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Corrosion behavior of AA7075/E-Glass/Cenosphere Hybrid MMCs

Sunil Kumar A[1]*, D.P .Girish[2]

[1*] Research Scholar, Department of Mechanical Engineering, Government Engineering College, Ramanagar, Karnataka India

[2] Professor, Department of Mechanical Engineering, Government Engineering College, Ramanagar, Karnataka India

Abstract

Aluminum alloys and composites are often employed in naval applications because of their low weight and great formability. Multiple reinforcements, including mica, graphite, and e-glass fibers, were used in this work to synthesize Al7075 alloy-based composites. These reinforcements included cenosphere and e-glass fibers. The liquid metallurgy approach was used to manufacture the hybrid composites, which had varying amounts of reinforcement. The microstructure and corrosion behavior of Al7075 alloy and hybrid composites have been investigated. The salt spray corrosion test, which was performed in accordance with ASTM standards, was used to determine the alloy's corrosion properties. Hybrid reinforcements are dispersed rather uniformly throughout the microstructure, indicating a strong metallurgical connection between the hybrid reinforcements and aluminum alloy. An investigation was conducted on the influence of time lengths ranging from zero to fifty on weight loss. Increasing the amount of hybrid reinforcement in a structure reduces weight loss. Increasing the length of the salt spray test improves the weight reduction of each alloy as well as hybrid composites. When compared to unreinforced aluminum alloy, hybrid composites show less weight reduction under all of the conditions evaluated.

Keywords: Hybrid composites, Al7075 alloy, stir casting, salt spray test, E-glass fiber. Cenosphere.

1.0 Introduction

Aluminum-based composites are gaining widespread acceptance worldwide, particularly in applications where strength and weight are critical. Aluminum and its alloys have found uses in a wide variety of fields due to its reasonable strength and low density. They are now used to manufacture little domestic items such as foil, beverage cans, and culinary utensils as well as major items like as structural components for commercial and military airplanes. Aluminum alloy-based composites are required in some areas, such as aircraft, car, and transportation, due to their light weight and high strength [1-6].

Al7075 alloy is regarded the most malleable of all aluminum alloys due to its superior mechanical qualities, acceptable formability, low CTE, and toughness characteristics, which enables it to be used as a substantial promising matrix material in composite manufacturing. Additionally, this alloy is heat treatable, which means that stronger composites may be predicted after heat treatment. Researchers have concentrated their efforts on aluminum-based hybrid metal matrix composites during the last decade due to its capacity to offer customized material characteristics. However, there is an increasing difficulty in synthesizing hybrid aluminum MMCs with significantly improved mechanical and physical characteristics. This might be because the addition of two or more reinforcements to the lightweight aluminum matrix enhances the functioning of composites by introducing novel properties [7-10].

The parameters required to determine the behavior of the specimens are reliant on their mechanical and physical properties and must provide corrosion resistance. Reliability, the material's reactivity at low and high temperatures, and manufacturing capability at a range of temperatures are other considerations to consider throughout the selection process. Aluminum and its alloys are widely used in mechanical and chemical sectors for the manufacture of pumps, valves, heat exchangers, textiles, food, paper, and maritime industries [11]. Material expertise is critical when selecting materials for industries. The corrosion behavior of the material must be determined in advance to avoid unwanted situations during use. Nunes et al. [12] investigated alumina-aluminum and SiC-aluminum in the presence of sodium chloride. To determine the corrosion property, an immersion test and polarization test were conducted. The corrosion resistance of the composite alloy was found to be greater than that of pure aluminum. It was observed that pits developed at the interface between the matrix and secondary particles, resulting in secondary particle extraction from the composite. According to Bhat et al.,[13], the cast composite extruded from the cast demonstrated improved corrosion resistance because to a reduced pore count. Corrosion is slowed significantly by heat treatment. Mclnyre et al. conducted an in-depth investigation on the genesis of pitting behavior and precipitation in heat-treated alloys containing SiC [14]. Bienias et al. produced an aluminum composite by using cenosphere as secondary particles in order to investigate the influence of secondary particles on the corrosion parameters of the composite [15]. According to some research, the particle size, processing method, casting flaws, and alloying element % all have an influence on corrosion behavior [16]. Tazaskoma et al. [17] did a similar investigation and concluded that pitting was same for composites and their alloys, but was different for Al2024 alloys. According to them, the corrosion rate was caused more by the presence of oxygen than by SiC. SiC has a little function in strengthening the pitting resistance of the composite; rather, the response between the matrix and secondary particles dictates the degree of pitting susceptibility. Their investigation into the corrosion of aluminum- graphite composites revealed that the development of aluminum carbide at the interface resulted in an increase in corrosion of the produced composite. Trowsdale et al. observed considerable pitting around the fractures and surrounding the secondary particles in Al-SiC composites [18]. Numerous reinforcements, including Si_3N_4, TiC, TiO_2, SiC, SiO_2, Al_2O_3, carbon fiber, TiB_2, TiC, and glass fiber, are employed to fabricate composites [19-23].

However, due to the presence of numerous oxides, cenosphere is a common alternative for reinforcing. It is lightweight, strong, and resistant to wear and corrosion. The synthesis and assessment of cenosphere reinforced aluminum composites have been widely explored in the past [24–27].

No study has been conducted on the combined effect of E-glass fiber and cenosphere on the corrosion characteristics of Al7075-based hybrid mmc's. Numerous researchers have investigated this alloy as a potential material for hybrid and metal matrix composites. Additionally, there is inadequate information available on the effect of heat treatment on the corrosion behavior of aluminum-based hybrid mmc's reinforced with particles and fibers.

As a result, the present examination aimed to synthesize composites using low-cost reinforcements such as E-glass fiber and cenosphere in combination with an Al7075-alloy using the liquid metallurgical approach. Cenosphere was chosen as a particle type reinforcing material because to its unique attributes, which include tiny particle size, superior physical properties, and, most significantly, low cost in comparison to other commonly used particle type reinforcement materials. On the other hand, E-Glass is a fiber-reinforced material with a number of advantageous properties, including low CTE, high modulus, chemical inertness with exceptional tribological properties, and increased temperature stability, all of which contribute to the improvement of MMCs' mechanical and tribological properties [28-30].

In view of the foregoing, our research focuses on manufacturing Al7075-based hybrid MMCs using the stir casting process by adding Cenosphere and E-Glass fiber reinforcements. The content of Cenosphere and E-Glass fiber reinforcements was changed and their effect was investigated. Optical and corrosion tests were used to characterize and analyze the produced hybrid composites. Additionally, the effect of heat treatment (Solutionizing and Aging time) on the corrosion characteristics of hybrid metal matrix composites has been discussed.

2.0 Experimentation

As a matrix material, aluminum alloy 7075 was employed (Cu: 1.81, Cr: 0.2, Mn: 0.42, Mg: 1.75, Si: 0.52, Ti: 0.16, Zn: 3.21, Fe: 0.52, Balance: Al). Due to its excellent strength-to-weight ratio, 7000 series aluminum alloys are commonly utilized as components in transportation applications such as marine, automobile, and aeronautics. Cenosphere particles and E-glass fiber were used as hybrid reinforcements in the A17075 matrix material. To synthesize the composites, the Cenosphere particles were changed from zero to six weight percentages of two weight percentages, while the E-glass fiber was added at a weight % of zero to five. Figure 1 (a-b) and Figure.2 (a-b) show scanning electron micrographs and EDS patterns of Chopped E-glass fiber and Cenosphere particles, respectively. The sizes of the Cenosphere particles are discovered to be irregular in nature, ranging between twenty and fifty microns, whereas the rough length of cut of the E-glass fiber is five to eight mm.

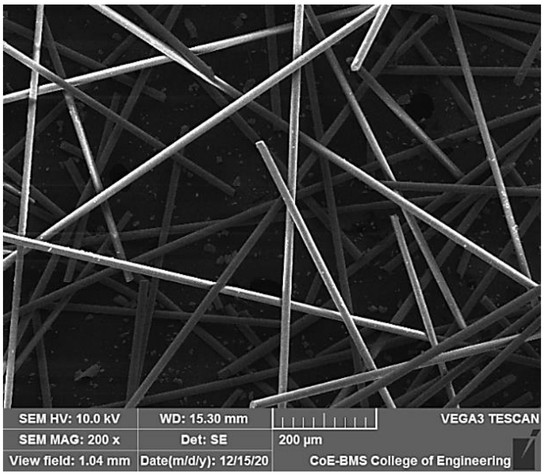

Fig.1(a): SEM of chopped E-glass fibre

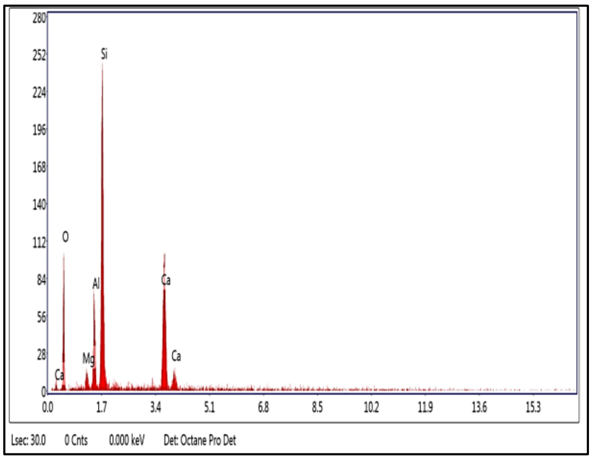

Fig.1(b): EDS of chopped E-glass fibre

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Fig.2 (a): SEM of Cenosphere particle

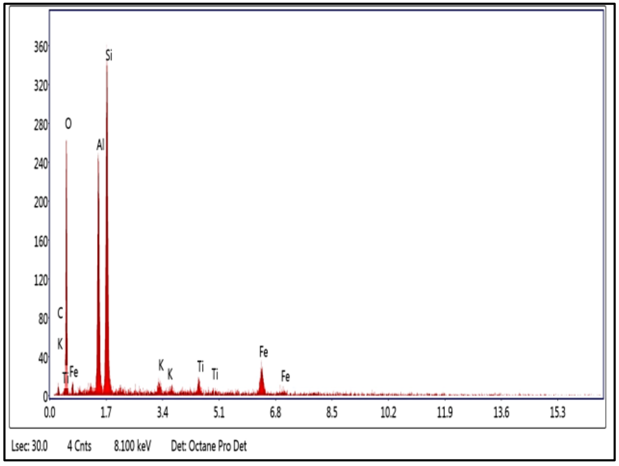


Fig.2 (b): EDS of Cenosphere particle

The hybrid aluminum composites are manufactured using an electric resistance melting furnace and a ceramic powder-coated mechanical stirrer to ensure the stirrer's longevity is increased. The composites were manufactured with the aid of a clay graphite pot by liquidizing the Al7075 alloy at a temperature of 750 ºC. To remove dissolved gases, oxides, and other contaminants from liquid metal, degassing tablets are included into the liquid, as well as to ensure the formation of slag. At about 250 revolutions per minute, the stirrer was turned and a vortex was created in liquid aluminum. To scatter E-glass fibers and cenosphere in liquid Al7075 alloy, it is believed that the vortex on the liquid metal's surface area is critical. At high speeds, the combination of liquid metals creates a more impressive vortex, which ensures homogeneous mixing. The composite slurry was then transferred to metallic molds and allowed to solidify.

Heat treatment of the cast specimens was accomplished by machining samples of Al7075 alloy and its hybrid composites in a heat treatment furnace. The examples had been solutionised for approximately 120 minutes and quenched in water media when they reached 520°C. Following quenching, both artificial and natural aging were utilized. At 190 ºC, the artificial aging process was completed for a variety of hours ranging from one to seven hours in increments of two hours for the water quenched samples. According to the ASTM B11 standard test protocol, salt spray analysis was performed on Al7075 alloy hybrid composites. The cubes 10*10*10 have been metallographically polished to maintain a constant area finish. The polished samples were weighed to the third decimal place. Following that, the polished samples were subjected to a Salt Spray test. Fig.3 illustrates the size of the salt spray test specimens. The test samples were brought to a halt in a salt spray chamber and subjected to an intermittent spray of dissolved 5% sodium chloride in distilled water for various totals of ninety-six hours. Following the examination, the samples were rinsed with running water and allowed to air dry before weight loss was calculated.

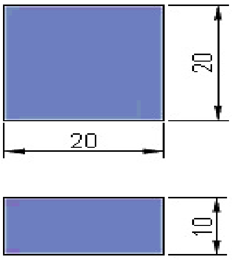
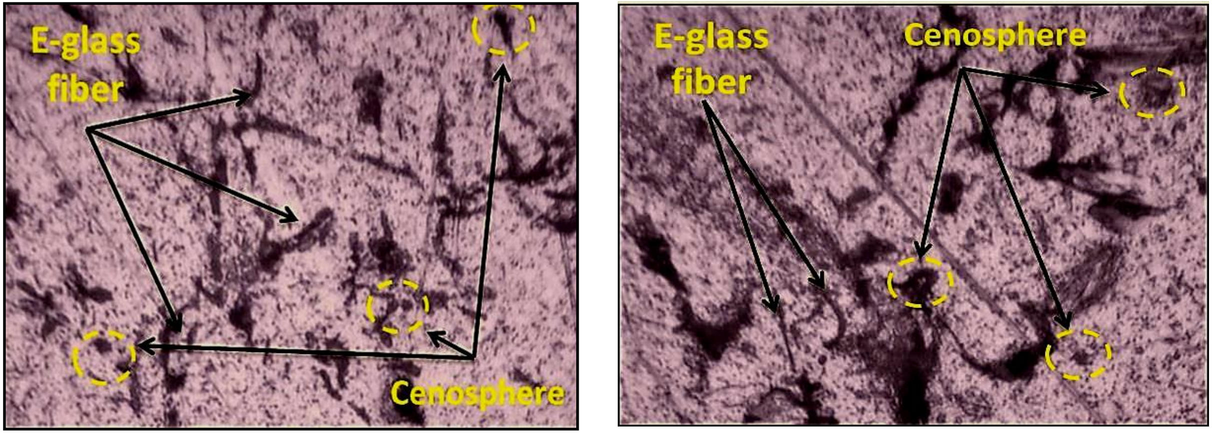


Fig 3: Dimension of Salt spray test specimen

3.0 Results and discussions

3.1 Microstructure:

Fig.4 shows optical images of Al7075–EGF–Cenosphere hybrid composites. Fig.4 illustrates the varied percentages of cenosphere particles and E-glass fibers in the hybrid composites. The reinforced phase's dispersion (both fiber and particle) is generally even in all micrographs. The agglomerations of cenosphere particles and E-glass fibers are hardly discernible in both systems. Numerous researches have proven that wettability and surface tension are the two primary properties that influence the dispersion and bonding of reinforced particles in aluminum alloys. The dispersion of fibers and particles, in particular, is largely determined by the wetting properties of the reinforced phase. The optimal processing parameters during the stir casting process are critical for resolving the wettability problems associated with MMCs. To improve control over dispersion properties and wettability, the stirring temperature, stirring duration, and mixing time must be optimized. The optimal processing conditions prevent fibers and particles added to liquid aluminum from clustering [29-30].



(a) Al7075/3% E-glass fibre/6%Cenosphere (b) Al7075/5% E-glass fibre/6%Cenosphere

Fig. 4(a-b): Optical micrographs of Al7075/EGF/Cenosphere composites

3.2 Corrosion studies

3.2.1 Impact of dual Reinforcement

The variance in weight loss is seen in Fig 5 for salt-sprayed specimens of alloy and its hybrid MMCs. According to the graph, all of the specimens investigated can attest that as test length increases, weight loss increases. Additionally, as compared to unreinforced alloys, the MMCs shown less weight loss. Corrosion weight loss of hybrid MMCs increases when the dual reinforcement percentage is increased. As can be observed from the data, the weight loss of the alloy increases as the number of dual reinforcement's increases. For a fixed number of glass fiber and cenosphere particles, the weight loss of the MMCs increases indefinitely in each of the instances investigated. Under identical test settings, matrix material demonstrated the greatest weight decrease. As a result, hybrid MMCs may exhibit worse corrosion protection as compared to unreinforced alloys.

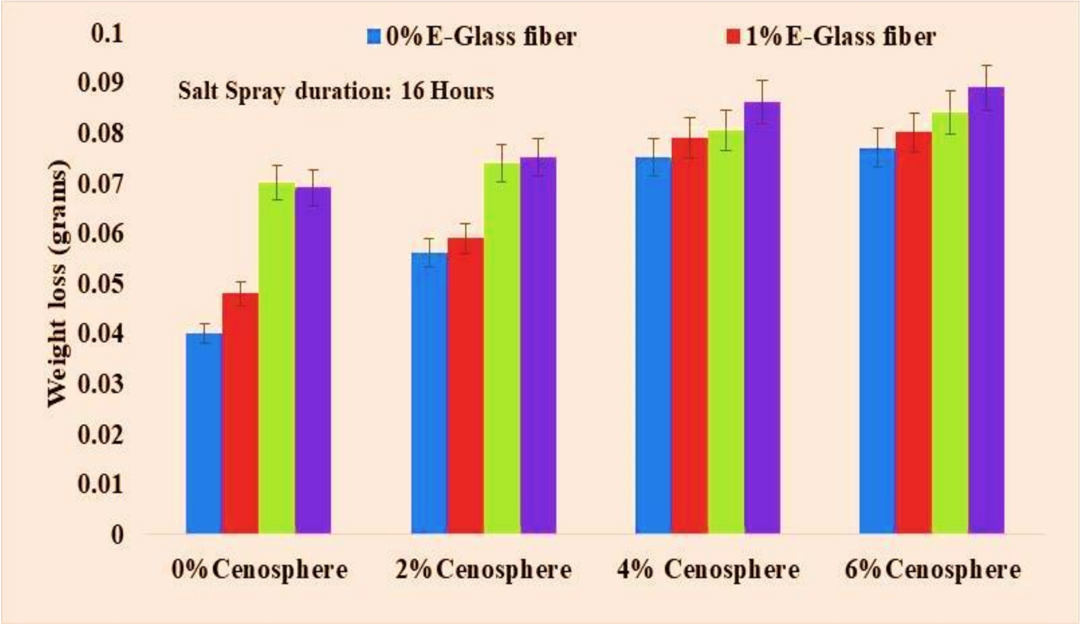


Fig.5: Impact of dual Reinforcement on corrosion

3.2.2 Impact of Salt Spray Duration

The weight loss in days as a function of immersion time is depicted in Fig.6. It is shown that while weight loss initially rises with increasing immersion duration up to 30 hours, after this point, weight loss decreases significantly for both matrix and its hybrid MMCs up to 50 hours. Additionally, it is seen that hybrid MMCs lose less weight after 30 hours. This can be attributed to the fact that the composite is framed by a continuous oxide layer; the formation of such oxides diminishes the corrosion rate response over time. With anodic ions, solution saturation and the formation of a far more stable passive oxide layer, a steady-state condition, occurs within a few days, regardless of whether it is an unreinforced matrix alloy or hybrid composite. This is because a continuous oxide layer forms across the composite; the formation of such oxides decreases the corrosion rate responsiveness over time.

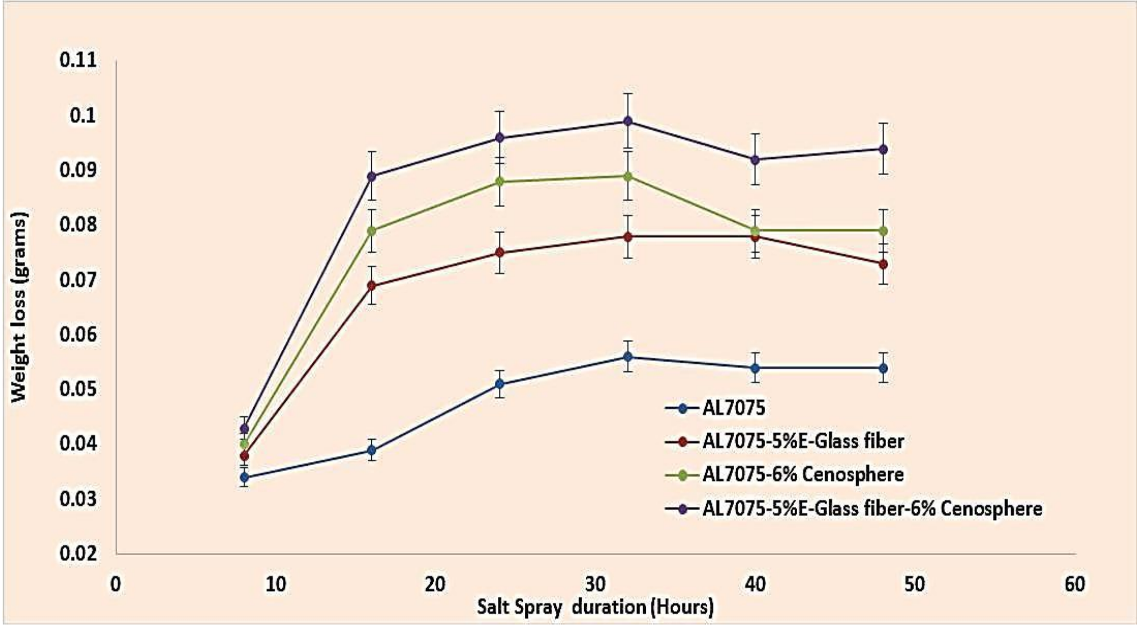


Fig. 6: Impact of salt spray duration on weight loss

3.3.3 Impact of heat treatment

Fig.7 illustrates the effect of heat treatment on the weight reduction of both the alloy and its hybrid MMCs. The figure demonstrates that heat treatment has a significant effect on the corrosion conductivity of both the matrix material and its hybrid MMCs. Regardless, as compared to the unreinforced matrix alloy, the hybrid MMCs exhibit slightly insufficient corrosion protection under all heat treatment settings. Additionally, as compared to unreinforced alloys, hybrid MMCs exhibit subtly improved corrosion protection.

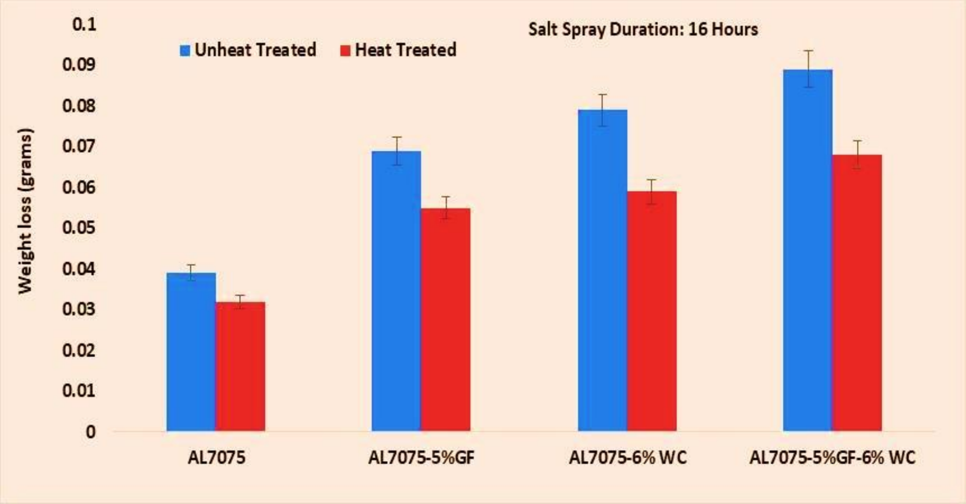


Fig.7 : Heat treatment effect on weight loss

3.3.4 Mechanism of Corrosion

The micrograph of hybrid MMCs sprayed with salt is shown in Figure 8.(a-d). Each micrograph demonstrates that the composite is heavily corroded by pitting corrosion, which can be felt. However, this phenomenon is influenced by both the distribution and the substance of reinforcement. Among the several corrosion processes suggested by the researchers.

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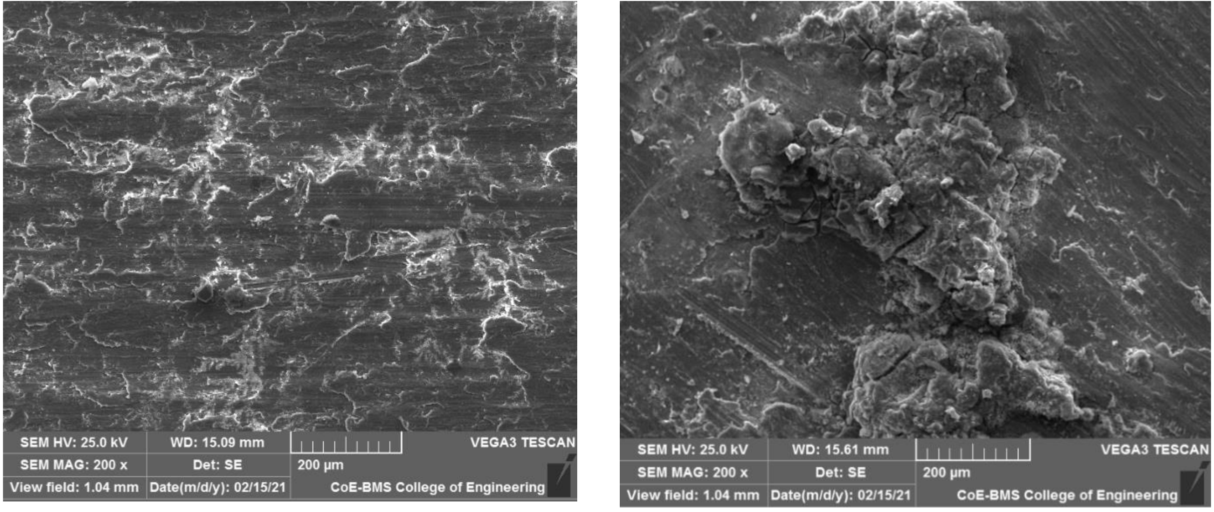
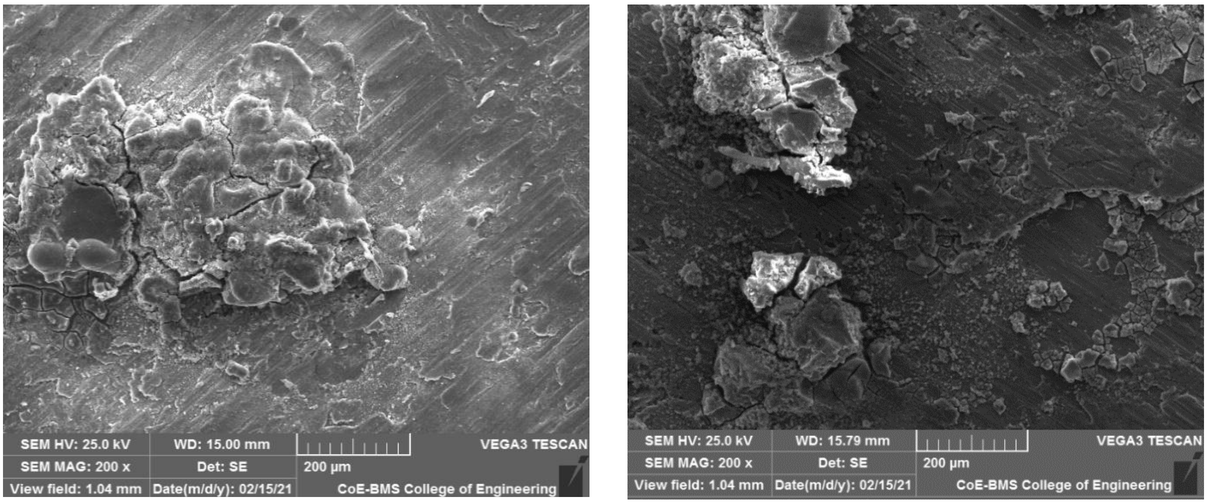


(a)Al7075 alloy (b)Al7075 alloy



(c)Al7075-6%cenopshere-5%EGF (d)Al7075-6%cenopshere-5%EGF

Fig. 8(a-d): SEM of corroded surfaces of alloy and hybrid MMCs

The passive layer breakdown process is a significant one that is experienced by chloride ions and chlorine penetration through the oxide layer. The production of corrosion pits in alloys and MMCs is discussed in the present study using the following procedures [31-34].

- On the surface, the creation of a protective passive layer following initial exposure to the attacking/solution CI ions.
- At the metal/oxide interface, localized dissolution generates an acidic environment that promotes matrix breakdown and the formation of blisters under the oxide layer. The region of the surface that cannot form the passive layer plays a critical role in the creation of the pit. The blister development, which is said to occur below the oxide layer due to Cl ion adsorption, is supported by samples of the positively charged surface and intermetallic partners, which act as local cathodes for the Cl ions.
- Under favorable conditions, these blisters enlarge and rupture, forming a brand new open pit.
- The oxide layer is also undergoing continuous breakdown, and repair and breakdowns become more difficult to heal due to the retardation of passivation by chlorine, a robust species that now attacks the newly exposed area.

4.0 Conclusions

1. Optical micrographs reveal excellent homogeneity in reinforced fibers and particle dispersion due to the reinforcement's union with the matrix. The interface is unambiguous and devoid of reaction products.
2. Corrosion of Al7075 alloy and hybrid composites increases as salt spray duration increases up to 30 hours. After 30 hours, weight loss was reduced for the alloy and its hybrid composites.
3. Heat treatment improved the corrosion resistance of the alloy and its hybrid composites marginally.

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References:

[1] I.A. Ibrahim, F.A. Mohamed, E.J. Lavernia, "Particulate reinforced metal matrix composites—a Review", Journal of Material Science Vol 26, (1991), Page 1137–1156.

[2] KV Shivananda Murthy, R Keshavamurthy, DP Girish "Mechanical characteristics of hot forged Al6061-Al2O3 composite", Applied Mechanics and Materials 787, 598-601.

[3] C.S. Ramesh, R. Keshavamurthy, B.H.Channabasappa, S.Pramod: Tribology International Vol. 64(2010), P.623 – 634.

[4] R. Deaquino-Lara, E. Gutierrez-Castaneda, I. Estrada-Guel, G. Hinojosa-Ruiz, E. Garcia-Sanchez, J.M. Herrera-Ramirez, R. Perez-Bustamante, R. Martinez-Sanchez, "Structural characterization of Aluminum alloy 7075-graphite composites fabricated by mechanical alloying and hot extrusion", Materials & Design, Volume 53, January 2014, Pages 1104-1111.

[5] A kumar Gajakosh, R Keshavamurthy, T Jagadeesha, RS Kumar "Investigations on mechanical behavior of hot rolled Al7075/TiO2/Gr hybrid composites" Ceramics International.

[6] RV Kumar, R Keshavamurthy, CS Perugu, PG Koppad, M Alipour "Influence of hot rolling on microstructure and mechanical behaviour of Al6061-ZrB2 in-situ metal matrix composites" Materials Science and Engineering: A 738, 344-352.

[7] K.V.S. Murthy, D.P. Girish, R. Keshavamurthy, T. Varol, P.G. Koppad, "Mechanical and thermal properties of AA7075/TiO_2/Fly ash hybrid composites obtained by hot forging", Progress in Natural Science: Materials International, Volume 27, Issue-4, August 2017, Pages 474-481.

[8] P.Agarwal, and C.T. Sun, "Fracture in metal ceramic composites". Composite Science &Technology 64 2004) 1167-1178.

[9] S.R Nimbalkar, MhaseVijay ,Manoj Satpute (2015) , Aluminiumalloy Al-7075 reinforcement and Stir casting -a Review.

[10] R.C. Paciej, V.S. Agarwala, "Corrosion", 44, 10, (1998), 680.

[11] Robert Akid, Handbook of Advanced Materials, (2004), 4th Edition, John Wiley and Sons, 487 – 488

[12] R.C.R. Nunes and L.V. Ramanathan, Corrosion Behaviour of Alumina-Aluminium and SiC-Aluminium Metal Matrix Composites", Corrosion.(1995), 610-617

[13] S.N. Bhat, M.K. Surappa, HVS Naik, "Corrosion behaviour of SiC particle reinforced 6061/Al alloy composites", J. Mat. Sci., 26, 18, (1991), 49-91

[14] J.F. Mclntyre, R.K. Conrad, S.L. Goledge, J. Corrosion, 46 (11), (1990), 902.

[15] J. Bienias, M. Walezake, "Microstructure and Corrosion Behaviour of Aluminium Flyash composites", J. Optoelectronics and Advanced Materials, 52, (2003), 493 – 502.

[16] H.J. Greene and Mansfield, "Corrosion Protection of Aluminium Metal Matrix Composites", J. Corrosion, 53 (12), (1997), 920 – 927

[17] P.P. Tazaskoma, E. Mc Cafferty and C.R. Crowe, "Corrosion behaviour of SiC/Al metal matrix composites", J. Electrochem. Soc., 130, (1983), 1804.

[18] A.J.Trowsdale, B.Noble, S.J.Harris, I.S.R.Gibbins, G.E.Thompson, and G.C.Wood, "The Influence of Silicon Carbide Reinforcement on the Pitting Behaviour of Aluminium", Corrosion Science, V38, N2, (1996),177-191

[19] Shorowordi KM, Haseeb ASMA, Celis JP. Tribo-surface characteristics of Al– B4C and Al–SiC composites worn under different contact pressures. Wear 2006; 261:634–41.

[20] Ramesh CS, Safiulla M. Wear behavior of hot extruded Al6061 based composites. Wear 2007; 263:629–35.

[21] Kumar S, Chakraborty M, Subramanya sarma V, Murthy BS. Tensile and wear behaviour of in situ Al–Si/TiB_2 particulate composites. Wear 2008; 265: 134–42.

[22] Sudarshan, Surappa MK. Dry sliding wear of fly ash particulate reinforced A356 Al composites. Wear 2008; 265:349–60.

[23] R. Asthana, P.K. Rohatgi, "on the melt infiltration of plain and nickel- coated with aluminum alloys" J. Mater. Sci. Lett. 11 (1993) 442.

[24] Sachin Malhotra, Ram Narayan, R. D Gupta, "Synthesis and Characterization of Aluminium 6061 Alloy-Fly ash& Zirconia Metal Matrix Composite", International Journal of Current Engineering and Technology, Vol. 3, No. 5, pp. 1716-1719, 2013.

[25] R Keshavamurthy, BE Naveena, A Ahamed, N Sekhar, D Peer "Corrosion characteristics of plasma sprayed flyash–SiC and flyash–Al_2O_3 composite coatings on the Al-6061 alloy" Materials Research Express 6 (8), 0865i4.

[26] BE Naveena, R Keshavamurthy, N Sekhar "Dry Sliding Wear Behaviour of Plasma Sprayed Flyash-Al_2O_3 and Flyash-SiC Coatings on the Al6061 Aluminum Alloy" Silicon 11 (3), 1575-1584.

[27] BE Naveena, R Keshavamurthy, N Sekhar "Comparative study on effects of slurry erosive parameters on plasma sprayed flyash-Al_2O_3 and flyash-SiC composite coatings on Al6061 alloy" International Journal of Computational Materials Science and Surface. Vol. 8, No. 1, 2019.

[28] J. W. Pinto, G. Sujaykumar, Sushiledra R. M "Effect of Heat Treatment on Mechanical and Wear Characterization of Coconut Shell Ash and E-glass Fiber Reinforced Aluminum Hybrid Composites" American Journal of Materials Science 2016, 6(4A): 15-19.

[29] Siddharth Patela and R.S. Rana and Swadesh Kumar Singh, "Study on mechanical properties of environment friendly Aluminium E-waste Composite with Fly ash and E-glass fiber" Materials Today: Proceedings 4 (2017) 3441–3450.

[30] C. M. Rejil, I. Dinaharan, S.J. Vijay, N. Murugan, Microstructure and sliding wear behavior of AA6360/(TiC + B_4C) hybrid surface composite layer synthesized by friction stir processing on aluminum substrate, Materials Science and Engineering A 552 (2012) 336–344.

[31] Frankel, G.S., 1998. "Pitting corrosion of metals a review of the critical factors". Journal of the Electrochemical Society, 145(6), pp.2186-2198.

[32] McCafferty, E., 2003. "Sequence of steps in the pitting of aluminum by chloride ions. Corrosion Science", 45(7), pp.1421-1438.

[33] Natishan, P.M. and O'grady, W.E., 2014. "Chloride ion interactions with oxide-covered aluminum leading to pitting corrosion": a review. Journal of The Electrochemical Society, 161(9), pp.C421-C432.

[34] Y.L.Saraswathi, S.Das, D.P.Mondal, "A comparative study of corrosion behaviour Al-SiCp composites with cast Iron" Corrosion, 57, (7) (2001) 643-660.