

Corrosion Behaviour of Thermomechanically Processed AA6063-SiC_p Composites in NaCl and H₂SO₄ Environment

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Abstract

The influence of thermomechanical treatment on the corrosion behaviour of silicon carbide particulate reinforced Aluminium (6063) composites in 3.5 wt% NaCl and 0.3M H₂SO₄ solution was investigated. AA6063 – SiC particulate composites having 6 and 9 volume percent of SiC were produced using two-step stir casting process. The composites were cold rolled to 20 % and 35 % deformation before solution heat-treating at 550°C for 1hour cooling rapidly in water. Mass loss and corrosion rate measurements were utilized as criteria for evaluating the corrosion behaviour of the composites. It is observed that AA (6063) – SiC_p composites exhibited superior corrosion resistance in 3.5 wt% NaCl solution when compared to 0.3M H₂SO₄ solution. Furthermore, the thermomechanical treatment resulted in significant improvement in the corrosion resistance of the composites in H₂SO₄ solution.

Keywords: Stir casting; Al (6063) – SiC_p composite; Thermomechanical treatment; Corrosion rate; mass loss.

1.0 Introduction

Design of components and equipment to meet service conditions requires a critical task of selecting the appropriate materials [1]. It is on this basis that efforts have been made by researchers to develop novel materials and processes that will enhance optimum performance in service. An example of the classes of materials that have been developed in recent time is metal matrix composites. Metal Matrix Composites which possesses attractive combination of mechanical properties (specific stiffness, high strength, wear resistance) contain a pure metal or alloy (typically aluminium, copper, titanium and magnesium) as the matrix and a ceramic

(usually particles, fibres, or intermetallics) as the reinforcement. MMCs are either reinforced continuously (with fibers) or discontinuously (whiskers or particles) but discontinuously reinforced MMCs have isotropic mechanical properties and good tribological properties [2]. In addition, discontinuously reinforced composites especially those produced via stir casting are easier to produce and are compatible with further processing such as machining, welding and deformation [3, 11]. Aluminium matrix composites, an epitome of metal matrix composites have been given much attention by researchers due to light weight, ductility, low melting point and corrosion resistance offered by aluminium alloys [4, 12]. As a result, they have been used extensively in aerospace, automotive, recreational and marine industries. The application of these materials in the marine industries exposes the materials to chloride ions which could attack and deplete the materials [14]. In addition, the interest in studying the corrosion behaviour of the composite in sulphuric acid medium is informed by its potential applications in chemical industries where it could come in contact with acids during operations such as cleaning, pickling, and de-scaling [1, 9]. Unlike unreinforced alloys, research effort seeking knowledge about the corrosion behavior of aluminium matrix composites has yielded results that are not matching [5, 6] and as a result, it is difficult to give a general conclusion on the corrosion behaviour of these materials. The reason for this has been ascribed to variations in the alloys used, reinforcement used, production methods, secondary processing and interfacial reactions [7]. Despite the fact that corrosion behaviour of Aluminium Matrix Composites (Al6063-Al₂O_{3p}, Al6061-SiC_p, Al7075-SiC_w, Al2024-SiC_p, Al356-Al₂O_{3p} among others) in marine environment have been well documented [5, 6, 8, 9], only few research papers have been published on the effect of thermo-mechanical treatment on the corrosion behaviour of composite. Alaneme and Bodunrin [10] in their previous research studied the corrosion behaviour of as cast and solution treated aluminium 6063-alumina composites in three different media (NaCl, H₂SO₄, NaOH). The researchers discovered that no significant corrosion was observed in NaCl environment for both as cast and solution treated samples. Some components utilized in service are not used in as cast form but are subjected to secondary processing (cold deformation and heat treatment) before use in order to improve the mechanical properties. However, it has been reported that these secondary processes influence the corrosion behaviour of metal matrix composites [11]. Therefore, this present study aims at studying the effect of secondary processing (thermo-mechanical) on the corrosion behaviours of aluminium 6063 matrix composites reinforced with

silicon carbide particulates in both marine and acidic environment so as to provide information for material selection purposes.

2.0 Material and Method

Composite Production

Aluminium (6063) with composition in table 1 was utilized as the metal matrix while silicon carbide with particle sizes of 28 μ m was used as the reinforcement. The composites having 6 and 9 volume percent silicon carbide were produced by adopting a two-step stir casting technique. The wettability of the composites was improved by mixing the silicon carbide particulates with borax (wetting agent) in ratio 2 to 1 prior to introduction into the liquid alloy. The two step stirring technique was adopted to improve the distribution of particles in the matrix. It entails melting the aluminium alloy in a gas fired crucible furnace, the melt was allowed to solidify to a semi-solid state after which the reinforcements were introduced and stirred manually for 5 minutes to break the surface gas layers. This was then followed by heating the mix to a temperature of 30°C above the liquidus accompanied with mechanical stirring at 300 rpm for 10 minutes before pouring into a cylindrical rod (220 \times Ø20 mm) mould. Monolithic aluminium alloy was also prepared for control experimentation.

Sample Preparation

Four different temper conditions were utilized in this present study, as cast condition and three others namely, solutionized only, 20% deformation plus solution heat treatment; and 35% deformation plus solution heat treatment. The solution treatment was carried out by heating the samples to 550°C, held for 1 hour and quenched in water.

Immersion Testing

The tests were carried out in 3.5 % NaCl (pH 7.4) and 0.3M H₂SO₄ (pH 0.85) which was prepared following standard procedures. The specimens for the test were cut to sizes 20 \times 20 \times 5 mm, after which the sample surfaces were mechanically polished with emery papers starting from 120grit down to 640grit size. The samples were degreased in acetone and then rinsed with distilled water before immersion in still solutions which were exposed to atmospheric air. The solution-to-specimen surface area ratio was about 150 ml cm⁻². The result of the corrosion test

was evaluated using mass loss and corrosion rate measurement and the experiment was monitored on forty-eight hours interval for 768 hours. Mass loss (g/cm^2) was determined by dividing the cumulative weight loss (measured using a four decimal digit electronic weighing balance) by its total surface area in accordance with ASTM G31 standard recommended practices [13]. The corrosion rate in millimeter per year (mmy) was determined from the weight loss following standard procedures.

Table 1- Composition of Aluminium 6063 alloy

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.45	0.22	0.02	0.03	0.50	0.02	0.03	0.02	Bal.

3.0 Results and Discussion

Corrosion Behaviour in H_2SO_4 Environment and Marine (3.5% NaCl) Environment

Figures 1a, 1b and 1c represent the corrosion rate against exposure time of unreinforced AA6063, AA6063 - 6%SiCp and AA 6063 - 9%SiCp in H_2SO_4 environment. From the figures, it was observed that the corrosion rate of the unreinforced alloy and the composite were quite high when compared with that of the samples immersed in marine environment. The corrosion rates of the samples immersed in H_2SO_4 environment were above 0.5 mmy as compared to < 0.15 mmy of the samples immersed in marine (3.5% NaCl) environment. However, it is noticable from figures 1a, 1b and 1c that the thermomechanical treatment given to both the unreinforced alloy and the composites improved their corrosion resistance in H_2SO_4 environment.

Figures 2a, 2b, and 2c represent the plot of mass loss against exposure time of the unreinforced AA6063, AA6063- 6%SiCp and AA 6063- 9%SiCp in H_2SO_4 environment. It was discovered that the mass loss of both the unreinforced AA6063 and the composites increases with increase in exposure time. This clearly indicated that the corrosion susceptibility increases with increase in exposure time. However, the mass loss plot in agreement with the corrosion rate plot apparently reveal that the thermomechanically processed samples exhibited improved corrosion resistance than the as-cast samples.

Figure 3a, 3b and 3c show the graphs of corrosion rate against exposure time for unreinforced AA6063, AA6063- 6%SiC_p and AA6063- 9%SiC_p composites immersed in marine environment. From the graphs, it was observed that there was no clear difference between the corrosion rates of both unreinforced alloy and the composites in all temper conditions (as cast, solely solution treated, 20% cold rolled and solution treated and 35% cold rolled and solution treated). This is an indication that the corrosion behaviour of these materials in marine environment is not influenced by thermomechanical treatment. It was also observed that the corrosion rate for all the samples (AA6063 and AA6063-SiC_p Composites) were less than 0.15 mmy. This indicated that the corrosion rates were low in marine environment when compared with H₂SO₄ environment.

Figures 4a, 4b and 4c represent the mass loss against exposure time for unreinforced AA6063, AA6063 - 6%SiC_p and AA6063 - 9%SiC_p composites respectively in marine environment. Figures 4a and 4b revealed that the unreinforced alloy and AA6063- 6%SiC_p composite in the as- cast condition are more susceptible to corrosion while there was no distinct difference in the corrosion resistance of the samples with other temper conditions (solely solution treated, 20% cold rolled and solution treated and 35% cold rolled and solution treated). However, for 9% AA6063-SiC composites, there was no visible difference between corrosion resistance of the as cast, solely solution treated, and the thermomechanically processed composites.

The superior corrosion resistance exhibited by AA6063- SiC_p composites in marine environment concurs with the findings of Alaneme [1]. In addition, Bienias et al [14], reported that the addition of silicon carbide particulates did not influence the corrosion behaviour of the composites in marine environment [14] while Trowsdale et al [10], reported that induced residual stress and dislocation density imparted by cold deformation are insignificant on the corrosion resistance of Al/SiC composites in marine environment [10].

Dikicci et al [7], explained that thermomechanical treatment reduces the corrosion resistance of Al-Si-Mg/SiC MMCs due to the increased amount of dislocation and point defects introduced into the materials by thermomechanical treatment. The researchers stressed further that dislocation density and point defects in the composites serve as high energy sites for the nucleation of pits [7]. Although visual examination of the AA6063- SiC_p samples immersed in the acidic medium established pitting and metal dissolution as the major corrosion mechanism, the cold rolled and solution treated sample exhibited superior corrosion resistance in sulphuric

acid environment. The improved corrosion resistance of the thermomechanically processed AA6063- SiC_p composites immersed in the sulphuric acid medium has been ascribed to the fact that cold rolling treatment results in improved particulate distribution and reduction in the apparent porosity of the composites. The subsequent solution heat-treatment helps in the dissolution of the second-phase intermetallic compounds and elimination of dislocations and residual stresses developed during the cold rolling process [13].

4.0 Conclusion

The effect of thermomechanical treatment on the corrosion behaviour of AA6063-SiC_p composites in both marine and sulphuric acid environment have been investigated. Mass loss and corrosion rate plots were used to evaluate the corrosion behaviour of these materials in these media. The results show that AA6063-SiC_p composites have superior corrosion resistance in marine (NaCl) environment when compared to the sulphuric acid (H₂SO₄) environment. Also, the thermomechanical processing significantly improve the corrosion resistance of the AA6063-SiC_p composites in H₂SO₄ environment while it does not influence the corrosion resistance in marine (3.5 % NaCl) environment.

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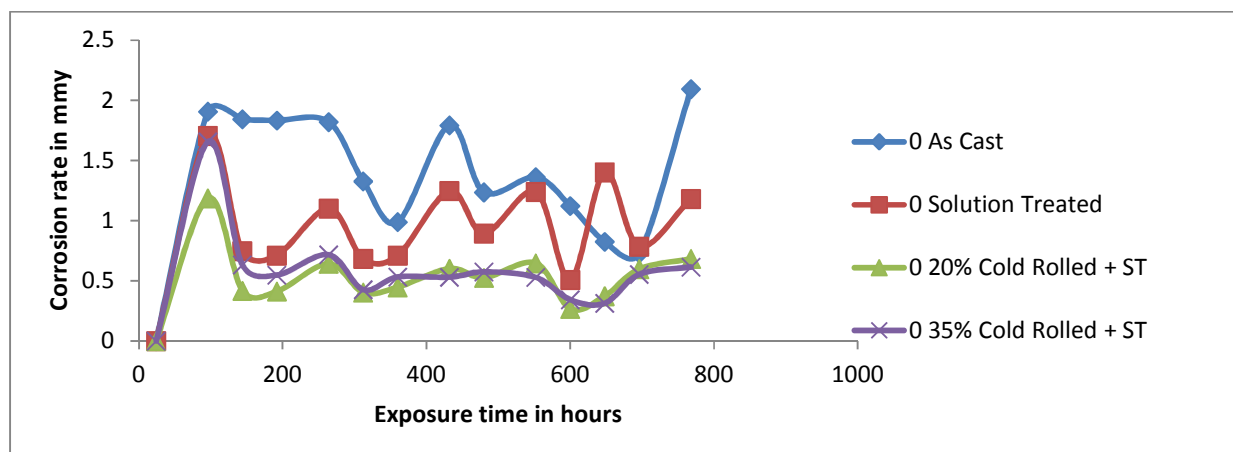


Fig 1a- Corrosion rate against exposure time for AA6063 in H_2SO_4 Environment

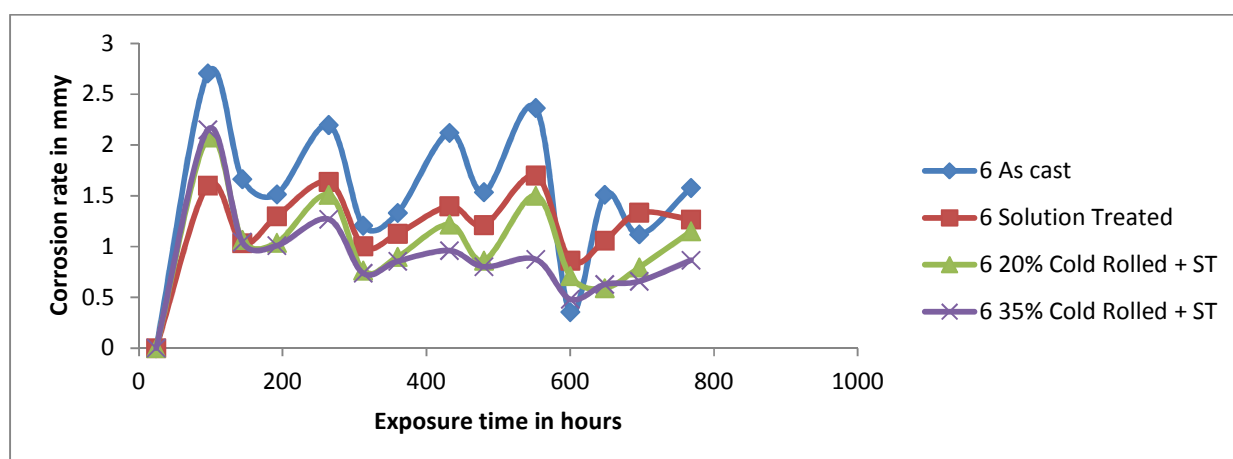


Fig 1b- Corrosion rate against exposure time for 6% AA6063- SiC_p Composites in H_2SO_4 Environment

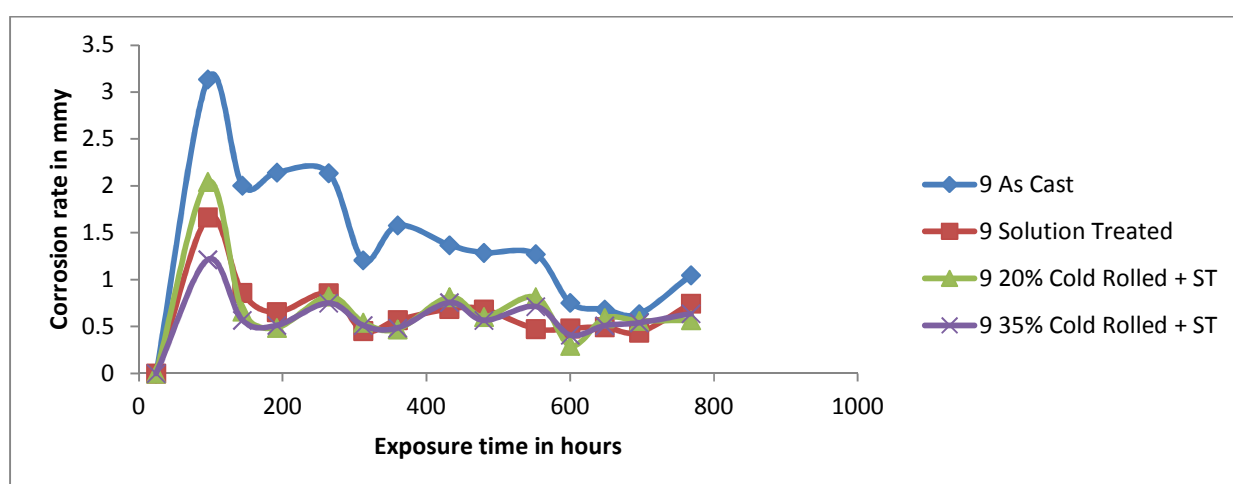


Fig 1c- Corrosion rate against exposure time for 9% AA6063- SiC_p Composites in H_2SO_4 Environment

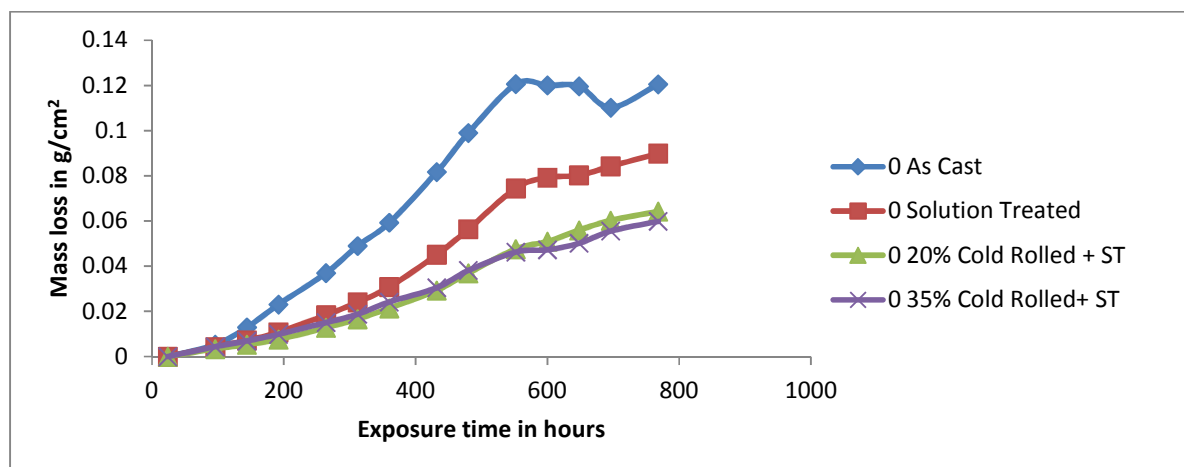


Fig 2a- Mass loss against exposure time for AA6063 in H_2SO_4 Environment

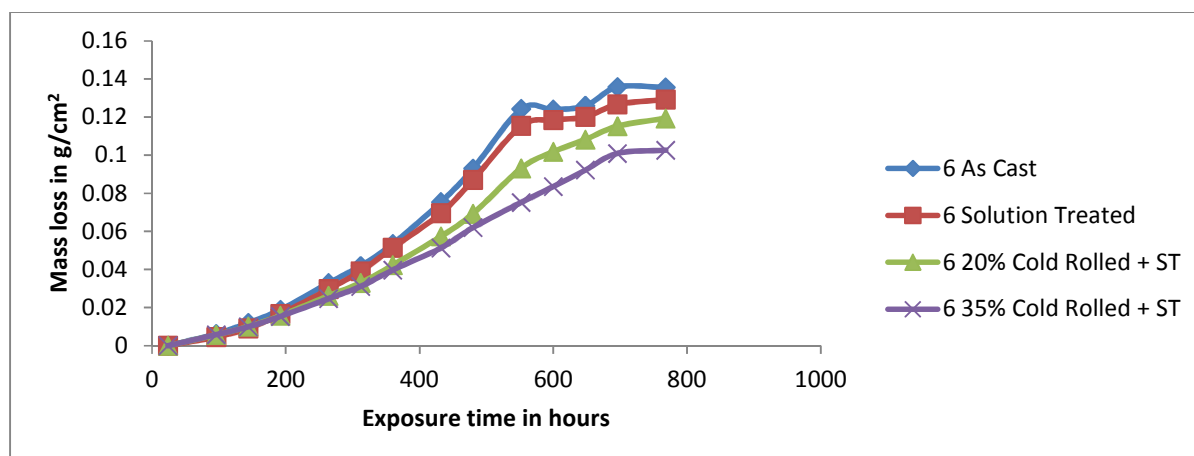


Fig 2b- Mass loss against exposure time for 6 % AA6063- SiC_p Composites in H_2SO_4 Environment

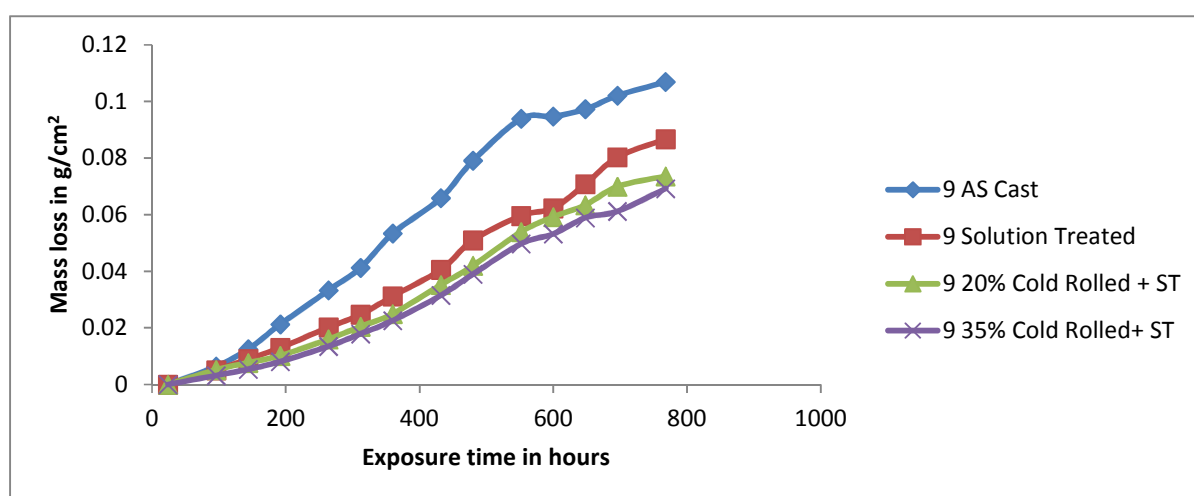


Fig 2c- Mass loss against exposure time for 9% AA6063- SiC_p Composites in H_2SO_4 Environment

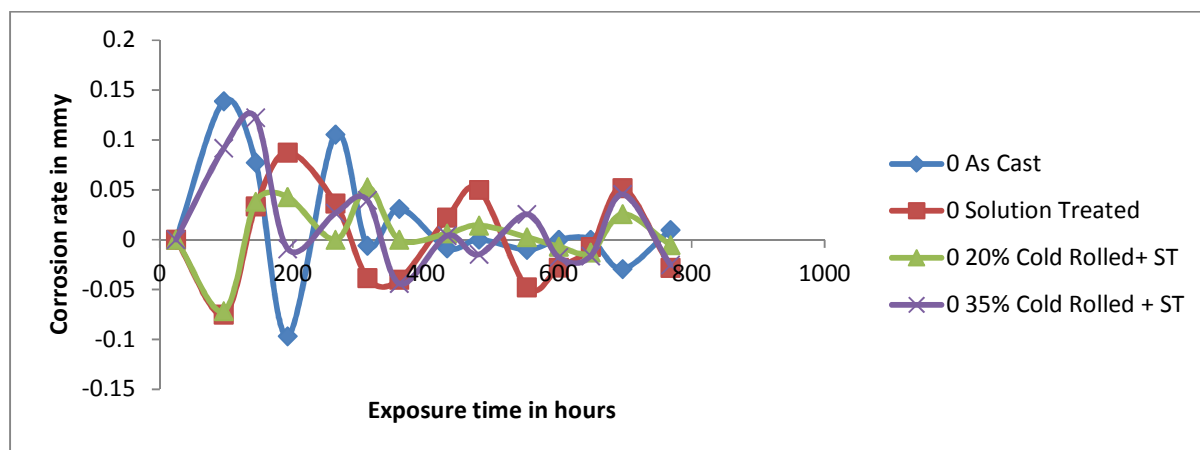


Fig 3a- Corrosion rate against exposure time for AA6063 in NaCl Environment

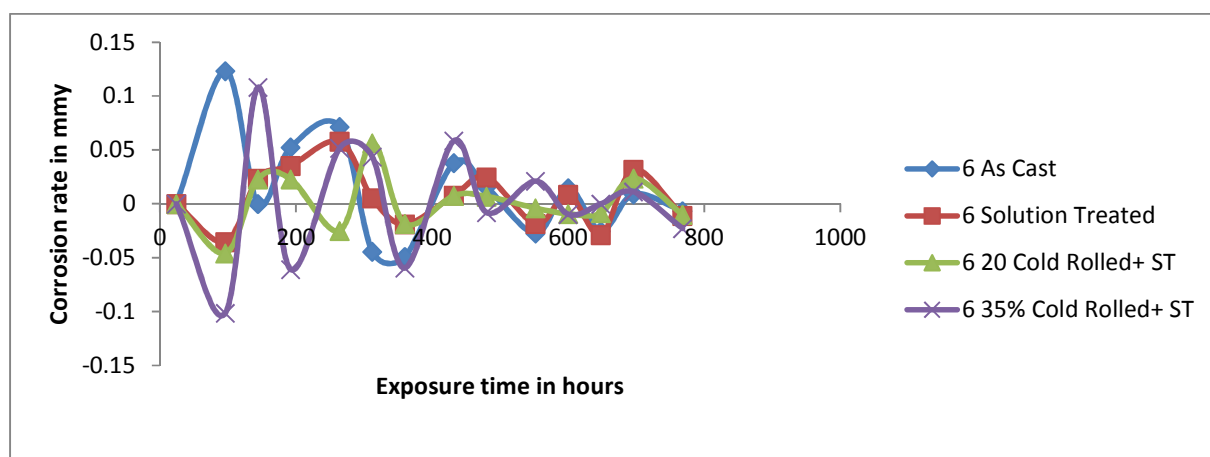


Fig 3b- Corrosion rate against exposure time for 6% AA6063- SiC_p Composites in NaCl Environment

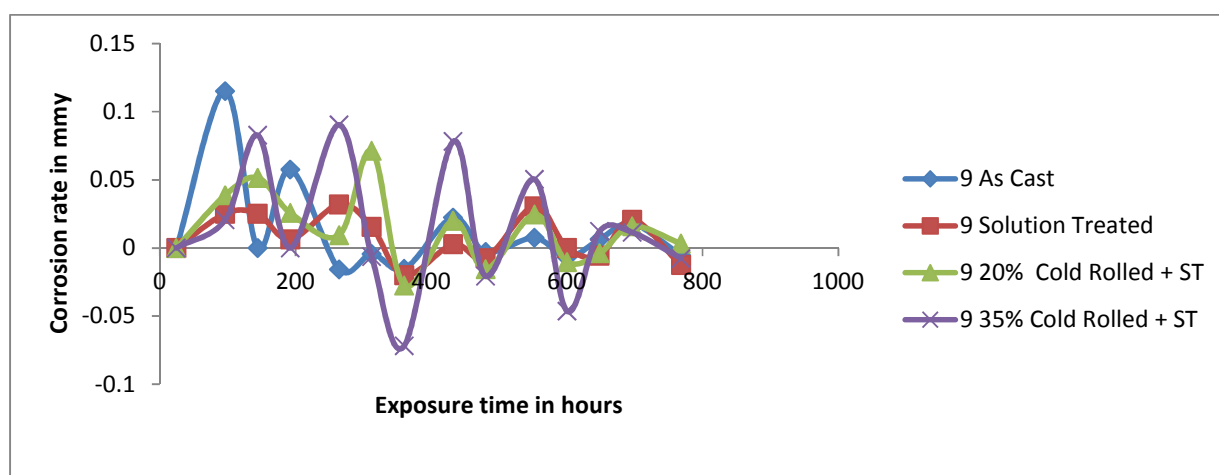


Fig 3c- Corrosion rate against exposure time for 9% AA6063- SiC_p Composites in NaCl Environment

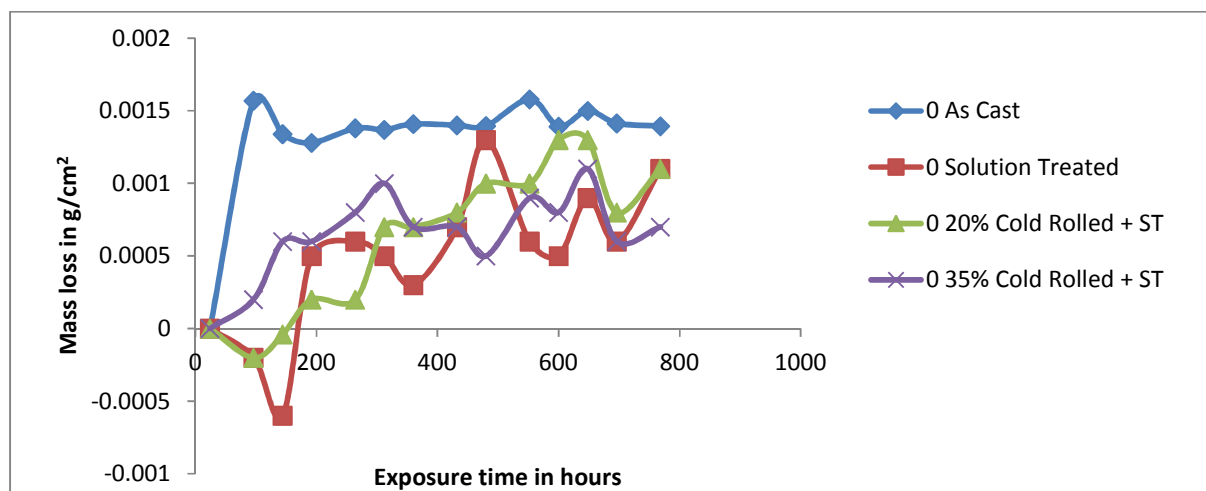


Fig 4a- Mass loss against exposure time for 9% AA6063 in NaCl Environment

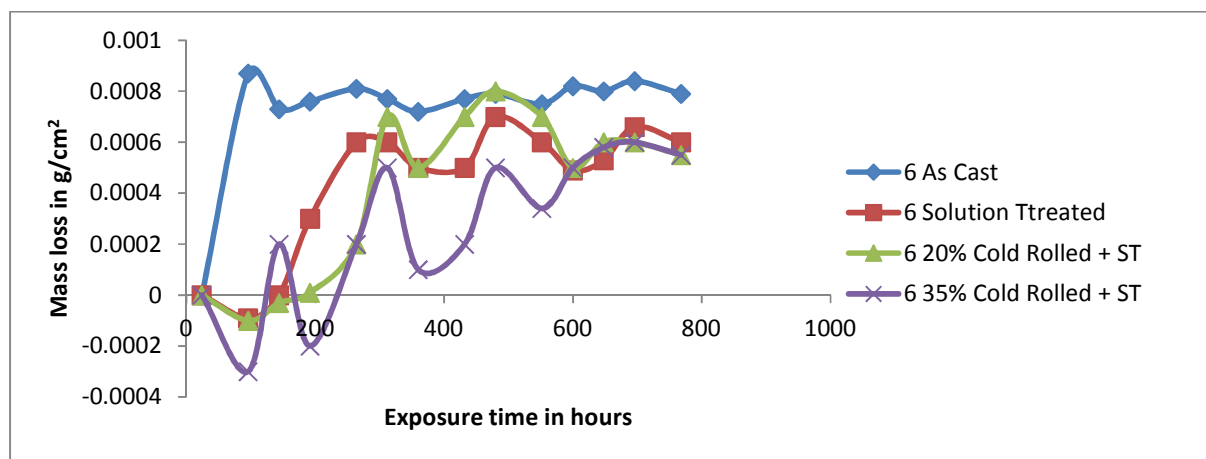


Fig 4b- Mass loss against exposure time for 6% AA6063- SiC_p Composites in NaCl Environment

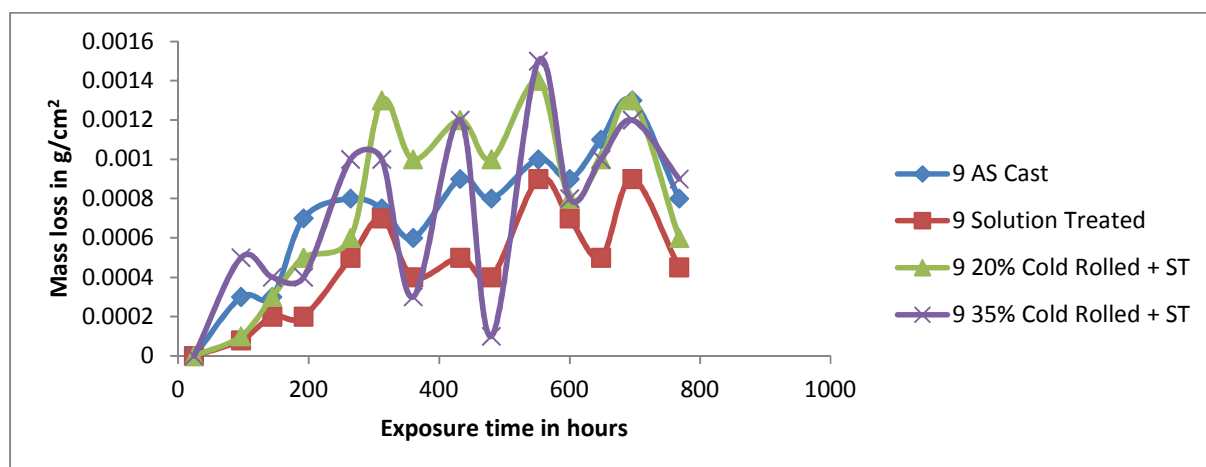


Fig 4c- Mass loss against exposure time for 9% AA6063- SiC_p Composites in NaCl Environment