

Research Article

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Investigating the influence of SiC and B₄C reinforcements on the mechanical and microstructural properties of stir-casted magnesium hybrid composites

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Abstract: This study based on Mg-based hybrid composites investigates the impact of silicon carbide (SiC) and boron carbide (B₄C) reinforcements on the mechanical and microstructural properties of magnesium (Mg) hybrid composites fabricated via the novel vacuum-assisted stir casting. Three hybrid Mg composites, MC1 (Mg-2 wt% SiC-3 wt% B₄C), MC2 (Mg-3 wt% SiC-2 wt% B₄C), and MC3 (Mg-2.5 wt% SiC-2.5 wt% B₄C) were fabricated to evaluate the influence of variations in reinforcement ratios on mechanical, microstructural and hardness of the composites. Results showed that magnesium composite MC2 exhibited the highest compressive strength and microhardness, which is attributed to the optimal load transfer and refined grains by SiC, whereas MC3 achieved the best ultimate tensile strength. The microstructural analysis confirmed uniformly dispersed particles without agglomeration. These findings suggest that SiC- and B₄C-reinforced Mg hybrid composites offer enhanced strength, hardness, and wear resistance, making them suitable for high-performance applications in aerospace and automotive industries.

Keywords: magnesium, hybrid composites, silicon carbide, boron carbide, stir casting, mechanical properties, microstructural properties

1 Introduction

Aluminum and its alloys have demonstrated themselves to be the most dependable lightweight materials in recent decades, and they have been extensively utilized in the production of space and automotive components. Because of their low-density and high specific strength, which can reduce fuel consumption and carbon emissions, magnesium and its composites have found substantial applications as listed in Figure 1. Unfortunately, the low strength, low modulus, inadequate resistance to creep at elevated temperatures, and wear resistance of applications for magnesium alloys are limited [1]. Consequently, to enhance the base metals' qualities, reinforcements are required. The lightest metal structural material available, magnesium matrix composites offer greater creep and wear resistance at high temperatures, high strength, and high elasticity over monolithic magnesium or magnesium alloys [2,3]. In particular, magnesium is the lightest structural metal, weighing 33% less than aluminum. Unfortunately, some disadvantages that limit the application of magnesium alloys under service circumstances include their high oxidation rate and low wear resistance [4,5]. Nevertheless, metal matrix composites based on magnesium can be used to get around these restrictions. The creation of magnesium-based composites is a demanding task since magnesium can oxidize or cause nanoparticles to aggregate [6,7].

When reinforced with different materials, magnesium metal matrix composites show excellent mechanical properties like high strength, high elasticity, and hardness at extreme temperatures as listed in Figure 2. When it comes to composite materials, the choice of reinforcement is crucial [8]. Under the specified operating conditions, reinforcement material shall have a non-reactive nature and be thermally stable. The size and distribution of the reinforcing particles are key factors in improving the mechanical

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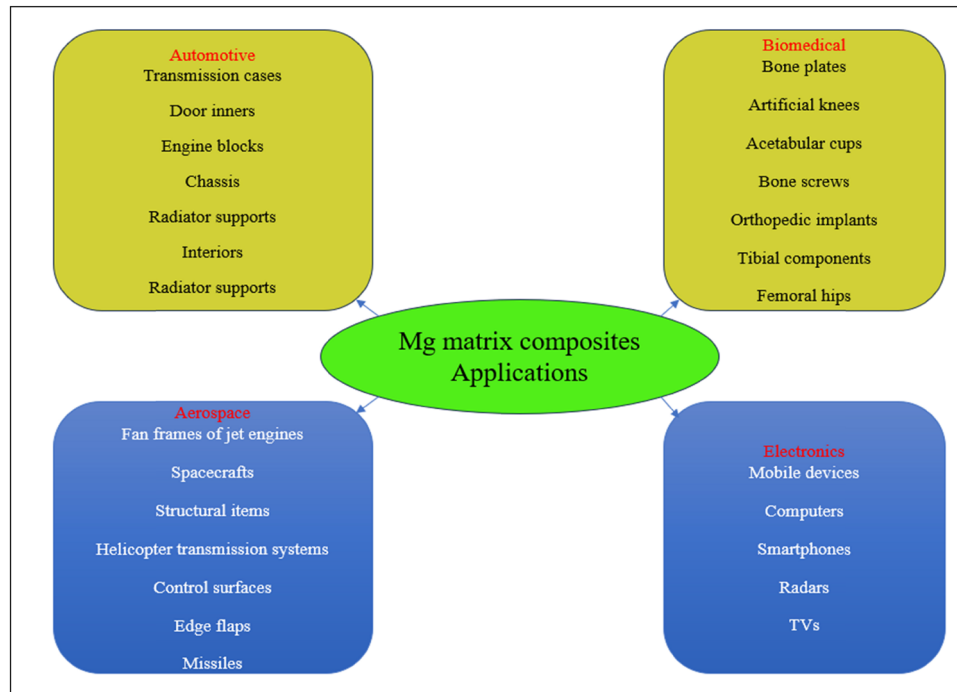


Figure 1: Applications of Mg-based MMC.

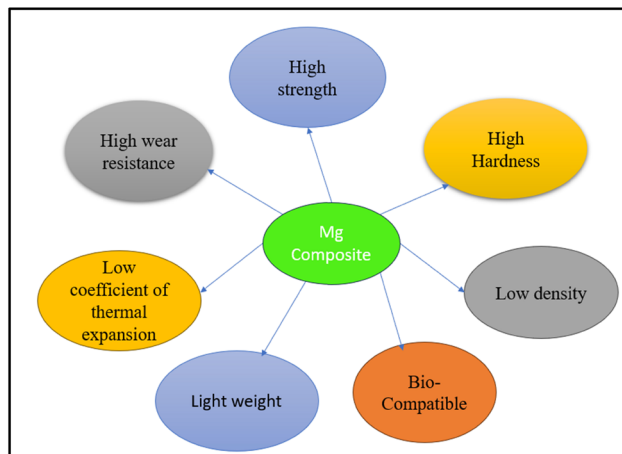


Figure 2: Different magnesium matrix composite properties.

qualities of metal matrix composite (MMC). Particulate-reinforced metal matrix composites, however, can be made using a variety of methods, including spray deposition, powder metallurgy, and stir casting [9,10].

Some of the commonly used reinforcements like SiC improve magnesium and its alloys' ultimate tensile strength, yield strength, hardness, ductility, and wear resistance [11]. Al_2O_3 reinforcement results in strong compressive strength and good creep resistance. The effective load transmission between the plastic flow in the matrix and the fibers causes creep strengthening [12]. The addition of

carbon nanotubes to magnesium matrix composites improves their wettability, bonding strength, and tensile strength. However, the basal plane texture may become weaker as a result of the CNT addition [13,14]. One of the known hardest elements is boron carbide (B_4C). Its fracture toughness and elastic modulus are high. The incorporation of magnesium with B_4C improves the hybrid composite's hardness, wear resistance, flexural strength, and interfacial bonding strength [15].

The impact of particle size on the microstructure and mechanical properties of the SiCp/AZ91 magnesium matrix composite was examined by Wang *et al.* [10]. Submicron SiCp particle volume fractions as low as 2% in composites significantly impacted the strengthening and refining of the grain. Agglomerated submicron SiC particles caused mechanical characteristics to decrease as the volume percentage rose to 5 and 10%. The strengthening impact increased as the volume fraction increased. Using an ultrasonic technique, Zhao-Hui *et al.* [11] created a magnesium matrix composite enhanced with SiC nanoparticles. According to the microstructural assessment, ultrasonic vibration can help distribute the nanoparticles evenly and effectively throughout magnesium alloys. When compared to matrix alloy, the mechanical characteristics of composites were much better and their grains were more polished. The heterogeneous nucleation of β -Mg can be facilitated by SiC nanoparticles. The microstructure and mechanical characteristics of

particulate-reinforced magnesium matrix composites were assessed by Deng *et al.* [12] at a high temperature and 50% lower height. Using neutron diffraction, the texture of the forged composites was assessed. During forging, a robust basal plane texture developed, and as the forging temperature rose, the texture's intensity decreased. The hot forging greatly increased the particle distribution. The microstructure and mechanical characteristics of SiC-reinforced magnesium composites made using spark plasma sintering technology were assessed by Sajuri *et al.* [13]. The investigation revealed that the optimal sintering temperatures for the magnesium and AZ31 alloy were 585 and 552°C, respectively. Hardness and tensile strength – two mechanical properties – rose as the SiC content rose to 10 wt%. The aggregation of SiC particles causes the tensile strength to diminish with further increases in SiC concentration. The decrease in the interfacial bonding strength between the matrix and reinforcement was seen as a result of the agglomeration of SiC particles. The B₄C particulate-reinforced magnesium metal matrix composites with varying volume fractions (10, 15, and 20 vol% B₄C) were created by Jiang *et al.* [14]. The microstructure's characterization showed that the B₄C particle distribution in the matrix was necklaced. MgO and MgB₂ production was revealed by X-ray diffraction (XRD) analysis in B₄C/Mg composites. The composites' hardness and wear resistance increased dramatically when B₄C particle content rose from 10 to 20 vol%. A novel technique for manufacturing B₄C particulate-reinforced magnesium-matrix composites was put forth by Yao and Chen [15]. Enhancing the wettability of the metal melt infiltration composite production process is necessary. The ceramic performs with the metal melting. Shen *et al.* [16] have examined the mechanical behavior of a lanthanum-doped magnesium alloy, AZXE7111 (Mg–7Al–1Zn–1Ca–1La, all in weight percent), extruded at various temperatures. Comparing the

unreinforced AZ91D alloy and AZ91D-B₄C composites examined by Aattisuhgan [17], graphite-reinforced hybrid composites showed less wear loss. On the other hand, at 800 rpm and 40 mm/min travel speed, the inclusion of Al₂O₃ reinforced in a magnesium (AZ91 alloy) matrix with 0.8 vol% Al₂O₃ demonstrated optimal hardness and wear resistance [18]. For Mg MMCs, 10, 20, and 30 wt% additions of SiC particles were made. The porosity of the composites changed dramatically, while the density did not. The Mg/30 wt% SiC particle composite showed notable improvements in hardness, tensile strength, and compressive strength [19,20]. The Mg-10% SiC + 10 wt% Al₂O₃ sample had the maximum hardness and the Mg-5% SiC + 5 wt% Al₂O₃ sample had the best wear resistance [21]. The hardness of reinforced magnesium was higher than that of non-reinforced magnesium [9,22]. This work examined the effects of SiC, and B₄C, as reinforcing materials on the microstructural and mechanical characteristics of Mg-based MMC [23,24].

2 Experimentation

2.1 Materials

To fabricate the hybrid composite, the selected matrix material is Mg and the selected reinforcements are silicon carbide (SiC) and B₄C. The turnings of Mg were procured to ensure a lower content of impurities and also easy melting of the matrix. Both the reinforcements procured are ceramic particles of purity of 99.5%. The SiC powder has an average particle size of 40 µm and is white in color. The B₄C powder also has a particulate structure with an average particle size of 150 µm and is black in color. The physical images of the procured materials are shown in Figure 3.

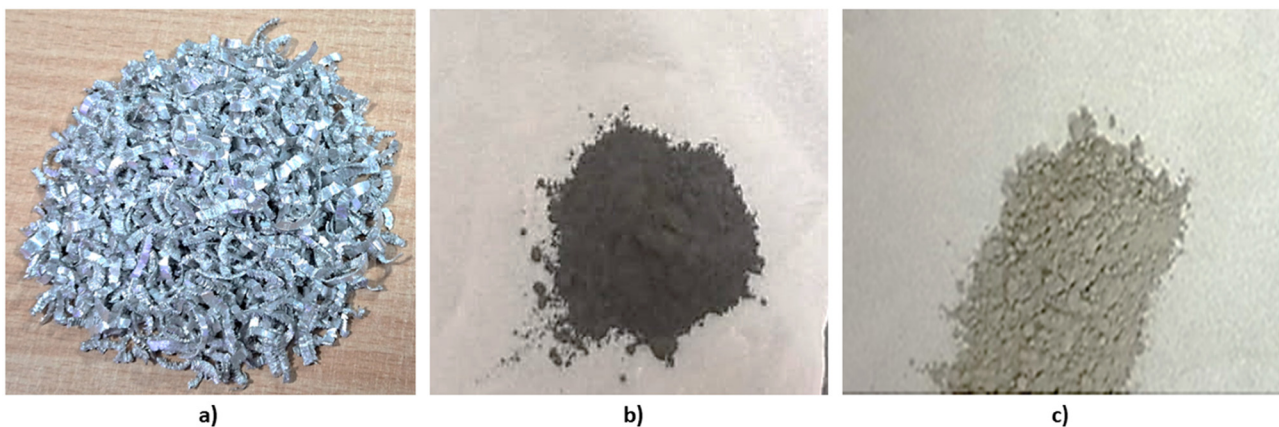


Figure 3: Images of the procured materials: (a) magnesium turnings, (b) SiC, and (c) B₄C.

2.2 Hybrid composite fabrication

The Mg turnings of 97.5 wt% were melted at a temperature of 720°C under a protective gas mixture (80% Argon [Ar] and 20% SF₆) within the furnace of a vacuum-assisted stir casting machine. Subsequently, the microparticles of SiC and B₄C were added as reinforcements by varying their compositions as shown in Table 1 to fabricate the desired magnesium hybrid composites (MHCs).

Prior to addition, the reinforcements were heated initially at 200°C to eliminate any presence of moisture or unwanted impurities. To prevent oxidation of the MHCs, a stir casting machine with a gas purging facility was selected and the entire process of stir casting was performed in a controlled, inert atmosphere comprising 80:20 Ar:SF₆ ratio. 300 rpm of stirring speed and 25 min of stirring duration were employed to ensure uniform dispersion of the reinforcement particles within the composite. The melt temperature was maintained at 700°C in the furnace. The mould cavity was maintained in a vacuum and the air was pumped out. This was done to ensure that no oxidation occurs within the casting during the pouring time. This process also eliminates porosity and a nice, dense casting is formed which is devoid of any casting defects. Vacuum-assisted stir casting was chosen to minimize porosity,

Table 2: The operating parameters of the stir-casting machine

S. no.	Description	Specification
1	Furnace temperature	800°C
2	Melt temperature	700°C
3	Preheater temperature	200°C
4	Mould temperature	200°C
5	Gas flowrate	2 LPM
6	Argon-sulfur hexafluoride ratio	80–20
7	Stirrer speed	300 rpm
8	Stirring duration	25 min

oxidation, and agglomeration during fabrication, ensuring dense and defect-free composites. The process parameters are shown in Table 2.

The typical stir-casting set-up is represented in Figure 4. The final casting was obtained after allowing it to be cooled naturally under ambient conditions. Three MHC samples MC1 (Mg-2SiC-3B₄C), MC2 (Mg-3SiC-2B₄C), and MC3 (Mg-2.5SiC-2.5B₄C) of varying reinforcement compositions have been prepared of dimensions 300 mm length, 15 mm width, and 15 mm thickness.

2.3 Tensile test

The dog bone-shaped tensile test samples, of the MHCs were cut using wire-cut electrical discharge machine (WEDM) from the obtained casting. The ASTM E8 standard was followed for tensile testing of MHCs. The cut samples are represented in Figure 5. A universal testing machine of Instron, WTI Company having a crosshead speed of 0.01 mm/s was used for the study. The testing was done at Osmania University, Hyderabad.

Table 1: The compositions of the prepared MHCs

Sample code	Magnesium matrix (wt%)	Reinforcement 1 SiC (wt%)	Reinforcement 2 B ₄ C (wt%)
MC1	95	2	3
MC2	95	3	2
MC3	95	2.5	2.5

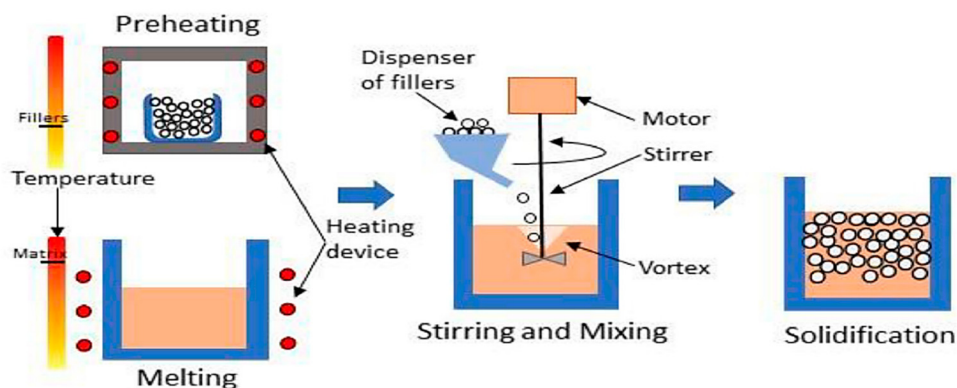


Figure 4: Stir casting set-up.

2.4 Compressive test

The compressive test samples of the MHCs were cut according to the ASTM E9 standards into a 10 mm cube through WEDM. The testing was done at Osmania University Hyderabad. A universal testing machine of Instron, WTI Company, was used for the study.

2.5 XRD test

The XRD test was done on the fabricated MHCs with Cu-K α radiation. 45 kV was the operating voltage and 40 mA was the operating current. The XRD was done to know about the various phase components within the MHC. The scanning of the MHC samples was done through a 20°–80° incidence angle over 2θ range. The XRD analysis was carried out to identify the phases as well as the reaction products within the fabricated MHCs. The specimens needed for XRD test were cut into a square of 10 mm side and 5 mm thickness and subsequently ground to make it free of errors. The X-ray diffractometer's geometry is such that the sample spins at an angle θ in the collimated X-ray beam path, while the X-ray detector is mounted to an arm and rotates at an angle of 2θ to collect the diffracted X-rays. With the help of a goniometer, an instrument that measures the angle, is measured by rotating the sample.

2.6 Microhardness

The microhardness indentation tests were performed on the samples cut out from the composite casting obtained from the vacuum-assisted stir-casting machine using Vickers Hardness Tester available at Adityapur Auto Cluster (Hi-tech Lab & Business Centre), Jamshedpur. Prior to the test, the cut

samples were prepared as per the ASTM standards. The specimens were polished with SiC emery papers of different grits up to 2,500 grits to eliminate all kinds of impurities and obtain a smooth surface [25]. This was followed by polishing the samples on a disc polishing machine which makes use of a diamond paste of 1 μ m particle size. The paste acted as a fine polishing agent over the material surface to obtain a mirror-like surface. To perform the Vickers hardness test, a diamond indenter with a square base and having 136° vertex angle was used and a load of 100 gf was applied. The dwell time of the applied load was 10 s. The impression made due to the application of the load was analyzed and the microhardness value was determined. To obtain the average microhardness, the values were analyzed at five different locations on each of the specimens.

2.7 Microstructural characterization

The observation of the composite's microstructure was accomplished through a scanning electron microscope. The composite samples were cut into a cube of dimensions of 10 mm³. The samples were cut from the obtained casting and prepared so as to be observed under the SEM. Emery papers of different grades were used to polish the surface of the cut composite sample and also to remove any unwanted contaminations. This ensured that the sample was free of impurities and also ready to be observed under SEM.

3 Results and discussion

3.1 Microstructure analysis

The microstructure of the fabricated MHCs has been imaged via scanning electron microscopy. The SEM images of the



Figure 5: Dimensions of the tensile test specimen as per ASTM standards.

samples MC1, MC2, and MC3 are represented in Figure 6. It can be seen in the SEM images that the morphologies of all the composites are similar. Also, from the SEM images it can be observed that the fabricated MHCs are devoid of cavities. This is a clear indication that good quality castings have been produced and the selected stir casting parameters are best suited for the fabrication of the composites. Good quality castings possess good mechanical strength. In the sample MC1, comprising of a higher quantity of B_4C , uniformly dispersed particles of B_4C are strikingly visible in the form of dark precipitates. The precipitation of B_4C in the form of dark precipitates increases with increasing content of B_4C in the magnesium matrix [23]. The particles of B_4C are depicted using red arrows in Figure 6a). The visibility of SiC particles in MC1 is negligible. In the hybrid composite sample MC2, which comprises a higher concentration of SiC than B_4C , uniformly dispersed particles of SiC are strikingly visible, but there is no visibility of the B_4C particles. It has been depicted in yellow arrows in Figure 6b). The properties of SiC make it the most suitable for magnesium matrix as it has a significant, positive impact on the strength and hardness of a composite. Moreover, SiC reinforcement is inexpensive compared to other materials [24]. As seen in the sample MC3, a proper amalgamation of both the reinforcements SiC and B_4C can be seen. Moreover, this is spread

uniformly across the entire composite [26]. This signifies that the composites prepared are capable of exhibiting exceptional mechanical properties. One good aspect of the fabricated composite is that there are no clusters or agglomeration of the reinforcement seen anywhere. The composite thus shall exhibit enhanced properties uniformly throughout its area.

3.2 XRD analysis

The XRD analysis of MHC, S3 Mg-1.5SiC-1.5 B_4C , is seen in Figure 7. The XRD patterns show a wide range of diffraction peaks which can be associated with Mg, SiC, and B_4C structures. Among all the peaks, α Mg is the main phase in the composite as it is exhibited via high-intensity peaks. The peaks of Mg at 2θ values of 32° , 34° , 37° , 48° , and 70° demonstrate the hexagonal close-packed (HCP) structure of Mg crystal with (1 0 0), (0 0 2), and (1 0 1) planes. The observed peaks of SiC and B_4C are much smaller in comparison to Mg which is an indication that there is the presence of the reinforcements in small quantities. The peaks of SiC and B_4C are seen at 2θ angles 38° , 49° , and 70° of (2 0 0), (2 2 0), and (3 1 1) planes and 36.11° , 65.19° , and 72° of (1 1 1),

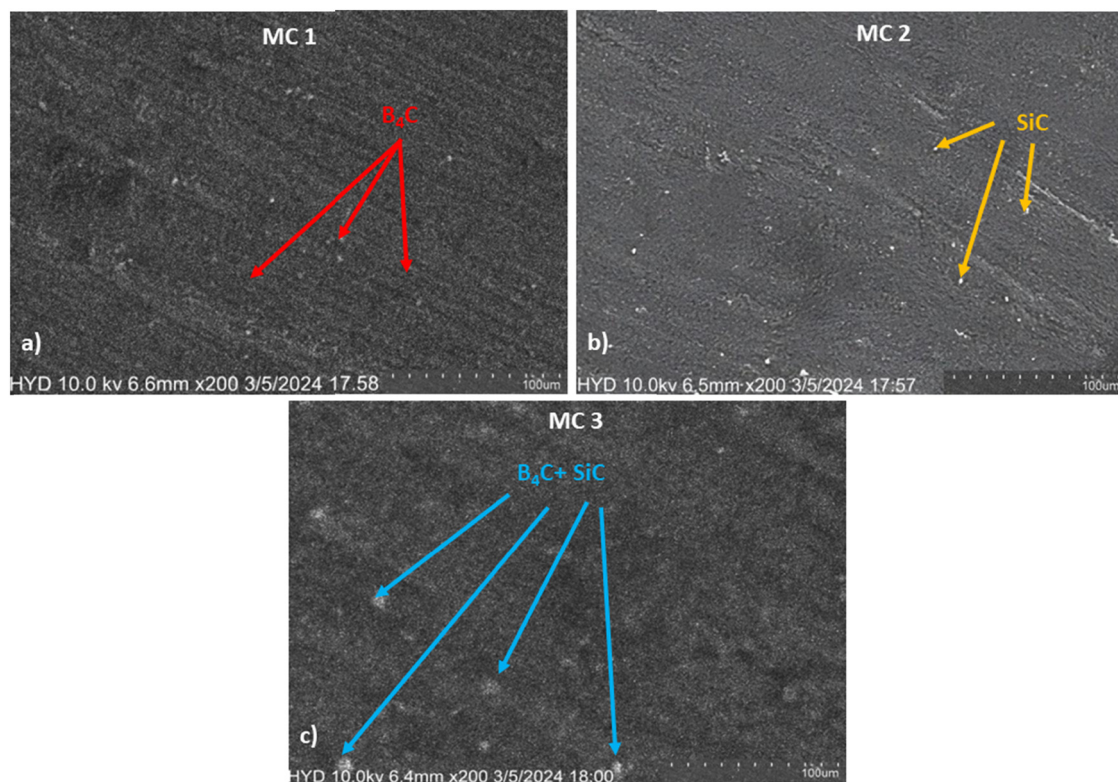


Figure 6: SEM images of the fabricated MHCs: (a) MC1 (Mg-2SiC-3 B_4C), (b) MC2 (Mg-3SiC-2 B_4C), and (c) MC3 (Mg-2.5SiC-2.5 B_4C).

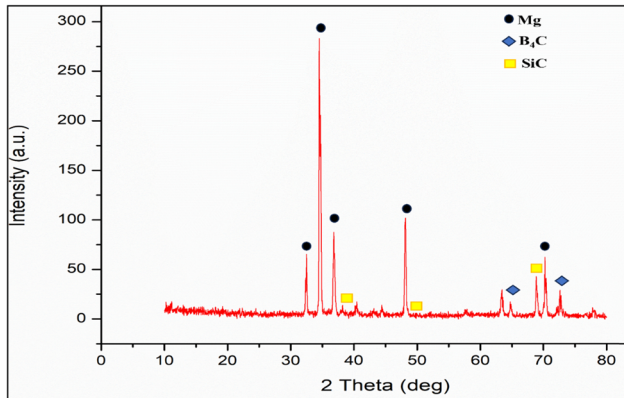


Figure 7: XRD patterns of the Mg hybrid composite sample MC3.

(2 2 0), and (3 2 1) planes, respectively. There are no indicators or the formation of any intermetallic compounds within the MHC. This is another proof of a good quality composite formed.

3.3 Tensile test

Figure 8(a) represents the stress–strain curve of the composite samples, after carrying out the tensile test on the UTM. The values of yield tensile stress (YTS), ultimate tensile stress (UTS), and percentage elongation of the samples are 124.7 MPa, 156.9 MPa, and 5.76% for MC1, 119.5 MPa, 162.6 MPa, and 5.51% for MC2, and 125.4 MPa, 173.5 MPa, and 5.34% for MC3, respectively. The values of the tensile

strength obtained are much superior than that of pure Mg which is about 100.47 MPa [27].

The graphs in Figure 8 indicate that adding SiC and B₄C has significantly enhanced the strength of the composites. Grain refining during the solidification process is responsible for the increased YTS and ultimate tensile strength. This increase in both tensile and yield strength follows the Hall–Petch relation, which is described by the following equation [28]:

$$\sigma_y = \sigma_0 + K_y d^{-1/2}. \quad (1)$$

In this formula, σ_y represents the yield strength, σ_0 is a constant that accounts for friction stress within the material, K_y is a constant that measures how much grain boundaries strengthen the material, and d is the average grain size. The value of K_y is influenced by the number of slip systems, which are specific planes and directions in the crystal structure that allow dislocations to move and cause deformation. Typically, metals with face-centered cubic or body-centered cubic structures offer multiple ways to deform. Interestingly, even HCP metals like magnesium can exhibit significant flexibility under specific conditions. For magnesium, the HCP structure makes grain size crucial. Smaller grains introduce more boundaries, hindering the movement of defects known as dislocations. This increased resistance to dislocation movement ultimately enhances the metal's yield strength [29].

The presence of SiC and B₄C reinforcements also improves the load-bearing capacity of the composite, as these particles have a much higher modulus of elasticity

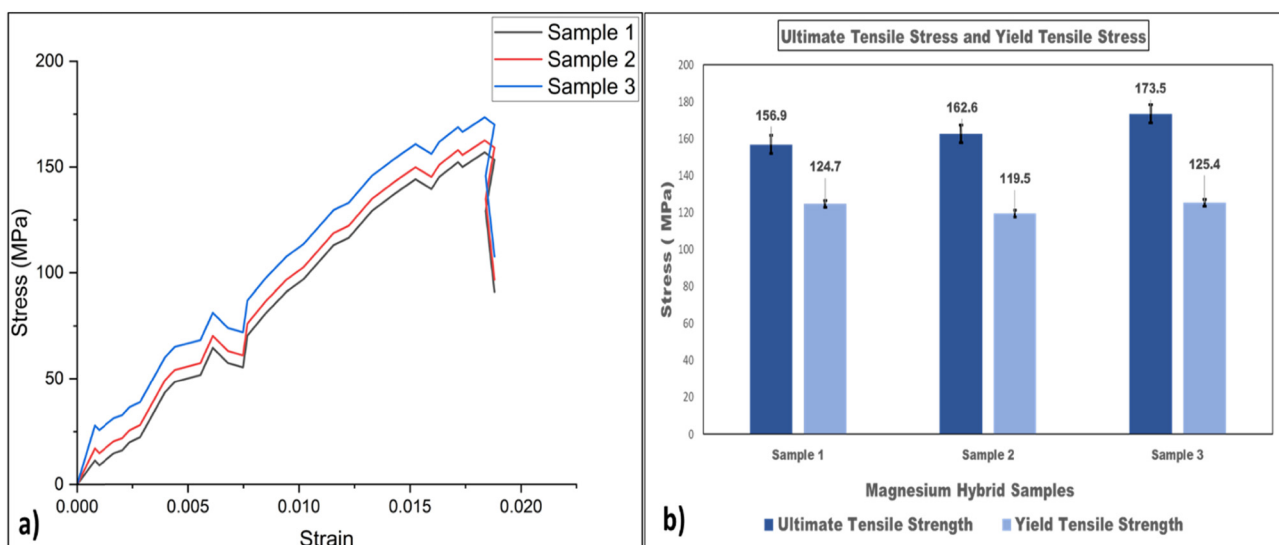


Figure 8: (a) Stress–strain curves of the composite samples obtained in the tensile test. (b) Bar graphs indicating the UTS and YTS values of the composite samples.

compared to the magnesium matrix. This disparity means that the ceramic particles can carry more of the applied load, resulting in an overall increase in the tensile strength of the composite. Additionally, these reinforcements can refine the grain size of the magnesium matrix through a process known as grain boundary pinning, which also contributes to the enhanced strength.

However, it is important to note that while the tensile strength increases with the addition of SiC and B₄C, this may also lead to a reduction in ductility. The ceramic particles can act as stress concentrators, making the composite more prone to cracking under high strain.

The stress–strain curve in Figure 8 clearly demonstrates that adding 2.5 wt% to each of both the reinforcements to the composites enhances the yield and tensile strength, meaning that they can handle greater stress before starting to deform. This is clearly evident in sample 3 consisting of equal quantities of SiC and B₄C. This is an indication that both reinforcements contribute toward the enhancement of material strength. However, the increased quantity of SiC reinforcement also causes a reduction in tensile strain, indicating that the material loses some of its flexibility and becomes less ductile. This is evident in sample MC2 with 3 wt% of SiC. In simpler terms, although the composites become stronger and can bear more load, they also

become more brittle and less capable of stretching or bending without breaking. Also, the samples with a higher quantity of reinforcement SiC exhibited better tensile properties than the sample with a higher B₄C weight percentage. SiC and B₄C reinforcements can significantly enhance the tensile strength of magnesium (Mg) composites. When these ceramic particles are added to magnesium, they act as strengthening agents, distributing the load more effectively across the composite and impeding the movement of dislocations, which are defects in the crystal structure that can lead to deformation. The high hardness and strength of SiC and B₄C particles contribute to this effect, making the Mg composites more resistant to tensile stress.

In magnesium (Mg) composites with both B₄C and SiC reinforcements, the resulting microstructure has a big impact on how the material fractures. The B₄C particles create more interfaces within the composite, which act as obstacles to crack growth, making the composite stronger and harder. This leads to a more complex fracture surface. Adding B₄C and SiC also improves the material's fracture toughness by promoting crack deflection and bridging at the interfaces between the magnesium matrix and the reinforcement particles. This better stress distribution slows down crack growth and results in a more ductile failure. When these composites break, they often show a mix of

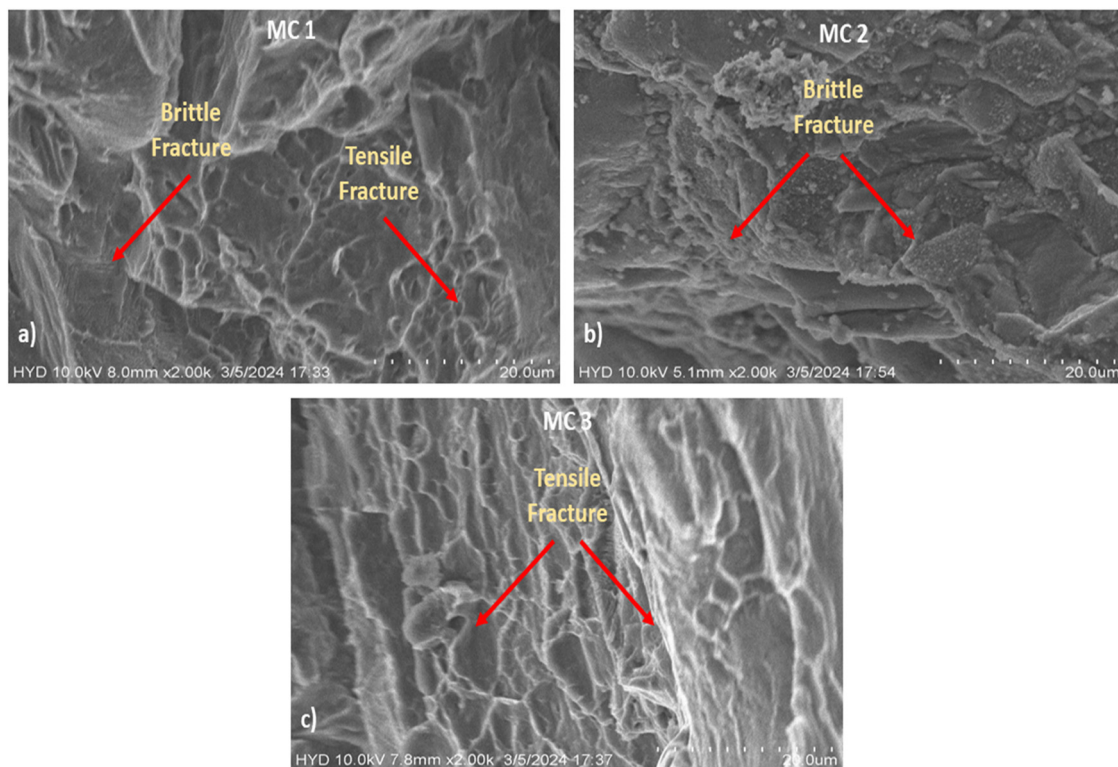


Figure 9: Tensile fracture morphologies of (a) sample MC1, (b) sample MC2, and (c) sample MC3.

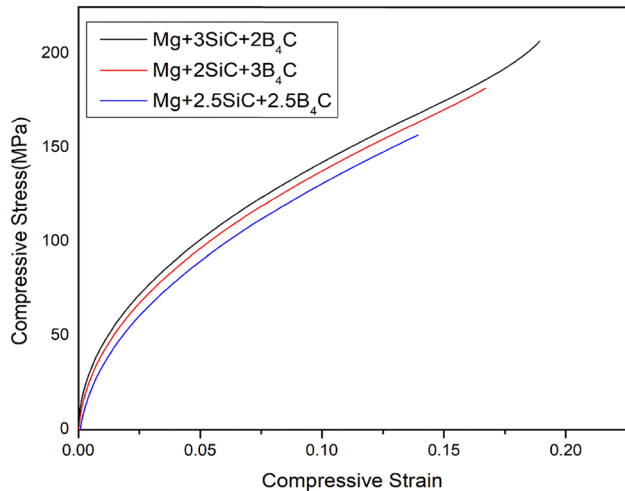


Figure 10: The compressive stress–strain curve of the fabricated magnesium composite samples.

ductile dimpling and brittle failure patterns, thanks to the hard reinforcement particles. Cracks typically start at the interfaces but are often slowed or redirected within the more flexible magnesium, which helps make the material tougher overall.

Figure 9 represents the tensile fracture morphologies of the composites MC1 (Mg-2SiC-3B₄C), MC2 (Mg-3SiC-2B₄C), and MC3 (Mg-2.5SiC-2.5B₄C), respectively. In the composite sample MC1, from the fractography images, it can be observed that there is the presence of both tensile and brittle fractures. This is also called a mixed-mode fracture. The presence of SiC particles has resulted in the formation of cleavages and micro-cracks which indicates brittle fracture. Due to the presence of B₄C, there is the formation of dimples which indicates tensile fracture. Due to the high concentration of B₄C, it can be seen that the percentage of dimples is higher than that of the cleavages. This is an

indication that high content of B₄C leads to tensile fractures. In the case of MC2 sample due to the existence of 3 wt% SiC, it can be seen that the composite exhibits brittle fracture. SiC usually favors a balance between strength and ductility, enhancing ultimate tensile strength while providing some brittleness, especially at higher concentrations. Though there is an increase in the tensile strength, it is due to the presence of B₄C. SiC also adds to the tensile strength; however, its high content has led to brittle fracture. In the composite sample MC3 with equal weight percentages (2.5 wt% each) of SiC and B₄C, the fractography image shows only tensile fracture, and thus, it has the highest value of UTS among all the composite samples. This is an indication that both the reinforcements add to the tensile strength and also it is the presence of B₄C and SiC that led to this fracture morphology.

3.4 Compressive test

The results obtained from the compression test of the composite specimens are plotted in Figure 10. The UCS values of the composites MC1 (Mg-2SiC-3B₄C) 206.82 MPa, MC2 (Mg-3SiC-2B₄C) 181.81 MPa, and MC3 (Mg-2.5SiC-2.5B₄C) 156.82 MPa, respectively.

From the stress–strain curve of the compressive strength, it can be clearly observed that the sample MC2 comprising 3 wt% of SiC and 2 wt% B₄C exhibits the highest compressive strength as compared to MC2 and MC3. This is due to the fact that SiC particles have a significant effect in enhancing the compressive properties in the Mg-based composite due to better load distribution and fewer stress concentrations at the particle–matrix interface, which contributes to overall strength. Moreover, an increase in SiC particles increases the compressive strength. This is due to the refined grains

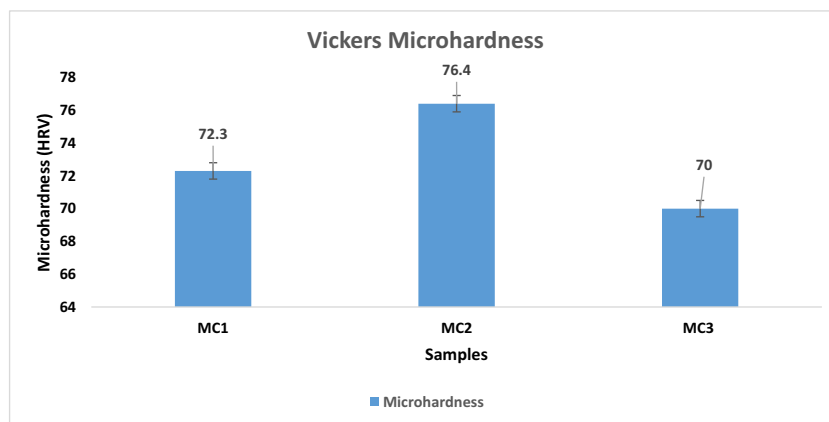


Figure 11: Vickers microhardness values of the composites.

which occurs when increasing the percentage of SiC particulate. Also, B₄C reinforcement improves interfacial bonding between the matrix and reinforcing particles, which is crucial for enhancing the compressive strength of the Mg composites. The least compressive strength is seen in MC3 with 2.5 wt% each of both the SiC and B₄C reinforcements. This is due to the fact that the presence of a high weight fraction of B₄C (2.5 wt%) reinforces ductility and toughness in the composite than the compression strength. Also, the B₄C particles enhance overall strength and facilitate a more favorable ductile fracture mode by more efficiently absorbing energy during deformation.

3.5 Microhardness

The Vickers microhardness test was carried out on the magnesium composite samples as represented in the bar graphs in Figure 11. The microhardness values obtained for samples MC1 (Mg-2SiC-3B₄C), MC2 (Mg-3SiC-2B₄C), and MC3 (Mg-2.5SiC-2.5B₄C) are 72.3, 76.4, and 71.2, respectively.

All the obtained microhardness values are close to each other. It is to be understood that both SiC and B₄C significantly enhance the microhardness of the magnesium-based composites, but they do so through different mechanisms. SiC tends to provide greater strength by forming hard phases and improving load transfer, whereas B₄C enhances both hardness and toughness due to its superior interfacial bonding and structural attributes. As per the obtained values, it can be seen that the maximum hardness value has been observed in the MC2 MHC which consists of 3 wt% of SiC and 2 wt% of B₄C. This is due to the fact that, at 3 wt%, an ideal dispersion of SiC particles within the magnesium matrix is achieved, facilitating the transfer of stress from the matrix to the SiC particles under applied loads, resulting in enhanced resistance to deformation and improved hardness. Effective load transfer and microstructural strengthening are the prime reasons for this. Adding 2 wt% B₄C greatly boosts microhardness. The inherent features of B₄C particles increase the composite's toughness and resistance to deformation.

4 Conclusions

- The following are the conclusions of the fabricated magnesium-based hybrid composites comprising SiC and B₄C as the reinforcements *via* the process of stir casting.

- Microstructural analysis revealed uniform dispersion of both SiC and B₄C particles without agglomeration, contributing to consistent mechanical performance across the composite material.
- The XRD analysis confirmed the absence of intermetallic compounds, indicating a high-quality composite that retains the properties of the reinforcements without undesirable phase formations.
- The addition of SiC and B₄C reinforcements significantly improved the mechanical properties of magnesium composites, with optimized samples showing higher tensile and compressive strength, microhardness, and wear resistance.
- The sample MC3 with equal reinforcement distribution (2.5 wt% each of SiC and B₄C) exhibited the highest UTS ultimate tensile strength, implying a balanced reinforcement impact that enhances tensile properties without sacrificing ductility.
- The composite with 3 wt% SiC and 2 wt% B₄C (MC2) exhibited the highest microhardness and compressive strength due to the refined grain structure and superior load transfer capabilities of SiC.
- Thus, from the study conducted, it can be said that Mg-based hybrid composites reinforced with SiC and B₄C have promising potential for high-performance applications requiring lightweight materials with enhanced strength, hardness, and durability. In the fabricated hybrids, by considering all of the factors like tensile strength, compressive strength, hardness, and uniform microstructural dispersion of the reinforcements, it can be said that the composite MC2 (3 wt% SiC and 2 wt% B₄C) is the best suited for high-performance applications that require superior material characteristics.

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Conflict of interest: Authors state no conflict of interest.

Data availability statement: All data generated or analyzed during this study are included in this published article.

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