the matrix and reinforcement should be proper. The matrix material is melted in furnace and maintained at a certain temperature for two to three hours. At the same time, reinforcements are heated in a separate furnace [23]. Preheating the reinforcement powder at different temperatures between 250 and 600 degrees Celsius helps to increase the wettability of the reinforcing particle with the molten metal by removing volatile contaminants from the surface [2].

3.1.1 Mechanical stirrer

The vortex technique is one of the most well-known methods for achieving and maintaining a proper dispersion of reinforcing material in the matrix alloy. In this procedure, the matrix material is melted and forcefully churned to generate a vortex at the surface of the melt, and the reinforcing material is then inserted at the side of the vortex. A successful casting process must produce a composite in which the particles are uniformly dispersed [22]. During stir casting of composites, stirring helps transfer particles into the liquid metal, and maintain the particles in a state of suspension [22]. Stirring is essential for controlling the distribution of reinforcements inside the matrix, which in turn affects the final microstructure and mechanical characteristics of the cast composites [23]. If the dispersion of reinforcement particles is not uniform, then they have a high tendency to agglomeration and clustering. The mechanical stirrer consists of several major components such as the motor, speed controller, jointer, stir shaft and blade. The motor is used to generate a vortex, while the speed controller will control the rotation speed. The speed controller is essential to allow rotation parameters to be manipulated for effective use. The shaft is connected to the motor to obtain the required torque. Stainless steel stirrer blades frequently have zirconia coated on them because at higher temperatures, zirconia can stop interactions between stainless steel and aluminium alloys [2].

3.1.2 Stirring speed

Stirring speed is a critical characteristic that influences the distribution of reinforcement particles in the matrix material. Stirring plays a vital role in the final microstructure and mechanical properties of the cast composites as it controls the distribution of reinforcements within the matrix [23]. To achieve the optimum properties of the metal matrix composite, the distribution of the reinforcement material in the matrix alloy must be uniform [22]. Higher viscosity inhibits the intended finer mobility of reinforcement particles during stirring. The value of the spacing between particles increases as the speed of stirring increases. Therefore, it's not always possible to estimate the optimum speed with precision [24]. The reinforcement particles are more prone to agglomerate and cluster if their distribution is not uniform.

Subsequently, the density of the reinforcement particles and the matrix alloy melt differs if the reinforcement particles are not properly stirred in the molten matrix, they will probably sink or float to the molten melt [11]. A uniform distribution of particulates in the matrix was revealed by microstructural examination [2]. Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) should be conducted to investigate the morphological characteristics [25]. SEM provides high-resolution images and can be used to examine the distribution and morphology of the particles while EDS analyses elemental composition to confirm reinforcing particles' presence by analysing diffraction pattern consistency.

Based on a study conducted by Suresh and Moorthi [16], the drilling machine was used to assist in the stirring, which was done for around ten minutes at a speed of 450 rpm. the composite of aluminium matrix AA6061 and TiB_2 reinforcement resulted in increasing the mechanical properties, such as tensile strength, wear resistance and hardness. The composite maximum hardness is 72.46 HV and the tensile strength of 137.86MPa at 12wt% of TiB_2, an increase of 10.6% in hardness and 54% in tensile strength compared to the base material used in this experiment. SEM confirmed the uniform dispersion of fillers in the Al6061 matrix affecting the properties of the composite was achieved through a study conducted by Anand *et al.,* [26], investigated the tribological properties of Al6061 nanohybrid composites reinforced with nano alumina and molybdenum disulfide through the stir casting method by setting stirring parameters for ten minutes and a speed of 600 rpm. Optimal process parameters were identified as Al6061 + 5 wt% nano alumina + 5 wt% molybdenum disulfides.

3.1.3 Stirring time

One important process variable in the stir casting process is stirring time. Reduced stirring times can cause reinforcement particle clumping and a non-uniform dispersion of the particles, while increased stirring times can result in larger inter-particle distances and uniformity in the distribution [2]. On the other hand, longer stirring times may cause the stainless-steel stirrer impeller blade to distort at extremely high operating temperatures [23]. Stirring time varies according to the shape of the blade. So, specifying the optimum value accurately is not practical [2]. The study found that a 30-degree angled stirring blade performed well and shows a uniform dispersion without concentration particles with respect to stirrer axis [23]. Besides, the impeller should not be located more than 30% of the fluid's height from the base to prevent the agglomeration of reinforcing particles at the bottom of the crucible [23]. The ideal stirring time to improve reinforcement distribution and maintain a consistent hardness level is ten minutes [23].

4. AA6061 Composites Developed Through the Stir: Casting Route

Researchers have developed a composite AA6061 consisting of organic and inorganic reinforcement. The main purpose of the reinforcement is to improve matrix material qualities such as wear resistance, stiffness, corrosion resistance, strength, and Young's modulus [27]. Reinforcement materials added in weight (%) or volume (%) and in many forms [23], such as ceramic particles, fibers, and whiskers [18], should be highly hard and resistant, light in weight, and have a greater strength-to-weight ratio than matrix materials [27]. Generally, the reinforcing weight composition of the composite varies from 5 to 30 wt%, like the AA6061 alloy. This section discusses the research studies based on the different kinds of reinforcements used in the AA6061 composites. In this section, studies related to the AA6061 composites fabricated through the stir-casting method are classified according to the reinforcements used shown in Table 2

Table 2
List of studies of AA 6061 composites with different reinforcement types

No.	Reinforcement types	Reinforcement	Author	References
1.	Ceramic particles	SiC	Prajulraj and Sridhar	[28]
2.		ZrO_2	Pandiyarajan and Marimuthu	[21]
3.		ZrO_2	Khalili *et al.,*	[29]
4.		B_4C	Manohara	[30]
5.		Al_2O_3	Chandra *et al.,*	[31]
6.	Metal particles	TiB_2	Deshmukh and Thakur	[19]
7.		TiB_2	Suresh and Moorthi	[16]
8.		TiB_2	Pazhouhanfar and Eghbali	[25]
9.	Nano	Nano MoC	Felix *et al.,*	[32]
10.		Nano TiC	George *et al.,*	[33]
11.		Nano SiC	Naveen and Chaitanya	[34]
12.		Nano Ag	Pitchayyapillai *et al.,*	[35]
13.	Hybrid	SiC + B_4C + fly ash	Prasath and Madesh	[36]
14.		SiC + Al_2O_3	Kumar *et al.,*	[24]
15.		Nano Al_2O_3 + molybdenum	Anand *et al.,*	[26]
16.		ZrO_2 + Al_2O_3	JamesS and James	[37]
17.		SiC + fly ash	Sachinkumar *et al.,*	[38]

4.1 AA6061: SiC Composites

Silicon carbide (SiC) also known as carborundum, has good mechanical and thermal characteristics [2]. It is one of the most often utilized ceramic reinforcements made of silicon and carbon. Silicon carbide is a natural ceramic particle, it is used as an abrasive and sintering to form very hard ceramics [28]. It has high strength, low density, high hardness, low thermal expansion, high thermal conductivity, high thermal shock resistance, and superior chemical inertness [28]. Figure 2 indicates the morphology of the silicon carbide. It shows that the typical SiC particulates consist of round and angular grains with sharp cornered morphology.

The study conducted by Prajulraj and Sridhar [28], focuses on how the addition of SiC reinforcement at varying percentages affects the mechanical properties of the composite material. The fabrication process involves using the liquid state technique and stir casting method to create

Aluminium Metal Matrix Composites (AMMC) with 5%, 10%, and 15% SiC weight percentages. Various characterization techniques such as X-ray Diffraction (XRD), Optical Microscope (OM), Electron Dispersion Spectrum (EDS), and mechanical testing are employed to analyze the microstructure and mechanical properties of the composite material.

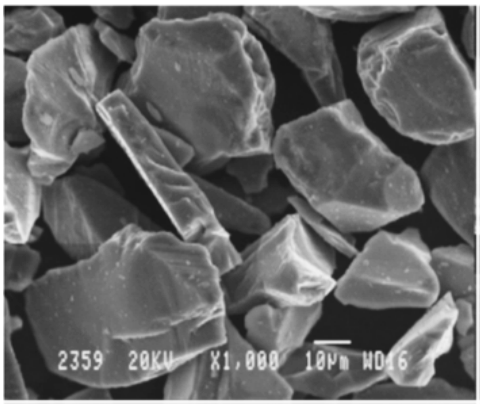
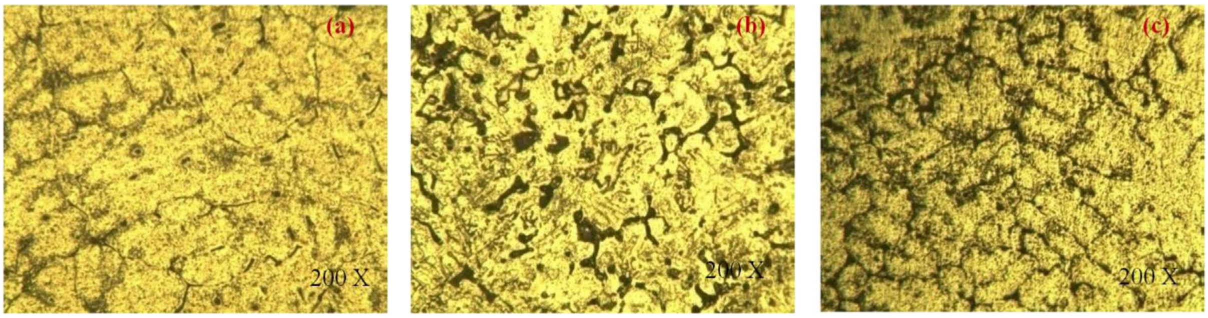


Fig. 2. Scanning electron micrograph of silicon carbide powder [2]

Figure 3 shows microstructure images of Al/SiC composites at 5 wt%, 10 wt% and 15 wt%. The homogeneous distribution of SiC particles was demonstrated by the optical microscopic pictures. The black spot on the matrix confirms that the increasing SiC particles increase uniformly in SiC weight percentage. The research findings indicate that incorporating SiC reinforcement enhances several mechanical properties of the AA6061/SiC composites, including hardness, tensile strength, Young's modulus, and buckling strength. The mechanical properties show improved properties on 10 wt% and 15 wt% of SiC reinforcement, while the density did not result in significant changes. Morphological analysis confirms the uniform distribution of SiC particles in the matrix and identifies the presence of key elements and oxide particles within the composite material.



(a) (b) (c)

Fig. 3. Microstructure images of Al/SiCcomposites (a) 5 wt% SiC (b) 10 wt% SiC (c) 15 wt% SiC [28]

4.2 AA6061: TiB_2 Composites

Titanium Diboride (TiB_2) is a ceramic material with restively high strength and durability as characterized by the relatively high value of its melting point, hardness, strength to density ratio and wear resistance [39]. This material is often used in areas such as impact-resistant Armor, cutting tools, and crucibles. TiB_2 is thermodynamically stable in molten aluminium, and this allows both solid-state and liquid-state techniques to be used for the fabrication of Al-TiB_2 composites [25]. Figure 4 shows the scanning electron micrograph (SEM) of titanium diboride, the observed size distribution of TiB_2 particles is 2-10 µm, appear irregular and angular without the distinct hexagonal shape.

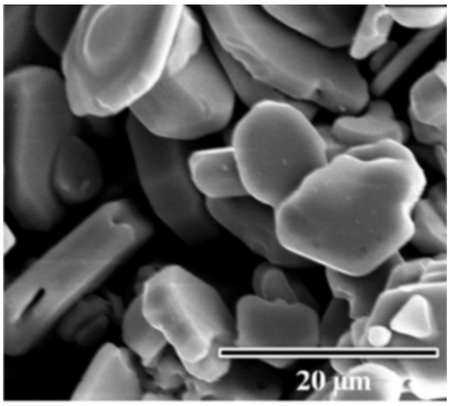


Fig. 4. Scanning electron micrograph (SEM) of titanium diboride [25]

The experiment conducted by (Y. Pazhouhanfar and B. Eghbali) [25] shows the mechanical properties of the composites exhibit notable improvements as the volume fraction of TiB_2 reinforcement increases. With increase of TiB_2 content, the micro-hardness of the samples increased by about 51.3%. Tensile strength shows enhancement without compromising elongation to failure, suggesting a balanced combination of strength and ductility. Similarly, bending strength rises with higher reinforcement fractions, reaching 690 MPa in AA6061-9 wt% TiB_2 composites, credited to TiB_2 particles impeding dislocation movement. These findings underscore the efficacy of TiB_2 reinforcement in bolstering the mechanical performance of the composites, reflecting a promising avenue for materials engineering applications.

The addition of K_2TIF_6 enhances the wettability of articles in the AA6061 melt. Various composite samples with different TiB_2 contents (0, 3, 6, and 9 wt%) undergo microstructural analysis, as shown in Figure 5, including optical and SEM analysis, X-ray diffraction, and mechanical testing. The microstructure of the base Al6061 alloy is shown in Figure 5(a). The microstructure comprises α phase and Al-Mg-Si ternary eutectic phases, which are dispersed along α phase boundaries, as shown. Likewise, in some areas within the α grains and at the α grain boundaries, Mg_2Si precipitates are seen. Figures 5(b)-(d) show the microstructures of stir-casted composites with varying TiB_2 reinforcement contents. TiB_2 particles are seen in these micrographs as white areas surrounded by α matrix. As can be observed, during stir casting, the quantity of reinforcements increases in the microstructure in proportion to the number of particles in the molten aluminium.

Another experiment conducted by Suresh and Moorthi [16] indicated that the mechanical properties improved with the increasing weight fraction of TiB_2 in the composites. The percentage of TiB_2 present in the samples influenced the mechanical properties of the composites, including tensile strength and hardness. Increasing the weight fraction of TiB_2 (0, 4, 8, and 12wt%) resulted in enhanced wear resistance of the composites. This improvement in wear resistance was attributed to the presence of TiB_2 particles in the matrix. Overall, the experiment demonstrated that the incorporation of TiB_2 particles through the stir casting method enhanced the wear resistance and mechanical properties of the AA6061 MMC, making them suitable for various applications where improved performance under wear conditions is required.

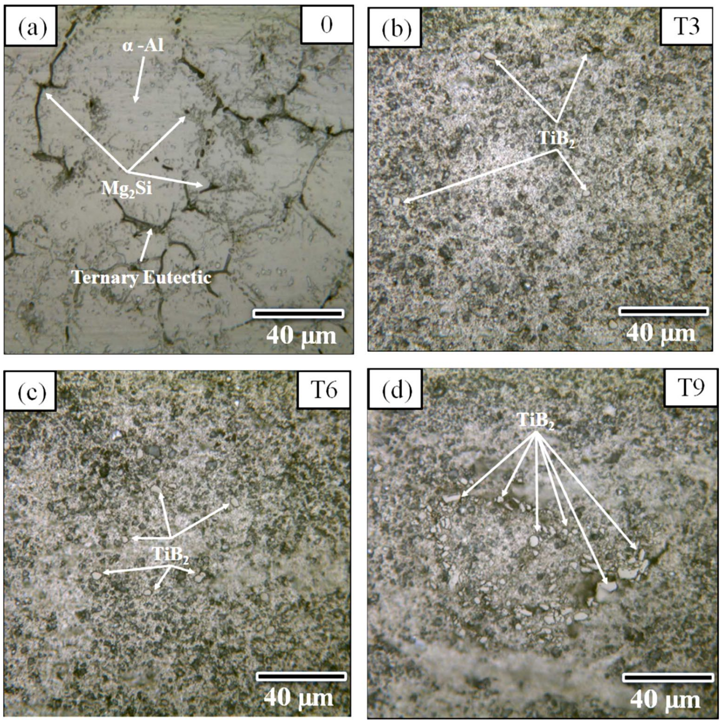


Fig. 5. (a) AA6061 matrix (b) AA6061-3wt% (c) AA6061-6wt% (d) AA6061-9wt% [25]

4.3 AA6061: ZrO_2 Composites

Zirconium Oxide (ZrO_2) also known as zirconia is a ceramic material used as reinforcement due to its characteristics. AA6061 is a metallic alloy with low density and high thermal conductivity, but it has poor wear resistance [29]. Zirconium Oxide is a material with very high resistance to crack propagation and high thermal expansion that makes it suitable for applications requiring wear resistance and durability. Based on an experiment conducted by Khalili *et al.,* [29]. The composite with 3 wt.% ZrO_2 content exhibited optimal mechanical properties and corrosion resistance, attributed to its uniform distribution and finer grain sizes. Nanoindentation tests revealed heightened hardness and wear resistance in these composites. Additionally, electrochemical analysis demonstrated high corrosion resistance, attributed to the formation of a passive layer in the 3 wt.% ZrO_2 composites.

4.4 AA6061: Hybrid Composites

Composites that include several types of reinforcements inorganic or organic are designed to achieve enhanced properties that are often attributed to secondary reinforcements inside the matrix [2]. Hybrid composites are composites which produced from several types of reinforcements to achieve superior characteristics. The creation of these hybrids based on aluminium is facilitated by the commonly used stir-casting technology. Material properties can be precisely adjusted by methodically optimizing the kind and quantity of component materials through rigorous scientific optimization [2]. The use of variety reinforcement in hybrid composite increased mechanical characteristics. To avoid decreasing returns due to increasing porosity and agglomeration at greater reinforcement contents, reinforcements must only be added up to a certain weight percent. The significant variation in the ideal weight percentage of reinforcing. A summary of the research studies in the stir-casting process of hybrid AA 6061 composites is given in Table 3.

Table 3
Summary of research studies in the stir-casting process of hybrid AA6061 composites

No.	Author	Hybrid composite	Remark			Application	Ref.
			Hardness	Tensile	Wear resistance		
1.	James and James	Zirconium dioxide (10wt%) Alumina (10wt%)	70% increase	70% increase	increase	Aerospace, automotive and defence industries	[37]
2.	Sharma *et al.,*	5 wt% (Al_2O_3 + SiC) 10 wt% (Al_2O_3 + SiC) 15 wt% (Al_2O_3 + SiC) 5 wt% (Al_2O_3 + SiC) + 0.5 wt% CeO_2 10 wt% (Al_2O_3 + SiC) + 1.5 wt% CeO_2 15wt% (Al_2O_3 + SiC) + 2.5 wt% CeO_2	17.02% increase	310% increase (From 30MPa to 123MPa)	87.28% increase	Aerospace, automobile and electronic sector (Heat exchanger)	[40]
3.	Nathan *et al.,*	Silicon carbide (2, 4, 6 wt %) Zirconium dioxide (3 wt %)	39% increase	20.4% increase (384.4 MPa maximum)	increase	Automobile component (brake rotor and drums)	[41]
4.	Devanathan *et al.,*	Silicon carbide (10 wt %) Fly ash (10, 12.5, 15, 20 wt %) Coconut shell ash (2.5, 5, 10 wt %)	30.49% increase	23.12 % `increase (213MPa maximum)	increase	Automobile component	[42]
5.	Jawalkarr *et al.,*	Alumina (5 wt%) Bagasse ash (8wt%)	Decrease	Decrease	Decrease	Aerospace and automotive industries	[43]

4.5 AA6061: Nano Composites

Metal matrix nanocomposite (MMNCs) is a matrix composite employ with nano size reinforcement. Technological progression in the nanoscience makes possible to employ matrix composite with Micro-level reinforcement. Reinforcement in MMNCs is in the nano-meter range (10^9 m) [2]. The factors such as homogenous distribution, finer size of particles, hardening mechanism, inter-particle spacing, and high-temperature thermal stability are the primary reasons for the improvement. The nano-sized particle-reinforced MMNCs possess superior strength, ductility, and more resistance to wear compared to MMCs reinforced with micro-sized particles. A summary of the research studies in the stir-casting process of nano composite AA6061 composites is given in the Table 4.

Table 4
Summary of research studies in the stir-casting process of nano AA6061 composites

No.	Author	Nano composite	Remark		Application	Ref.
			Hardness	Wear resistance		
1.	George *et al.,*	Nano-Titanium Carbide (TiC) (50nm size, 99.99% purity)	45% increase	Increase	Terrestrial transport, aircraft, and sport	[33]
2.	Anand *et al.,*	5 wt% Nano-Alumina (Al2O3) 5 wt% Molybdenum Disulfide (MoS2)	Increase	Decrease	Energy sector industries	[26]
3.	Naveen and Chaitanya	Micro silica	Increase	-	Biomedical, sport and recreation industries	[34]
4.	Pitchayyapillai *et al.,*	Nano silver (Ag)	6.5% increase	Decrease	Electronic industries	[35]
5.	Sozhamannan *et al.,*	Nano	-	Increase	Automotive (brake & shaft part)	[44]

5. Conclusions

This review has discussed the production of AA 6061 metal matrix composites by the stir-casting process. Stir casting is identified as the most cost-effective and commercially fabrication technique among other processing techniques. The reviews lead to the following conclusions.

i. AA6061 is one of the most popular aluminium alloys in 6xxx series, used in various applications. Numerous AA6061 composites were produced by reinforcing various organic and inorganic materials by the stir-casting method. The composites fabricated showed superior properties to those of the base alloy.
ii. Stir-casting process parameters such as the speed of the stirrer, stirring time, stirrer blade design, reinforcement size, and melt temperature have a great effect on the AA6061 composite characteristics. Optimization should be done to achieve suitable parameters.
iii. The reinforcement addition has a significant role in the solidification of the molten composite and results in grain refinement.
iv. There was a significant correlation between the weight percentage of reinforcing particles and the characteristics of AA6061 composites. The mechanical and tribological characteristics of the composite may be enhanced by raising the weight percentage of reinforcement. Beyond a certain point, though, the addition of reinforcement would cause agglomeration and the development of pores, which would alter the characteristics.
v. Hybrid AA6061 composites having enhanced properties were developed by stir casting techniques. The combination of proper reinforcements improved the mechanical, tribological, and corrosion properties of composites.
vi. Nanocomposites can also be fabricated by stir casting. Limited research studies were done in this area. The high porosity and heterogenous distribution of reinforcement particles were reported in the stir casting of some nanocomposites.

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