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Review Article

Mechanical Properties of Titanium Diboride Particles Reinforced Aluminum Alloy Matrix Composites: A Comprehensive Review

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Aluminum alloys with silicon, magnesium, and copper were extensively used alloying elements in various applications because of their excellent properties. In recent decades, aluminum matrix composites (AMCs) are an advanced engineering material widely utilized in diverse engineering applications, including aircraft, automobile, marine, and shipbuilding, owing to their low density, lightweight, good stiffness, superior strength, and good tribological properties. Aluminum is abundant and its use is as vast as the ocean. It is also the most used matrix material in the composite arena. Therefore, incorporating a ceramic particle into a relatively soft aluminum matrix improves hardness, strength, stiffness, creep, fatigue, and wear properties instead of the conventional materials. This article is an assay to review and spotlight some recent works on the mechanical behaviors of aluminum-based titanium diboride reinforced metal matrix composite. This review article concentrates on the mechanical properties and the fabrication processes of Al-TiB_2 composites to provide a valuable reference to nurture future research precisely.

1. Introduction

In the past few decades, aluminum matrix composite has acted an essential role in material science, especially in aircraft, marine, automobile, transportation, and defense sectors [1]. Several investigations have reported that the inclusion of ceramic filler contents to the matrix improves the mechanical, physical, and tribological properties [2]. Aluminum matrices that are incorporated with hard ceramic filler contents expose the augmented mechanical properties as compared to the plain alloy materials [3]. Figure 1 exhibits the list of wrought aluminum alloy. Due to their high strength-to-weight ratio, high thermal conductivity, good corrosion resistance, and improved mechanical properties, aluminum metal matrix composites (AMCs) are increasingly used as structural materials. Composite materials are becoming more popular due to their unique properties and high strength-to-weight ratio. Ceramic particles provide exceptional strength and wear resistance to AMCs [4–6]. Figure 2 reveals the classification of aluminum composites fabrication process. A large range of filler particles such as SiC, Si_3N_4, ZrN, TiN, TiB_2, Al_2O_3, BN, WC, and SiO_2 has used the reinforcements for the manufacture of composites. Amid the other filler materials, titanium diboride (TiB_2) is a promising candidate filler material for aluminum-based composites. It exhibits an enticing combination of mechanical and physical properties, superior

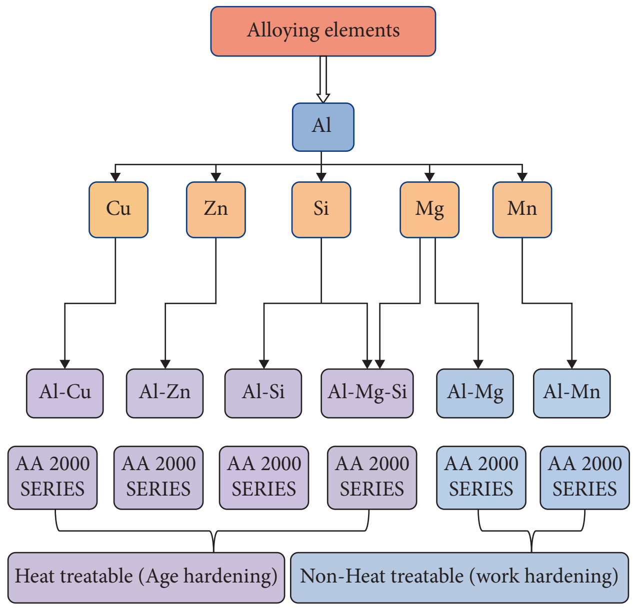


Figure 1: List of wrought aluminum alloy.

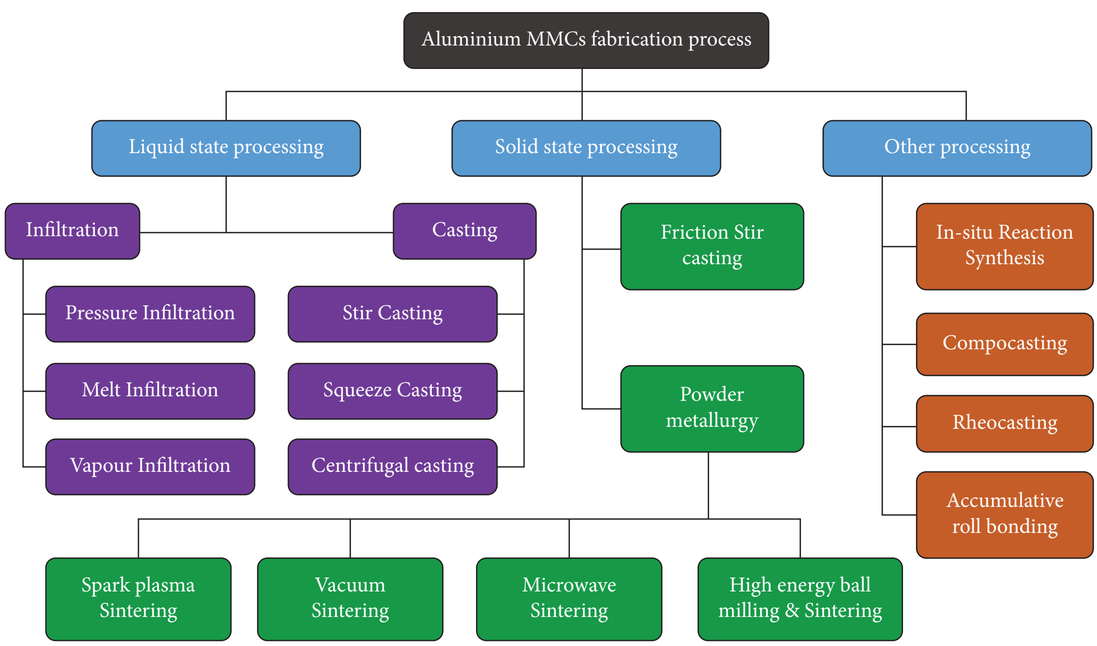


Figure 2: Classification of aluminum composites fabrication process.

strength, perfect hardness, high melting point, excellent corrosion resistance, and excellent wear protection [7–10]. Figure 3 illustrates the advantages and disadvantages of different techniques for composites.

Titanium diboride (TiB_2) particle does not react with molten aluminum and cannot form reaction products at the intergap between matrix and reinforcement [11]. Compared with the other filler contents, TiB_2 is a desirable strengthening agent for aluminum-based metal matrix composites [12]. Titanium diboride based aluminum matrix composites were recently employed in the manufacturing of automobile piston, vehicle drive shaft, cylinder liners, cutting tools, crank shaft, brake drum, and bicycle frames and were also employed in aerospace, marine, and automotive industries because of their good stiffness, superior strength, high temperature stability, and lightweight [13]. AMCs have been fabricated using a variety of methods like compocasting, melt stirring casting, powder metallurgy, in situ casting, squeeze casting, and spray forming and mechanical alloying methods. Figures 4(a)–4(c) reveal the schematic diagram of stir casting, powder metallurgy, and hot extrusion process.

Liquid state processing method contains incorporation of ceramic particles externally or formed inside the molten metal. The former is known as ex situ (stir casting technique)

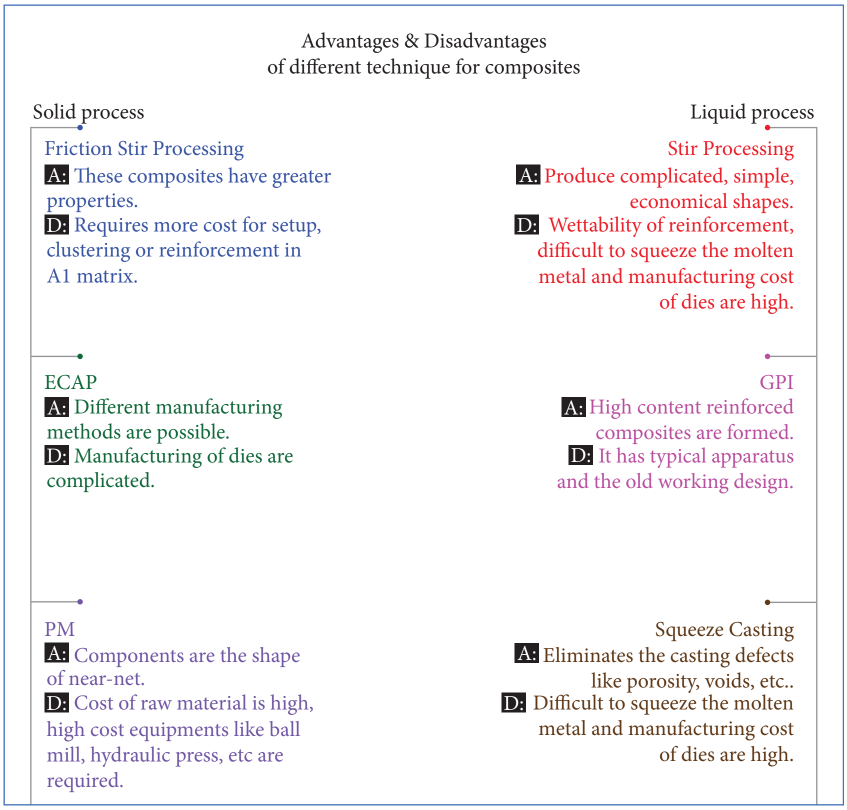


FIGURE 3: Advantages and disadvantages of different techniques for composites.

while the latter is called as in situ (direct melt reaction technique or exothermic salt-metal reaction technique) fabrication. Liquid state casting techniques have shown some incomparable benefits like constant dissemination of filler particles in the matrix and strong interfacial attachment between the matrix and the filler particle [14]. Figure 5 reveals the classification of fabrication method of AMCs.

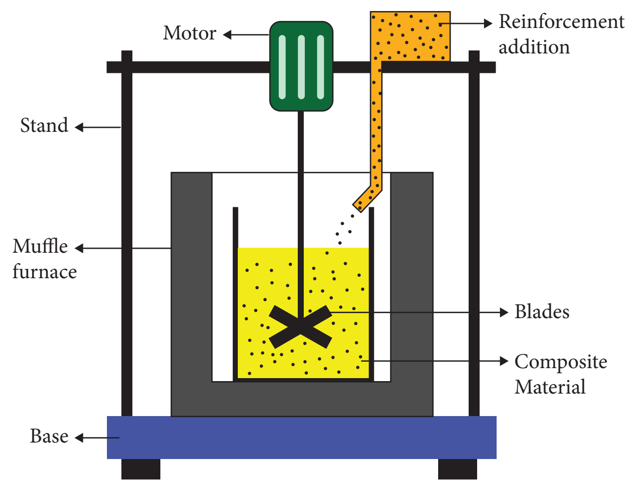
Figure 6 exhibits the influence of various parameters on hardness. A number of researchers have produced titanium diboride reinforced AMCs using various techniques. This scientific review article provides an aerial view of research efforts that are focused on mechanical properties and synthesizing techniques of aluminum-based titanium diboride composites. Table 1 reveals the physical and mechanical properties of several ceramics reinforcements. The SEM image of the TiB_2 particles is depicted in Figure 7.

2. Fabrication Techniques of Al-TiB_2 Composites

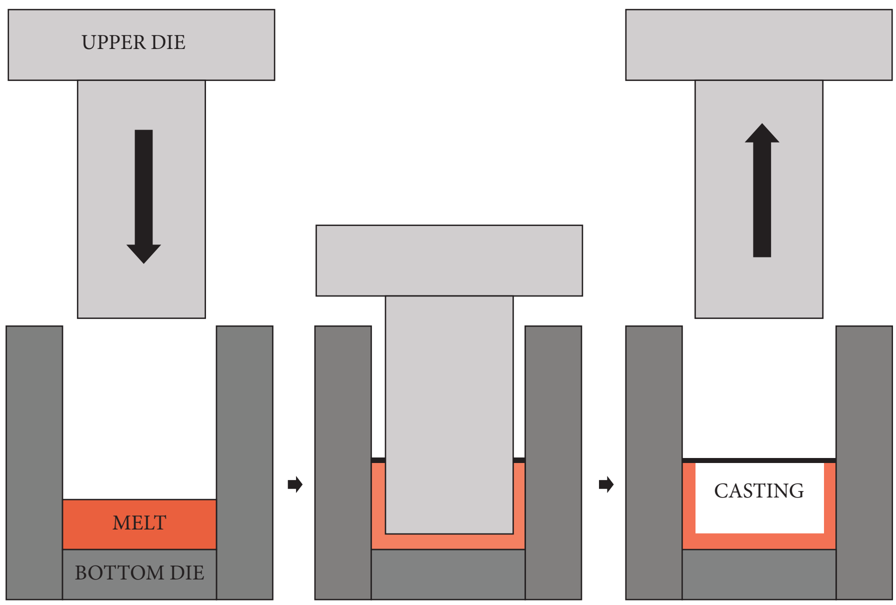
Among the several manufacturing techniques, the two techniques that are being used quite often are in situ casting and stir casting. Figure 8 reveals the process parameters influence the production of composites through the melt stirring route.

2.1. Stir Casting. The processing route is the most significant consideration in the fabrication of AMCs. In 1968, S. Ray dispersed alumina (Al_2O_3) ceramic filler materials into the Al melt, and in this process the incorporated filler material is blended with a molten state alloy by means of mechanical stirring [15]. For the processing of discontinuous rein-forced AMCs, several researchers prefer to employ stir casting route. The foremost objective of melt stirring is that it is trouble-free, flexible, unproblematic, reasonable, and appropriate for bulk production [16, 17]. Mohanavel et al. [18] utilized melt stirring to manufacture AA6351/SiC AMCs. SEM images of the resultant AA6351/SiC AMCs comprising 4%, 8%, and 12% SiC, respectively, are revealed in Figures 9(a)–9(c). The SEM images demonstrate a nearly homogeneous dispersion of the SiC in the AA6351 alloy. Moreover, the stir casting is affordable and provides an efficient stirring movement in the melts due to the sound particle-matrix association in the filler material. The cast-on route for the development of inhomogeneous filler in integrated MMCs is the most widely used liquid state casting process. Figure 10 reveals the experimental structure for the fabrication of composites through melt stirring route.

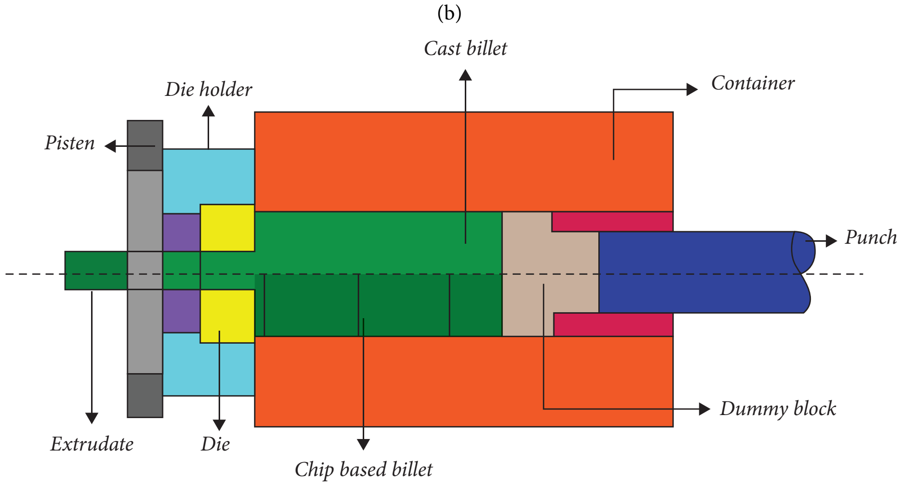
2.2. In Situ Casting. The in situ technique has been an attractive processing route for producing AMCs. In situ synthesizing technique was started in the early 1990s. In this process in situ reaction between the halide salts and molten metal takes place to form reinforcement particles. Exothermic method is more effective than the stir casting process [19, 20]. In situ formed reinforcement exhibits homogeneous dissemination of fine sized filler materials. It



(a)



(b)



(c)

Figure 4: Schematic diagram of fabrication process: (a) stir casting, (b) powder metallurgy, and (c) hot extrusion.

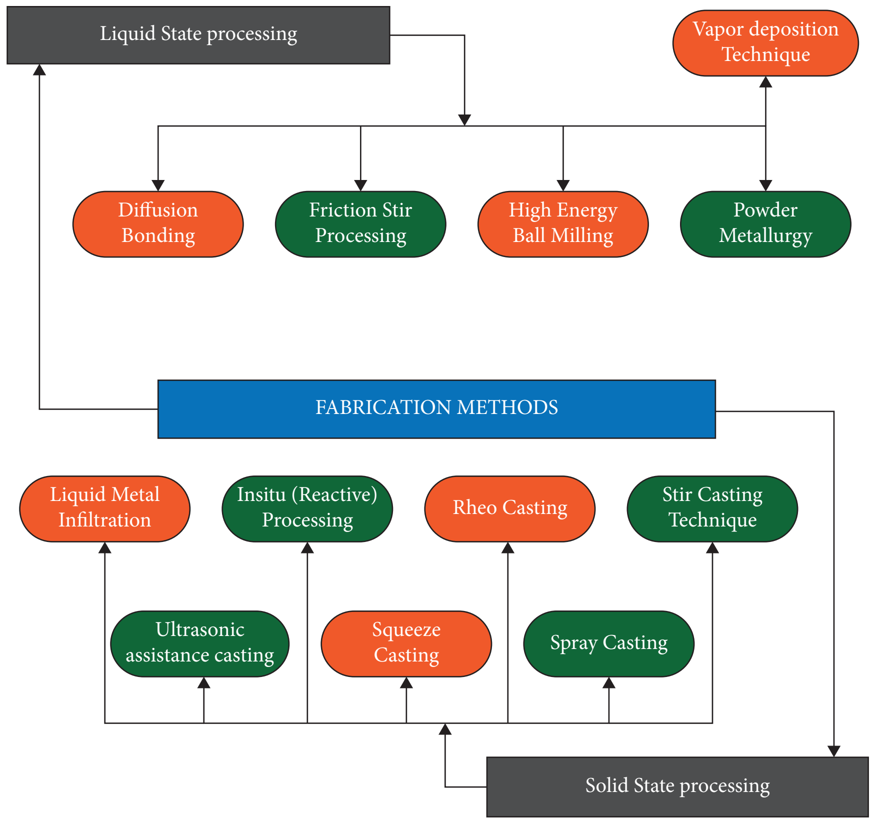


FIGURE 5: Classification of fabrication method of AMCs.

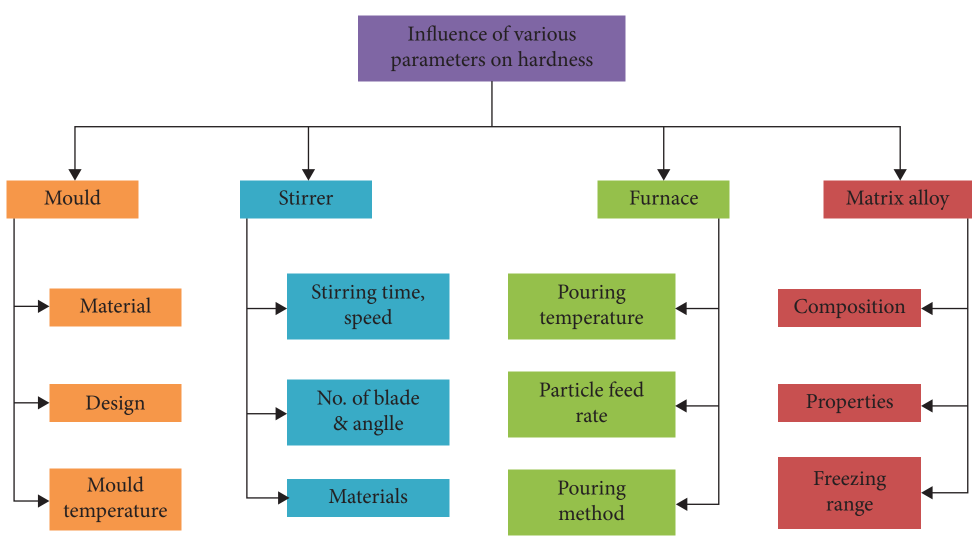


FIGURE 6: Influence of various parameters on hardness.

TABLE 1: Physical and mechanical properties of several ceramics reinforcements.

Sl. no	Properties	TiC	B_4C	ZrB_2	TiB_2
1	Melting point (°C)	2830	2780	3040	3225
2	Density (g cm^{-3})	4.77	2.52	6.08	4.52
3	Hardness (GPa)	22–24	18–20	35	25–35
4	Thermal conductivity ($Wm^{-1}K^{-1}$)	31.8	32.5	24.27	60–120
5	Molar mass (g/mol)	59.89	52.255	112.85	69.489
6	Crystal structure	Cubic	Rhombohedral	Hexagonal	Hexagonal
6	Elastic modulus (GPa)	450	472	451	560

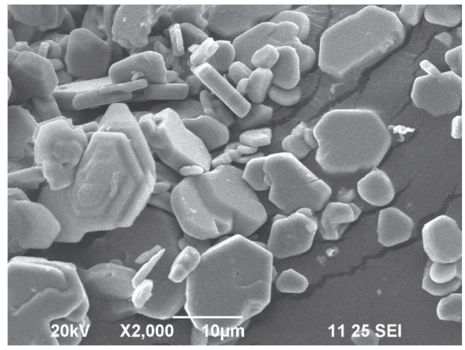


Figure 7: SEM image of TiB_2 particles.

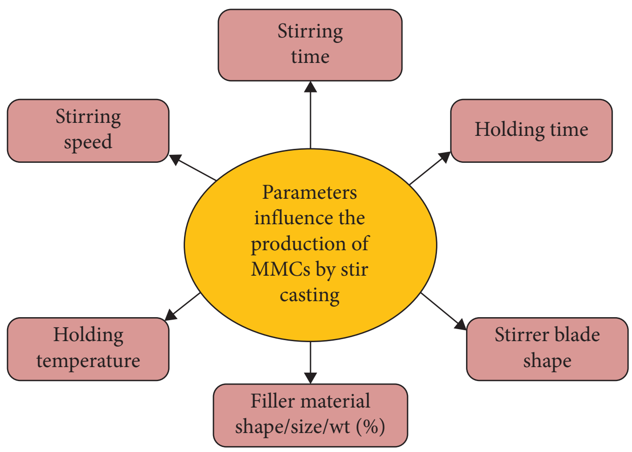
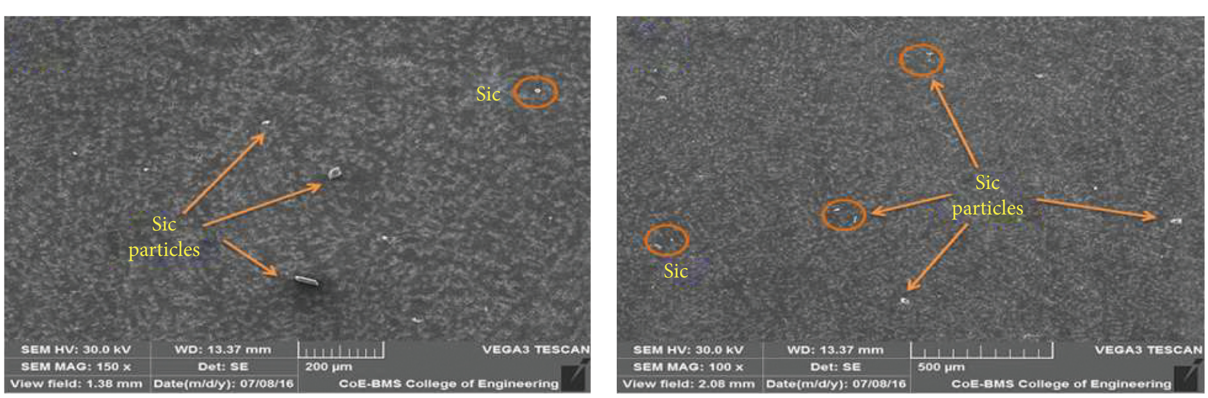
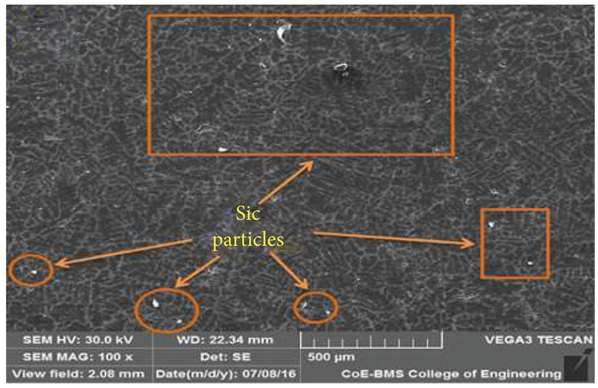


Figure 8: Process parameters influence the production of composites through the melt stirring route.



(a) (b)

Figure 9: Continued.



(c)

FIGURE 9: SEM images of (a) Al6351/4 wt% SiC AMCs, (b) Al6351/8 wt% SiC AMCs, and (c) Al6351/12 wt% SiC AMCs [18].

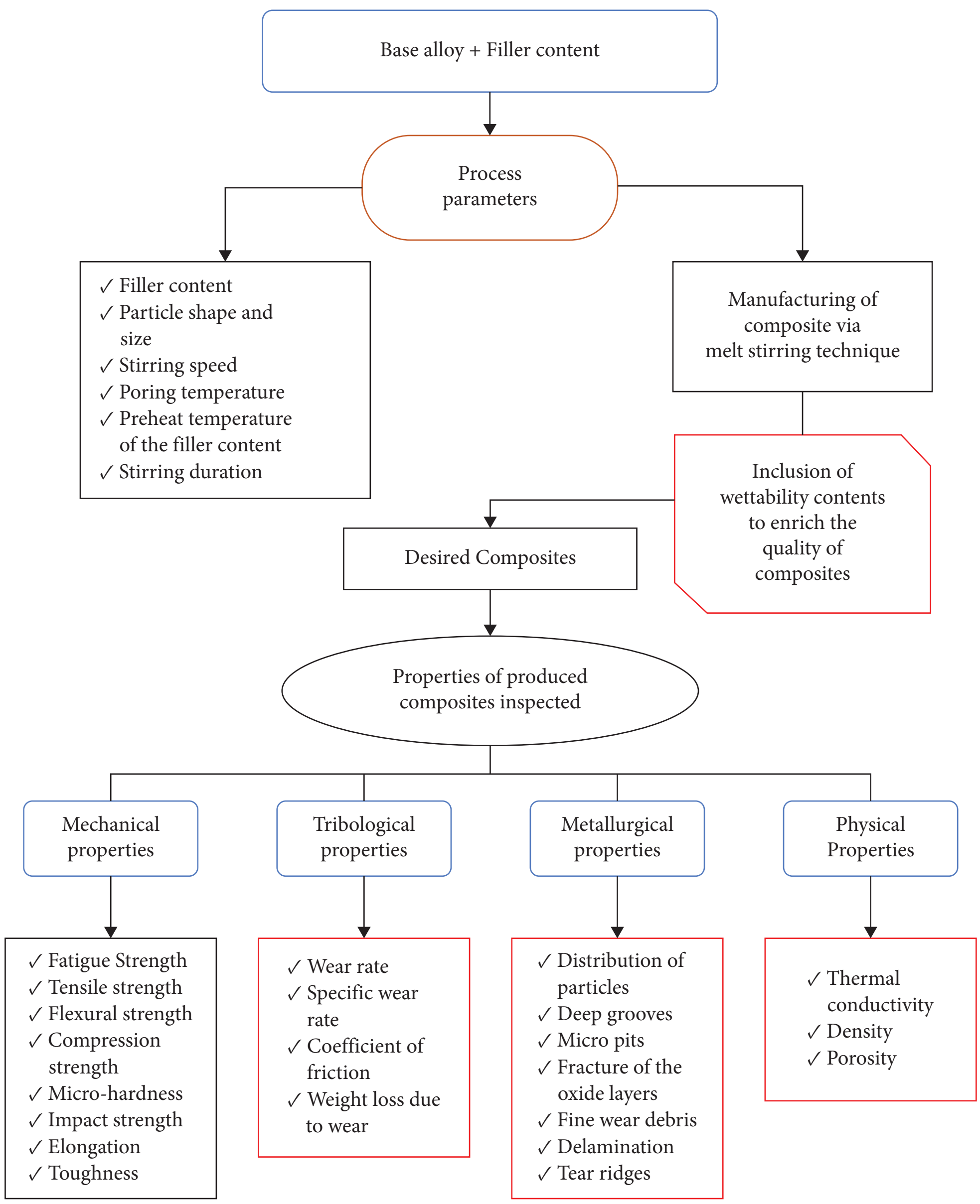


FIGURE 10: Experimental structure for the fabrication of composites through melt stirring route.

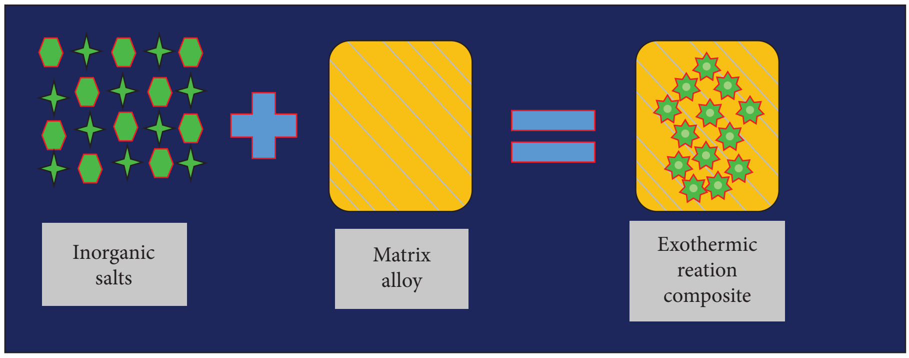


Figure 11: Manufacturing of in situ composite employing inorganic salts and aluminum matrix alloy.

is effortlessly accomplished without the need for incorporation of wetting agent. The in situ reactions, as provided in the following equations, resulted in the generation of TiB_2 particles. Consider the following:

$$
\begin{aligned}
&K_2TiF_6 + \frac{13}{2}Al \longrightarrow Al_3Ti + \frac{4}{3}AlF_3 + 2KF \\
&2KBF_4 + 3Al \longrightarrow AlB_2 + 2AlF_3 + 2KF \\
&Al_3Ti + AlB_2 \longrightarrow TiB_2 + 4Al
\end{aligned}
\quad (1)
$$

The formation pattern of TiB_2 can be classified as follows. (a) The incorporation of K_2TiF_6 (potassium hexafluorotitanate) and KBF_4 (potassium tetrafluoroborate) to molten aluminum generates intermetallic compounds, specifically Al_3Ti and AlB_2, which serve as for Ti and B atoms. (b) Boron atoms travel in the direction of particles from Al_3Ti. (c) The reaction occurred between atoms Ti and B in a gap from the surface of Al_3Ti to form TiB_2. (d) Boron atoms begin diffusing into TiB_2 particles because of the smaller scale. (e) Dissolution of Al_3Ti particle owing to normal cracking and fragmentation of Al_3Ti particles, which contribute to enriched TiB_2 generation rate. (f) Generation of TiB_2 particles, after the entire reaction. Moreover, the KBF_4 inorganic salt was incorporated slightly in excess of the stoichiometric ratio to avoid the formation of titanium trialuminide (Al_3Ti). Figure 11 reveals the manufacturing of in situ composite employing inorganic salts and aluminum matrix alloy.

In preparing AMCs, "in situ" techniques offer significant advantages over the conventional processing routes and in situ casting route is more economical. In situ type of processing is now in commercial use for TiB_2 particle reinforced aluminum matrix composites [21–23]. Moreover, the TiB_2 reinforcement particles in the composite inhibit dislocations, resulting in higher tensile strength. This interface allows for an efficient load transfer between the matrix alloy and the reinforcement. As the TiB_2 particle content increases, this composite has higher mechanical properties than pure aluminum alloy [22]. Figure 12 displays the experimental arrangement of in situ casting. In [23], the dry sliding wear parameters on LM4/TiB_2 composites were analyzed using the Taguchi method. Particulates reinforced

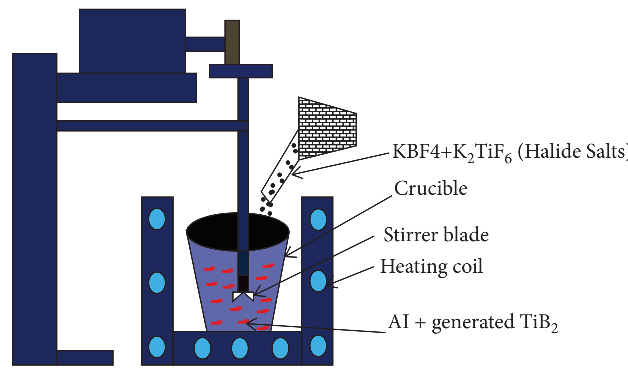
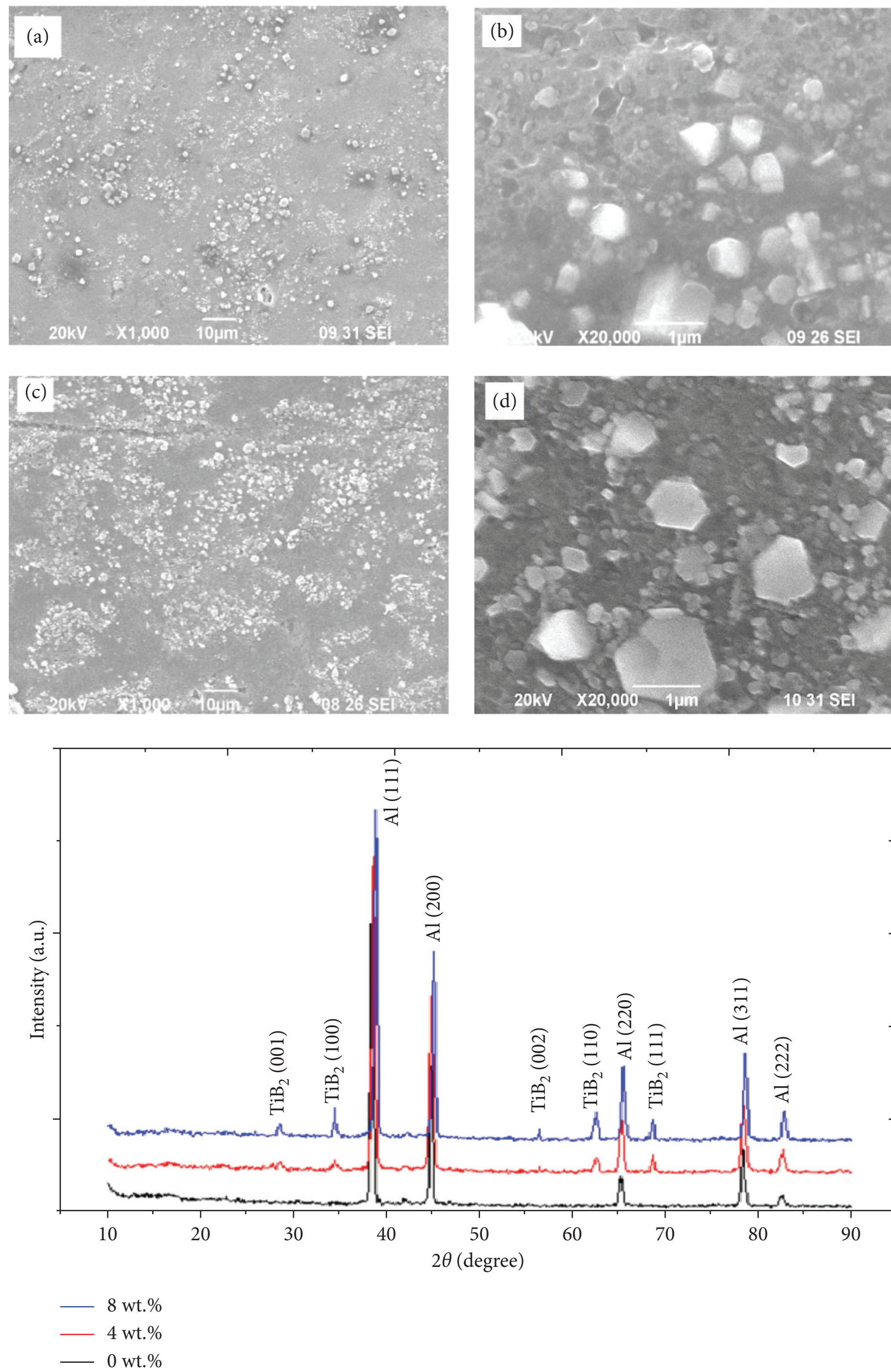


Figure 12: Experimental arrangement of Al-TiB_2 in situ composite.

aluminum matrix composite has better tribological properties compared to unreinforced aluminum matrix composite. Mohanavel et al. [21] employed in situ casting to manufacture AA6351/TiB_2 AMCs. Microhardness and strength increase with the enhancement of the weight percentages of TiB_2 particles. SEM micrographs of the resultant AA6351/TiB_2 AMCs comprising 0%, 4%, and 8% TiB_2, respectively, are revealed in Figures 13(a)–13(e). The SEM micrographs demonstrate a homogeneous dispersion of the TiB_2 in the AA6351 alloy.

3. Comparison of In Situ versus Stir Casting

Table 2 explicates results obtained by various researchers where TiB_2 is the reinforcement and the processes involved mostly are in situ and stir casting and the percentages at which superior mechanical properties emerge are spotted in Table 3. Both in situ and stir casting method can fabricate Al-TiB_2 composites with strong mechanical and wear properties. Most of the explorations have been done on titanium diboride filler particle for aluminum based in situ AMCs. Titanium diboride reinforced aluminum matrix composites are fabricated using halide salt reaction technique and it has proven to be cost effective [24]. Al-TiB_2 in situ composites are usually synthesized by the incorporation of inorganic salts like K_2TiF_6 and KBF_4 which react with molten aluminum and form TiB_2 in the Al melt [25–30]. The Al-TiB_2 in situ AMCs reveal superior mechanical and tribological



(e)

FIGURE 13: SEM micrograph of AA6351/TiB_2 AMCs containing: (a) 4% TiB_2, (b) 4% TiB_2, (c) 8% TiB_2, (d) 8% TiB_2, and (e) XRD patterns of AA6351/TiB_2 in situ composites [21].

properties compared with the base matrix alloy. In situ technique offers high mechanical bonding, homogeneous dissemination of small size of fillers in the matrix, thermodynamic stability, and clear interfacing between the solid and liquid in contrast to stir casting [31, 32]. TiB_2 involved composites have utilized stir casting, squeeze casting, centrifugal casting, and compocasting rarely. It is also more economical when compared to in situ casting. Mechanical and physical properties like density, porosity, flexural strength, and compression strength are analyzed by a few researchers only, where TiB_2 plays a vital role as reinforcement.

Table 2: Titanium diboride reinforced composites properties.

MMC within (wt %)	Manufacturing process	Mechanical properties	Remarks	Reference
Al 6061- TiB_2 (0, 4.98, 9.29, 13.62 wt %)	In situ casting	Microhardness, ultimate tensile strength	Hardness and tensile strength of the composite enhanced as compared to nonreinforced plain alloy matrix.	[33]
AA6061-TiB_2 (0, 12 wt %)	In situ casting	Brinell hardness, UTS, % elongation	All these mechanical characteristics of the AMCs were superior to those of pure Al matrix alloy. The incorporation of TiB_2 filler contents into the AA6061 alloy has diminished the elongation of the composite.	[34]
Al-TiB_2 (1, 4, 7 wt %)	Salt-metal reaction route	Hardness, UTS	All these mechanical properties of the AMCs were superior to those of plain aluminum.	[35]
A356-TiB_2 (0, 2.12, 4.66, 8.37 wt %)	In situ reaction process	UTS, YS, elongation	Mechanical behaviors of the AMCs were greater than those of plain alloy but superior testing results are obtained at 8.37 vol% of TiB_2 reinforced composites.	[36]
AA2219-TiB_2 (0, 5, 10 wt %)	In situ route	Hardness, UTS, YS, and elongation	Both hardness and UTS are being increased when the mass concentration of TiB_2 filler contents reached up to 10%. Addition of TiB_2 reduced the elongation of the plain matrix alloy.	[37]
Al 6063- TiB_2 (0, 4.29, 9.15, 13.12 wt %)	In situ casting	Hardness and tensile strength	Hardness and tensile strength properties are improved with the augmented content of hard titanium boride reinforcement.	[38]
Al 6061- TiB_2 (0, 2, 4, 6, 8, 10 wt %)	High energy metal stirring route	Hardness, UTS	Hardness and UTS of the developed AMCs were superior to those of base matrix but better results are obtained at the maximum percentage of TiB_2 reinforced composite.	[39]
AA7075-TiB_2 (0, 3, 6, 9 wt %)	Exothermic reaction process	Microhardness, UTS, % elongation	Both the UTS and the microhardness were enriched as compared to pure Al matrix. Incorporation of hard TiB_2 reduced the elongation of the base matrix.	[40]
Al 6063/TiB_2 (0, 5, 10 wt %)	Salt base exothermic reaction process	Microhardness	Microhardness of the produced composite increased steadily as hard TiB_2 reinforcement content increased.	[41]
A356-TiB_2 (0, 12.5 wt %)	In situ casting process	Ultimate tensile strength, yield strength.	Yield strength and tensile strength of the aluminum metal matrix composites were higher than those of unreinforced plain matrix alloy and then increased with the increase in the content of TiB_2 particle.	[42]
AA6061-TiB_2 (0, 4, 8, 12 wt %)	Stir casting	Hardness, tensile strength	The tensile strength and the microhardness of the prepared composite tend to increase with the increase in TiB_2 content.	[43]
Al-6Cu-0.2Mg-Mn-TiB_2 (0, 1, 3, 5 wt %)	In situ casting	Microhardness	Microhardness was greater than that of base matrix alloy. The variation in the presence of reinforcement particles is visible with increased content of TiB_2.	[44]
AA6061-TiB_2 (10 wt %)	Stir casting	Hardness and tensile strength	AA6061/10 wt%TiB_2 AMC exhibits 58HV of microhardness and 195 MPa of tensile strength. These AMCs are fabricated in liquid state by stir casting method.	[45]

Table 2: Continued.

MMC within (wt %)	Manufacturing process	Mechanical properties	Remarks	Reference
A390-TiB_2	In situ casting	Hardness, UTS, and % elongation	Ultimate tensile strength, ductility, and hardness of the produced composite were greater than those of nonreinforced matrix alloy but highest results are obtained at the largest percentage of TiB_2 reinforced composite.	[46]
AA2219/TiB_2 (0, 5, 10 wt %)	In situ reaction process	UTS, yield strength, ductility	Tensile and yield strength were greater than those of parent alloy and they raised with the raise in reinforcement, in all composites. Incorporation of TiB_2 reduced the elongation of the pure Al matrix.	[47]
LM 25/TiB_2 (0, 2.5, 5, 7.5)	Mixed salt method	UTS, yield strength, % elongation	UTS and yield strength were superior to those of base aluminum and they were enriched with the augmented mass proportion of reinforcement while the mechanical characteristics of the composite increases owing to the presence of TiB_2 filler materials.	[48]
Al/TiB_2 (0, 1.5, 2.5, 3.5, 5 and 10 wt % TiB_2)	Powder metallurgy	Compressive strength	Mechanical property was greater than that of basic alloy.	[49]
A356/TiB_2 (0, 0.5, 1.5, 3, and 5 vol %)	Stir casting	Hardness	Use of hard TiB_2 has a remarkable effect in increasing microhardness and UTS of the Al composite.	[50]
A356/TiB_2 (0, 3, 5.6, 7.8 vol%)	In situ casting	UTS, yield strength, and fracture toughness	The produced composite with 7.8 vol% TiB_2 shows the greatest improvement in mechanical performance when compared to the base metal.	[51]
AA6061/TiB_2 (0, 5, 7 wt%)	In situ casting	Microhardness, UTS, elongation	In all the composites microhardness and UTS were greater than those of unreinforced base matrix and they increased with increase in reinforcement content. The addition of TiB_2 particulates to the AA6061 matrix has led to reduced ductility of the AMC.	[52]
AA7075/TiB_2 (0, 5, 10 wt%)	In situ casting (mixing salt route)	Bending strength	Bending characteristics are enhanced with the increased content of filler materials.	[53]
AA6061- TiB_2 (0, 3, 6, 9 wt %)	In situ reaction process	Microhardness (HV)	Microhardness of the experimental AMCs was greater than that of plain alloy but highest results are achieved at the superior percentage of TiB_2 reinforced composite.	[54]
AA1100-TiB_2 (0, Al4.5%Cu-15 vol %TiB_2, Al4.5%Cu3 %C-15 vol% TiB_2)	In situ method	Tensile strength, elongation	Tensile strength of the composite was greater than that of unreinforced plain alloy and all these characteristics were enriched when augmented amount of filler content is found. Addition of TiB_2 reduced the ductility of the matrix alloy.	[55]
Commercial pure (CP) Al-TiB_2 (0, 5, 10, 15, 20 vol %)	Powder metallurgy	UTS, yield strength	UTS and yield strength were superior to those of base alloy in both processes and were enhanced with increase in filler material, in all composites.	[56]
LM 25-TiB_2 (0, 2.5, 5, 7.5 wt %)	In situ method	Brinell hardness, UTS, yield strength, elongation	The improved hardness and the reduction in the ductility of LM25-TiB_2 AMCs are observed when TiB_2 content is increased in the AMCs.	[57]

Table 2: Continued.

MMC within (wt %)	Manufacturing process	Mechanical properties	Remarks	Reference
Al-4Cu-TiB_2 (0, 2.5, 5, 7.5, 10 wt %)	In situ method	Hardness (HV)	The microhardness of the fabricated composite tends to augment with the rise in TiB_2 content.	[58]
Al-2.5% TiB_2 (25%, 120%, 140% KBF_4 excess than stoichiometry) 2.5% TiB_2	In situ method	Microhardness (HV)	Microhardness of the AMCs increased as compared to nonreinforced alloy matrix.	[59]
AA6061-TiB_2 (0, 3, 6, 9, 12 wt %)	Stir casting	Hardness, UTS, yield strength,	Yield strength, hardness, and tensile strength were superior to those of nonreinforced base matrix alloy.	[60]
AA6061-TiB_2 (0, 2, 4, 6, 8, 10, 12 wt %)	In situ and equal channel angular pressing (ECAP)	Hardness, UTS, elongation,	Both the tensile strength and the hardness were enhanced as compared to pure plain matrix alloy. The elongation of the AMCs was found to be somewhat lower than that of the base alloy.	[61]
Al-B_4C-TiB_2 (10, 20, 30, 40 wt % TiB_2)	Vacuum infiltration	Hardness (HRA) and flexural strength	The hardness and flexural strength of the specimens tend to decrease during the increment of the reinforcement content.	[62]
AA6061, AA6061-5 wt% TiB_2, AA7015, AA7015-5 wt% TiB_2	Hot extrusion	Hardness	Hardness of the AMCs was superior to that of plain alloy and it is enhanced with the rising content of hard TiB_2 reinforcement.	[63]
AA6061, AA6061-10% SiC- 2.5% TiB_2, 5% TiB_2	Stir casting	Hardness (HV)	Hardness of the Al-10%SiC-2.5%TiB_2 AMCs increased as compared to basic alloy matrix.	[64]
Al6061-TiB_2 (0, 6, 8, 10)	In situ casting route	Hardness, UTS, elongation	Hardness and UTS of the prepared AMCs were enriched linearly as TiB_2 content increased. The incorporation of hard TiB_2 filler materials into the AA6061 matrix has led to diminished elongation of the AMC.	[65]
Commercial pure aluminium (CP)-TiB_2 (0, 2.5, 5 wt% TiB_2)	In situ casting process	Hardness, UTS	Hardness, fracture, and tensile strength improved with enhanced titanium diboride particle content.	[66]
AA7178—0, 3, 6, 9 wt%TiB_2)	In situ casting method	Hardness, compression strength, and tensile strength	Microhardness, compression, and tensile strength are being improved when the weight fraction of TiB_2 particles reached up to 9%.	[67]
A1100-TiB_2, AlCu TiB_2 (15Vf% TiB_2)	Exothermic reaction process	UTS, yield strength	Mechanical properties of the AMMCs increased as compared to unreinforced plain matrix alloy.	[68]
Al-7Si/TiB_2 (0, 5, 10 wt% TiB_2)	In situ	Hardness, UTS, yield strength	Maximum hardness, yield, and tensile strength of the AMCs are obtained where the TiB_2 filler material reached 10%.	[69]
Al-4%Cu-TiB_2 (chemical reaction time-15, 25, 35 min)	In situ casting	Hardness, UTS, yield strength, elongation	Mechanical properties of the developed aluminum matrix AMCs were superior to those of unreinforced matrix.	[70]
A356-TiB_2 (0, 0.5, 1.5, 3.5-micron and nano TiB_2) (casting temperature 750, 800, 900°C)	Melt stirring casting	UTS and yield strength	Yield and tensile strength were augmented compared to those of basic alloy. A356-1.5 wt%TiB_2-900°C AMC exhibits higher mechanical properties.	[71]
AA6061/TiB_2/Gr 0%, 5%, 10%, 20%TiB_2 + 2%Gr, 5%, 10%, 20% TiB_2,	Melt stirring method	UTS and hardness	UTS and hardness of the AMCs were augmented compared to those of base alloy and were then boosted with the augmented content of filler material.	[72]

Table 2: Continued.

MMC within (wt %)	Manufacturing process	Mechanical properties	Remarks	Reference
AA6063/TiB_2 (0, 5, 10)	In situ	Hardness (HV)	Bulk hardness of the composite was superior to that of base alloy and it was enriched with the increasing content of filler material.	[73]
Al6063- TiB_2 (2.8, 6.7, 10 wt%)	In situ	Microhardness (HV)	Microhardness was 27.25% times superior to that of base aluminum while hardness increased with increased content of reinforcement.	[74]
A356- TiB_2 (2, 3, 4, 5, 6 wt% TiB_2) reaction time (20, 25, 30, 35, 40 min) temperature (800, 850, 900, 950, 1000°C)	In situ	Hardness (HV), UTS	Use of TiB_2 has a significant influence in enriching the hardness and tensile strength of the AMCs.	[75]
AA6061-10%SiC-(0, 2.5, 5 wt % TiB_2)	Stir casting	Hardness, tensile strength	Higher hardness was achieved at the percentage of Al-10%SiC-2.5TiB_2 AMC and maximum tensile strength obtained at the percentage of Al-10%SiC-0%TiB_2 AMC.	[76]
AA6061-5%, 10%TiB_2-1, 2, 3, 4% Gr	Stir casting	Hardness, compressive strength, tensile strength	Hardness and UTS of the aluminum composites were superior to those of parent matrix alloy and it is enriched by the increasing content of 10 wt%TiB_2 and 2 wt%Gr.	[77]
Al2014-TiB_2 (0, 5 wt% TiB_2 (5 wt% TiB_2 + 0.5% Ceo_2)	In situ casting	Hardness, tensile strength, yield strength	Hardness, yield, and tensile strength were superior to those of base alloy and they were enriched by augmenting the amount of filler content (TiB_2 + CeO_2).	[78]
AA2219-TiB_2/ZrB_2 (0, 3, 6%)	In situ casting	Microhardness (HV)	Microhardness of the composite was superior to that of basic alloy.	[79]
Commercial pure aluminum (CP)-TiB_2 (0, 5 vol% TiB_2, 5 vol% TiB_2 + 0.5 wt%CeO_2)	In situ casting	UTS, YS, elastic modulus	Mechanical properties of the experimental composites were superior to those of parent matrix alloy.	[80]
A356-TiB_2 (0, 2.5, 5, 7.5, 10%) At T6 treated	In situ composite	Vickers hardness (HV)	Microhardness was improved as compared to pure base matrix aluminum alloy.	[81]
Al-4 wt%Cu-5, 10, 15, 20%TiB_2)	Hot isostatic processing	Hardness, yield strength, UTS	All these properties of the composite were superior to those of base material.	[82]
Al6061-TiB_2 (10, 11, 12, 13, 14 wt% TiB_2)	In situ casting process	Hardness, UTS	Peak UTS and hardness of the produced AMCs are obtained where the TiB_2 content reached 14%.	[83]
A356-TiB_2 (0, 2.5, 5, 7.5, 10 wt %)	Salt metal reaction process	Hardness, UTS, % elongation	Mechanical behaviors of the produced aluminum-based metal matrix composites were superior to those of nonreinforced alloy.	[84]
AA7075-TiB_2 (0, 9 wt% TiB_2)	In situ method	Microhardness and tensile strength	UTS and hardness of the AA7075-9 wt % titanium boride AMCs increased as compared to nonreinforced alloy matrix.	[85]
AA2009-TiB_2 (8 wt% TiB_2) solution temperature (498, 508, 520, 530°C)	Exothermic reaction process	Hardness and UTS	The manufactured AMCs reveal the maximum hardness after solution was treated at 530°C and the superior tensile strength after solution was treated at 520°C.	[86]
AA2024-TiB_2 (0, 7 wt% TiB_2)	Stir casting	Microhardness	Microhardness of the developed composite was higher than that of unreinforced monolithic alloy.	[87]

Table 2: Continued.

MMC within (wt %)	Manufacturing process	Mechanical properties	Remarks	Reference
AA7075-TiB_2 (0, 6, 9, 12 wt% TiB_2)	In situ method	Microhardness and tensile strength	Mechanical properties of the manufactured composites were superior to those of monolithic alloy. Superior UTS and hardness of the proposed AMCs is achieved where the TiB_2 content reached 12%.	[88]

Table 3: Superior mechanical properties of titanium diboride based aluminum matrix composites.

MMCs	Manufacturing process	Macrohardness (BHN)	Microhardness (HV)	UTS (MPa)	YS (MPa)	Reference
AA7050/6 wt% TiB_2	In situ casting technique	—	—	746	701	[25]
AA6061/12 wt% TiB_2	Exothermic reaction process	88.6	—	173.6	94.2	[34]
Al/7 wt% TiB_2	Salt-metal reaction route	30	—	136.6	—	[35]
A356/8.37 vol% TiB_2	In situ reaction process	—	—	258.5	217.6	[36]
AA2219/10 wt% TiB_2	In situ casting technique	—	96	234	205	[37]
AA6063/13.12 wt% TiB_2	In situ casting	—	59.25	140.9	—	[38]
AA6061/10 wt% TiB_2	High energy stir casting	—	73.93	171	—	[39]
AA7075/9 wt% TiB_2	In situ method	—	128	285	—	[40, 85]
AA6063/10 wt% TiB_2	In situ casting route	—	110	—	—	[41, 73]
A356/12.5 wt% TiB_2	Exothermic reaction process	—	—	382	324	[42]
AA6061/12 wt% TiB_2	Stir casting	—	72.46	137.86	—	[43]
Al-6Cu-0.2Mg-1Mn/5 wt% TiB_2	In situ casting	—	84	—	—	[44]
AA6061/10 wt% TiB_2	Melt stirring process	—	58	195	—	[45]
AA2219/10 wt% TiB_2	In situ reaction method	—	—	426.97	301.75	[47]
LM/7.5 wt% TiB_2	Mixed salts method	—	—	202	164	[48]
A356/0.5 wt% TiB_2	Stir casting	—	118	—	—	[50]
AA356/7.8 vol% TiB_2	In situ casting	—	—	382	328	[51]
AA6061/7 wt% TiB_2	Mixed salt route	—	47	145	—	[52]
AA6061/9 wt% TiB_2	Exothermic reaction process	—	123	—	—	[54]
Al-4.5%Cu-3%C/15 vol% TiB_2	In situ method	—	—	257.6	—	[55]
Al(CP)/20 vol% TiB_2	Powder metallurgy	—-	—	191	115	[56]
LM25/7.5 wt% TiB_2	In situ reaction casting	81	—	202	164	[57]
Al-4Cu/10 wt% TiB_2	Liquid state in situ casting	—	138	—	—	[58]
AA6061/12 wt% TiB_2	Stir casting	—	77.93	140	—	[60]
AA6061/2.5 wt% TiB_2/10% SiC	Liquid state stir casting	—	71.46	—	—	[64]
AA6061/10 wt% TiB_2	In situ method	—	74.83	165.74	—	[65]
Al(CP)/wt% TiB_2	In situ method	—	—	180	96	[66]
AA7178/9 wt% TiB_2	In situ casting route	—	94	211	—	[67]
Al-7Si/13.12 wt% TiB_2	In situ reaction process	—	102	209	152	[69]
AA6061/20 wt% TiB_2/2Gr	Stir casting route	—	91.4	170	—	[72]
AA6061/2.5 wt% TiB_2/10 wt% SiC	Stir casting	—	75	—	—	[76]
AA6061/10 wt% TiB_2/2 wt% gr	Stir casting	—	79.04	—	—	[77]
AA2219—6 wt%TiB_2/ZrB_2	In situ casting	—	155.6	—	—	[79]
A356/2.5 wt% TiB_2	In situ technique	—	92	—	—	[81, 84]
AA6061/14 wt% TiB_2	In situ technique	—	128	334	—	[83]
AA2009/8 wt% TiB_2 (solution temperature 520°C)	In situ method	—	—	538	364	[86]
AA2024/7 wt% TiB_2	Stir casting	—	116	—	—	[87]
AA7075/12 wt% TiB_2	In situ technique	—	141	287.95	—	[88]

4. Conclusions

This review article examines the impact of titanium diboride (TiB_2) on aluminum matrix composites (AMCs). As seen in the previous section, various authors have discussed the mechanical properties of fabricated Al/TiB_2 composites, such as hardness, tensile strength, compressive strength, and yield strength. It shall be opined that the stir casting technique is the rare one in making Al-TiB_2 composite, whereas the in situ technique is the often-used technique due to its formation of more uniform TiB_2 particles in the matrix. The TiB_2 particles involved composites have rarely utilized squeeze casting, centrifugal casting, stir casting, and compocasting. Al alloys containing TiB_2 reinforcements are to reveal enriched mechanical properties compared to monolithic alloys. Reported works also indicate the linearly augmented mechanical properties with the incorporation of TiB_2. Several research works recommended that tensile strength and hardness of the AMCs were enriched with the inclusion of a rise in mass fraction of TiB_2 particle contents.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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