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Research Article

Characteristics of A6061/(Glass Fibre + AL_2O_3 + SiC + B_4C) Reinforced Hybrid Composite Prepared through STIR Casting

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In this article, A6061 and its reinforcement particles like aluminium oxide/glass fibres/SiCp/B_4C (4% and 5%) with mixed composite and aluminium oxide/SiCp/B_4C mixed without glass fibre composite are produced with different proportions using the stir casting method. Here, some experimental study is carried out on the composite layer through scanning electron microscopy and XRD test to show the influence of the reinforcement on A6061, and the percentage of gold-silver-copper (AuAgCu), aluminium-zinc (ZA), and palladium deuteride is increased in this composition and justified through the graphical representation of the XRD image. Mechanical properties of the stir casting composites were evaluated through microhardness, wear test under 200 rpm and 300 rpm and 20 N and 50 N, and tensile tests. The results were compared with the properties of the base metal, with glass fibre reinforcement specimen and without adding glass fibre specimen; this will help us to check the strength and weakness of the glass fibres in A6061.

1. Introduction

Stir casting is an economical process for the fabrication of aluminium matrix composites. There are many parameters in this process, which affect the final microstructure and mechanical properties of the composites. In this study, micron-sized SiC particles were used as reinforcement to fabricate Al-3 wt% SiC composites at two casting temperatures (680 and 850°C) and stirring periods (2 and 6 min). From microstructural characterizations, it is concluded that a shorter stirring period is required for ceramic incorporation to achieve metal/ceramic bonding at the interface. The higher stirring temperature (850°C) also leads to improved ceramic incorporation. In some cases, shrinkage porosity and intensive formation of Al_4C_3 at the metal/ceramic interface are also observed [1].

The unique properties of the composites include high specific stiffness matrix with the reinforcement and controlled coefficient of thermal enlargement because of low density and great strength, and they can withstand up to its raised temperatures to maintain the superior dimensional stability [1–9]. In the dispersed form of the matrix phase, it is more vigorous. So, it is called as the reinforcement phase. In this work, the different propositions of the specimens are made, and the appearance of the wear demeanour of MMC has been investigated with positive results [1, 2]. Aluminium-based Al_2O_3 composite is found in various engineering applications specifically producing the automotive components. These are very difficult to machine because of the hardness and abrasive nature of the reinforcement element like alumina particles [4]. So, if we add the reinforcement Al_2O_3/glass fibres/SiCp/B_4C with A6061, we can improve the machinability.

This paper depicts an examination strategy to enhance the creation procedure states of the high wear opposition of Al compound lattice composites strengthened with various volume rates of boron carbide particles. A trial examination was then completed on the rough wear conduct of the composites as far as grating molecule size, weight part, and connected burden in stick on-circle sort of wear machine [10].

The research explicits that these kinds of alloys are the best suited for the bulk production of casting components. A6061 has enormous benefits such as machinability and good weldable characteristics, and these can be manufactured at very economic price [5, 6, 11].

The hybrid composite performance is a considered sum of the separate components in which there is a more favorable balance between reinforcement added and the advantages and disadvantages of its characteristic. The objective of this work is to investigate the wear and friction behavior of A6061 alloy reinforced with PRMMC for good performance and produce light-weight hybrid metal matrix composite materials [7, 8].

This research [12] positively says that if SiC is added with A6061, the wear tendency can be improved accordingly. Thus, adding SiC up to the limit 6% wt proportioned to increase the wear characteristic in this composite. In this work, composite with two different supports (SiC and Al_2O_3) was prepared with stir casting setup. The properties of the developed composites were studied, and the values were reported positively. The reinforcements increase the strength and reduce the weight of the composites [13]. Many investigators have carried out the mechanical and wear properties and machining appearances of aluminium metal matrix composites with SiC and Al_2O_3 as reinforcing materials [14–16].

The aim of the research is to produce low-cost materials that are similar to high-cost materials like stainless steel and tungsten which are corrosion- and wear resistant. If the low-cost material is produced, it can be used in all applications including surgical products also. In this case of hybrid A6061/Al_2O_3/glass fibres/SiCp/B_4C composites, a limited literature is only available, encompassing various aspects such as mechanical properties and SEM studies and conducting the XRD study of the composites. So, we took this opportunity to prepare a new composite material which can have a greater strength and properties by mixing aluminium oxide, SiC, B_4C, and E-field glass fibre in A6061 by using stir casting setup.

1.1. Fabrication of Samples. The objective of the present written report is to investigate the mechanical behaviour of A6061 reinforced with aluminium oxide, SiC, B_4C, and E-field glass fibre and without E-glass fibre. The properties of Al_2O_3, SiC, B_4C, and glass fibres are given in Table 1. With respect to the material property, the following experiment is made to increase the material strength by increasing its tensile and wear and hardness. The selected composition of the E-glass fibre is 54% SiO_2, 15% Al_2O_3, and 12% CaO. The glass fibres are chopped into 6 mm length pieces. The matrix material used for the MMCs in this study is A6061. The aluminium composites are produced by various methods such as stir casting, centrifugal casting, powder metallurgy, and squeeze casting process. In this research, the stir casting process is used which is most adaptable. The additional benefit of this process is the near net shape formation of the composites by conventional boundary process. Stir casting method is an economic process and easy in operation.

Step 1. In sample 1, the following reinforcements are used: glass fibre, aluminium oxide, silicon carbide, and boron carbide. They were used with A6061 and their properties are mentioned in Tables 2 and 3, and sample 2 mixed without the glass fibre by adding these reinforcements with A6061, aluminium oxide, silicon carbide, and boron carbide is prewarmed and the aluminium 6061 compound is liquefied up to its softening point 660°C in the cauldron heater. Here, induction furnace setup with stirrer mechanism is used, as shown in Figure 1. With the expansion of blending time and speed, the appropriation was progressively homogeneous [6, 7]. Higher blending velocity and time gave higher hardness to the composite. The blending can be in a semistrong state or above melting state. There must be varieties in the geometry of the stirrer and encouraging instrument to get a homogenized material [17].

Step 2. Fortifications, for example, glass fibre, aluminium oxide, silicon carbide, and boron carbide were preheated at a predetermined temperature for 30 min keeping in mind the end goal to expel dampness or some other gases introduced inside the support. The preheating of likewise advances the wettability of fortification with the matrix [7]. Fortifications are included as 5% and 4% structure with aluminium 6061. The preheating of reinforcements in a heater is demonstrated as follows [8]. The glass fibres are added to the mixture very keen, while the molten metal is slowly reduced to its temperature to remain with the glass fibres' strength.

Step 3. Prewarmed materials are included and stirred up with liquid aluminium physically and warming up for appropriate appropriation with the aluminium matrix [8]. The softening of aluminium alongside boron carbide, aluminium oxide, silicon carbide is completed in the pot by using the oil-filled heater before the melting stage. Pouring of preheated fortifications at the semisolid phase of the matrix upgrades the wettability of the support and diminishes the molecule settling at the base of the cauldron. Fortifications are poured physically with the assistance of a tapered container [9].

Step 4. Mixing up liquid aluminium with fortifications at a steady rate upgrades the uniform appropriation all through the matrix stage which is important to bordering the fortifications with network material.

Step 5. When the slurry is poured into the mould, the slurry stream is kept constant to withhold from catching of gas. At that point, it is snappy extinguished with the assistance of air to lessen the time for the particles to get settled. In the wake of blending, liquid slurry is filled in the coveted mould with favoured measurements which would be encouraged for direct different tests on it [13].

2. Results and Discussion

In this examination, the aluminium-constructed metal matrix composite was prepared under two categories A6061/aluminium oxide/glass fibres/SiC/B_4C and A6061/aluminium

Table 1: Mechanical properties of Al_2O_3, SiC, B_4C, and glass fibres.

Reinforcements	Density (gm/cc)	Poisson's ratio	Compressive strength (MPa)	Hardness (kg/mm^2)	Elastic modulus (MPa)	Young's modulus (GPa)	Tensile strength (MPa)
Al_2O_3	3.69	0.21	2100	1175	300		
SiC	3.1	0.14	3900	2800	410	90	240
B_4C	2.52	0.18	2583	3810	261	261	261
Glass fibres	2.55	0.21	4000	3000	2750	72	1950

Table 2: Chemical composition of A6061.

Chemical composition limits	
Weight (%)	6061
Al	Bal
Si	0.40–0.80
Fe	0.70 max
Cu	0.15–0.40
Mn	0.15
Mg	0.8–1.2
Cr	0.04–0.35
Zn	0.25 max
Ti	0.15 max
Others each	0.05 max
Others total	0.15 max

Table 3: Mechanical properties of A6061.

Ultimate tensile strength (MPa)	124
Yield strength (MPa)	55.2
Property elongation (%)	25.0
Brinell hardness at 500 g load BHN-10 mm ball	30

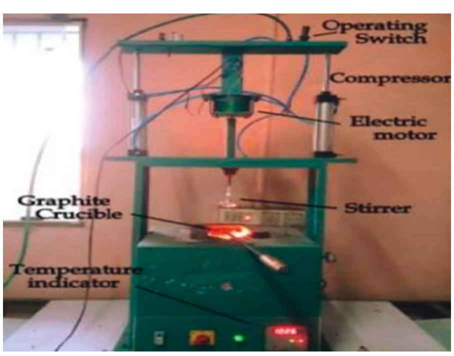


Figure 1: Stir casting process.

oxide/SiC/B_4C without glass fibres and delivered in the lab by utilizing mix throwing strategy. Aluminium 6061 was chosen as matrix material, and the reinforcement materials used were glass fibres, aluminium oxide, silicon carbide, and boron carbide. The fabricated samples of 5% reinforcement with A6061 and 4% reinforcement with A6061 are taken in to the following tests [13, 18].

(i) Hardness test
(ii) Tensile test
(iii) X-ray diffraction analysis test
(iv) SEM test
(v) Wear test

2.1. Hardness Test. Hardness tests were carried over to achieve the produced composites to know the effect of A6061/aluminium oxide/glass fibres/SiC/B_4C in matrix material. The polished specimens were tested using the HBW microhardness tester, and the values are tabulated and shown in Table 4 [10, 19–22].

The hardness test is performed for the samples provided in accordance with the information given below:

Ball intender size: 10 mm

Ball load`: 500 kg

Location: cross section

Test: HBW

The values show that after adding the E-glass fibre, the hardness of the material prepared is increasing gradually with respect to the percentage increase of glass fibre, 4% to 5%.

2.2. Tensile Test. The material capability to endure a static load is determined by testing the material in tension or in compression. UTM with a maximum load rate of 40 kN is used for analysis. The test specimen prepared under the following dimension is shown in the diagram as per the ASTM E8 standard, shown in Figures 2 and 3, and the test has been conducted and the results are tabulated in Table 5 [10, 22–24].

The table value shows that after adding the E-glass fibre, the tensile strength of the material is increasing with respect to the percentage increase of glass fibre, 4% to 5%. Decrease in tensile strength in the 4% mixture .

2.3. X-Ray Diffraction Analysis Test.

(a) X-ray diffraction analysis (XRD) results confirmed the appearance of SiC, graphite, B_4C, and Al_2O_3 with adding glass fibre particles (4%) in the alloy matrix as small peaks in the XRD pattern. As shown in Figure 4, sodium, calcium, cadmium, yatrium oxide are traced as small peaks. In the XRD (Figure 5) without glass fibre (4%), nickel oxide (NiO) which is used to produce nickel steels and alloys and palladium deuteride. According to the Kelvin statement, this type of material can withstand high temperature and also super conductivity materials. Conventional superconductivity at about 10 K was discovered in palladium hydride and palladium deuteride in 1972.

(b) X-ray diffraction analysis (XRD) results confirmed the appearance of SiC, graphite, B_4C, and Al_2O_3 by adding glass fibre particles in the alloy matrix as small peaks in the XRD pattern, as shown in

Table 4: Hardness test.

Trial no.	Samples with glass fibres: 5% of reinforcement	Avg	Samples with glass fibres: 4% of reinforcement	Avg	Samples without glass fibres: 5% of reinforcement	Avg	Samples without glass fibres: 4% of reinforcement	Avg
1	45.4		40.6		50.3		38.1	
2	46.7	46.2	40.9	40.8	49.4	49.7	40.2	39.5
3	46.7		41.1		49.2		40.4	

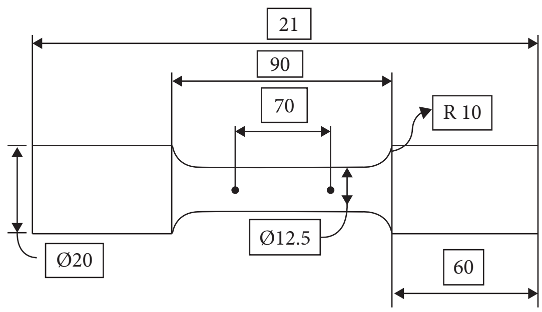


Figure 2: Dimensions of tensile test specimen. (ASTM E8 standard).

Figure 3: Test specimen (after test).

Table 5: Tensile test.

Test parameters (avg)	With glass fibres 5%	With glass fibres 4%	Without glass fibres 5%	Without glass fibres 4%
Ultimate tensile Strength (MPa)	125	81	122	100
Yield strength 0.2% offset (MPa)	114	96	100	84
% elongation	3.1	2.7	3.4	3.4

Figures 6 and 7. The highest peak indicates copper gold palladium and silver in the 5% glass fibre sample which is an electrical resistivity component. The highest peak shows aluminium-zinc in 5% without the glass fibre which increases the tensile property and corrosion resistance, and it gives dimensional stability and it can withstand the impact load.

2.4. SEM Test [25–30].

(1) The SEM images without adding glass fibres in Figures 8 and 9 show the reinforced particulates are scattered in the A6061 structure [12, 33, 34].

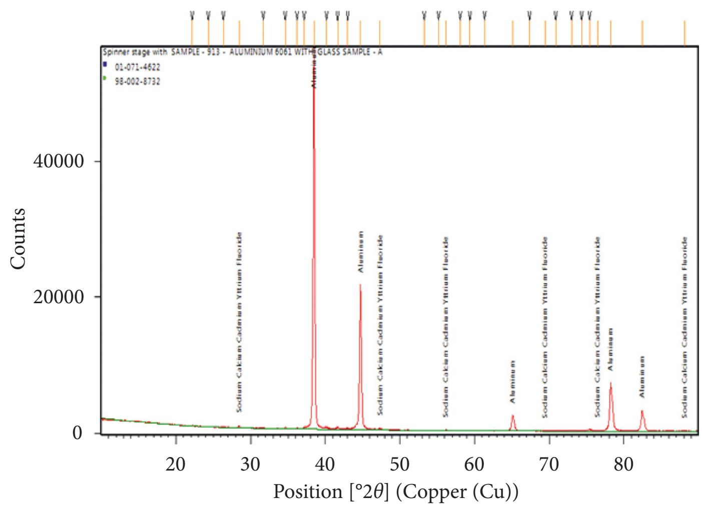
Figures 9 and 10 show the microstructure images of A6061 reinforced with the constitutions like Al_2O_3, B_4C, and SiC wihout glass fibres. In this SEM image, black dots represent the boron and grey ash color represents the SiC [11, 12, 25, 33, 34].

(2) The SEM images with adding glass fibres, in Figures 10 and 11, show the reinforced particulates are scattered in the A6061 structure.

Figures 10 and 11 show the microstructure images of A6061 reinforced with the constitutions like Al_2O_3, B_4C, SiC, and glass fibre. In this, glass fibres formed a small line structure, and black dots represents the boron and grey ash color represents the SiC [11, 14–16].

2.5. Wear Test [26–35]. Wear test is carried out for the prepared composites under 4% and 5% E-glass fibre to predict the wear performance and investigate the wear mechanism. It is performed to evaluate the wear property of a material to determine whether the material is adequate for specific wear application. In this method, wear of the material is determined during sliding using pin-on desk apparatus under the laboratory conditions with respect to speed and load pin diameter 10 mm and track radius 40 mm. The wear of the composite material is given in Table 6 that shows the minimum and maximum wear conditions of the prepared material.

Wear rate has significantly reduced for the composite with the addition of reinforcing phase (5%) for both varying RPM and varying load, and meanwhile, when the percentage of SiC and B_4C increases, it also contributes towards the wear properties positively. The positive and negative test analysis and comparison graphs are shown in Figures 12–14. From obtained results from wear testing, a considerable decrease in wear rate was noticed with increasing load and speed for the E-glass fibre-reinforced composite.

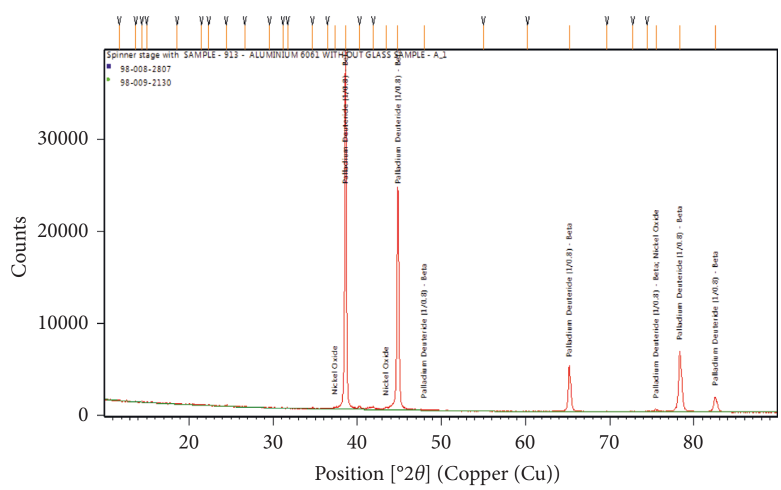


Sample: aluminium 6061 with glass sample - a

Pattern list

Score	Compound name	Chem. formula	Mineral name	Cryst. syst.
57	Aluminium	Al	Aluminium, syn	Cubic
40	Sodium Calcium Cadmium Yttrium Fluoride	Ca1 Cd1 F8 Na1 Y1		Cubic

FIGURE 4: X-ray diffraction analysis pattern of 4% of reinforcement with glass fibre.

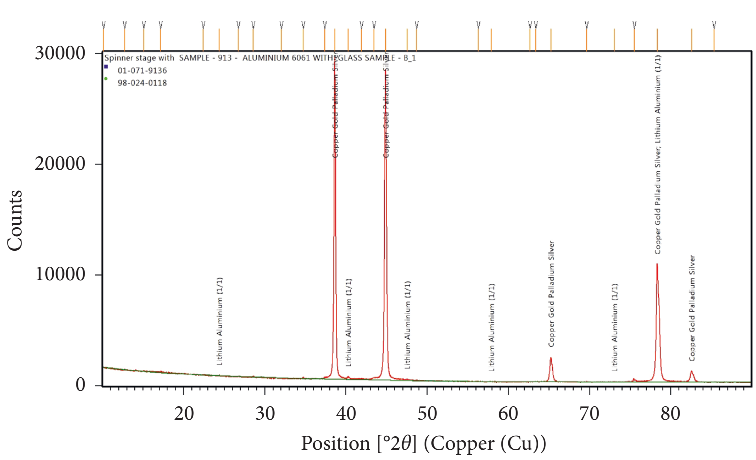


Sample: aluminium 6061 without glass sample - a

Pattern list

Score	Compound name	Chem. formula	Mineral name	Cryst. syst.
60	Palladium Deuteride (1/0.8)-Beta	D0.778 Pd1		Tetragonal
30	Nickel oxide	Ni1 O1		Hexagonal

FIGURE 5: X-ray diffraction analysis pattern of 4% of reinforcement without glass fibre.

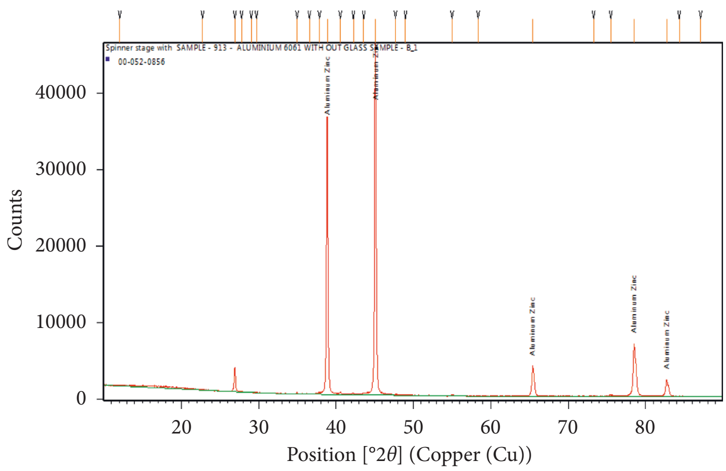


Sample: aluminium 6061 with glass sample - b

Pattern list

Score	Compound name	Chem. formula	Mineral name	Cryst. syst.
50	Copper gold palladium silver	(Ag0.18 Au0.37 Cu0.36 Pd0.09)		Cubic
22	Lithium aluminium (1/1)	Al1 Li1		Tetragonal

FIGURE 6: X-ray diffraction analysis pattern of 5% of reinforcement with glass fibre.



Sample: aluminium 6061 without glass sample - b

Pattern list

Score	Compound name	Chem. formula	Mineral name	Cryst. syst.
57	Aluminium Zinc	Al0.403 Zn0.597		Anorthic

Figure 7: X-ray diffraction analysis pattern of 5% of reinforcement without glass fibre.

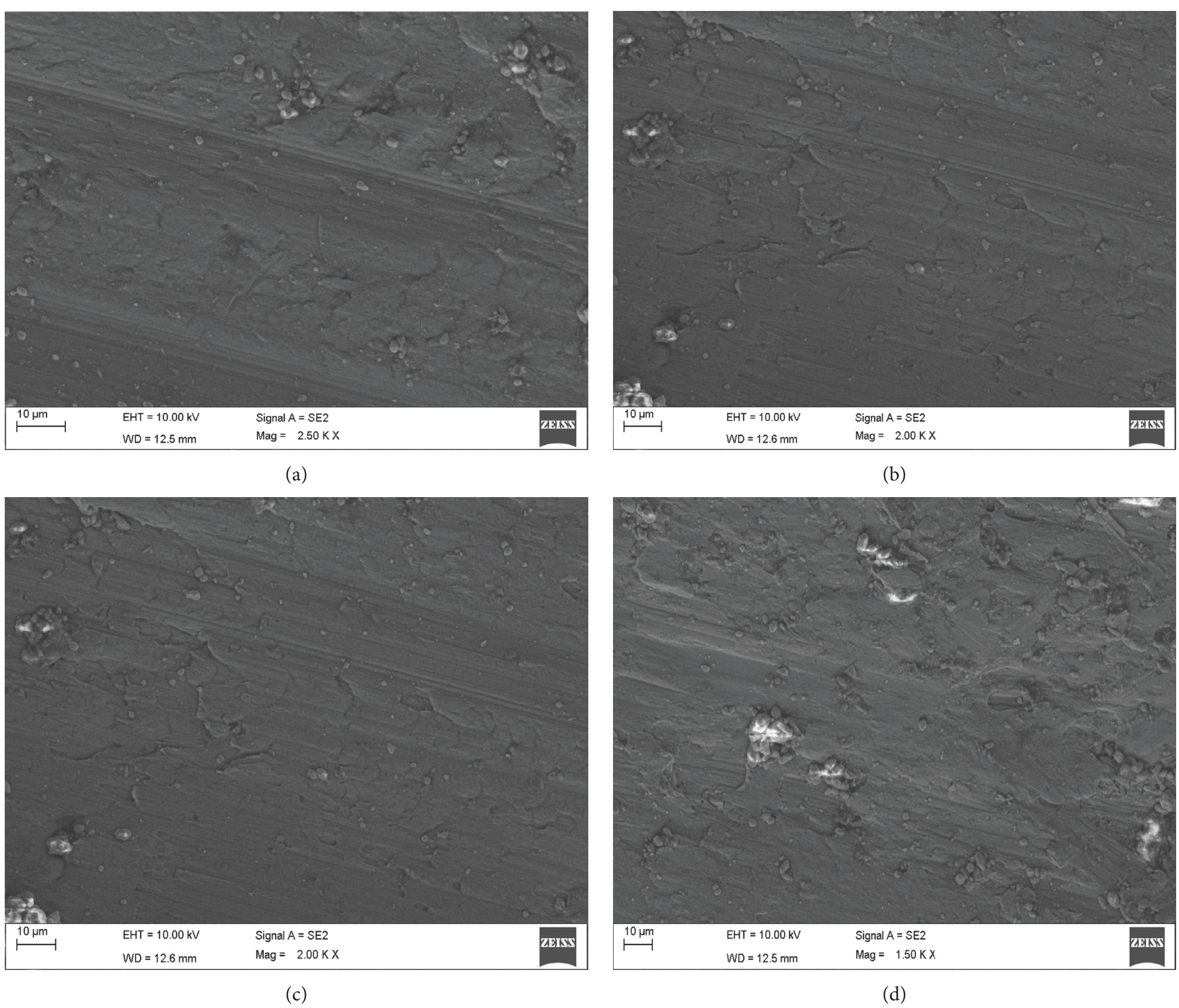
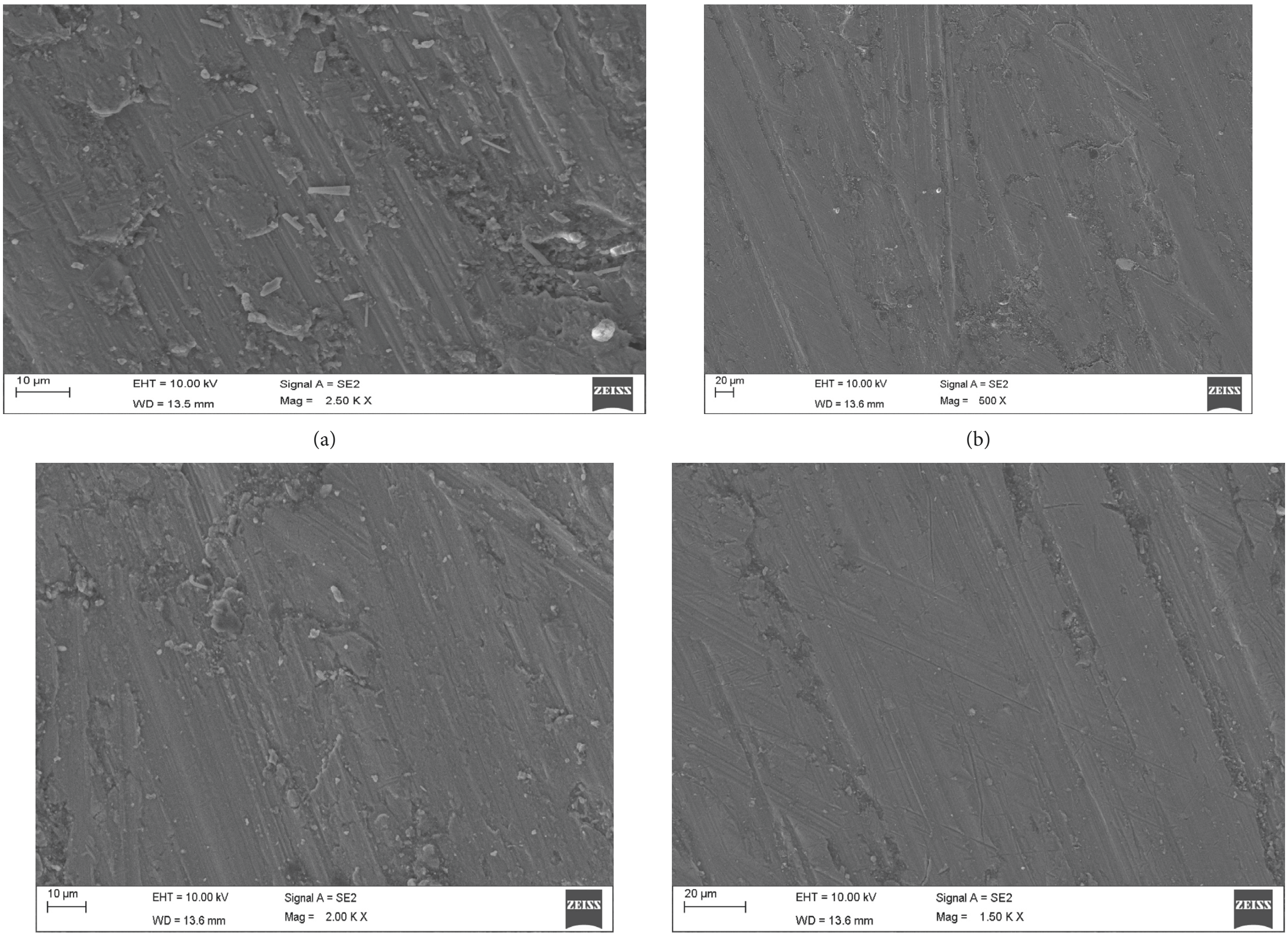


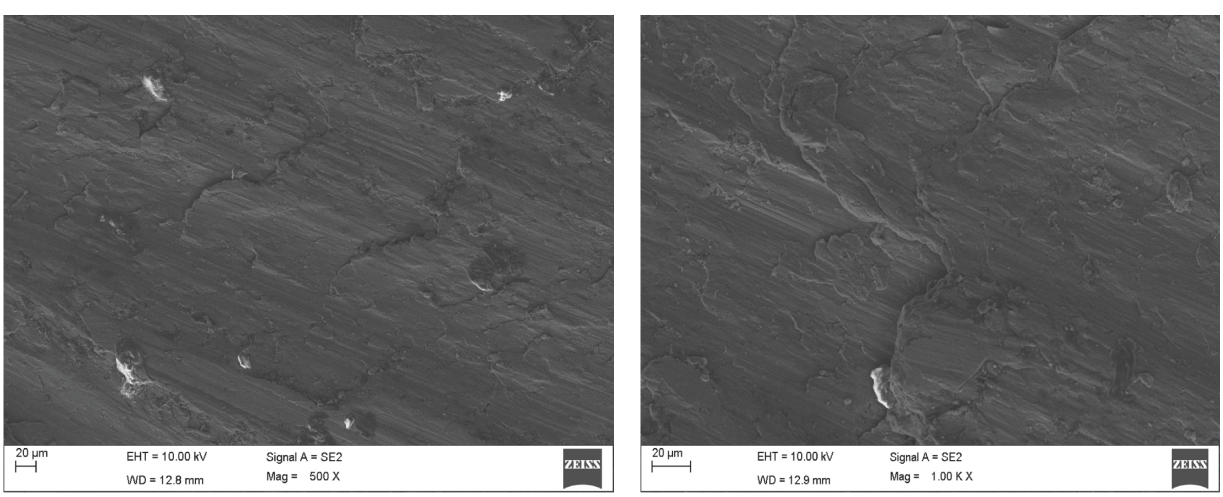
Figure 8: SEM analysis for 5% of reinforcement Al composite without glass fibre.



(a) (b)

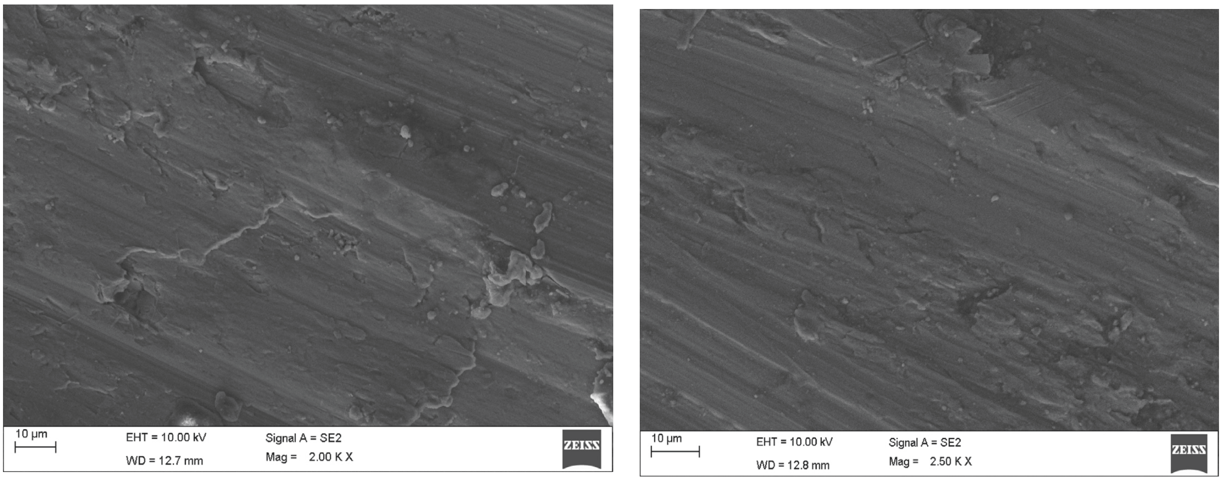
(c) (d)

Figure 9: SEM analysis for 4% of reinforcement Al composite without glass fibre.



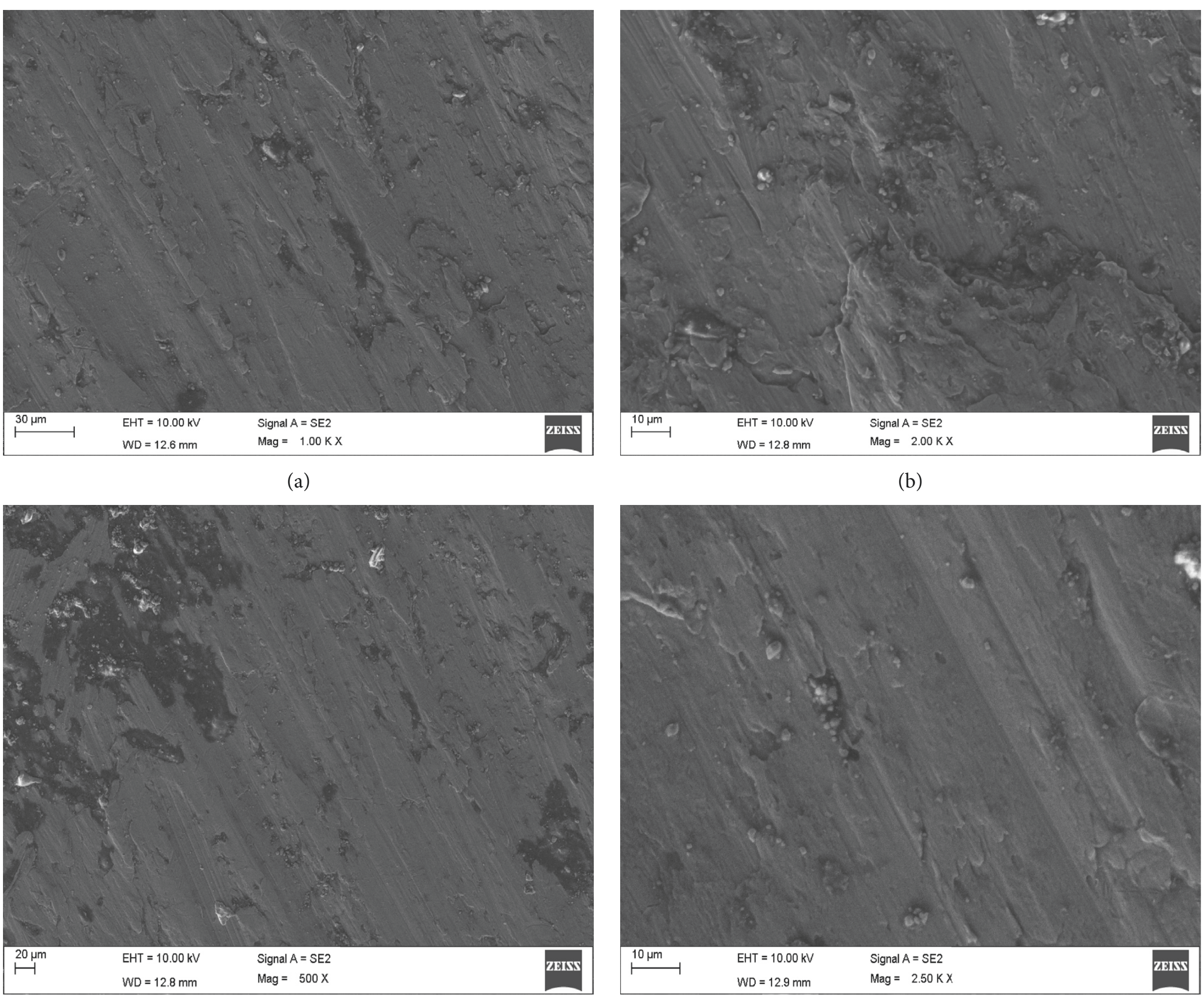
(a) (b)

Figure 10: Continued.



(c) (d)

Figure 10: SEM analysis for 5% of reinforcement Al composite with glass fibre.



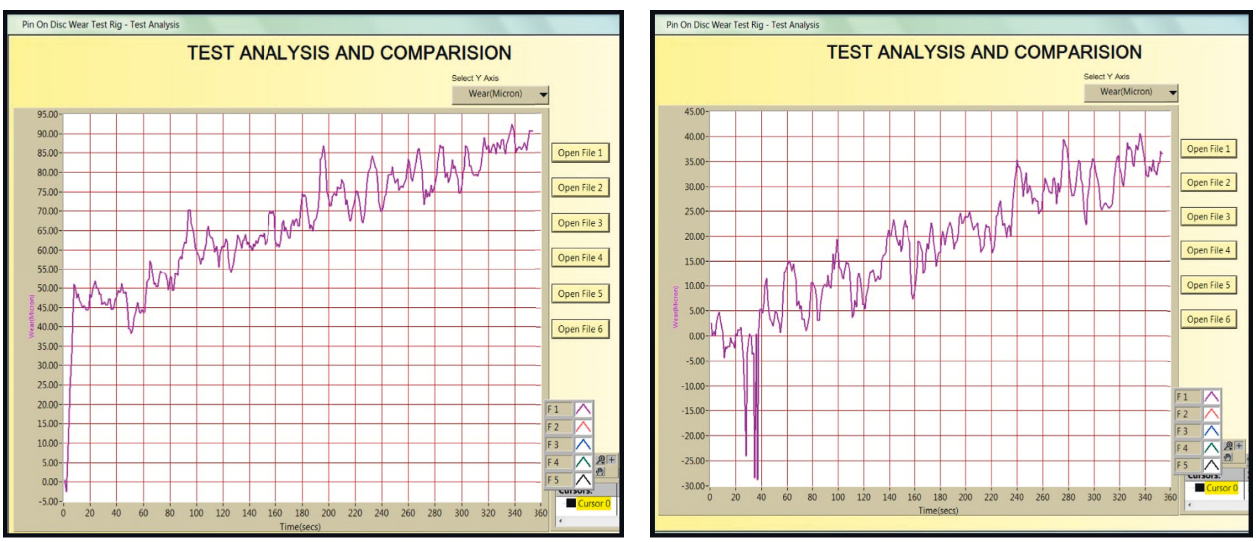
(a) (b)

(c) (d)

Figure 11: SEM analysis for 4% of reinforcement Al composite with glass fibre.

Table 6: Wear rates of the proposed hybrid MMC specimens.

Wt. (%)	Specimen	Load (N)	Speed (rpm)	Sliding velocity (m/s)	Wear rate (mm^3/Nm)	Sliding distance (m)
4% A6061/(glass fibre + Al_2O_3 + B_4C + SiC)	A-with glass fibre	20	200	0.837758	0.0044780	300
		50	200	0.837758	0.0005042	
		20	300	1.25664	0.0017956	400
		50	300	1.25664	0.0002459	
4% A6061/(Al_2O_3 + B_4C + SiC)	B-without glass fibre	20	200	0.837758	0.0002130	300
		50	200	0.837758	0.0004150	
		20	300	1.25664	0.0001956	400
		50	300	1.25664	0.00017950	
5% A6061/(glass fibre + Al_2O_3 + B_4C + SiC)	C-with glass fibre	20	200	0.837758	0.0058780	300
		50	200	0.837758	0.0015042	
		20	300	1.25664	0.0021956	400
		50	300	1.25664	0.0005459	
5% A6061/(Al_2O_3 + B_4C + SiC)	D-without glass fibre	20	200	0.837758	0.0003130	300
		50	200	0.837758	0.0005150	
		20	300	1.25664	0.001556	400
		50	300	1.25664	0.00022950	



(a) (b)

Figure 12: Wear test specimen-A.

3. Conclusion

The investigation made on the fabrication and evaluation of mechanical behaviour of aluminium 6061 with 4% of reinforcement and aluminium 6061 with 5% of reinforcement with glass fibre and without glass fibre metal matrix composite by stir casting method has been made successfully and led to the following conclusions. Results show a positive response on the mechanical strength and composite bonding, but there is only minimum difference in the wear rate compared with the glass fibre composites. But, the tensile and hardness are comparatively good in the glass fibre-reinforced composites. With 5% glass fiber, the tensile strength is showing an increased positive result compared with the 4%.

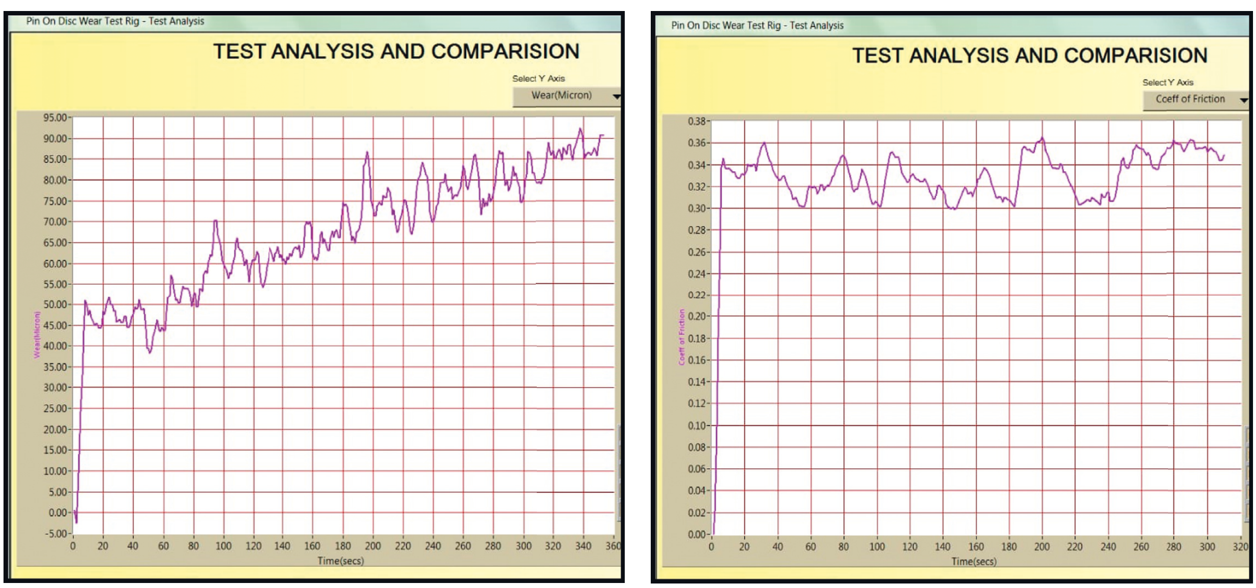
(i) The hardness values without adding glass fibres show a minimum difference considering the 5% of A6061 with glass fibre specimen. Ultimately, the difference is not a great impact but decreased gradually.

(ii) This paper results show that the inclusion of reinforcement SiC and B_4C will improve the mechanical properties of the aluminium composite.

(iii) Adding with glass fibres and mixing with B_4C/SiC/aluminium oxide, a different material composition is made, and the ratio of palladium deuteride, copper-gold-silver, and aluminium-zinc shows the highest peak, as shown in the XRD, which put a new

(a) (b)

Figure 13: Wear test specimen-B.



(a) (b)

Figure 14: Wear test specimen-C.

platform to produce new material which can withstand high strength in nature.

(iv) Herewith, the experimental results explicit that A6061/aluminium oxide/glass fibres/SiCp/B_4C will improve the composite characteristics.

(v) The wear test results show that the glass fibre percentage will resist the wear comparatively good and slightly lowered, while the reinforcement of SiC and B_4C increased without adding glass fibre particles.

(vi) We extensively try to analyze the properties of each material to prepare a reinforcement material with less expenditure.

Data Availability

The data that support the findings of this study are available from the corresponding author on request. We are ready to share the data and findings to the research community.

Conflicts of Interest

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

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