# A Review Study on the Effect of Reinforcing Materials on the Properties of Aluminum Metal Matrix Composites

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This paper provides an overview of the impact of reinforcement on metal composites. Aluminium metal matrix composites, or AlMMCs, have attracted a lot of attention because of their better mechanical, thermal, and tribological properties than traditional aluminium alloys. Aluminium metal matrix is becoming more and more in demand in the automotive, aircraft, defence, sports and other industries because of its lightweight, higher strength, resistance to corrosion and workability. This review explores advancements in enhancing these properties through the incorporation of advanced reinforcing materials. The study looks at how different reinforcements work together to improve the mechanical performance of a matrix. Various reinforcing materials, including ceramics, are discussed in terms of their influence on strengthening mechanisms and performance improvements of Al-MMCs. Research papers indicate that mechanical strength increases with a higher percentage of reinforcement.

**Keywords:** aluminium alloy, reinforced material (Al2O3, B4C, Gr, SiC, TiC, TiO2), stir casting.

## 1. Introduction

Currently, there is an increasing need and demand worldwide for advanced materials to achieve desired properties. Composite materials are created by combining at least two distinct materials with dissimilar characteristics (Yaspal, Sumankant, Jawalkar, 2017). There are two components to the composite materials. One serves as a reinforcement, while the other as a matrix. The composite materials are divided into three categories: Composite materials made of metal, ceramic, and organic materials (K. Balalji. Murari, 2018). High physical qualities, strength, low weight, increased fatigue strength, smooth surface finish, and better look are the key benefits of composite materials. Compared to conventional materials, the novel material can be used to accomplish goals like greater strength, reduced weight, and corrosion resistance (Singh, Brar, Kumar, & Aggrawal, 2021).

Since they are lightweight and have improved mechanical strength and wear resistance, aluminium metal matrix are popular in various industries, including aerospace, automotive, sports, building and construction, defence applications, and electronics ( Ujah, & Kallon,2022 &, Ramnath, Elanchezhian, 2014 & Moona, Walia, Ratogi, Sharma, 2018 & Reddy, Krishna, Rao, Murthy, 2017). The integration of reinforcing materials into the aluminium matrix plays a pivotal role in tailoring these properties to meet specific application requirements. Many kind of ceramic materials like Alumina, Silicon carbide, Boron carbide, Titanium Carbide, Graphite, Boron Nitride and Titanium dioxide, Carbon Nanotube and Aluminium Nitride are used as reinforced materials (Reddy et.al., 2017 & Singh,L., Ram, Singh,A., 2013). Reinforcement significantly increases the composite materials' yield strength, tear strength, and hardness (Surya, Gugulothu, 2022 & Kumar, Angra, Singh, 2022). The accomplishment of various strengthening processes, such as reinforcement, particle downsizing, load acceptance effect, etc., contributes to the improvement of strength ( Mahato, Shivarkar, Vishvakarma, Paliwal, & Sonawale, 2022 ).

Although most reinforcements are employed at the micro level, composites that contain nanoscale reinforcements are referred to as nano -composites. Hybrid-metal matrix composites (HMMCs) are a novel type of composites produced by adding at least two reinforcement. In HMMCs, a variety of materials, including SiC + Ti, $Al_2O_3$ + B4C, SiC + Gr, and SiC + $Al_2O_3$, can be utilised as reinforcement ( Muley, Arvindan, & Singh, 2015). Because of the extensive range of applications and industrial needs for metal matrix composites, many researchers are tasked with discovering cost-effective production techniques ( Verma, Sharma & Kumar, 2017). Reviewing the type of aluminium alloy, fabrication techniques, and how reinforcement affects Al-MMC characteristics are the main objectives of this paper.

## 2. Category of Aluminium Alloy Used in Matrix

Because of their special mix of qualities, aluminium and its alloys are among the most inexpensive, attractive and adaptable metallic materials for a variety of uses. Aluminium alloys find widespread application in everything from highly ductile, soft wrapping foil to the most demanding engineering application, in terms of structural metal utilisation, they are only surpassed by steel.

There are two types of aluminium alloys: cast composition and wrought composition. The sequence of aluminium varies from 1xxx to 7xxx. 1xxx series are used in electrical and chemical fields. Alloys from the 2xxxx family are frequently utilized in aircraft because of their exceptional strength. 3xxx: Alloys used as general-purpose alloys for architectural purposes and a variety of products, where manganese is the main alloying ingredient. 4xxx: Alloys used in brazing sheets and welding rods where silicon is the main alloying ingredient. 5xxx: Alloys used in gangplanks, boat hulls, and other products exposed to maritime environments; these alloys have magnesium as the primary alloying element. 6xxx: Alloys with silicon and magnesium as the main alloying elements; these alloys are frequently utilized in automotive and architectural. 7xxx: Alloys utilized in aircraft structural components and other high-strength applications where zinc serves as the primary alloying element (additional constituents include copper, magnesium, chromium, and zirconium) (Davis, 2014). Table 1 and 2 Shows the different series of aluminium alloys and main composition.

Table 1. Classification of aluminium wrought alloy

| Alumnium Series | Alloy | Main Alloy composition |
|---|---|---|
| 1xxx | 1050,1060,1100, 1145,1199 | Pure Al |
| 2xxx | 2011, 2014, 2024, 2036, 2124, 2219, 2319 | Al, Cu, Mg |
| 3xxx | 3003, 3004, 3105 | Al, Mn |
| 4xxx | 4032, 4043 | Al, Si |
| 5xxx | 5005, 5052, 5056, 5083, 5154, 5252, 5454, 5456 | Al, Mg |
| 6xxx | 6010,6061,6063,6101,6205, 6262, 6351,6463 | Al, Mg, Si |
| 7xxx | 7005,7049,7050,7075,7175, 7178, 7475 | Al, Zn, Mg / Al, Zn, Mg, Cu |

From " Aluminium and Aluminium alloy" by Davis, J. R., ASM international, pp. 351-416.

Table 2. Aluminum alloy's composition

| Alumnium Series | Alloy Composition |
|---|---|
| 1050 | Al 99.5% min, Fe 0- 0.4%, Cu 0 - 0.05% |
| 1100 | Al 99 to 99.5%, Fe 0- 0.95%,Cu 0.05 to 0.20 |
| 2024 | Al 90.7-94.7%, Fe 0- 0.5%, Cu 4.3 – 4.4%, Mg 1.3-1.5%, Mn 0.5-0.6%,Si 0- 0.5%, Cr 0-0.1%, Ti 0-0.15%, Zn 0- 0.25% |
| 2319 | Al 91.4-93.8%, Fe 0-0.3%, Cu 5.8-6.8%, Mg 0-0.02%, Mn 0.2-0.4%, Si 0-0.2%, Zn 0-0.1%, Ti 0.1-0.2%, Zr 0.1-0.25%, V 0.05-0.15 |
| 3004 | Al 97.8%, Mg 1%, Mn 1.2% |
| 4032 | Al 85%, Mg 1%, Si 12.2%, Cu 0.9%, Ni 0.9% |
| 5005 | Al 97-99.5%, Fe 0-0.07%, Cu 0-0.2%, Mg 0.5-1.1%, Mn 0-0.2%, Si 0-0.3%, Cr 0-0.1% , Zn 0-0.25% |
| 6061 | Al 95.8- 98.6%, Fe 0-0.7%, Cu 0.15-0.4%, Mg 0.8-1.2%, Mn 0-0.15% , Si 0.4-0.8%, Cr 0.04-0.35%, Zn 0-0.25% |
| 6063 | Al 98.9%, Fe 0-0.35, Cu 0-0.1% , Mg 0.45-0.90%, Mn 0-0.1%, Si 0.2-0.6% , Cr 0-0.1%, Zn 0-0.1%, Ti 0-0.1% |
| 6351 | Al 96-98.5.%, Fe 0-0.5%, Cu 0-0.1%, Mg 0.4-0.8%, Mn 0.4-0.8%, Si 0.7-1.3%, Zn 0-0.2%, Ti 0-0.2% |
| 7075 | Al 87.1-91.4% , Fe 0-0.5%, Cu 1.2-2%, Mg 2.1-2.9%, Mn 0-0.3%, Si 0-0.4%, Cr 0.18-0.28%, Zn 5.10-6.10%, Ti 0- 0.2% |

From " Aluminium and Aluminium alloy" by Davis, J. R., ASM international, pp. 351-416.

## 3. Fabrication Technique for Al-MMC

The reinforcement materials are important in the fabrication of MMC. They can be added in different percentages to the matrix to alter their properties. As reinforced materials, a wide variety of ceramic materials are commonly used, such as $Al_2O_3$, SiC, $B_4C$, TiC, Gr, Graphene, and $TiO_2$ (Samathkumar , Gukendran, Mohanraj, 2023 & Rajesh, 2016). According to the application and required characteristics of matrix composite these reinforced materials are added in the base material mentioned in table. 1 and 2.

Both liquid-state and solid-state methods can be used to create Al-MMCs. Powder metallurgy, diffusion bonding, ball milling, friction stir- casting are examples of solid-state processes. On the other hand, liquid-state processes include squeeze casting, spray casting, stir casting, ultrasonic assisted casting and vacuum pressure infilteration. Liquid-Solid techniques include semisolid forming and compo casting. When weighed against other options, stir casting is the most economical fabrication technique ( Ujah et.al., 2022 & Mavhungu, Akinlabi, Onitiri , Varachia, 2017).

3.1 Stir-casting

One technique of fabricating in a liquid state is stir casting. When compared to other fabrication techniques, it is the most straightforward and widely utilized method. It is also the cheapest process (Dagale, Kumar & Harne, 2023). In this process, pure aluminium or aluminium alloy is melted in a crucible as shown in fig. 1. When it reaches a semi-solid state, preheated reinforcing materials are added. This mixture is stirred manually or automatically for a certain time, depending on the application. Then, it is heated again to its melting point and mixed with a stirrer.

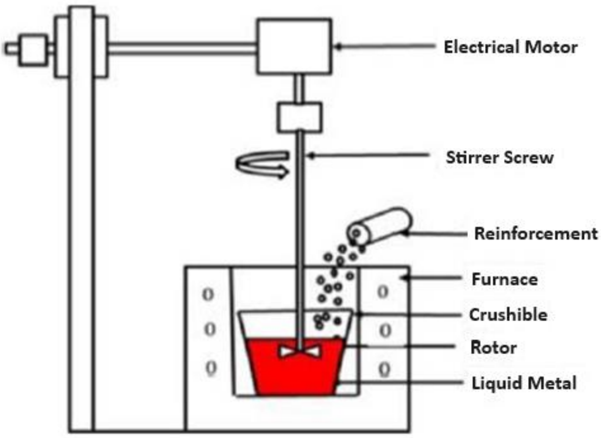


Figure 1. Stir casting setup

From “ Characterization of Aluminium Alloy 6063 Hybrid Metal Matrix Composite by Using Stir Casting Method” by Singh,B. WASET, International Journal of Industrial and Systems Engineering, Volume: 12, Issue: 10, pp. 1016-1020, 2018.

The characteristics of Al-MMC can be changed by adjusting the stir-casting process variables, such as stir temperature, speed, preheat temperature, mixing duration, pouring temperature, and mould temperature (Cheluka, Reddy, Venktesh, 2021). With this technique, composites with volume fractions as high as 30% can be produced efficiently (Rao, Ramanaiah & Sarcar, 2014).

3.2 Squeeze casting

This process is a combination of casting and forging. Liquid forging is also known as squeeze casting. This method uses high pressure during melt solidification to integrate the casting and forging operations. Controlling the wettability of reinforcement in molten metal by applying high pressure can lead to uniform dispersion of reinforcement and better bond formation ( Moona et.al., 2018 & Cheluka et.al.2021).

3.3 Spray Deposition

Spray forming is also known as spray casting. There are two methods of fabrication. Prior to spraying, the molten metal and reinforcing material are combined in the first procedure. The second method involves spraying both the reinforcing material and the molten metal simultaneously. Fig.2 shows the setup of spray deposition.

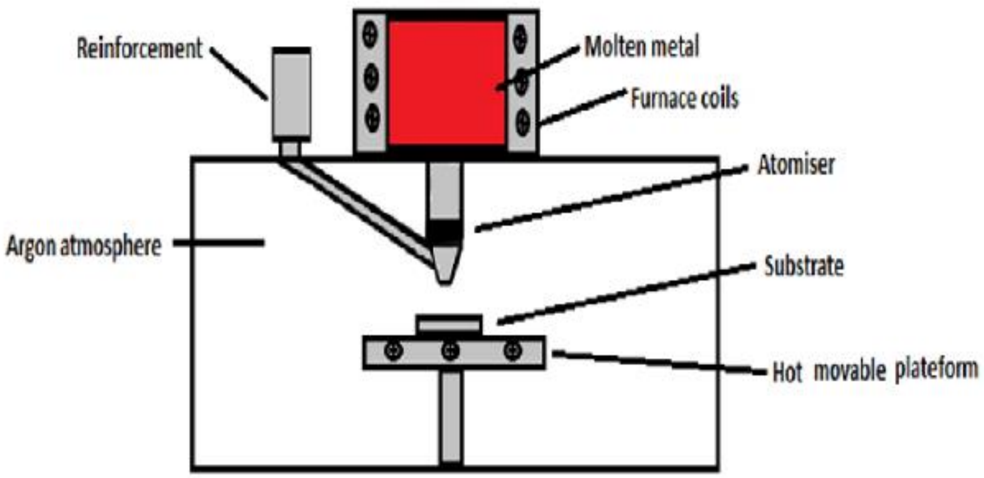


Figure 2. Spray deposition setup

From "A Brief Introduction to Aluminium Metal Matrix Composites", by " Negi,A.S., Journal of Metallurgy and Material Science, Volume: 61, Issue: 04, pp. 161-184, Oct- Dec 2019.

3.4 Compo casting

Compo casting involves the strong agitation of warmed particles or short fibers into very viscous, partially solid molten metal slurries. This action embeds the reinforcement within the proeutectic phase of the alloy slurry, preventing segregation. By reducing the viscosity of the slurry and fortifying the contact between the metal matrix and reinforcement, continuous stirring enhances wetting and bonding (Gafur, Ahmed, Abrar, Soshi, 2023).

3.5 Powder metallurgy

Powder metallurgy involves blending the aluminum powder with reinforcing materials, followed by compaction and sintering. This technique ensures uniform distribution of reinforcements. Ample diffusion must take place during sintering to achieve a consistent microstructure (Moona et.al.).

3.6 Diffusion bonding

It works on the basis of the solid-state diffusion principle, which describes how over time, atoms from two solid metallic surfaces mix. Metal foils and ceramic fiber monofilaments are stacked one after the other in order to form diffusion bonds between them. The bonding between the reinforcement and the metallic foil occurs through hot pressing. To achieve perfect bonding, the process parameters must be precisely controlled. Fig. 3 shows the diagram of diffusion bonding

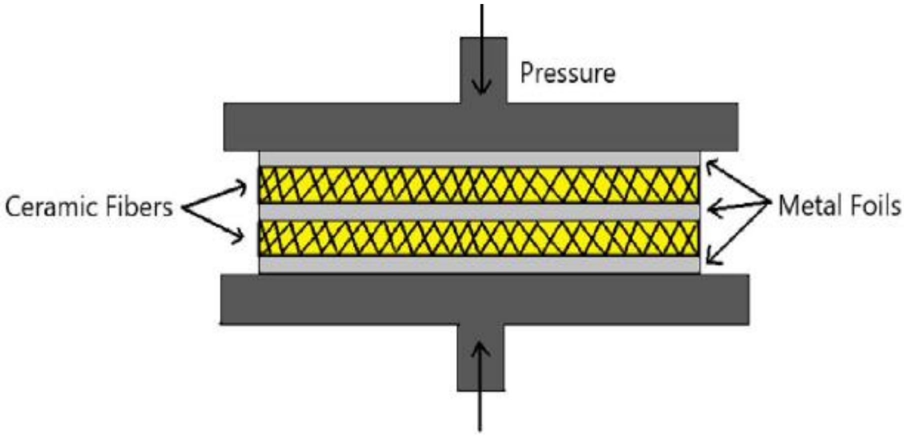


Figure 3. Schematic of diffusion bonding

From "A Brief Introduction to Aluminium Metal Matrix Composites", by " Negi,A.S., Journal of Metallurgy and Material Science, Volume: 61, Issue: 04, pp. 161-184, Oct- Dec 2019.

Negi (2019) summarized the fabrication processes with their advantages. The stir casting process has no restrictions on shape and product size, and it is low-cost. However, it has some drawbacks such as particle distribution, porosity, particle settling, and reinforcement degradation. In the spray deposition method, a very thin layer of metal matrix reinforced material is coated on the parts. Restricted coating thickness, porosity, inadequate bonding between reinforcement and matrix metal, and uneven reinforcement distribution are a few of the drawbacks. Better particle distribution and pieces free of porosity are the results of the powder metallurgy process. Nevertheless, the powder metallurgy method is expensive, limits the product's size and form, and isn't suitable for continually reinforced MMCs. Diffusion bonding results in a thin laminated matrix composite. The range of shapes and sizes is limited because it is only appropriate for laminates and not for MMCs that are fiber- and particle-reinforced. The friction stir process has good reinforced particle distribution, but it is a costly process and applicable only to surface composites with particulate reinforcement.

## 4. Effect of Reinforced Material on AL-MMC

4.1 Silicon Carbide (SiC):

Its characteristics include resistance to wear, low density, high temperature, and thermal shock (Gill, Samra , Kumar, 2021). A study on Al7075/SiC composite made using powder metallurgy was published in Surya et al. (2022). Increasing the percentage SiC improves density and hardness. The finest mechanical and tribological performances are exhibited by the metal matrix composite supplemented with 15% SiC (Surya et.al., 2022). Verma et al. (2017) looked at the Al356/Sic composite, which is made via liquid-casting and contains 10% SiC. In comparison to base Al356, the author believes that there is an increase in mechanical strength. The authors conducted experiments on laser-assisted and ultrasonic-assisted turning procedures using Al2124/Sic. The hybrid turning technique, which combines laser and ultrasonic assistance, produced reduced machining forces and enhanced surface topology (Kim, Zani, Kadir, Jones, Roy, Zhao & Silberschmidt, 2022). As the ratio of SiC rises, Al-MMC becomes harder, according to Sankhala, Patel, Makhesana, Giasin, Pimenov, Wojciechowski, Khanna , 2022. Gafur et. al. (2023) fabricated AA6-6061/SiC by stir casting technique. When compared to base material, it is observed that MMC has higher density, hardness, tensile strength, impact energy, and % elongation . Al/SiC metal matrix composite was created by Liu, Zhou, Xu , Han & Zhou (2020) via microwave sintering. The author noted that microwave sintering greatly improves the microstructure. Al6061 with 5% SiC offers superior wear properties than the base metal, according to Bhat, Kakandikar, 2019. In 2014, Pawar and Utpat examined Al/SiC composites with different SiC percentages (2.5, 5%, 7.5%, 10%). High toughness and hardness were demonstrated by the 10% SiC matrix composite. According to Alaneme & Aluko (2012), at 180°C to 190°C, a 12% vol SiC composition offers a good age-hardening response. Packirisamy and Ramachandran, (2022) found that the tensile strength and hardness of Al-MMC increased as the amount of SiC (3%, 6%, 9%) was increased. In their work, Shamim, Dvivedi, and Kumar (2022) looked into how adding more SiC% to the Al6063 matrix could improve their tensile strength and hardness.

4.2 Alumina ($Al_2O_3$)

Alumina is an electrical non-conductor composed of aluminium and oxygen that has good thermal conductivity (Gill et.al., 2021). The Al356/$Al_2O_3$ composite with 10% $Al_2O_3$ that was produced by the stir casting method was studied by Verma et al. (2017). In comparison to basic Al356, the author found that the tensile strength, yield strength, hardness, impact strength, compressive strength, and shear strength all increased. Compared to Al356/Sic, there were greater values for hardness and compressive strength. Singh, L.(2013) reported on pure aluminium with $Al_2O_3$ matrix manufactured by the liquid stir-casting. The percentage of alumina, stirring duration, and reduction in reinforcing particle size all contributed to increases in hardness, tensile strength, and impact strength. Gafur et al. used the stir casting process to make AA-4032/ $Al_2O_3$. In comparison to the basic material, it was found that the MMC had higher density, hardness, tensile strength, and impact energy while having a lower percentage of elongation. Al6351/$Al_2O_3$ MMC was created by Kumar,A., and Kumar, V.(2020) using a stir casting method with 2.5%, 5%, and 7.5% weight of $Al_2O_3$. Toughness dropped as the weight % of $Al_2O_3$ grew, whereas hardness and tensile strength increased. Al2O3 reinforcement was consistently dispersed throughout the cast component's microstructure. The author found that the metal matrix composite (Al7075/ $Al_2O_3$) has better tensile, impact, flexural, and hardness properties than the Al7075 ( Raturi, Mer, Pant, 2017).

4.3 Boron Carbide ($B_4C$)

The hardest ceramic substance, boron carbide, is created in an electric furnace by combining carbon with $B_2O_3$. It is then processed and refined to remove impurities for use in industrial applications (Gill et.al.). The hybrid Al6063/B4C and Al6063/B4C/eggshell was created by Kesarwani, Nirajan and Singh (2020) using the stir casting method, with a CNC machine being used for the turning process. The hybrid AMC produced the largest MRR and the lowest surface roughness rating, according to the author's findings. Al6063/B4C had a lower cutting temperature than hybrid AMC. According to Manohar, Pandey and Maity (2021), Al-MMC's mechanical, tribological, and physical characteristics, like porosity and density, are much improved by the B4C reinforcement. Khalid et.al. (2023) studied Al7075/ $B_4C$ matrix composites and found that $B_4C$ improved the wear characteristic (Khalid, Umer, Khan, 2023).

4.4 Titanium Carbide (TiC)

An efficient and promising material reinforcement is the titanium carbide reinforced composite material, which exhibits a particularly good bonding with aluminium to enhance attributes (Gill et.al.). Al7075/TiC MMC was made by Rao et al.(2014) using the stir casting technique. The hardness rises with the % weight of TiC. As the weight percentage of TiC rose, the composite's ultimate tensile strength grew, as revealed by the author. According to K. Ravikimar, K. Kiran & V.S. Shreebalaji (2017), the hardness value of Al6063/TiC increased up to a maximum of 20% of TiC. Pandey, Purohit, Agarwal and Singh (2018) have studied in-situ and ex-situ process of Al6061/TiC composites. In-situ process mechanical properties were improved. Wear rate decrease with increasing the %TiC.

4.5 Graphite (Gr)

Under typical circumstances, it is the most dependable form of carbon, the lightest reinforcement available, and has the highest natural lubricity and chemical, electrical, and thermal resistance (Gill et.al.). Khalid et.al. (2023) studied graphite as reinforcement and found that it improves wear resistance in MMC. Ujah et al. (2022) studied stir casting to create the matrix composite Al-9$Al_2O_3$-3Gr. Hard alumina and soft graphite particles had an impact on the improved properties. Mechanical strength increased with the increase in the percentage of graphite in Al-MMC, according to research done by Iqbal (2020) on the mechanical properties of Al6063 with graphite-reinforced material. Kansari and Dwivedi (2016) experimented on Al6063/SiC/Gr composite material and found that for 2% Gr and varying %SiC, both hardness and tensile strength increased.

4.6 Titanium dioxide ($TiO_2$)

According to M.Ravichandran and S. Dineshkumar (2014), when titanium dioxide was introduced into a pure aluminum matrix, the mechanical characteristics improved. Mahan, Konovalov, Osinstev, & Panchenko (2023) found that the strength and plasticity of the composite metal AA2024/$TiO_2$ increased with the proportion of TiO2 in the matrix. Kumar, Guada & Rao (2017) experimented on Al6061-$TiO_2$ MMC using the Powder Metallurgy method and found that 3% $TiO_2$ in the base material matrix improves mechanical and tribological properties. Mahesh and Reddy (2015) reported on the use of powder metallurgy to create Al-$TiO_2$ matrix composites with reinforced Al at 5%,10%, and 15% levels. The microstructure analysis revealed that the reinforced particles were homogeneously mixed in AL-MMCs. As the weight percentage of $TiO_2$ grew, so did the compressive strength, density, and Brinell hardness.

Table 3. Summary of Authors Reported Work

| Searcher | Fabrication Method | Aluminium/ Reinfoced material | Remarks |
|---|---|---|---|
| Singh, B. (2018) | Stir- Casting | Al6063/SiC/Red mud-fly ash | Tensile strength rise by addition of given reinforcement |
| Pandey, U. (2017) | In-situ, ex-situ | Al6061/TiC | Wear rate decrease |
| Raju (2022) | Stir- Casting | Al7075/Sic | optimised parameter for improved surface quality and a better material removal rate |
| Santosh (2018) | Stir- Casting | Al6063/Sic/Gr | For SiC 2%, Gr 2% tensile, compressive, flexural strength and Hardness increased |
| Shabana (2019) | Stir- Casting | Al6063/ SiC/ Mica | Addition of %SiC, tensile and compressive strength decrease, Hardness and flexural strength increase |
| Shaik (2019) | Stir- Casting | Al6063/Sic/ Neem leaf Ash | In Al6063/SiC , the addition of Neem leaf ash hardness is slightly increased. |
| Dr. Subramaniyan (2020) | Stir- Casting | Al6063/SiC/ $Al_2O_3$ | For Al6063/6%SiC/15%$Al_2O_3$, micro-hardness and tensile-strength improved. |
| Sasimurugan (2011) | Stir- Casting | Al6061/ SiC/$Al_2O_3$ | For good surface roughness, use a minimum feed rate, a lesser depth of cut, and a medium cutting speed. |
| Dr.Chawla (2023) | Stir- Casting | Al6063/SiC/$B_4C$ | For Al6063/7%SiC/3%$B_4C$ , tensile, hardness, % elongation, impact energy increased |
| Selvakumar (2017) | Stir- Casting | Al6063/SiC/Ti | For Al6063/15%SiC/10%Ti , hardness and compressive strength increase |
| Johny James (2014) | Stir- Casting | Al6061/SiC/ $TiB_2$ | By increasing % $TiB_2$, tensile strength decrease, tool wear and surface roughness value increase. |
| Ramasamy (2021) | Compo Casting | Al7075/TiC/BN | Surface roughness is affected by %TiC reinforcement. |
| Chandrasekhar (2019) | Stir- Casting | Al6063/ Gr/SiC | With 5%Sic, 2%Gr tensile and hardness increase, Compressive strength decrease |
| Karthikeyan (2020) | Stir- Casting | Al6063/ Borosilicate | Mechanical properties enhanced by 7.5% borosilicate powder |
| Shuvho (2020) | Stir- Casting | Al6063/SiC/ $Al_2O_3$/ $TiO_2$ | Tribological properties increased |
| Rasid (2019) | Stir- Casting | Al6063/Sic/ 2%Gr | Tensile, Compressive strength & hardness increased by increasing %SiC in matrix |
| Reddy (2010) | Stir- Casting | Al6061/SiC<br>Al6063/SiC<br>Al7072/SiC | Al6061,Al6063,Al7072 matrix composites are in descending order for the yield, ultimate strength and ductility |
| Balaji (2015) | Stir- Casting | Al7075/SiC | Mechanical , Tribological properties improved |
| Ahamad (2020) | Stir- Casting | Al6351/$Al_2O_3$ /C | Hardness rises and wear rate decreases as the percentage of % $Al_2O_3$ and % Carbon reinforcing rise. |

## 5. Conclusion

Because of an extensive range of applications and industrial requirements for metal matrix composites, numerous researchers are currently working to establish cost-effective production methods for these materials. The conclusions that follow are derived from the literature.

• Al-MMCs are created by combining various aluminum alloys with reinforced elements like $Al_2O_3$, SiC, $B_4C$, TiC, Gr, and TiO2 to provide improved characteristics. AL-MMCs are utilized in sports, automotive, aerospace, defence and other structural applications because of their exceptional qualities, which include their high strength and low-weight.

• The mechanical characteristics of Al-MMC increased in tandem with the weight percentage of reinforcement.

• When weighed against other options, stir casting is the most economical fabrication technique.

• The characteristics of Al-MMC can be changed by adjusting the stir-casting process variables

• The wt/vol %, size, and shape of the reinforcement have an impact on the characteristics of metal matrix composites.

• Compared to base alloys and single-reinforced composites, hybrid aluminum metal matrix composites have improved mechanical, tribological, corrosion, and thermal properties.

• Every study report demonstrates that the mechanical, physical, and tribological characteristics of various series of aluminum materials are strongly influenced by reinforcement materials. This finding seems to inspire other researchers to explore the use of novel materials in combination with aluminium to achieve optimal mechanical and tribological performance.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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