In the current research, AA6082 aluminium alloy matrix composites (AAMCs) incorporated with various weight fractions of titanium diboride (0, 3, 6, and 9 wt%) were prepared via an in situ casting technique. The exothermic reaction between inorganic powders like dipotassium hexafluorotitanate (K2TiF6) and potassium tetrafluoroborate (KBF4) in molten Al metal contributes to the development of titanium diboride content. The manufactured AA6082-TiB2 AAMCs were evaluated using a scanning electron microscope (SEM) and X-ray diffraction (XRD). The mechanical properties and wear rate (WR) of the AAMCs were investigated. XRD guarantees the creation of TiB2 phases and proves the nonappearance of reaction products in the AAMCs. SEM studies depict the even dispersion of TiB2 in the matrix alloy. The mechanical and tribological properties (MTP) of the AAMCs showed improvement by the dispersion of TiB2 particles. The WR decreases steadily with TiB2 and the least WR is seen at nine weight concentrations of TiB2/AA6082 AAMCs. Fabricated composites revealed 47.9% higher flexural strength and 14.2% superior compression strength than the base AA6082 alloy.

1. Introduction

In recent scenarios, a huge number of research studies has shifted from monolithic materials to composite materials to meet the improving universal demand for high performance, ecofriendly corrosion, erosion, and wear-resistant materials. The improvement of lightweight and fewer costly materials with enriched performance for automobiles, construction, aviation, aircraft, and several engineering applications is always a concern of numerous research workers [1, 2]. The foremost goal involved in developing composite (AMC) materials is to merge the ductile matrix metals and hard
ceramic particles. AAMCs have enormous potential in being tailored for several applications and are qualified for replacing conventional materials. Some of the good-locking properties of AAMCs comprise superior specific strength, excellent elastic modulus, and excellent specific stiffness in comparison with their monolithic alloy [3–5].

The AAMCs are broadly manufactured through the liquid state route. The liquid state processing method may be of two types: ex situ (stir casting technique) and in situ (direct melt reaction technique or exothermic salt-metal reaction technique) fabrication [6–8]. The in situ process exhibits even scattering of particles [9]. The type of filler or reinforcement material significantly influences the MTP of the AMCs. Titanium diboride (TiB2) is an ultrahigh temperature ceramic particle with good covalent bonding, providing it with a high melting temperature of 3225°C, a higher Vickers hardness of 3400 HV, and a low density of 4.5 g/m3. Moreover, in contrast to most ceramics, TiB2 reveals good thermal shock confrontation and superior electrical and thermal conductivity [10, 11]. Tjong and Lau [12] developed Al-4%Cu/TiB2 AAMCs through the hot isostatic pressing method and found that the hardness and yield strength enriches with the inclusion of TiB2 filler material. Natarajan et al. [13] achieved a dry sliding wear test on an AA6063 composite strengthened with in situ TiB2 content and observed that the inclusion of harder ceramic TiB2 enriches the MTP of the proposed AAMCs. Christy et al. [14] carried out their research on aluminum alloy AA6061/TiB2 AMCs, where the TiB2 filler contents were made through the magneto chemistry exothermic reaction of halide powders in the Al melt at 840°C and examined the microstructural and mechanical behavior of the composites. Rajasekaran and Sampath [15] produced AA2219/TiB2 in situ AMCs synthesized through an exothermic reaction process at 800°C employing KBF4 and K2TiF6 inorganic salts. SEM micrograph examination exhibited the hexagonal shape of in situ TiB2 particle content. Ramesh et al. [16] produced AA6061/TiB2 AAMCs through an exothermic reaction process and analyzed the tensile strength (UTS) of the AMCs. Wang et al. [17] synthesized Al3Ti formTiB2(0.3,6, and 9wt%). If we increase the appropriate % wt to greater than 10% in situ, it leads to large-sized blow holes and castings that will be brittle in nature. To prevent Al1/Ti formation, KBF4 halide powder was marginally higher than the stoichiometric ratio. The melting temperature was held at 850°C. The AA6082/TiB2 melt was constantly stirred at 400 rpm and held for 1800 sec. The AA6082/TiB2 AAMC thaw was poured into a preheated mould and composite samples were obtained.

2. Experimental Work

2.1. Manufacturing of AA6082/TiB2 AAMCs. Aluminum alloy (AA6082) was used in this work as the material matrix and the AA6082 chemical constituents are displayed in Table 1. The AA6082 alloy in rod shape was melted using a melting furnace with a graphite crucible. Table.2 shows the properties of the AA6082 aluminium. Figure 1 displays the casting furnace arrangement.

The gauged quantities of chemicals are revealed in Table 3 which were incorporated into the molten AA6082 to form TiB2 (0, 3, 6, and 9 wt%). If we increase the appropriate % wt to greater than 10% in situ, it leads to large-sized blow holes and castings that will be brittle in nature. To prevent Al1/Ti formation, KBF4 halide powder was marginally higher than the stoichiometric ratio. The melting temperature was held at 850°C. The AA6082/TiB2 melt was constantly stirred at 400 rpm and held for 1800 sec. The AA6082/TiB2 AAMC thaw was poured into a preheated mould and composite samples were obtained.

2.2. Microstructure and Testing. The essential dimension of the specimens was cut from the synthesized castings. The test samples were refined as per a standard metallographic procedure. The microstructure was witnessed utilizing an SEM. XRD spectrums were documented by a Panalytical X-ray diffractometer. Applying a load of 0.5 Kgf for a dwell interval of 15s, Vicker’s hardness test has measured the microhardness. The hardness was tested at six different places, and the mean hardness value was determined for the sample.

Figure 2(a) displays the fabricated tensile specimens. Tensile tests were performed as per ASTM using a
The tensile samples were processed by measuring the length of 40 mm, the width of 7 mm, and the thickness of 6 mm. Four tests and the mean values have been recorded in each combination. In compliance with ASTM E9 standards, the compression strength (CS) was borne in the UTM. The compression test specimens have also been manufactured in cylinder forms of 8 mm in diameter and 24 mm in height. The specimens machined from the synthesized AAMCs were machined and polished metallographically. The specimens after the compression test are exposed in Figure 2(b). Flexural tests were achieved on the AA6082 parent material and the prepared AAMCs using the computerized UTM.

Using a DUCOM TR20-LE pin on the disc (POD) wear testing unit, wear resistance was assessed at room temperature in dry wear conditions as per the ASTM G99-04 standard. The POD system schematic diagram is presented in Figure 2(c). The test sample is made from AA6082 alloy and is a manufactured composite of diameter 8 mm and length 32 mm. After extensive washing using acetone solvent, the specimen was measured using an automated measuring system before and after the sliding wear test. Initial and final weight disparities resulted in mass loss due to sliding wear. The WR was assessed employing the following relation:

$$ W = \frac{M}{\rho D}, $$

where $W$ is the WR (mm$^3$/m), $M$ is weight loss (g), $\rho$ is density (g/mm$^3$), and $D$ is the rotating distance (m). The pin surface was polished and the end of the pin was attached to a hard steel disc (62 HRc). Testing was carried out with the usual forces of 10N, 20N, and 30N and a sliding speed of 1 m/s at sliding distances of 1500 m. The samples before the wear test are illustrated in Figure 2(d).

### 3. Results and Discussion

#### 3.1. SEM Analysis of AA6082/TiB$_2$ AAMCs

Figure 3(a) illustrates the SEM images of the base AA6082 alloy. The microstructure of AA6082 alloy exposes the occurrence of magnesium (Mg) and silica (Si) content in AA6082 alloy. Figure 3 depicts the SEM micrograph of the AA6082/TiB$_2$ AAMCs. Figures 3(b)–3(f) show the SEM photograph of AA6082/TiB$_2$ AMCs that exhibit the dissemination of TiB$_2$ contents in the Al material. Microstructural examination proves the homogeneous dissemination of TiB$_2$ filler content in the AA6082 alloy and also exhibits a strong attachment between the secondary and primary material. The SEM photograph presented in Figures 3(e) and 3(f) shows the stable and pure interface between the parent metal and TiB$_2$ filler content. The Al matrix-TiB$_2$ particle interface indicates a high level of interface consistency between the AA6082 matrix and the reinforcement without reaction product presence. The homogeneous dissemination of reinforcement particles is more essential to enrich the mechanical properties of the AA6082. These results are in line with the earlier studies by several researchers [16].

#### 3.2. XRD Analysis of AA6082-TiB$_2$ AAMCs

Figure 4 depicts the XRD spectrums of the AA6082 alloy and TiB$_2$ AAMCs. The XRD plot demonstrated the presence of respective elements of aluminium and TiB$_2$ particles in the prepared composites and also, the pattern reveals the absence of reaction products.
XRD spectrums guarantee the existence of aluminum (in the most prominent peaks) and TiB$_2$ (revealed by minor peaks) in the AAMCs. With a rise in the mass concentration of TiB$_2$ in the AAMCs, the amplitude of the peaks of TiB$_2$ improved [10, 13]. The prepared composites’ aluminum peaks are slightly higher than the AAMCs, as shown in Figure 4. In the composites, no other unwanted compounds were discovered. The thermodynamically stable TiB$_2$ particles can be ensured.

### 3.3. Hardness

The microhardness (MH) of the AA6082/TiB$_2$ AAMCs is exposed in Figure 5. The MH increases with a rise in TiB$_2$ particles. The test outcomes reveal the enrichment in MH of the AA6082/TiB$_2$ AAMCs from 51 HV to 87 HV. The enrichment in MH could be attributed to even allocating TiB$_2$ in the Al matrix [13]. The accretion of TiB$_2$ content in the AA6082 matrix improves the surface area, thereby reducing the matrix’s grain size. Aluminium alloys with 9 wt% of TiB$_2$ composites exhibit superior hardness. It can be ascribed to the enriched surface area of the TiB$_2$ contents that presents huge protection to plastic deformation (PD), which directs to raise the MH of AAMCs.

Other researchers showed similar forms of findings in their analysis. The AA6061/AlN AMCs are due to the grain alteration of the matrix (Hall–Petch mechanism) and the impact of particulate matter on the Orowan strengthening of AAMCs, according to Ashok Kumar and others [23].

Even the strong AlN secondary materials act as barricades against dislocation movement, thereby increasing the hardness of the composite in contrast with the monolithic Al alloy. Ravi Kumar et al. [24] noted that the rise in hardness of the composites AA6063/TiC with 10wt% of TiC has more robust plastic resistance. Rajeswari et al. [25] have identified the effects on the hardness and UTS of the AAMCs of stirring speed, mass concentration, and processing temperature. Mathan Kumar et al. [26] have observed that

![Figure 2: (a) Tensile test samples. (b) Compression test samples. (c) Schematic illustration of tribometer. (d) Wear samples.](image-url)
Figure 3: SEM micrographs of AA6082/TiB₂ AAMCs with TiB₂ content. (a) 0 wt%, (b) 3 wt%, (c) 6 wt%, (d) 9 wt%, and (e, f) 9 wt% (higher magnification).
because PD decreases by the strengthening particles, adding AlN, ZrB₂, and Si₃N₄ particles increased the hardness of AMCs. The strength of the AA6082/TiB₂ AMCs then increased to an overall 70.58% and 9% of TiB₂.

3.4. Tensile Strength of AA6082/TiB₂ AAMCs. Figure 6 illustrates the influence of TiB₂ particles on the UTS of the AAMCs. The UTS of the fabricated AAMCs was augmented from 176 MPa to 201 MPa. The UTS of the composite was originated to be higher at 9 wt% TiB₂ content. Such kinds of escalation were stated by other investigators while incorporating SiO₂ [27], rice husk ash [28], eggshell [29], nanosilver [30], basalt [31], AlN [32], and WC [33] particles in AMCs. Although the incorporation of graphite [34], SiC [35, 36], coconut shell ash [37], and mica [38] particles declined the UTS of the AAMCs.

The following can be clarified as the critical reasons behind the enrichment of the AA6082/TiB₂ AMC in UTS. The penetration of secondary TiB₂ material into the matrix results in many dislocation densities in solidification around the reinforcing particles. This is due to a misfit between the soft matrix AA6082 and the hard TiB₂ secondary material, caused by the coefficient of thermal expansion. As well as the thermal misfit between matrix and reinforcement, upshots are often introduced to enhance the load-bearing capacity of strong reinforcing particles that enrich the strength of composites [15, 20].

Tensile strength is enriched to a maximum of 14.20% while incorporating 9% of TiB₂. A similar trend of outcomes was revealed by other investigators in their study. Gopalakrishnan and Murugan [39] noticed the appreciable enrichment in the UTS of the AA6061/TiC AAMCs. Pardeep Sharma et al. [40] reported that the sound integrity closeness between the Si₃N₄/graphite contents and the AA6082 alloy augmented the UTS of the AAMCs. Jebeen Moses et al. [41] have described the influence of blade angle, stirring speed, and stirring time on the hardness and UTS of the AAMCs. Shalaby and Churyumov [42] observed that the load transfer between the hard AlNp and soft matrix A359 alloy results in strengthening and improved tensile strength. Sivananth et al. [43] exhibited that the UTS and fatigue strength of AAMCs were enhanced with augmenting TiC particles, and the occurrence of TiC particles in AAMCs serves as an obstruction to dislocation, thereby enriching the UTS of the AMC. This kind of intensifying factor enhances the rise in the inclusion of TiB₂ particles. The direct mechanism achieved the strengthening of AMCs, precisely the escalation in PD of the AAMCs and the secondary mechanism, specifically the thermal misfit between the liquid matrix and solid reinforcement [18, 23].

3.5. Tensile Fracture Surface Analysis of AA6082/TiB₂ AAMCs. Figure 7 depicts the tensile fracture morphology of AA6082/TiB₂ AAMCs. The fracture of the monolithic alloy shows ductile fracture with bigger size dimples, as shown in Figure 7(a). Figures 7(b)–7(d) show that the inclusion of TiB₂ content significantly diminishes the quantum of dimples. The participation of incorporated content in the parent alloy steadily changes the mode of failure between ductile fractures and brittle and ductile fractures. A significant number of flat areas are located on the AA6082/TiB₂ AAMCs fracture area, which reveals sufficiently high brittle fracture and minor ductile fracture. Figure 7(d) indicates a tremendous number of broken reinforcing particles on the fracture site, which allows for superior interfacial connections between the matrix and strengthening contents [18, 20]. A similar form of findings was revealed by other investigators in their analysis. Tian et al. [44] described that the fractography exhibits strong evidence of sound attachment between the matrix and the secondary materials leading to enriching the UTS of the AAMCs. Thangarasu et al. [45] noticed that the uniformly distributed bigger-sized voids occurred in the fracture surface of the AA6082 alloy which reveals that ductile rupture is the principal fracture mechanism. Dinaharan et al. [46] expressed the tensile fractography of AA6061/10 wt% of ZrB₂ composites exhibiting smaller size dimples compared to that of AA6061 alloy. Karbala Akbari et al. [47] noted that the presence of the
Figure 6: Influence of tensile strength on the wt% of TiB₂ particles.

Figure 7: SEM microphotographs of tensile fracture surfaces of AA6082/TiB₂ AMCs with TiB₂ content. (a) 0 wt%, (b) 3 wt%, (c) 6 wt%, and (d) 9 wt%.
The impact of TiB$_2$ on the CS of the AA6082/TiB$_2$ composite is illustrated in Figure 8. The CS was observed to enhance with the rise of TiB$_2$, and it is extremely superior to the CS of the unreinforced monolithic alloy. The occurrence of brittle and hard TiB$_2$ particles in the matrix works as a hindrance for the dislocation movement that enriches the CS of the AA6082/TiB$_2$ AAMCs. Thus, the CS of the AAMCs is drastically enhanced. The CS reaches peak values at 9 wt% of TiB$_2$ particles in the AA6082 base alloy. The important reason for the enhancement in the CS of AAMCs is the occurrence of the solid nature of TiB$_2$ particles in the soft matrix which resists the PD during compressive load. Superior compression strength may be owed to the strengthening impact of the TiB$_2$ contents. Moreover, the enhancement in the sound connection between the AA6082 and TiB$_2$ contents improves the compression strength. This outcome is in decent agreement with the upshot of Sajjadi et al. [48], Baradeswaran et al. [49] and Auradi et al. [50] have ensured that up to 20 wt% B$_4$C particles and up to 7 wt% B$_4$C particles’ compression strength is enhanced, notably with an increase in weight fraction of boron carbide.

The influence of TiB$_2$ particles on the flexural strength (FS) of AA6082/TiB$_2$ AAMCs is shown in Figure 9. The FS of AAMCs was boosted steadily with an escalation in the weight concentration of TiB$_2$ content in the matrix. The magnificent enhancement in FS of AAMCs is obtained at 9 wt% TiB$_2$ particles in the AA6082 matrix. This can be mainly ascribed to the conveying of the applied load from the soft matrix to the hard nature of TiB$_2$ particles. Enhancement in FS is also owing to the superior mechanical attachment between the TiB$_2$ and the AA6082 alloy. Hence, the value of FS at 9 wt% of TiB$_2$/AA6082 composites exhibits superior results as compared to monolithic alloys. The even dispersion of TiB$_2$ in the AAMCs offered more protection to the PD of the AAMCs which was intended to enhance the flexural strength. Normally, the addition of TiB$_2$ content upshots in a significant increase in composite strength, and the enrichment in flexural strength of the AAMCs was due to the enhanced particle weight percentage of the AAMCs. A similar enrichment is also stated by the investigator Mohanavel et al. [51] for the AA6351/AIN AAMCs.

3.7. Flexural Strength of the AA6082/TiB$_2$ AAMCs. The influence of TiB$_2$ particles on the flexural strength (FS) of AA6082/TiB$_2$ AAMCs is shown in Figure 9. The FS of AAMCs was boosted steadily with an escalation in the weight concentration of TiB$_2$ content in the matrix. The magnificent enhancement in FS of AAMCs is obtained at 9 wt% TiB$_2$ particles in the AA6082 matrix. This can be mainly ascribed to the conveying of the applied load from the soft matrix to the hard nature of TiB$_2$ particles. Enhancement in FS is also owing to the superior mechanical attachment between the TiB$_2$ and the AA6082
on the surface of the softened pin contribute to increased WR speeds. In addition, the wear protection of the composites at all loads considered was higher than that of the parent alloy.

3.9. Worn Surface Analysis of AA6082/TiB2 AMCs. The impact of TiB2 content on the morphology of the worn surfaces (WS) of AA6082/TiB2 composites is illustrated in Figure 11(a). It is detected from the figure that the worn surface of the AA6082 alloy reveals a huge quantum of plastic flow (PF) of the matrix alloy. FH is generated between the surface of the rotating pin and the counter steel disc which induces plasticity along with the matrix. The wear mode appears to be adhesive. In Figures 11(b)–11(d), the worn surfaces of the AA6082/TiB2 composite exhibit occurrence of shallow grooves and a few pits. The occurrence of TiB2 particles opposes the PF of material during wear testing [6, 22]. A mild level of PF is noticed at the boundaries of the grooves. The PF of the WS is minimized, and distinct multiple grooves like shapes start to form (Figure 11(d) as

Figure 9: Influence of flexural strength on the wt% of TiB2 particles.

Figure 10: Wear rate with varying applied load for AA6082 and AA6082/TiB2 composites.
the weight proportion of TiB$_2$ is enhanced to 9 wt%. Moreover, the delicate and parallel grooves are visible along the direction of sliding. The TiB$_2$ particle proposes opposition to the mobility of the plasticized matrix and diminishes the contact surfaces. Thus, equivalent forms of grooves are formed as the wear mode progressively transfers from adhesive to abrasive. It is additionally seen from the figure that, due to the inclusion of TiB$_2$ in the matrix, the debris is loose but not adherent to it.

4. Conclusions

In the current investigation, AA6082/TiB$_2$ AMCs were developed by the salt-metal reaction technique, and the following conclusions were derived:

(1) The AA6082 alloy AMCs strengthened with 0, 3, 6, and 9 wt% of TiB$_2$ content were effectively prepared by the in situ method.

(2) The SEM micrograph reveals the homogeneous dispersion of TiB$_2$ content in the AA6082 alloy, and the XRD plots guarantee the existence of TiB$_2$ in the produced AMCs.

(3) The UTS of the AAMCs was boosted from 176 MPa to 201 MPa with the accumulation of TiB$_2$ particles.

(4) AA6082/TiB$_2$ AAMC tensile fractures demonstrate a hybrid fracture mode, i.e., a brittle and ductile fracture mode.

(5) Flexural strength and compression strength augments drastically with the rise in TiB$_2$ particle content. Composites exhibited 47.9% superior flexural strength and 14.2% higher compression strength compared to the monolithic AA6082 alloy.

(6) The WR decreases linearly with the addition of TiB$_2$, and the minimum WR is obtained at a 9 weight percentage of TiB$_2$. The enhanced weight of TiB$_2$ particulates altered the abrasive wear characteristic from adhesion.

(7) The inclusion of TiB$_2$ particles into the AA6082 matrix has shown a great enrichment in the mechanical and wear behavior of the AAMCs.
(8) The synthesized TiB$_2$ content exhibited several morphologies like hexagonal, spherical, and cubic structures.

**Data Availability**

The data used to support the findings of this study are included in the article. Further data or information required are available from the corresponding author upon reasonable request.

**Disclosure**

This research was performed as a part of the employment of Arba Minch University, Ethiopia.

**Conflicts of Interest**

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

**Acknowledgments**

The authors thank Bharath Institute of Higher Education, Chennai, India, and K. Ramakrishnan College of Engineering, Tiruchirappalli, for providing facilities support to complete this research work. This project was supported by Researchers Supporting Project number (RSP-2021/283) King Saud University, Riyadh, Saudi Arabia.

**References**

[1] H. R. Ezatpour, M. Torabi-parizi, and S. A. Sajjadi, “Microstructure and mechanical properties of extruded Al/Al2O3 composites fabricated by stir-casting process,” Transactions of Nonferrous Metals Society of China, vol. 23, no. 5, pp. 1262–1268, 2013.

[2] K. S. A. Ali, V. Mohanavel, S. A. Vendan et al., “Mechanical and microstructural characterization of friction stir welded SiC and B4C reinforced aluminium alloy AA6061 metal matrix composites,” Materials, vol. 14, no. 11, 3110 pages, 2021.

[3] K. Ravi Kumar, T. Pridhar, and V. S. Sree Balaji, “Mechanical properties and characterization of zirconium oxide (ZrO2) and coconut shell ash(CSA) reinforced aluminium (Al 6082) matrix hybrid composite,” Journal of Alloys and Compounds, vol. 765, pp. 171–179, 2018.

[4] C. Mallikarjuna, S. M. Shashidhara, U. S. Mallik, and K. I. Parashivamurthy, “Grain refinement and wear properties evaluation of aluminum alloy 2014 matrix-TiB$_2$ in-situ composites,” Materials & Design, vol. 32, no. 6, pp. 3554–3559, 2011.

[5] V. Mohanavel, M. Ravichandran, V. Anandakrishnan et al., “Mechanical properties of titanium diboride particles reinforced aluminum alloy matrix composites: a comprehensive review,” Advances in Materials Science and Engineering, vol. 2021, Article ID 7602160, 2021.

[6] C. S. Ramesh and A. Ahamed, “Friction and wear behaviour of cast Al 6063 based in situ metal matrix composites,” Wear, vol. 271, no. 9-10, pp. 1928–1939, 2011.

[7] V. Mohanavel, K. S. Ashraff Ali, S. Prasath, T. Sathish, and M. Ravichandran, “Microstructural and tribological characteristics of AA6351/Si3N4 composites manufactured by stir casting,” Journal of Materials Research and Technology, vol. 9, no. 6, pp. 14662–14672, 2020.

[8] N. Muralidharan, K. Chockalingam, I. Dinaharan, and K. Kalaiselvan, “Microstructure and mechanical behavior of AA2024 aluminum matrix composites reinforced with in situ synthesized ZrB$_2$ particles,” Journal of Alloys and Compounds, vol. 735, pp. 2167–2174, 2018.

[9] S. Kumar, M. Chakraborty, V. Subramanya Sarma, and B. S. Murty, “Tensile and wear behaviour of in situ Al-7Si/TiB$_2$ particulate composites,” Wear, vol. 265, no. 1-2, pp. 134–142, 2008.

[10] K. Sivaprasad, S. P. K. Babu, S. Natarajan, R. Narayanasamy, B. A. Kumar, and G. Dinesh, “Study on abrasive and erosive wear behaviour of Al 6063/TiB$_2$ in situ composites,” Materials and Engineering: A, vol. 498, no. 1-2, pp. 495–500, 2008.

[11] L.-h. Zhong, Y.-t. Zhao, S.-l. Zhang, G. Chen, S. Chen, and Y.-h. Liu, “Microstructure and mechanical properties of in situ TiB$_2$/7055 composites synthesized by direct magneocoehemistry melt reaction,” Transactions of Nonferrous Metals Society of China, vol. 23, no. 9, pp. 2502–2508, 2013.

[12] S. C. Tjong and K. C. Lau, “Properties and abrasive wear of TiB$_2$/Al-4%Cu composites produced by hot isostatic pressing,” Composites Science and Technology, vol. 59, pp. 2005–2013, 1999.

[13] S. Natarajan, R. Narayanasamy, S. P. Kumares Babu, G. Dinesh, B. Anil Kumar, and K. Sivaprasad, “Sliding wear behaviour of Al 6063/TiB$_2$ in situ composites at elevated temperatures,” Materials & Design, vol. 30, no. 7, pp. 2521–2531, 2009.

[14] T. V. Christy, N. Murugan, and S. Kumar, “A comparative study on the microstructures and mechanical properties of Al 6061 alloy and the MMC Al 6061/TiB$_2$/12p,” Journal of Minerals and Materials Characterization and Engineering, vol. 09, no. 01, pp. 57–65, 2010.

[15] N. R. Rajasekaran and V. Sampath, “Effect of in-situ TiB$_2$ particle addition on the mechanical properties of AA 2219 Al alloy composite,” Journal of Minerals and Materials Characterization and Engineering, vol. 10, no. 6, pp. 527–534, 2011.

[16] C. S. Ramesh, S. Pramod, and R. Keshavamurthy, “A study on microstructure and mechanical properties of Al 6061-TiB$_2$ in-situ composites,” Materials Science and Engineering: A, vol. 528, no. 12, pp. 4125–4132, 2011.

[17] M. Wang, D. Chen, Z. Chen et al., “Mechanical properties of in-situ TiB$_2$/A356 composites,” Materials Science and Engineering: A, vol. 590, pp. 246–254, 2014.

[18] H. B. M. Rajan, I. Dinaharan, S. Ramabalan, and E. T. Akinlabi, “Influence of friction stir processing on microstructure and properties of AA7075/TiB$_2$ 2 in situ composites,” Journal of Alloys and Compounds, vol. 657, pp. 250–260, 2016.

[19] R. Shohba, K. R. Suresh, and H. B. Niranjan, “Mechanical and microstructural evaluation of InsituAluminium titanium boride composite processed by severe plastic deformation,” Procedia Materials Science, vol. 5, pp. 281–288, 2014.

[20] S. Suresh, N. Shenbagi Vinayaga Moorthi, S. C. Vettivel, and N. Selvakumar, “Mechanical behavior and wear prediction of stir cast Al-TiB$_2$ composites using response surface methodology,” Materials & Design, vol. 59, pp. 383–396, 2014.

[21] S. Poria, P. Sahoo, and G. Sutradhar, “Tribological characterization of stir-cast aluminium-TiB$_2$ metal matrix composites,” Silicon, vol. 8, no. 4, pp. 591–599, 2016.
[22] Y. Pazhouhanfar and B. Eghbali, "Microstructural characterization and mechanical properties of TiB2 reinforced Al6061 matrix composites produced using stir casting process," *Materials Science and Engineering: A*, vol. 710, pp. 172–180, 2018.

[23] B. Ashok Kumar and N. Murugan, "Metallurgical and mechanical characterization of stir cast AA6061-T6-AlINp composite," *Materials & Design*, vol. 40, pp. 52–58, 2012.

[24] K. Ravi Kumar, K. Kiran, and V. S. Sreebalaji, "Microstructural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide," *Journal of Alloys and Compounds*, vol. 723, pp. 795–801, 2017.

[25] B. Rajeswari, K. S. Amirthagadeswaran, and K. G. Anbarasu, "Investigation on mechanical properties of aluminium 7075-silicon carbide-alumina hybrid composite using Taguchi method," *Australian Journal of Mechanical Engineering*, vol. 13, no. 2, pp. 127–135, 2015.

[26] N. Mathan Kumar, S. Senthil Kumaran, and L. A. Kumarasawamidhas, "An investigation of mechanical properties and corrosion resistance of Al2618 alloy reinforced with Si3N4, AIN and ZrB2 composites," *Journal of Alloys and Compounds*, vol. 652, pp. 244–249, 2015.

[27] S. Joyson Abraham, S. Chandra Rao Madane, I. Dinaharan, and L. John Baruch, "Development of quartz particulate reinforced AA6063 aluminium matrix composites via friction stir processing," *Journal of Asian Ceramic Societies*, vol. 4, no. 4, pp. 381–389, 2016.

[28] S. D. Saravanan, M. Senthilkumar, and S. Shankar, "Effect of particle size on tribological behavior of rice husk ash-reinforced aluminum alloy (AlSi10Mg) matrix composites," *Tribology Transactions*, vol. 56, no. 6, pp. 1156–1167, 2013.

[29] S. P. Dwivedi, S. Sharma, and R. K. Mishra, "Mechanical and tribological behavior of reinforced AA6063/SiC composites," *Materials Science and Engineering: A*, vol. 7075, pp. 172–180, 2017.

[30] G. Pitchayapillai, P. Seenikannan, P. Balasundar, and P. Narayanasamy, "Effect of nano-silver on microstructure, mechanical and tribological properties of cast 6061 aluminum alloy," *Transactions of Nonferrous Metals Society of China*, vol. 27, no. 10, pp. 2137–2145, 2017.

[31] M. Ayyanar Raja, V. Manikandan, P. Amuthakannan, S. Rajesh, and I. Balasubramanian, "Wear resistance of basalt particulate-reinforced stir-cast Al7075 metal matrix composites," *Journal of the Australian Ceramic Society*, vol. 54, no. 1, pp. 119–128, 2018.

[32] S. Fale, A. Likhite, and J. Bhatt, "Compressive, tensile and wear behavior of ex situ Al/AlN metal matrix nanocomposites," *Journal of Composite Materials*, vol. 49, no. 16, pp. 1917–1928, 2015.

[33] K. Ravikumar, K. Kiran, and V. S. Sreebalaji, "Characterization of mechanical properties of aluminium/tungsten carbide composites," *Measurement*, vol. 102, pp. 142–149, 2017.

[34] P. Sharma, S. Sharma, and D. Khanduja, "A study on microstructure of aluminium matrix composites," *Journal of Asian Ceramic Societies*, vol. 3, no. 3, pp. 240–244, 2015.

[35] I. Balasubramanian and R. Maheswaran, "Effect of inclusion of SiC particulates on the mechanical resistance behaviour of stir-cast AA6063/SiC composites," *Materials and Design*, vol. 65, pp. 511–520, 2015.

[36] R. K. Bhusan and S. Kumar, "Influence of SiC particles distribution and their weight percentage on 7075 Al alloy," *Journal of Materials Engineering and Performance*, vol. 20, no. 2, pp. 317–323, 2011.

[37] P. Lakshmikanthan and B. Prabu, "Mechanical and tribological behaviour of aluminium Al6061-coconut shell ash composite using stir casting pellet method," *Journal of the Balkan Tribological Association*, vol. 22, pp. 4008–4018, 2016.

[38] T. Rajmohan, K. Palanikumar, and S. Ranganathan, "Evaluation of mechanical and wear properties of hybrid aluminium matrix composites," *Transactions of Nonferrous Metals Society of China*, vol. 23, no. 9, pp. 2589–2517, 2013.

[39] S. Gopalakrishnan and N. Murugan, "Production and wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method," *Composites Part B: Engineering*, vol. 43, no. 2, pp. 302–308, 2012.

[40] P. Sharma, S. Sharma, and D. Khanduja, "Production and characterization of AA6082-(Si3N4 + Gr) stir cast hybrid composites," *Particulate Science & Technology*, vol. 35, no. 2, pp. 158–165, 2017.

[41] J. Jebeen Moses and S. Joseph Sekhar, "Investigation on the tensile strength and microhardness of AA6061/TiC composites by stir casting," *Transactions of the Indian Institute of Metals*, vol. 70, no. 4, pp. 1035–1046, 2017.

[42] E. A. M. Shalaby and A. Y. Churyumov, "Development and characterization of A359/AIN composites for automotive applications," *Journal of Alloys and Compounds*, vol. 727, pp. 540–548, 2018.

[43] V. Sivananth, S. Vijayarangan, and N. Rajamanickam, "Evaluation of fatigue and impact behavior of titanium carbide reinforced metal matrix composites," *Materials Science and Engineering: A*, vol. 597, pp. 304–313, 2014.

[44] K. Tian, Y. Zhao, L. Jiao, S. Zhang, Z. Zhang, and X. Wu, "Effects of in situ generated ZrB2 nano-particles on microstructure and tensile properties of 2024Al matrix composites," *Journal of Alloys and Compounds*, vol. 594, pp. 1–6, 2014.

[45] A. Thangarasu, N. Murugan, I. Dinaharan, and S. J. Vijay, "Synthesis and characterization of titanium carbide particulate reinforced AA6082 aluminium alloy composites via friction stir processing," *Archives of Civil and Mechanical Engineering*, vol. 15, no. 2, pp. 324–334, 2015.

[46] I. Dinaharan, N. Murugan, and S. Parameswaran, "Influence of in situ formed ZrB2 particles on microstructure and mechanical properties of AA6061 metal matrix composites," *Materials Science and Engineering: A*, vol. 528, no. 18, pp. 5733–5740, 2011.

[47] M. Karbalaei Akbari, H. R. Baharvandi, and K. Shirvanimoghaddam, "Tensile and fracture behavior of nano/micro TiB2 particle reinforced casting A356 aluminum alloy composites," *Materials and Design*, vol. 66, pp. 150–161, 2015.

[48] A. S. Sajjadi, H. R. Ezaatpour, and H. Beygi, "Microstructure and mechanical properties of Al–AI2O3 micro and nano composites fabricated by stir casting," *Materials Science and Engineering: A*, vol. 528, no. 29–30, pp. 8765–8771, 2011.

[49] A. Baradewaran and A. Elaya Perumal, "Influence of B4C on the tribological and mechanical properties of Al 7075-B4C composites," *Composites Part B: Engineering*, vol. 54, pp. 146–152, 2013.

[50] V. Auradi, G. L. Rajesh, and S. A. Kori, "Preparation and characterization of mechanical and wear properties of stir cast AA6351-Al6061 alloy composites produced via two-stage melt stirring," *Materials and Manufacturing Processes*, vol. 29, no. 2, pp. 194–200, 2014.

[51] V. Mohanavel, K. Rajan, and M. Ravichandran, "Synthesis, characterization and properties of stir cast AA6351-
aluminium nitride (AlN) composites,” Journal of Materials Research, vol. 31, no. 24, pp. 3824–3831, 2016.

[52] S. Basavarajappa, G. Chandramohan, A. Mahadevan, M. Thangavelu, R. Subramanian, and P. Gopalakrishnan, “Influence of sliding speed on the dry sliding wear behaviour and the subsurface deformation on hybrid metal matrix composite,” Wear, vol. 262, no. 7-8, pp. 1007–1012, 2007.

[53] H. B. Michael Rajan, S. Ramabalan, I. Dinaharan, and S. J. Vijay, “Effect of TiB2 content and temperature on sliding wear behavior of AA7075/TiB2 in situ aluminum cast composites,” Archives of Civil and Mechanical Engineering, vol. 14, no. 1, pp. 72–79, 2014.

[54] K. Soorya Prakash, A. Kanagaraj, and P. M. Gopal, “Dry sliding wear characterization of Al 6061/rock dust composite,” Transactions of Nonferrous Metals Society of China, vol. 25, no. 12, pp. 3893–3903, 2015.

[55] J. J. Moses, I. Dinaharan, and S. J. Sekhar, “Production and characterization of titanium carbide particulate reinforced AA6061 aluminum alloy composites using stir casting,” Metallic Materials, vol. 54, no. 4, pp. 257–267, 2016.