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CORROSION BEHAVIOUR OF COLD DEFORMED AND SOLUTION HEAT-TREATED ALUMINA REINFORCED ALUMINIUM MATRIX COMPOSITES IN 0.3M H_2SO_4 SOLUTION

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Abstract: *The influence of cold rolling and solution heat-treatment on the corrosion behaviour of alumina reinforced Aluminium (6063) alloy composites in 0.3M H_2SO_4 solution was investigated. AA 6063 – Al_2O_3 particulate composites having 6, 9, and 12 volume percent of Al_2O_3 were produced using two step stir casting process. The composites were cold rolled to 20 and 35% deformation before solution heat-treating at 550^oC 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) – Al_2O_3 composites exhibited superior corrosion resistance in comparison to the unreinforced alloy in H_2SO_4 solution. Furthermore, the cold rolling – solution heat-treatment process resulted in significant improvement in corrosion resistance of the composites in comparison to the as-cast and solely solution heat-treated temper conditions.*

Keywords: *Stir casting; Al (6063) – Al_2O_3 composite; solution heat-treatment; Corrosion rate; mass loss*

INTRODUCTION

Improving the performance of Aluminium matrix composites (AMCs) in varied service applications is of paramount interest to Materials Engineers. This has contributed largely to the efforts in developing novel processing techniques for the production of AMCs [1-3]. Stir casting process has continued to attract patronage from researchers for the production of AMCs due to its low cost, simplicity of processing, and adaptability to mass production among others [4-5]. There have been sustained efforts to improve the properties of AMCs developed by stir casting through thermo-mechanical processing [6-7]. These secondary processing operations (extrusion, forging, rolling) have been observed to result in a marked improvement in mechanical properties [3, 7]; however conclusive information on its effect on the corrosion behaviour of AMCs is yet to be reported.

Understanding the corrosion behaviour of AMCs has been quite problematic – in some cases, reinforcements have been observed to improve corrosion resistance [8-10] while in some other reports, corrosion susceptibility was observed to increase [11]. The conflict in research observations has made it elusive for a comprehensive assessment of the corrosion behaviour of AMCs to be documented. This has created the necessity for corrosion studies to be carried out on specific aluminium alloy based composite systems. The present work is an effort to study the corrosion behaviour of cold rolled and solution heat-treated alumina particulate reinforced Aluminium alloy 6063 (AA 6063) composites in sulphuric acid medium. The cold deformation and solution heat-treatment processing has been reported to result in marked improvement in mechanical properties of the composite [12] but its impact on corrosion behaviour has not received considerable attention. 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 [13]. Aluminium alloys especially AA6063 are used extensively in developing countries for structural and architectural design due to their attractive mechanical properties, good extrusion properties, low cost and excellent corrosion resistance [4]

MATERIAL AND METHOD

Composite Production

Aluminium alloy (6063) with composition as presented in Table 1 was utilized as the metal matrix while 100% chemically pure alumina with particle size of 28μm was used as the reinforcement. The composites having 6, 9 and 12 volume percent alumina were produced by adopting a two-step stir casting technique. The wettability of the composite was improved by preheating the alumina particles before introducing it 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 preheated alumina was 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 720°C accompanied with mechanical stirring at 300rpm for 10 minutes before pouring into prepared sand moulds. Monolithic aluminium alloy was also prepared for control experimentation.

Table 1: Chemical Composition of the Aluminium Alloy 6063 (AA 6063)

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.

Mechanical and Thermal Processing

Four different temper conditions were utilized in this present study, the as cast condition and three others namely, solution heat-treated only, 20% cold rolled and solution heat-treated; and 35% cold rolled and solution heat-treated. The solution heat-treatment was carried out by heating the samples to 550°C, holding for 1 hour and then quenching rapidly in water.

Immersion Testing

The corrosion tests were carried out in 0.3 M H_2SO_4 (pH 0.3) which was prepared following standard procedures. The specimens for the test were cut to sizes 20 × 20 × 5 mm, after which the sample surfaces were mechanically polished with emery papers starting from 120 grit down to 640 grit 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 648 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 [14]. The corrosion rate in millimetre per year (mmy) was determined from the weight loss following standard procedures.

RESULTS AND DISCUSSION

Corrosion Behaviour of the AA 6063 Composites in 0.3M H_2SO_4 Solution

Figures 1 – 4 show the variation of mass loss and corrosion rate with volume percent alumina for the composites in as-cast, solution heat-treated, 20 % and 35 % cold rolled and solution heat-treated conditions. Figure 1 shows the mass loss and corrosion rate plots for the as-cast composites. The mass loss does not show any apparent difference in corrosion susceptibility of the composites but the corrosion rate plot (Figure 1b) indicates that the 12vol.% alumina reinforced AA 6063 composite exhibited the best resistance to corrosion in comparison with the unreinforced alloy and the lower vol.% alumina reinforced AA 6063 composites. In the case of the solution heat-treated condition, it is observed from the mass loss plot (Figure 2a) that corrosion resistance increases with increase in alumina volume percent with the unreinforced alloy showing the greatest susceptibility to corrosion. This trend is supported by the corrosion rate plots (Figure 2b) in which it is observed that peak corrosion rate was obtained after 72 hours of exposure in the sulphuric acid solution but stable corrosion rate was obtained for the remaining days of immersion. For the 20% cold rolled and solution heat-treated condition (Figure 3), it is also observed from the mass loss plots that the corrosion resistance of the composites was *superior to that of the unreinforced alloy. However, there was no particular trend observed with respect to volume percent alumina. In the case of the 35% cold rolled and solution heat-treated samples (Figure 4), again the composites exhibited superior corrosion resistance in comparison to the unreinforced alloy. The superior corrosion resistance of the composites over the unreinforced AA 6063 alloy indicates the composites will be suitable for use in mild H_2SO_4 environments.*

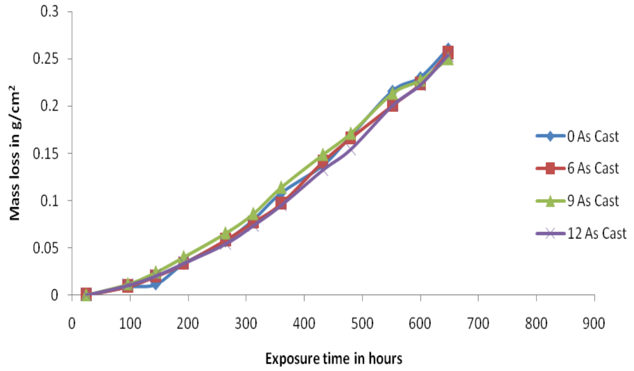

Figure 1(a): Variation of mass loss against exposure time for as cast alloy and composites

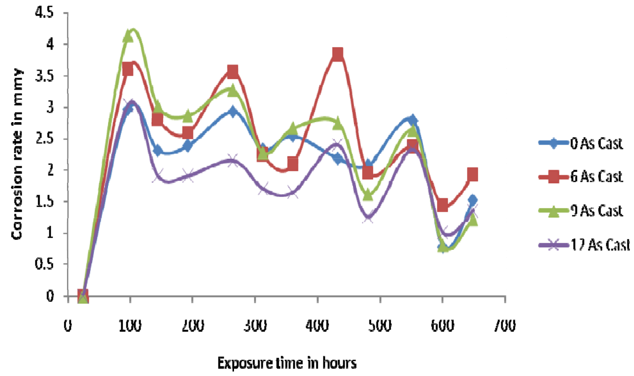

Figure 1(b): Variation of Corrosion rate against exposure time of as cast alloy and composites

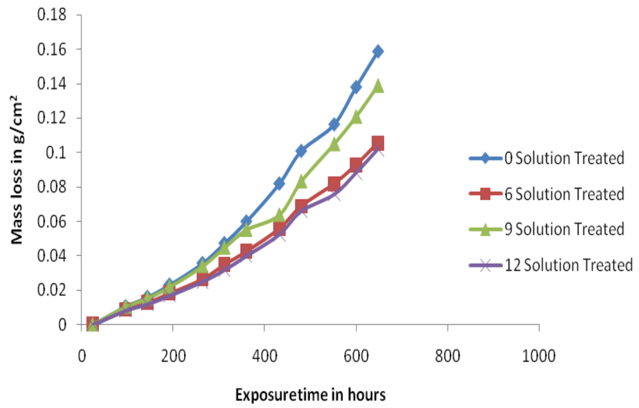

Figure 2(a): Variation of mass loss against explosion time of solution treated alloy and composites.

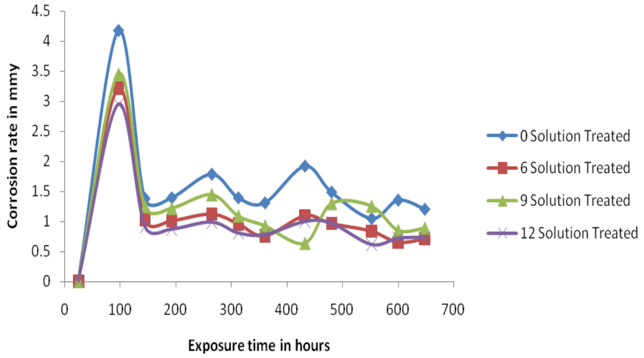

Figure 2(b): Variation of corrosion rate against exposure time of solution treated alloy and composites

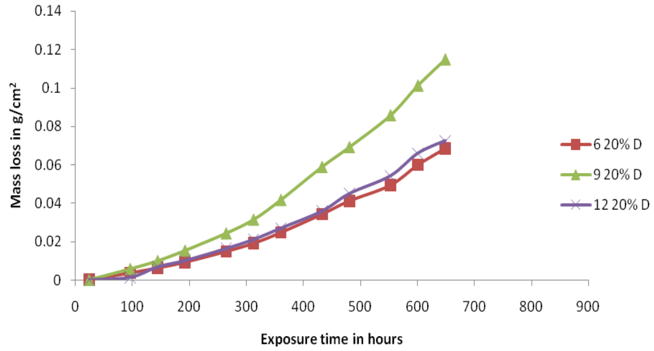

Figure 3(a): Variation of mass loss against exposure time of alloy and composites subjected to 20% deformation plus solution treatment.

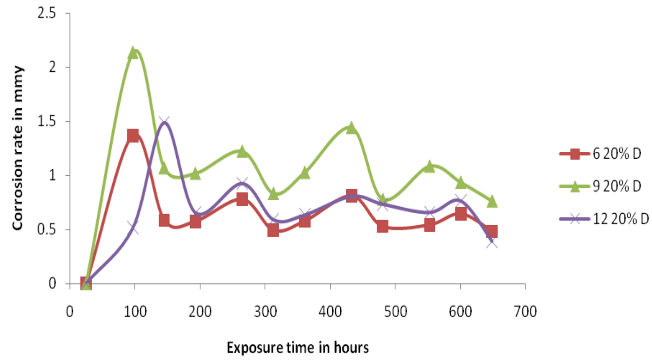

Figure 3(b): Variation of Corrosion rate against exposure time of alloy and composites subjected to 20% cold deformation plus solution treated

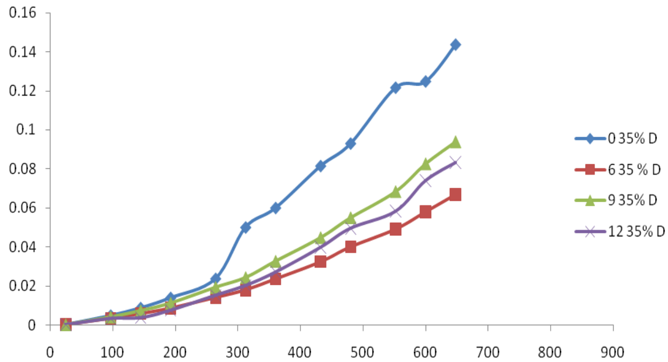

Figure 4(a): Variation of mass loss against exposure time of alloy and composites subjected to 35% deformation plus solution treatment.

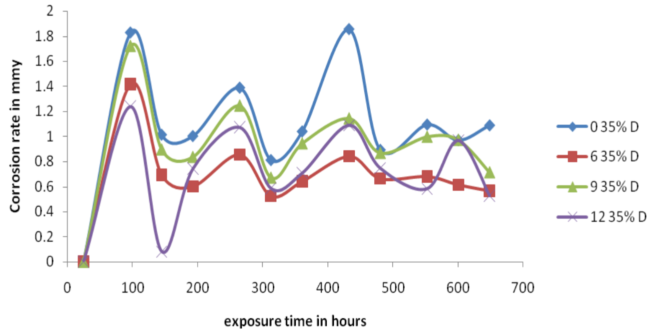

Figure 4(b): Variation of Corrosion rate against exposure time of alloy and composites subjected to 35% cold deformation plus solution treated

The superior corrosion resistance of the alumina reinforced AA 6063 composites is in agreement with observations of Alaneme and Bodunrin [15]. They reported that the improved corrosion resistance of the alumina reinforced AA 6063 composites over that of the unreinforced alloy is as a result of the inert nature of alumina. Hence the alumina particulates exhibits good resistance to corrosion attack. It has been stressed that galvanic corrosion that results from the formation of cathodic and anodic sites by the reinforcement and matrix as established in Al/SiC is unlikely in Al/Al_2O_3 composites [10]. The alumina particles are reported to have a very high resistivity (> 10^{14} Ohms) and thus functions as an insulator and as such do not have significant effect on the passive films formed on the aluminium matrix [16].

Corrosion behaviour of the Cold Rolled and Solution Heat-treated Composites in 0.3M H_2SO_4 Solution

Figures 5-7 show the influence of different temper conditions on the mass loss and corrosion rate of the alumina reinforced AA 6063 particulate composites. Figure 5 shows the variation of corrosion behaviour of the 6 vol. % alumina reinforced AA 6063 alloy with different temper treatment. It is observed from Figure 5(a) that the 20 % and 35 % cold rolled and solution heat-treated samples exhibited greater resistance to corrosion in comparison to the as-cast and solely solution heat-treated samples. For the exposure period of 720 hours in the H_2SO_4 solution, the 20% cold rolled and solution heat-treated sample for instance had mass loss of 0.06g/cm^2 which corresponds to 500% and 50% reduction in mass loss in comparison to the as-cast and solely solution heat-treated samples respectively. This indicates clearly that there is a significant improvement in corrosion resistance of the alumina reinforced AA 6063 composites with the adoption of the cold rolling and solution heat-treatment processing. Alaneme [12] reported 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 [17]. The combined process results in a composite with improved material properties. Figure 5(b) the corrosion rate plots support the mass loss trend as it is observed that the as-cast samples had the highest corrosion rate for the entire exposure period. For the 9 vol. % alumina reinforced AA 6063 composites, it is observed from the mass loss plots (Figure 6a) that the cold rolled – solution heat-treated and solely solution heat-treated samples had corrosion resistance superior to that of the as-cast sample. Figure 6(b) shows that the 20% and 35% cold rolled – solution heat-treated samples exhibited a significant resistance to corrosion in comparison to the solely solution heat-treated sample at the early stages of exposure in the H_2SO_4 solution. For the 12 vol. % alumina reinforced AA 6063 composites (Figure 7), it is also observed that the cold rolled and solution heat-treated samples had the least corrosion susceptibility. The corrosion rate plots confirm that the cold rolled – solution heat-treated samples had the least corrosion rate in comparison with the as-cast and solely solution heat-treated samples.

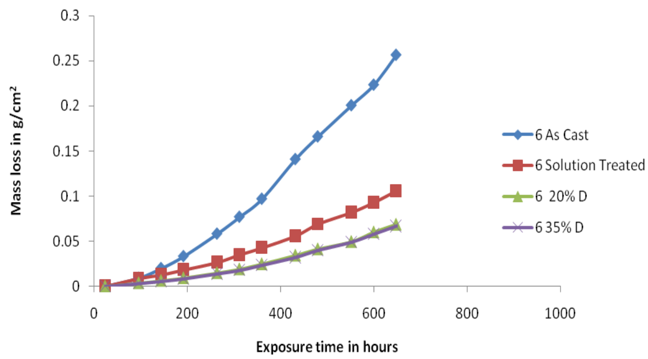

Figure 5(a): Variation of mass loss against exposure time of 6% alumina reinforced composite samples

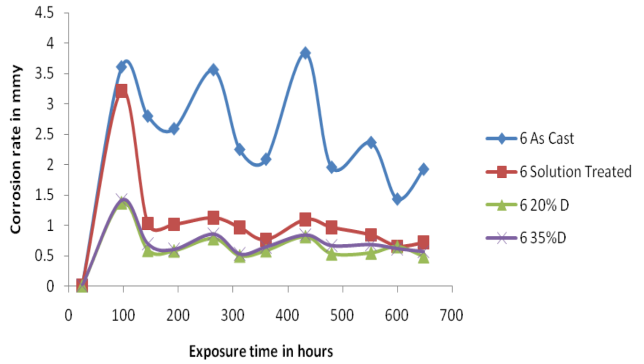

Figure 5(b): Variation of corrosion rate against exposure time of 6% alumina reinforced composite samples

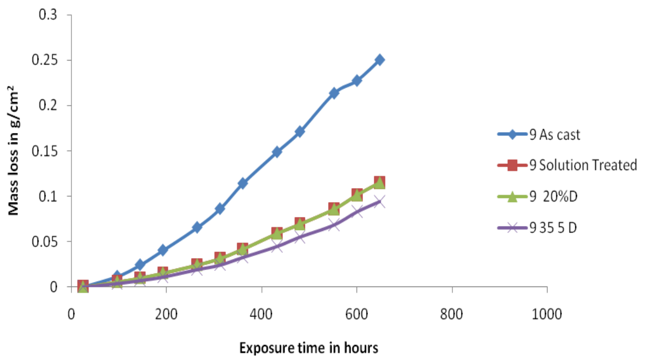

Figure 6(a): Variation of mass loss against exposure time of 9% alumina reinforced composite samples

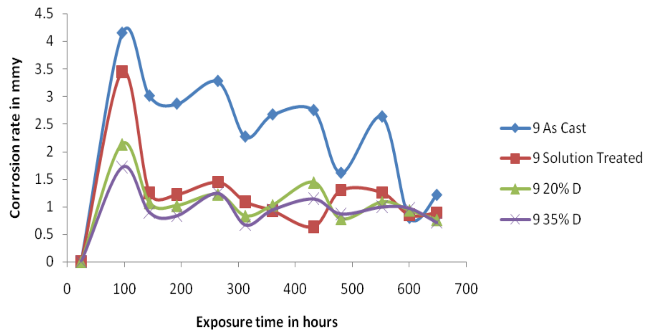

Figure 6(b): Variation of corrosion rate against exposure time of 9% alumina reinforced composite samples

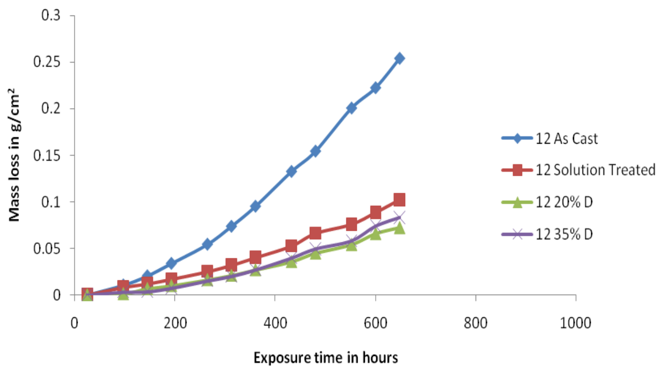

Figure 7(a):Variation of mass loss against exposure time of 12% alumina reinforced composite samples

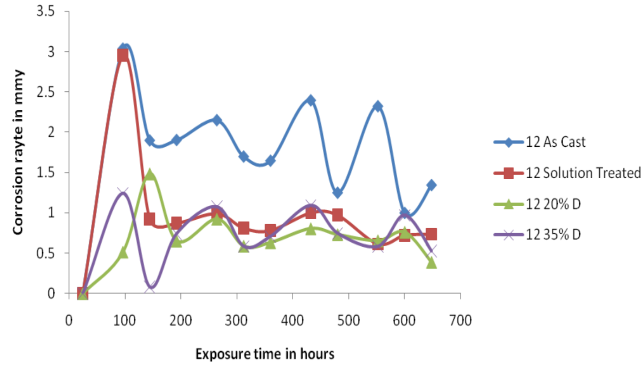

Figure 7(b): Variation of corrosion rate against exposure time of 12% alumina reinforced composite samples

CONCLUSION

The influence of cold rolling and solution heat-treatment on the corrosion behaviour of alumina reinforced Aluminium (6063) alloy composites in 0.3M H_2SO_4 solution was investigated. The results show that AA (6063) – Al_2O_3 composites exhibited superior corrosion resistance in comparison to the unreinforced alloy in H_2SO_4 solution. Also, the cold rolling – solution heat-treatment process resulted in significant improvement in corrosion resistance of the composites in comparison to the as-cast and solely solution heat-treated temper conditions.

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