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Corrosion behavior of particulates reinforced Aluminium metal matrix composite

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ABSTRACT

Aluminium-3%Magnesium-10% silicon carbide composite is prepared in an induction heating furnace. The physical characteristics of both as-casted sample and corroded samples have been studied. A slice of the composite sample is kept in sea water for 6 weeks (42 days) and the weight loss was measured with the help of an electronic weighing machine in every 7 days to study the corrosion behavior.

1.Introduction

Aluminum based MMCs (AMCs) is a suitable materials for structural and mechanical applications as they provide unique advantages over conventional monolithic materials in terms of more specific strength and stiffness, improved wear resistance and high temperature capabilities, adjustable coefficient of thermal expansion (CTE) and resistance to thermal fatigue [1-4]. The particulates reinforced metal matrix composites (PRMMC) exhibit high strength, hardness, and wear and erosion resistance which gives a wide application i.e. automobiles, fuel access door covers and ventral fins in automobiles, bicycle frames, golf club shafts, track shoes in military tanks, Cryostats, ice hockey sticks, flywheels, rocket turbine housing, missile nose tips, etc. [5-8]. The PRMMC have superior plastic forming potential than fiber and whisker strengthened composites which in turn reduces their manufacturing cost. The properties of PRMMCs depend upon the size and properties of the reinforcing particle, interparticle spacing, and particle-matrix interface condition and shape and volume fraction of the particle [9]. PRMMCs can be fabricated through a variety of manufacturing routes such as powder metallurgy, diffusion bonding (solid state processing), stir casting, melt infiltration, spray deposition (liquid state processing) and in-situ processing techniques. But the effect of segregation and the tendency to formation of intermetallic phases is reduced in powder metallurgy processing when compared to processing in liquid state [10-11].

The reinforcement in AMCs could be in the form of whisker or particulates, continuous/discontinuous fibers, in volume fractions having a range from a few percent to 70%. Addition of Mg to Al gives many advantages as follows [12-15]:

1) Magnesium has two thirds the weight of Aluminium, thus addition of Magnesium to Aluminium leads to decrease in the density of the alloy.

2) Magnesium has higher specific strength than Aluminium. Thus the addition of Magnesium results in increased strength of alloy as compared to Aluminium.

3) Magnesium addition leads to an increase in the strength to weight ratio. Thus the alloys are more suitable for automobile and aircraft parts as it increases the fuel efficiency.

4) Addition of magnesium to aluminium results in precipitation and age hardening ofalloy. Thus the strength is significantly increased.

5) The most important advantage of Magnesium addition is that it improves the wettability of solid ceramic reinforcement in Aluminium metal matrix composites. Better wettability would result in more homogeneous distribution of reinforcement inthe matrix.

6) Magnesium also improves the formability and castability of aluminium.

Silicon carbide is one of the most widely used ceramic reinforcements in AMCs and contributes following advantages [16-18]:

1) SiC have high corrosion resistance,
2) low thermal expansion coefficient,
3) high thermal conductivity,
4) High hardness and good refractory properties.
5) SiC improves strength of the alloy and the elevated temperature hardness.

In this paper we are investigating about 6XXX series of aluminum alloys (Al-3%Mg-10%SiC composite). Here the corrosion behavior of the Al-3%Mg-10%SiC composite sample studied when the composite is exposed to sea water.

2.Experimental procedure

Aluminium-3%Magnesium-10% silicon carbide alloy block of dimension 100 mm x 100 mm x 30 mm is prepared by stir casting route in an induction heating furnace. A modified stir casting technique for preparation of the Al-Mg alloy is designed using low cost scrap Mg, using a plunger for making the alloy addition. A mild steel cylinder container is coated with aluminium and used to hold the aluminium melt.

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A hollow spindle which has its stirrer blades attached to motor and V-belt arrangement for better stirring. The plunger rod is attached to perforated capsule which holds the magnesium. Aluminium blocks are melted in the crucible at temperature of 800 °C and stirred at 500 rpm. Magnesium turnings are added one after another through the hollow spindle. The magnesium is released after the aluminum foil coating melts and the Mg dissolves in 15 seconds. Then the reinforcement SiC particles are added in the similar manner. The melt is poured into the mould and cooled. Then samples of the required dimensions are cut for the wear and other tests. Three cylindrical samples of diameter 10 mm and a height of 30 mm were cut from the block using a highly calibrated lathe machine for the wear test. A slice of the composite sample is kept in sea water for 6 weeks (42 days) and the weight loss was measured with the help of an electronic weighing machine in every 7 days to study the corrosion behavior. Then the SEM analysis is done to get the corrosion mechanism.

3. Results and discussion

3.1 Surface morphology and phase analysis of as-casted sample:

Figure 1 shows the SEM surface morphology of as-casted Al-3%Mg-10%SiC composite. By the EDS analysis it is clear that 71.03 wt. % of Al, 1.85 wt % of Mg and 9.47 wt % of Si are present in the compound alongwith 17.65 wt % of O.

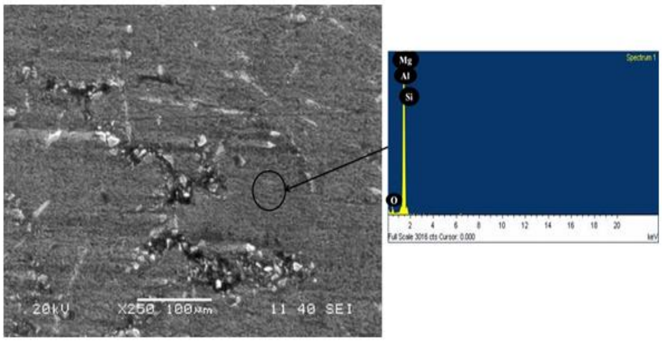

Fig 1. SEM micrograph of the as-casted Al-3% Mg-10% SiC composite sample before exposure to sea water.

Figure 2 shows XRD pattern of the as-cased Al-3%Mg-10%SiC composite. Here all the rainforced particles are present without forming any complex compound. The major elemental form of Al is identified at (111), (002) and (113) plane. Magnesium favorably grow in (011) plane. But SiC grows along with the Aluminum plane. Here it is clear that the homogenization and wettability of SiC along the Aluminum is better than the magnesium [19].

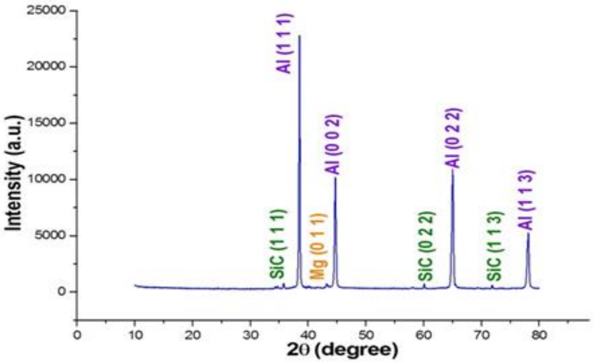

Fig 2. XRD pattern of the selected area of as-deposited Al-3% Mg-10% SiC composite.

3.2 Surface morphology of Corroded samples

After one week exposure to sea water, the surface morphology of corroded Al-3%Mg-10%SiC composite has been studied by the SEM (Figure 3). By the EDS analysis, it is found that 30.13 wt % of Al, 10.38 wt % of Mg, 4.97 wt % of Si are present alongwith little 49.23 wt % of O, 0.01 wt % of Na, 1.45 wt % of S, 0.61 wt % of Cl and 3.23 wt % of Fe are present. The corroded sample conforms the formation of compounds containing Sodium, Chlorine, Sulfur, Iron on the composite sample surface which is absorbed from the sea water. The SEM image of the corroding surface also confirms the formation of a large amount of compounds on the composite surface.

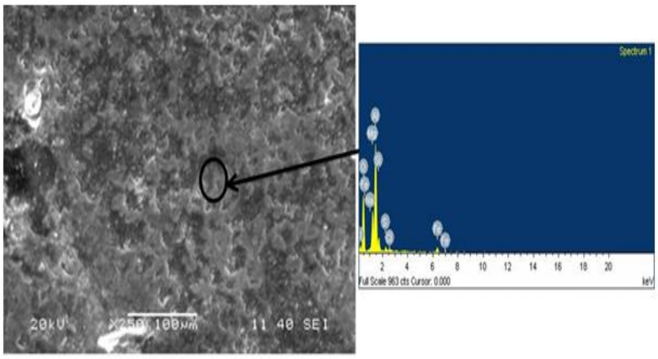

Fig 3. SEM micrograph of the composite sample after 1 week exposure to sea water.

Figure 4a and 4b shows the corroded sample after 3 week and 6 weak exposures to sea water, respectively. The SEM micrograph of the composite sample after 3 weeks exposure to sea water shows that the compounds formed due to the corrosive attack on the sample surface are removed continuously causing wt. loss of the sample. Then fresh surface is exposed to the sea water for fresh attack. The SEM image shows large corroded portions which are again exposed to fresh corrosive attack. Figure 4c showing the enlarge portion of pitting corrosion on the sample. The wt. of the corroding sample decreases continuously after 1st week till 6th week. The SEM micrograph of the composite sample after 3 weeks exposure to sea water shows that the compounds formed due to the corrosive attack on the sample surface are removed continuously causing wt. loss of the sample. Then fresh surface is exposed to the sea water for fresh attack. The SEM image shows large corroded portions which are again exposed to fresh corrosive attack. The corroded portions initiate pits for the starting of pitting corrosion. Then the corrosive elements present in the sea water like Na, Cl, S etc. attack around the pit boundary to form bigger pits and more wt. loss.

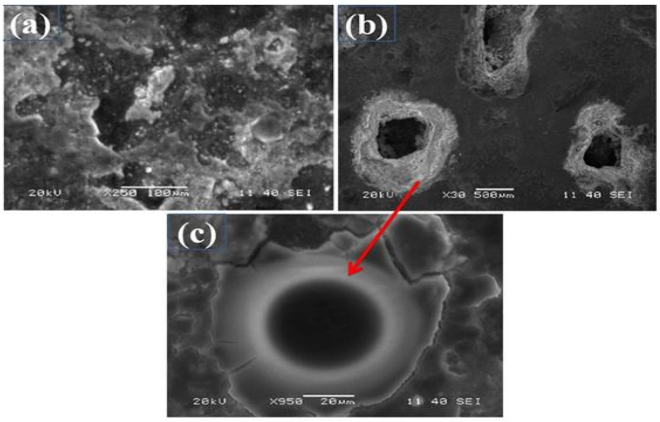

Fig 4. SEM micrograph of the composite (a) sample after 3 weeks exposure to sea water, (b) after 6 weeks showing pitting corrosion, (c) Enlarged view of a pit showing pitting corrosion.

3.3 Mass loss analysis

The composite sample is kept in sea water for 6 weeks (42 days) and the weight loss was measured with the help of an electronic weighing machine in every 7 days to study the corrosion behavior. A graph between the wt of the sample and no of days exposed to sea water is plotted and SEM images of the corroded sample are taken after 1st, 3rd and 6th week. The corroded sample conforms the formation of compounds containing Sodium, Chlorine, Sulfur, Iron on the composite sample surface which is absorbed from the sea water. This is the prime reason for the increase of the wt. of the composite after 1st week of the exposure to sea water. The wt. of the corroding sample decreases continuously after 1st week till 6th week. The SEM micrograph of the composite sample after 3 weeks exposure to sea water shows that the compounds formed due to the corrosive attack on the sample surface are removed continuously causing wt. loss of the sample. Then fresh surface is exposed to the sea water for fresh attack.

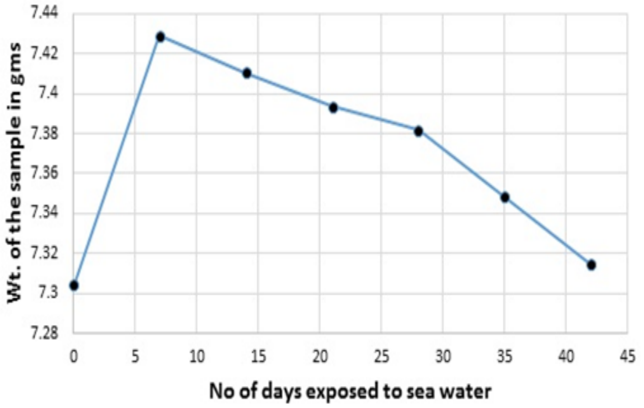

Fig 5. Graph between Wt. of the corroding sample and no. of days exposed to sea water The graph shows that there is an increase in wt. of the composite sample in the first week of the experiment. Then the wt. of the sample decreases continuously due to corrosion phenomena. The reason is clear from the EDX and SEM analysis.

Conclusion

The wt. of the corroding sample decreases continuously due to pitting corrosion. The composite was found more prone to pitting corrosion when it was exposed to sea water containing O_2, H_2, Cl, Na, Mg, S, Ca, K, Br, C, etc. Increase of the wt. of the composite after 1st week of the exposure to sea water. The wt. of the corroding sample decreases continuously after 1st week till 6th week.

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