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Mechanical and corrosion behaviour of Al7075 alloy reinforced with SiC and cenosphere particles

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Abstract

Hybrid composites are novel composites that can meet the demands of cutting-edge applications. They may be utilized to meet advanced applications by maximizing weight reduction by reducing adhesive film weight and performance through increased characteristics. The mechanical and corrosion study of Al 7075 hybrid metal matrix composites reinforced with weight percentage (wt.%) of silicon carbide 2, 4, 6, and 8 and 5 wt.% of cenosphere is studied in this work. Composites prepared by the liquid metallurgy route were studied at room temperature to estimate seawater's hardness, tensile strength, and corrosion rate for various silicon carbide (SiC) inclusions using the electrochemical method. The results revealed that an Al7075 hybrid composite reinforced with 6 wt.% SiC had a higher tensile strength of 263 MPa, an increase of approximately 43 MPa (20%) over the basic alloy. The hardness of the Al7075/SiC/cenosphere composite was 128 HV with the addition of wt.% SiC reinforcement. The actual density of the Al 7075/SiC/Cenosphere composite has resulted in increased density compared to the as-cast base metal. According to polarization characteristics in natural seawater, aluminum alloy reinforced with 8 wt.% SiC demonstrated an efficiency of 58.67%, whereas electrochemical impedance measurements in natural seawater indicated 76.91%. The hybrid Al7075 composite with 8 wt.% SiC has a reduced corrosion rate in saltwater compared to pure alloy. Tafel Polarization experiments demonstrate that the hybrid metal matrix composite with 8 wt.% SiC corroded at a lower rate than the base alloy. According to the micrographs, the SiC reinforcement with the matrix alloy reduced corrosion by forming strong interfacial and intermetallic bonding.

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Introduction

Compared to aluminum, aluminum matrix composites have various benefits, including lower density, better strength, enhanced high-temperature capabilities, corrosion and wear resistance, fatigue properties, and stiffness and damping qualities.[1,2] The choice of reinforcing materials, interface bonding, and manufacturing procedures mainly influence these properties.[3]

Numerous research works have focused on preparing and characterizing aluminum-based composites with various reinforcing combinations.[4] Composite materials have been created in a variety of ways.[5] Aluminum matrix composites have gained popularity due to their improved mechanical properties, increased strength, stiffness, wear resistance, and lower weight than traditional materials.[6] These qualities make them appropriate for several automotive, aerospace, and military applications. The selection of reinforcing elements, such as ceramics, oxides, carbides, and even nanomaterials, is crucial to the composites' performance.[7] The liquid metallurgy or stir casting technique includes inserting reinforcing particles into molten aluminum, followed by solidification.[8] It provides flexibility in managing the distribution of reinforcements, making it a preferred alternative for creating vast amounts of composites of consistent quality.[9,10] The liquid metallurgy route is the best composite production technique due to its simplicity, low cost, and mass production.[11]

Rajesh et al.[12] investigated the behavior of an Al 7075/SiC/Fly ash hybrid composite made efficiently using the stir cast process. The fly ash compounds in the composites improved hardness and tensile properties by adding SiC grains. Swapnil et al.[13] investigated Al 7075/SiC powder composites, which were efficiently made using a simple stir casting, with negligible clustering of SiC in the matrix and porosity in the fabricated composites. The microhardness of aluminum metal matrix composites (MMCs) improved as SiC increased.

Previous works have focused on the mechanical characterization of aluminum-based composites with different reinforcing materials and combinations. Emmy Prema et al.[14] found that combining boron carbide (B_4C) and nano alumina (Al_2O_3) particles with matrix in certain proportions increases hardness and tensile strength; further increase in Al_2O_3 decreases the strength. The hard ceramic phase in composites strengthens directly, whereas the reinforcing phase and matrix alloy's temperature mismatch during solidification causes indirect strengthening. Jamaluddin Hindi et al.[15] used a two-stage stir-casting process to produce age-hardened Al7075/wt.% gray CI specimens, both as-cast and age-hardened. When the reinforcing proportion is raised at an ageing temperature of 100°C, the composites display improved hardness and tensile strength. Regardless of the ageing temperature, ductility declines as the proportion of reinforcement increases. Shantharaj et al.[16] investigated the Al7075-B_4C composite and observed that the B_4C addition reduces the matrix density, and tensile strength was improved compared to the base alloy. Tarun Kumar Gupta et al.[17] studied the properties of Al7075/B_4C/SiC hybrid MMCs manufactured using stir casting. The results of the composite tensile test show that the UTS is increased for all specified reinforcement combinations compared to the base alloy. Compared to other proportions, the specimen produced by adding 1% SiC and 9% B_4C at 1.36% elongation had a maximum UTS of 58.9 MPa and a yield strength of 49.46 MPa. Hemalatha et al.[18] investigated stir-cast Al 7075/SiC/Graphene composites and discovered that adding reinforcement from 10% to 15% increases mechanical characteristics while decreasing wear rate. The quantity of reinforcing materials added to the mix enhanced the hardness, tensile strength, and impact strength. With the addition of reinforcement, the wear rate is reduced.

Aluminum-based MMCs are common in automobile and aerospace applications, and there is a great need for corrosion-resistant materials. Sambathkumar et al.[19] used a two-stage stir casting process to create Al 7075/garnet composites with varying volume percentages (0, 5, 10, 15), and the physical, mechanical, and corrosion characteristics were studied. The optimal percentage of garnet was found to be 15%. The results showed that Al 7075/15 wt.% garnet composite's microhardness and tensile strength were increased by 34% and 40%, respectively, and the corrosion rate decreased by 97% compared to the cast base matrix. Karthikraja et al.[20] studied corrosion characteristics of Al7075 hybrid composite reinforced with SiC and Al_2O_3 particles by varying weight proportions. When the rate of corrosion was estimated using weight loss in a 3.5% NaCl solution for five weeks, it was found that the 10 wt.% SiC and Al_2O_3 reinforced Al7075 hybrid had lower corrosion compared to other proportions due to good interfacial and intermetallic bonding between matrix and reinforcement. Ramadoss et al.[21] investigated the influence of B4C on the mechanical and corrosion behavior of Al7075/B_4C/BN hybrid MMCs produced using the stirring-squeeze cast process. The results demonstrated that producing an intermetallic secondary phase and better particle dispersion enhanced characteristics. The development of a protective layer on the examined samples, as determined by SEM, corroborated the corrosion resistance results. Yang et al.[22] synthesized a high-strength, heat-resistant Al-Ce-Sc-Zr alloy utilizing additive manufacturing, attaining exceptional tensile characteristics such as a yield strength of 344 MPa with a retention strength of 233 MPa at 300 °C. This performance was achieved by creating fine, stable Al11Ce3 intermetallic nanoparticles and Al3(Sc, Zr) nanoprecipitates and insighted into the creation of improved high-temperature aluminum alloys. Zhang et al.[23] investigated the electrochemical properties of a TiZrHfNb MPEA in Cl solution. Ti decreased point defects, Nb strengthened the passivation layer, and Hf and Zr boosted resistance. Hydroxides aided film repair, whereas alloying elements worked together to increase corrosion resistance.

Vignesh et al.[24] studied the corrosion behavior of three distinct samples in seawater and industrial environments: Al 7075 alloy Al 7075 reinforced with 10% and 15% wt of Al_2O_3 particles. It was observed that Al 7075 corrodes more quickly in seawater than in industrial environments, and its corrosion rate increases with reinforcement volume. Pitting corrosion was noticed in the seawater environment, and intergranular corrosion was detected in the industrial environment based on the analysis of SEM images.

Kumar et al.[25] carried out salt spray tests with NaCl and immersion tests with NaCl and NaOH as corrodents on aluminum-cenosphere composites fabricated using liquid metallurgy. The results revealed that as the weight percentage of reinforcement increased, corrosion resistance increased up to 7.5% reinforcement and then decreased somewhat. In all corrosive situations, solution heat-treated samples were more oxidation-resistant than cast samples. On the corrosion-tested specimens, SEM photos demonstrate the existence of tiny fractures and pitting corrosion. Chandrashekar et al.[26] studied the properties of AlMg4.5/Al_2O_3 nanocomposites, showing that the nano Al2O3 reinforcement increased composites' hardness and tensile strength. The static immersion corrosion tests in 3.5 wt.% NaCl aqueous solution revealed that the composites outperformed the pure Al alloy, and the 6 wt.% nano Al_2O_3 reinforced composites outperformed the other proportions substantially. The bond coating's high grain boundary density enabled selective oxidation of Al, considerably improving its oxidation resistance and the thermal barrier coating's rumpling resistance.[27]

Many researchers have studied the mechanical properties of MMCs; however, a thorough investigation of the corrosion behavior of cenosphere-reinforced MMCs is necessary. Aluminum-based MMCs are extensively utilized in industries like automotive, marine, and aviation, where there is a significant need for lightweight corrosion-resistant material. According to the preceding discussion, there is limited data on the mechanical properties and corrosion behavior of SiC and Cenosphere particle-reinforced Al7075 composites. Therefore, the purpose of this research is to investigate the implications of cenosphere and SiC on the aluminum-based composite comprising a hybrid of cenosphere and SiC manufactured by stir casting procedure with proportions of cenosphere (5 wt.%) and SiC (2, 4, 6, 8 wt.%). The samples' mechanical characteristics and corrosion behavior were investigated to identify the optimal percentage of SiC inclusion.

Experimental details

The base alloy Al-7075 is used as the matrix, supplied by Fenfe Metallurgical Pvt. Ltd, and exhibits medium strength with excellent corrosion resistance. Its chemical composition is presented in Table 1 and was found using the SEM-EDS (scanning electron microscopy with energy dispersive X-ray spectroscopy) facility. (Courtesy: BMS College of Engineering, R & D Centre, Bengaluru). Reinforcements such as SiC particles of an average size of 90 μm were procured from Mincotel, Bangalore, and cenosphere of average size 70 μm from cenosphere India Limited, Kolkata, were used. The compositions are presented in Tables 2 and 3. The stir-casting process is used for composite preparation. The base alloy was melted in a graphite crucible at 750 °C to get the homogenized melt and maintained for 20 min. The detailed process to develop the composite is shown in Figure 1.

Then, SiC and cenosphere were added into the melt in known proportions. The reinforcements were pre-heated at 300 °C to remove moisture and make melt compatible. The metal's temperature has been increased to 850 °C. It is continuously stirred for 15 min at a speed of 500 rpm. It employs a spiral-shaped stirrer coupled with a moto to achieve a uniform distribution of reinforced particles in the matrix.[28] A tensile test was done on a universal testing machine with a 10 kN load cell and 2.5 mm/min cross-head speed, following ASTM E08-8 standards. The tensile test specimen is shown in Figure 2. Vickers Micro Hardness testing apparatus is employed to measure microhardness, followed by E92-ASTM standards. All prepared samples, size of 1 cm^2 each, were subjected to potentiodynamic polarization to assess the corrosion rate in natural seawater, following ASTM standards G3-74. The EDAX pattern of the cenosphere, SiC, and base metal is shown in Figure 3. The obtained results are in good agreement with the available literature. Reference patterns JCPDS # 851327 were used.

Results and discussions

The density of the cast alloy and composite specimens was measured using the Archimedes method. The results are shown in Figure 4. Compared to the basic alloy, the composite has a higher density. Moreover,

Table 1. Chemical composition of Al7075 alloy (wt.%).

Composition	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
wt.%	88.85	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2

Table 2. Chemical composition of cenosphere.

Element	SiO2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	H_2O
wt.%	55	35	6	0.8	0.3	1.5	1	0.2	0.2

Table 3. Chemical composition of SiC.

Composition	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
wt.%	88.85	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2

when the quantity of SiC increases, the density of the composites increases.

An SEM image of a cenosphere, a hollow sphere mostly made of silica and alumina and filled with air or an inert gas, is shown in Figure 5(a), produced mostly as a byproduct in thermal power plants while burning coal. By nature, they are inert and light. Figure 5(b) displays the SiC SEM picture.

Figure 6(a) and (b) displays an optical microscopic image of hybrid MMCs consisting of Al7075 and 6 wt.% SiC-5 wt.% cenosphere reinforcement. The image clearly shows the presence of reinforcing particles at the grain boundaries. Furthermore, the picture demonstrates that the reinforced particles are equally dispersed throughout the matrix alloy, which may have been done by constant stirring action. When comparing these hybrid MMCs to the as-cast alloy, it is clear that they have smaller grain sizes due to the incorporation of strong reinforcements, which considerably help in increasing grain refinement.[29] The addition of SiC and cenosphere, which function as grain refiners, considerably improves the grain structure of the produced hybrid composites. The results showed that the homogeneous distribution of these reinforcing particles improved the mechanical characteristics of MMCs.[30] In general, including hard particles strengthens the Al matrix and improves the fineness of the grain structure. The microscopic image, which shows lower porosity in the hybrid MMCs, illustrates that new grains form within the grain boundaries. The superior bonding between the base matrix and reinforcements is due to the increased wettability of the particles, refinement of the reinforcements, and homogenous distribution of reinforcements within the matrix. These factors contribute to the overall improvement in hybrid MMC strength.[31]

Figure 7 shows the hardness values for the Al 7075 as-cast and SiC-Cenosphere reinforced composites. The addition of SiC and cenosphere particles over the base matrix enhanced hardness. Because of the ceramic particles, cast composites show increased dislocation density during solidification.[32] The material properties of the generated hybrid MMCs are enhanced due to the SiC and cenosphere particles being equally scattered throughout the base alloy. As a result, overall stress and hardness have increased.

According to Xuedan Dong et al.,[33] increasing the quantity of cenospheres in composites resulted in increased mechanical strength. Reinforcing ceramic particles within a soft matrix has traditionally provided load-carrying capacity and increased resistance. Hard ceramic particles are load-bearing elements, supporting the maximum applied load for plastic deformation. This increases the hardness of the hybrid composites. Furthermore, grain refinement can enhance hardness in SiC and cenosphere-reinforced hybrid composites. The addition of hard particles, SiC, and cenosphere significantly improved the hybrid MMCs' strength.[34]

Silicon carbide (SiC) particles have a high hardness, allowing the material to flow without distortion. Surpassing critical levels, on the other hand, results in fractures without additional deformations. Reduced grain size increases hardness, according to the Hall-Petch equation. Hard particle aggregation rises as the reinforcement's weight fraction increases.[35] The internal structure of these agglomerated particles becomes loose, leaving them ineffective in successfully bearing loads. The capacity to transmit stress is further diminished because the agglomerated particles have irregular morphologies, which leads to fracture initiation during plastic deformation.

Stir-casted hybrid composites have better hardness, up to 6 wt.% SiC, due to greater bonding between the matrix and reinforcements. However, hardness increases over 6 wt.% SiC, owing mostly to the accumulation/agglomeration of reinforcements with a high weight percentage. These findings are comparable with those of earlier research.[36] Another component contributing to hardness improvement is the restriction of dislocation movement by SiC and Cenosphere particles. These hard particles operate as barriers, restricting dislocation movement and increasing the stress required for dislocation mobility.

Figure 8 shows the behavior of monolithic and hybrid MMCs. The addition of SiC and cenosphere particles substantially increased the overall mechanical strength of the produced composites. The maximum tensile strength is 263 MPa for a composite containing 6 wt.% SiC/5 wt.% cenosphere, while the Brinell hardness number is 128 for a composite containing 6 wt.% SiC; the same trend has been noticed in.[37] This noticeable contribution to the improved mechanical performance of hybrid MMCs may be due to proper particle grain size, dispersion, and interfacial bonding between the matrix and reinforcements. The stirring motion often promotes a more equal distribution of reinforcements inside the base matrix. Furthermore, a new interface arises during casting, resulting in improved bonding between SiC and cenosphere particles and the matrix alloy, further improving the

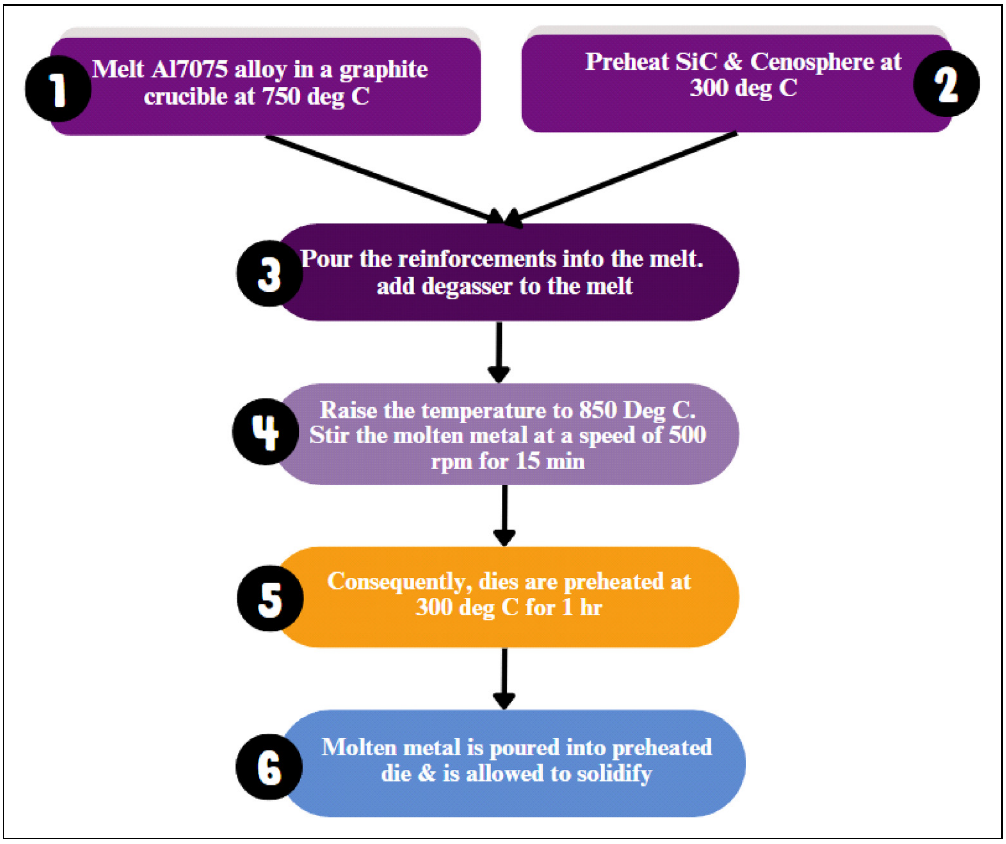

Figure 1. Flow chart of the process.

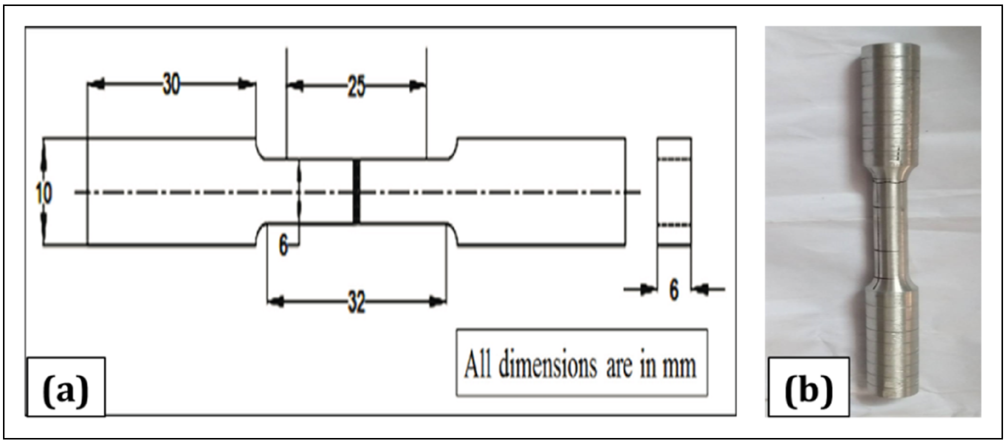

Figure 2. Tensile test specimen (a) dimensions of specimen as per standards (b) machined specimen.

mechanical characteristics of the composite by homogeneous solidification.

Tensile strength increases can be attributed to grain refining, dislocation, and load transfer. Maintaining stability between the matrix material and hard reinforcement particles when exposed to bulk material loads is critical to enable successful load transmission. The load is transferred from the matrix alloy to the hard reinforcements more effectively when there is stronger contact between the matrix and reinforcement particles.[31] Recrystallization is the mechanism by which thermomechanical processing is strengthened. Due to the mismatch between the hard particles and the foundation material, a deformation area arises near them throughout this process. Following the Hall-Petch ideas, including particles encourages grain refinement and nucleation, improving material strength for hybrid MMCs.

Furthermore, the greater density of dislocations in hybrid MMCs adds to considerable strength gains. It has been revealed that the "Orowan-Strengthening" process also contributes to the increased tensile strength of hybrid MMCs. This technique includes finely dispersed

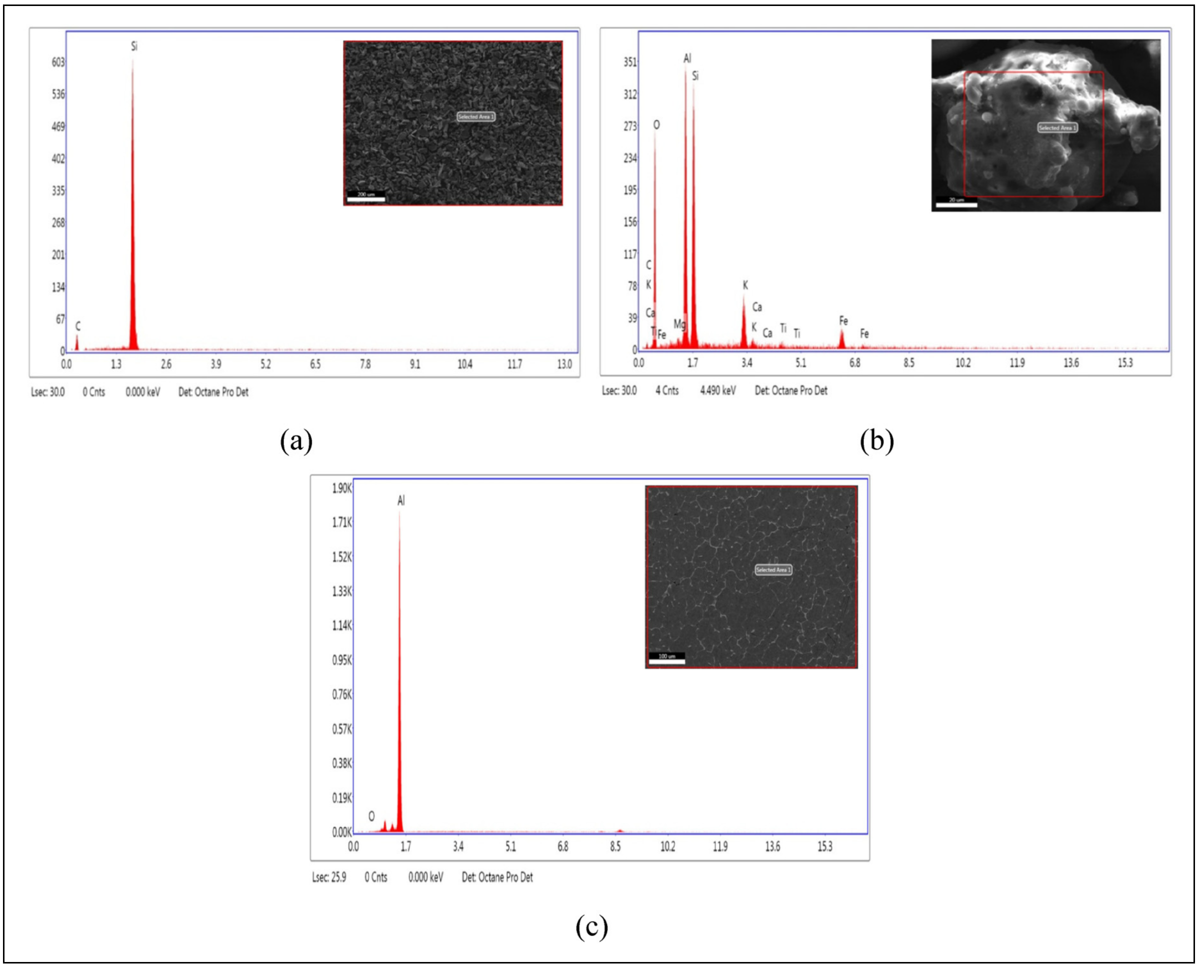

Figure 3. EDAX graph (a) silicon carbide (b) cenosphere (c) as-cast Al 7075.

hard particles such as SiC and Cenosphere, preventing dislocation mobility.[33] In this work, the hard particles generated are equally distributed throughout the base matrix, posing impediments for dislocations. This is because the particles have a high hardness and are non-deformable, making it extremely difficult for dislocations to traverse or sever them. The testing results showed that hybrid MMCs have enhanced tensile strength up to a SiC concentration of 6 wt.%. However, at 8 wt.% SiC concentration, there was a drop in tensile strength. This result shows that a larger reinforcement weight % reduces material strength owing to particle aggregation.[29]

Figure 9 shows that increasing the SiC particle concentration in Al7075 causes a slight decrease in ductility for both as-cast and hybrid composites. When compared to monolithic composites, hybrid composites have higher ductility. The existence of imperfections in the casting process, such as solidification shrinkages and porosities, which function as fracture nucleation sites under load, promoting crack propagation, might be linked to this improvement. Furthermore, adding hard particles causes grain refinement, improving the hybrid composites' ductility.

The increased weight percentage of SiC and Cenosphere particulates reduces ductility primarily due to the presence of a large number of crack nucleation sites at the interface between the reinforcement and base alloy and the presence of micro-porosities. The presence of SiC and Cenosphere alters the direction of crack propagation, resulting in crack bridging, branching, and deflection along the direction of the tension load. This phenomenon requires a significant amount of energy. Moreover, it increases resistance against crack propagation, improving ductility and fracture toughness. When a high weight percentage of reinforcements is used, debonding occurs at the interface between the matrix and reinforcements under tensile loading, thereby reducing ductility.[31] Figure 10 depicts the tensile fracture images of both monolithic and hybrid composites.

Figure 10 shows the SEM of fracture surfaces of (a) base alloy and (b) hybrid composites. In MMC manufacturing, developing small pores on the surfaces of broken materials results in an exceptionally high level of ductility. Monolithic materials with fractured surfaces show a higher abundance of dimple shapes than hybrid MMCs, increasing ductile strength. According to fractographic research, the failure type changes from ductile to brittle when SiC and cenosphere content rises. The deformed area and dimples on the broken surface make this transition clear. A loss in ductility is indicated by an increase

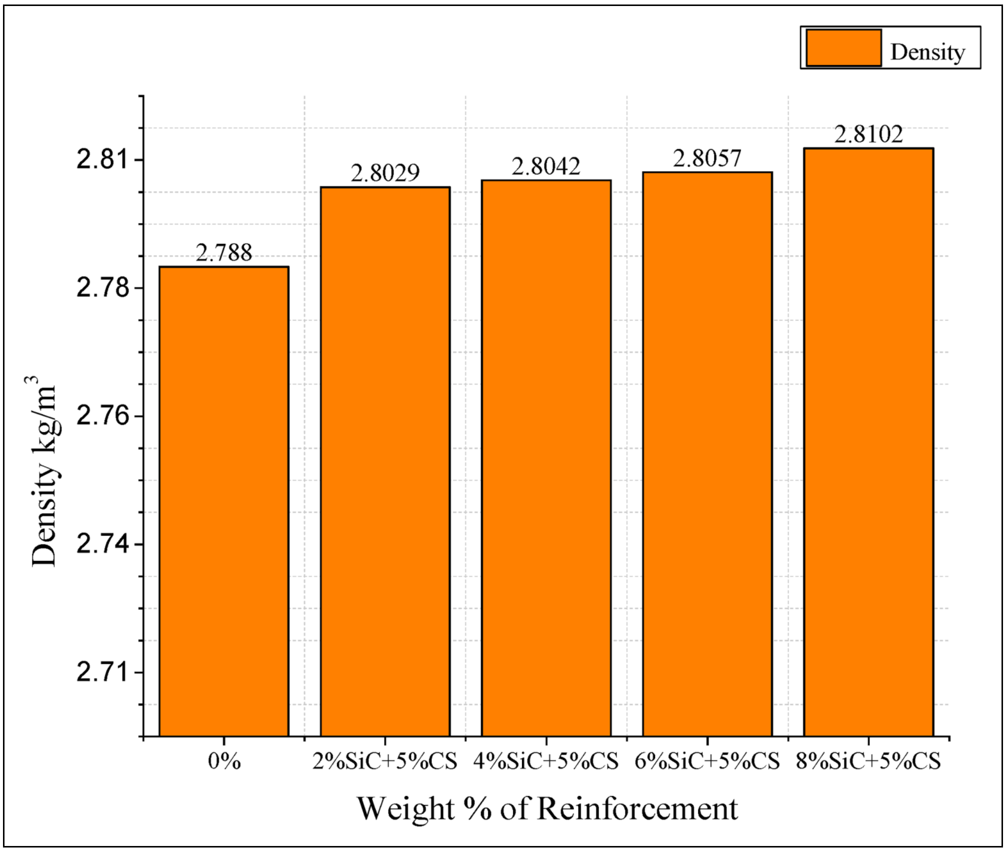

Figure 4. Density values of as cast and reinforced composites.

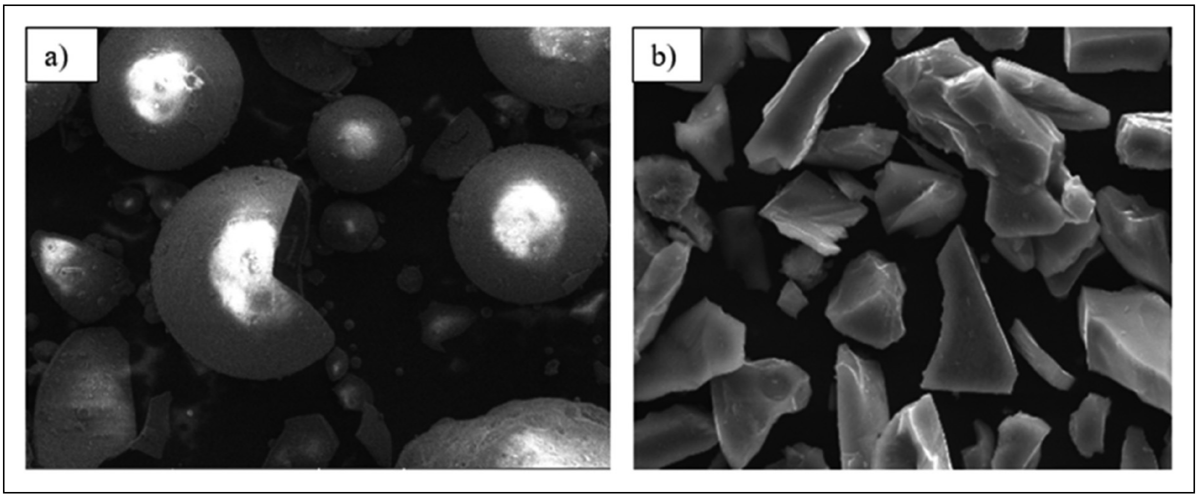

Figure 5. SEM images of (a) cenosphere and (b) silicon carbide.

in microcracks when high-density ceramic reinforcements are used. Fractures and voids are often more prevalent in the topology of shattered surfaces. A triaxial stress state is started close to the hard ceramic particles when they are embedded in a soft matrix, ultimately leading to the creation of voids. The shape of the reinforcements and the grain size frequently have an impact on how well the reinforcements adhere to the matrix material. The sizes of the dimples demonstrate the correlation between dimple size and composite strength. The fracture processes are hard particle pullout and fracture because the shattered surfaces of the tensile samples show the presence of a mixture of hard particles at the interface. Mechanical strength is increased by hard particles on broken surfaces and microvoids, which strengthens the link between the base matrix and reduces ductility. Voids at the particle-matrix interfaces accelerate the outward spread of cracks from their centers.[33]

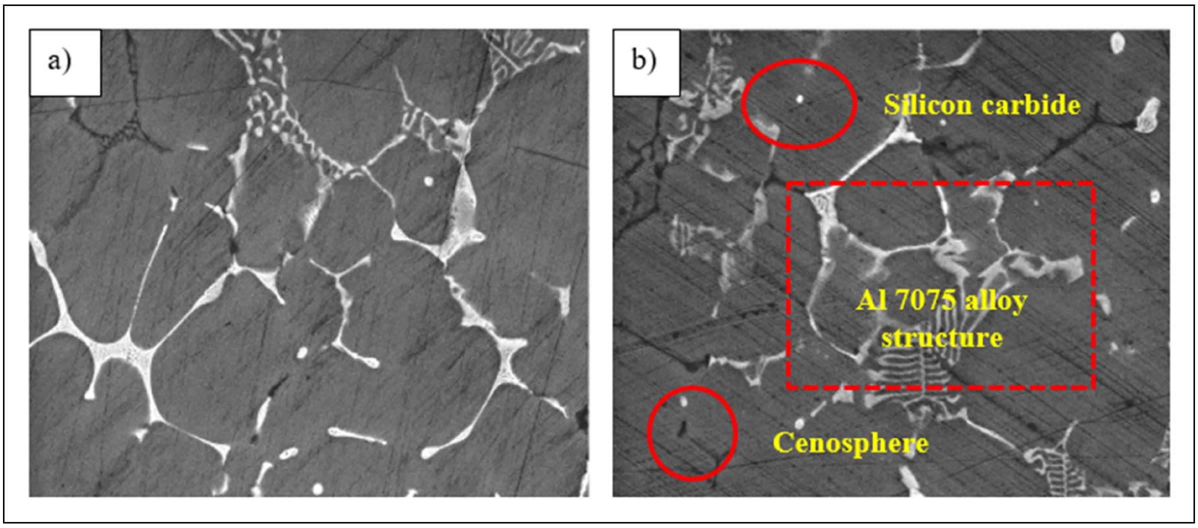

Figure 6. Optical-micrograph of (a) monolithic (as-cast) (b) Al7075 reinforced with 6 wt.% SiC and 5 wt.% cenosphere.

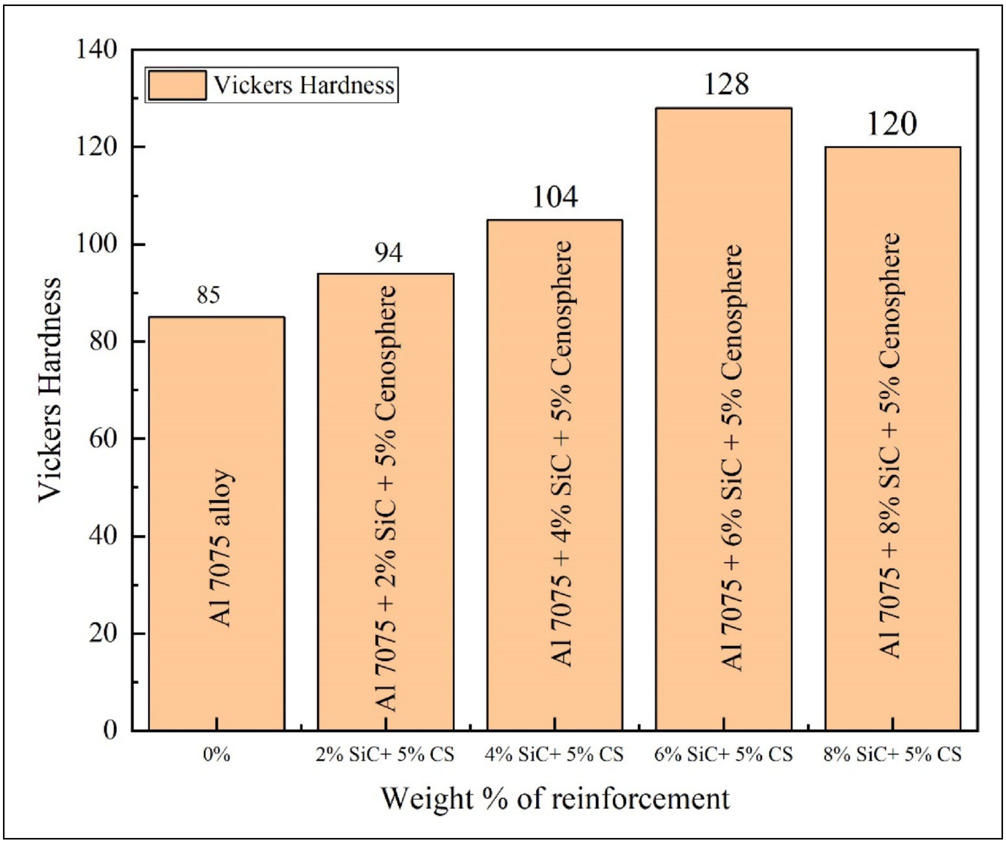

Figure 7. Hardness results of monolithic and hybrid MMCs.

Potentiodynamic polarization tests were carried out to distinguish the impact of anodic substrate dissolving and cathodic hydrogen ion reduction of Al7075/SiC/cenosphere at various wt.% of SiC. The Tafel plot of Al 7075/SiC/cenosphere corrosion in seawater is shown in Figure 11. The polarization curves for all wt.% of SiC have a similar form. The typical potential-current density (E-i) characteristics of aluminum alloy systems in 3.5 weight percent NaCl solution are displayed by the cathodic and anodic branches of the curves. Increased temperature causes the medium's conductance, accelerating metal breakdown and overcoming binding energy. The polarization curves have comparable shapes at different wt.% of SiC, implying that hydrogen evolution is activation-controlled and has no effect on the reduction reaction mechanism.[38] The anodic and cathodic Tafel

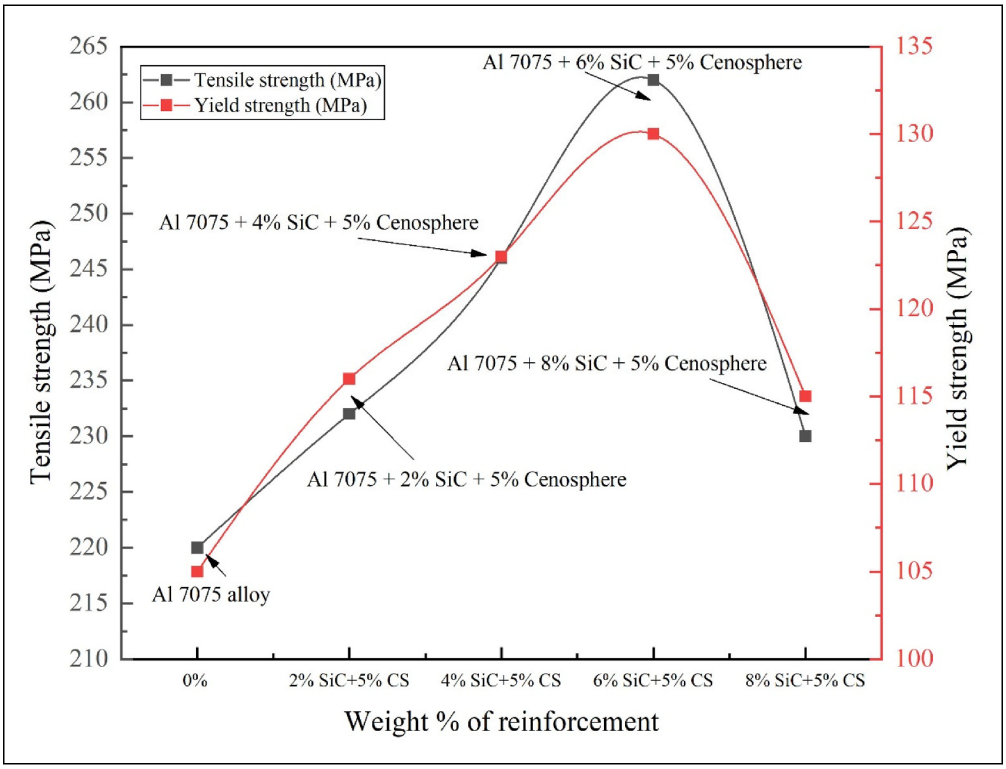

Figure 8. Tensile strength of monolithic and hybrid MMCs.

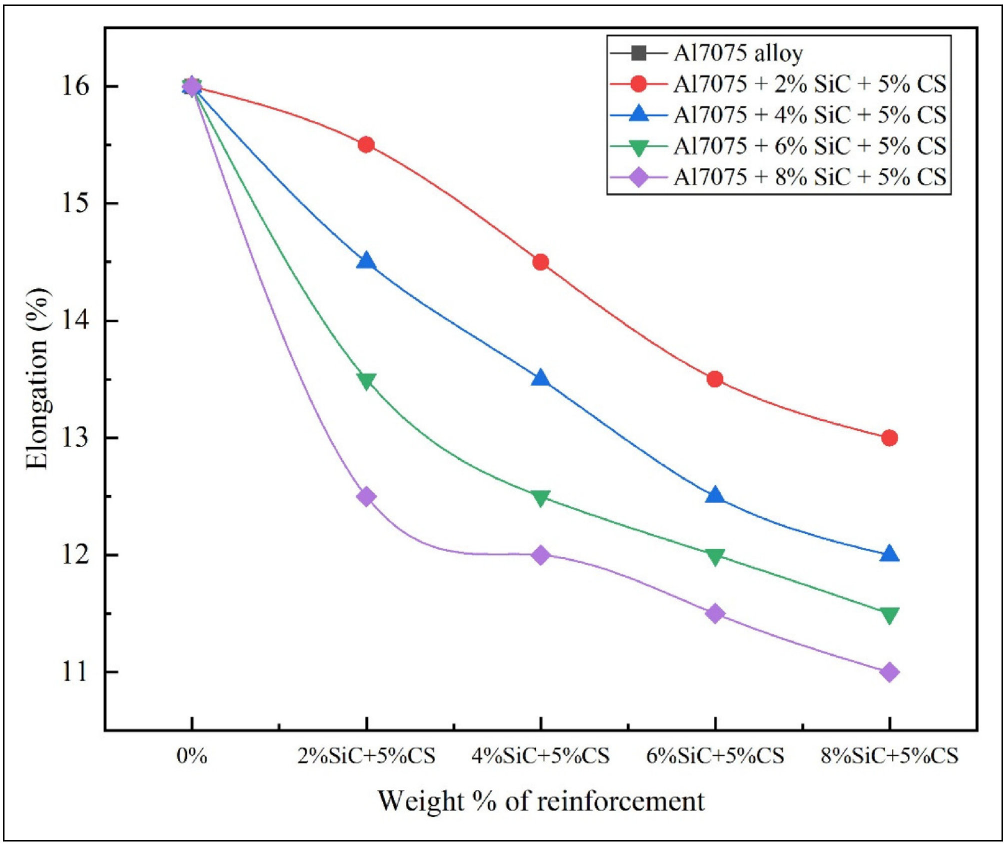

Figure 9. Elongation (%) of monolithic and hybrid MMCs.

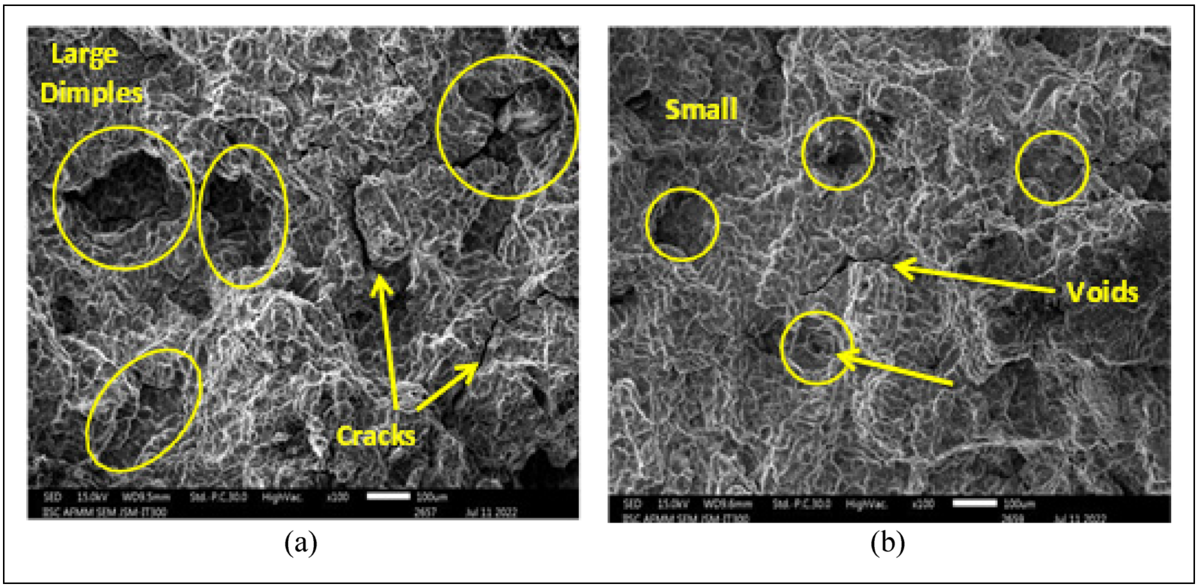

Figure 10. SEM of the fracture surface of the tensile test samples (a) monolithic (b) hybrid composites.

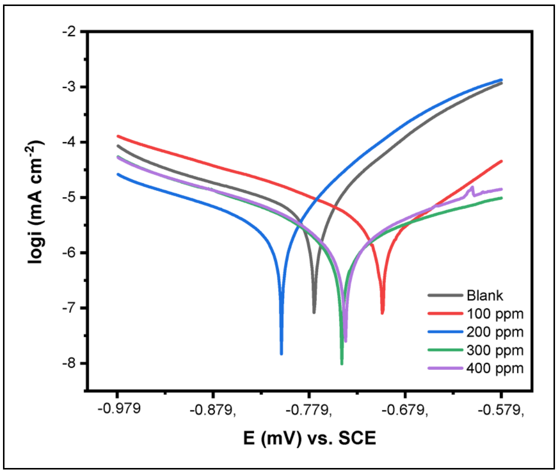

Figure 11. Tafel plot of Al7075/SiC/cenosphere (sea water) corrosion at various wt.% of SiC.

line slopes did not change much as the SiC percent rise because activation controlled hydrogen release and the inhibitor concentration had little influence on the inhibitory mechanism. Increasing the reinforcement reduces the corrosion rate by moving anodic and cathodic branches to lower current densities. Table 4 shows polarization factors such as corrosion current (icorr), corrosion potential (Ecorr), cathodic Tafel slope (-βc), and anodic Tafel slope (βa) in natural seawater for different wt.% SiC. The difference between blank and (Ecorr) deviation readings should not exceed ± 85 mV for mixed-type inhibitors. Anodic corrosion inhibition activity is confirmed if (Ecorr) results are more positive than zero.

Similarly, increasing negative (Ecorr) values away from zero implies cathodic corrosion inhibition activity.[39] The investigation showed that the corrosion rate steadily dropped when adding the SiC filler. Table 5 shows electrochemical impedance parameters in natural seawater for different wt.% SiC. Figure 12 depicts the EIS test results for various Al7075/SiC/Cenosphere concentrations in seawater. Figure 12(a) depicts a system's impedance response, whereas Figure 12(b) depicts a bode impedance plot of logz vs log frequency (Hz), and Figure 12(c) depicts a bode phase angle (deg) versus log frequency (Hz). A logz vs. log frequency graph does not equal −1. The discrepancy above causes an uneven surface. One time constant behavior is seen in Figure 10(c) when the phase angle (deg) and log frequency (Hz) are shown on the Y and X axes, respectively. The Nyquist plot shows a single half circle whose diameter grows when reinforcement increases, but the curve's pattern stays the same when an inhibitor is added. A comparable electrical circuit serves as the basis for describing the Nyquist plot. Figure 13 depicts the corroded surfaces of the specimens, demonstrating that the wt.% increase in reinforcement significantly reduced widespread pitting. These findings are consistent with the polarization curve results.

Conclusions

The mechanical and corrosion behavior of an Al7075-based composite with known amounts of SiC and cenosphere was investigated. The following findings have been drawn from the investigation:

1. Based on the Archimedes principle, the Al7075/SiC/cenosphere composite's actual density was determined to be 0.8% higher than that of the as-cast base metal.
2. The tensile strength of the Al7075/SiC/cenosphere composite is first increased till 6 wt.% SiC and then decreased with the increase in the additional amount, which may be due to reinforcement agglomerations caused at the larger weight percentage. The composite comprises 6 wt.% SiC, and the cenosphere

Table 4. Polarization parameters in natural seawater for different wt.% SiC.

Medium	*Metal sample*	(E_{corr}) (*mV*)	(i_{corr}) ($\mu A\ cm^{-2}$)	β_a (*mA dec*$^{-1}$)	$-\beta_c$ (*mA dec*$^{-1}$)	η (%)
Natural seawater	Al 7075	−0.7742	5.130×10^{-6}	13.97	4.835	—
	Al 7075 + 2 wt.% SiC + 5 wt.% Cenosphere	−0.7032	3.051×10^{-6}	11.86	6.648	40.52
	Al 7075 + 4 wt.% SiC + 5 wt.% Cenosphere	−0.8088	2.675×10^{-6}	15.63	5.534	47.85
	Al 7075 + 6 wt.% SiC + 5 wt.% Cenosphere	−0.7455	2.312×10^{-6}	4.400	6.393	54.93
	Al 7075 + 8 wt.% SiC + 5 wt.% Cenosphere	−0.7417	2.120×10^{-6}	6.020	6.538	58.67

Table 5. Electrochemical impedance parameters in natural seawater for different wt.% SiC.

Medium	*Metal sample*	R_p ($\Omega\ cm^2$)	Q ($\mu\Omega^{-1}\ s^n$)	n	C_{dl} ($F\ cm^2$)	η (%)
Natural sea water	Al 7075	1057	9.504×10^{-6}	0.798	2.966×10^{-6}	_
	Al 7075 + 2 wt.% SiC + 5 wt.% Cenosphere	1449	5.629×10^{-5}	0.8241	3.297×10^{-5}	27.05
	Al 7075 + 4 wt.% SiC + 5 wt.% Cenosphere	1645	7.346×10^{-5}	0.4955	8.543×10^{-6}	35.74
	Al 7075 + 6 wt.% SiC + 5 wt.% Cenosphere	2183	3.895×10^{-5}	0.8218	2.282×10^{-5}	51.58
	Al 7075 + 8 wt.% SiC + 5 wt.% Cenosphere	4578	1.029×10^{-4}	0.5278	5.247×10^{-5}	76.91

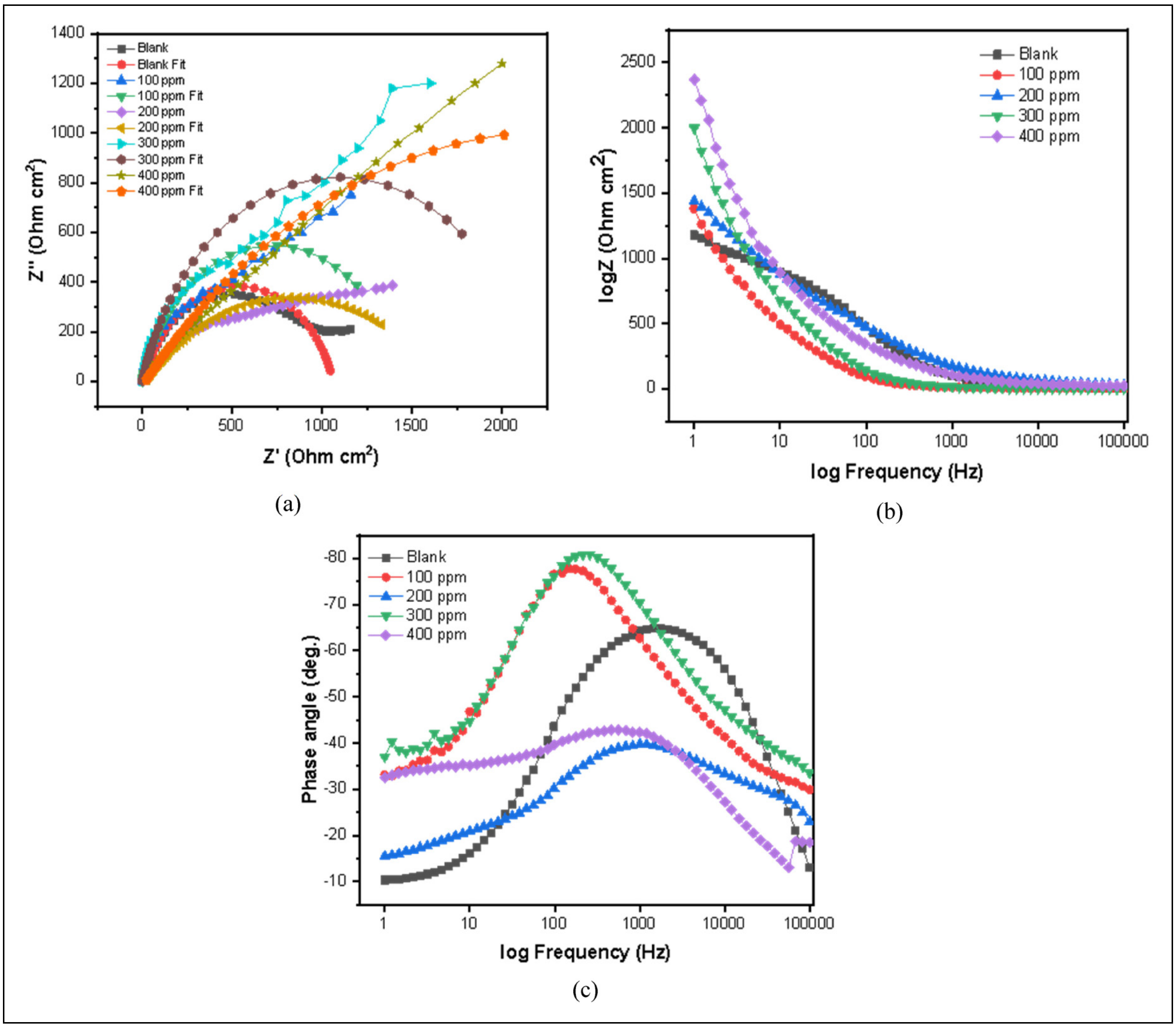

Figure 12. (a) Electrochemical impedance, (b) bode and (c) bode phase angle parameters in natural seawater at various wt.% of SiC.

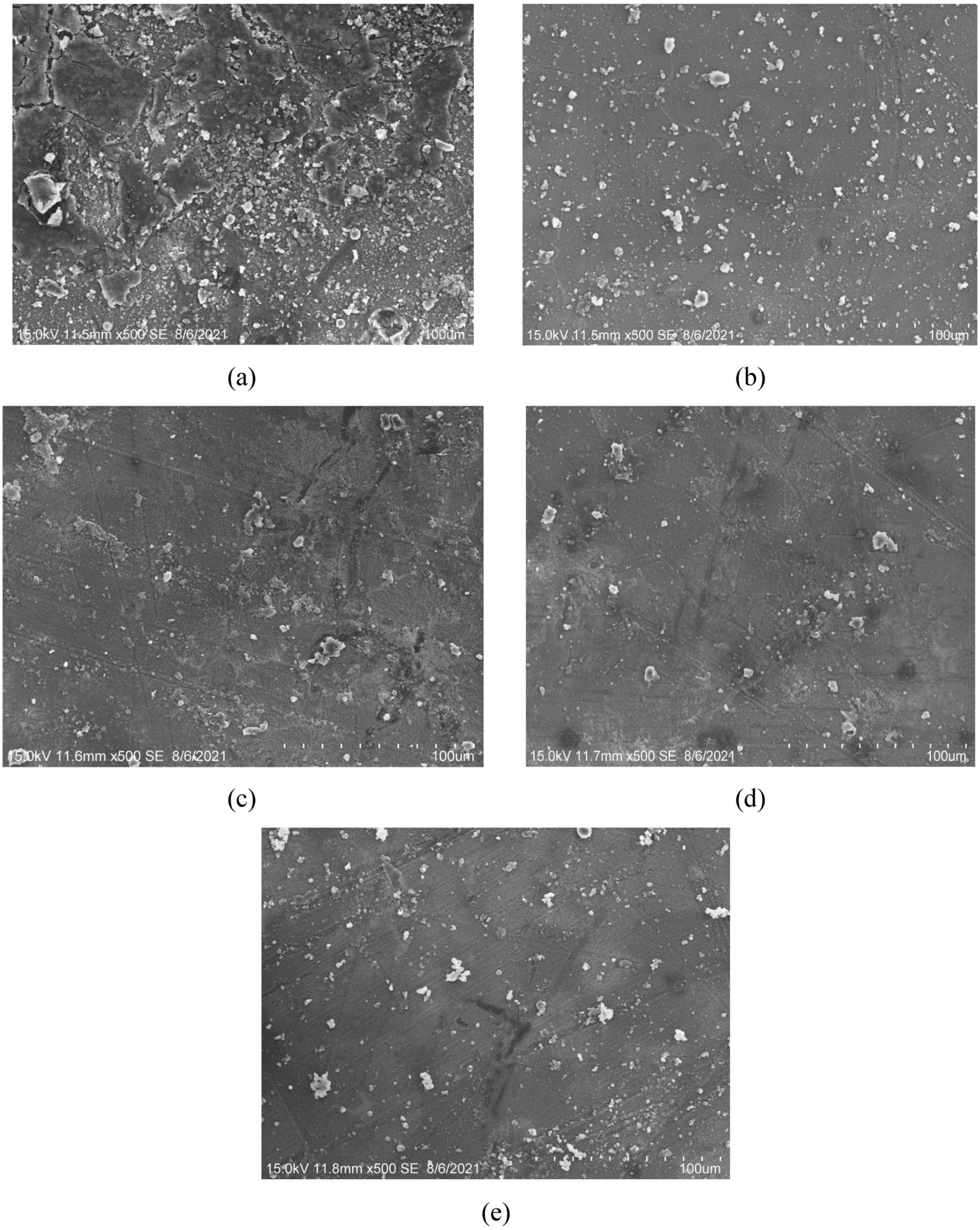

Figure 13. Corroded surfaces in natural seawater at various wt.% of SiC (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% and (e) 8 wt.%.

demonstrated a maximum strength of 263 MPa, an increase of approximately 43 MPa (20%) over the basic alloy.

3. Compared to the base alloy, the hardness of the Al7075/SiC/cenosphere composite steadily increased from 85 to 128 HV with the addition of wt.% SiC reinforcement. The composite comprises 6 wt.% SiC and 5 wt.% cenosphere demonstrated a maximum hardness. Further increase in reinforcement leads to a decrease in hardness.
4. In 3.5 wt.% NaCl, Al7075/SiC/cenosphere hybrid metal matrix composites outperformed pure Al matrix corrosion resistance. As the proportion of reinforcement increases, corrosion resistance increases as well.

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Data availability

The data that support the findings are included within the manuscript itself.

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