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Corrosion Studies of AA6061-SiC Composites and AA6061-4.5%Cu-SiC Hybrid Composites before and after Friction Stir Welding

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Abstract:
In the present research work an attempt has been made to study the corrosion behavior of AA6061 composites & AA6061-4. 5%Cu hybrid composites containing Silicon carbide (0 to 9%) in a step of 3% by weight, before and after FSW. The corrosion rate mainly depends on the percentage of SiC particles added to the composites, in the present work the AA6061-SiC Composites and AA6061-4. 5%Cu-SiC hybrid composite blocks of 100mm×100mm×50mm were produced by stir casting method, the castings were machined to get composite plates of dimensions 100mm×50mm×6mm. The rectangular composite plates are Friction Stir Welded at tool rotation speed 650rpm, axial load 6KN using square profile tool pin with a constant welding speed 45mm/min, from the rectangular composite plates and friction stir welded joints the corrosion test specimens as per ASTM standards were cut, To study the percentage of SiC particle effect on corrosion rate, the results shows that. The corrosion rate of AA6061-SiC composites decreases with increase in percentage SiC particles in composites, further it is noticed that the corrosion rate of AA6061-4. 5%Cu-9%SiC hybrid composites is lower compared to the cast AA6061 and AA6061-SiC composites before FSW and after FSW. The corrosion rate decreases with increase in time before and after FSW

Key Words: Friction Stir Welding (FSW), Corrosion rate, hybrid composites

I. INTRODUCTION

Friction Stir Welding (FSW) is a latest welding process, it works below the melting point of the metals to being joined and hence now melting takes place during the process. Friction Stir welding (FSW) process uses a non-consumable rotating tool which extruded into rigidly clamped work piece and moves along the weld line. The square or cylindrical profile tool used where as probe length lower than the weld depth, and extruding from the tool shoulder. As the tool rotates and moves along the weld line, forcing material to flow around the rotating tip to consolidate on the pin tool's backside. K. K. Alaneme et al [1] in their work "Al (6063) – Al_2O_3 composite corrosion behavior reported that excellent corrosion resistance in NaCl medium compare with NaOH and H_2SO_4 media. A. Albiter1et al [2] in his work "Al-2024/TiC composite corrosion behavior reported that Immersion in 3.5 wt.% NaCl solution produces a number of pits. K. K. Alaneme, et al [3] in his work Corrosion Behavior of heat-Treated alumina reinforced Aluminium Matrix Composites reported that corrosion resistance increases with alumina volume fraction increase. J. Zhu et al [4] in his work Corrosion behavior of alumina-fiber composites reported that localized corrosion begins along the alumina fiber and matrix. Batluri Tilak Chandr et al [5] in his Corrosion studies of Al7075 composites reported that corrosion rate decrease gradually due to passivation in the metal matrix alloy and the development of protected layer which affect the corrosion process. Chandrashekara.K. N et al [6] in his work Corrosion studies of Aluminium 6013 metal matrix composites reported that increased in the percentage of reinforcement particles in the matrix results in a decreased corrosion rate irrespective of corrosion medium. Sravanthi M. et al [7] in his work corrosion Studies on Aluminium-7075 metal matrix composites reported that the corrosion rate of the composites was lower than that of the corresponding matrix alloy. M. S. Kaiser et al [8] in his work Corrosion studies on aluminium engine block reported that accumulation of corrosion products including aluminium oxide and hydroxide decreases corrosion rate. P.V.Krupakara et al [9] in his work corrosion behavior of Al 6061/red mud metal matrix composites reported that improvement in corrosion resistance as the percentage of red mud particulates increased in the composite. Palkar Aman Manohar et al [10] in his work Corrosion behaviour of Al 7075-T6 alloy reported that the occurrence of fast corrosion reaction that increases with exposure period possibly due to start of intergranular corrosion. In the present research work is conducted to find the effect of SiC particles on corrosion rate and aimed to study the corrosion rate of AA6061-SiC composites and AA6061-4.5%Cu-SiC hybrid composites before and after FSW.

II. EXPERIMENTATION

2.1 Materials Selection

In the present research work AA6061 used as a matrix material because of its excellent welding properties. The AA6061 chemical composition is shown in the Table 1, the silicon carbide of particle size 60µm was used as reinforcement material for cast composites, The SiC particles (0 to 9%) 3% in each step by weight were used to prepare cast composites.

Table. 1. AA6061 Chemical composition

Content	Zn	Cu	Fe	Mn	Mg	Si
%	0.14	0.32	0.153	0.024	0.81	0.662
Content	Ti		Ni	Pb	Sn	Al
%	0.107		<0.045	0.024	0.01	Balance

2.2. Composites Preparation

The AA6061 ingots was placed in a crucible of electric arc furnace (Make: Hitech, Power 9hp, Crucible material- mild steel) the ingots are heated till it melts, a hexachloro ethane degassing tablet is added to remove dissolved gases present in melt. The vortex is formed by stirring melt at a speed of 90 rpm, Silicon carbide particles (3 to 9%) in a step 3% each is added to vortex to produce the AA6061- SiC composites and AA6061-4.5% Cu hybrid composites these composites was machined to obtained rectangular composite plates of dimensions 100mm×50mm×6mm.

2.3 Friction Stir welding of composite plates

In the present research work the cast AA6061, AA6061-SiC composites and AA6061-4.5%Cu-SiC hybrid composites plates are friction stir welded (Make: RV Machine Tools Coimbatore, Model: FSW 3T-300-NC, Tool rotation range : 450-1500rpm, Power 7.5KW, Welding speed range 30-100mm/sec, Z axis thrust force 0-4 tons, optional servo control) at tool rotation 650 rpm, axial load 6 KN, welding speed 45 mm/min, tool material high carbon steel, Square pin tool profile, Figure 1 depicts the friction stir welding equipment.

Figure.1. Friction stir welding Equipment

2.4 Corrosion test

Figure 2 depicts corrosion immersion test details, the immersion corrosion test was conducted in 3.5%NaCl are prepared using standards,The test specimens dimensions are 20mm× 20mm× 6mm the samples were polished using emery paper 100 to 600 grite size to remove the dust particles, the samples were degreased with acetone solution and rinsed with distilled water before immersion in to prepared still solution of 3.5%NaCl and exposed to the atmospheric air, the samples were exposed to the basic environment for about 0 to 96 hours. Corrosion rate for each sample was evaluated using formula corrosion rate =534 W/DAT mpy given by Fontana M.G, where W is weight loss in gm, D is the density of specimen in gm/cc, A is the exposed area in square inch and T is exposure time in hours.

Figure.2. Immersion test details

III. RESULTS AND DISCUSSION

3.1 Corrosion behavior of AA6061-SiC composites before FSW

Figure 3 presents the percentage of SiC particles effect on corrosion rate of AA6061-SiC composites before FSW with 3.5% NaCl solution from the fig it is observed that with increased in volume fraction of SiC particles in composite decreases corrosion rate because during casting an interface bonding is developed between the matrix alloy and reinforced particulates, which is mainly responsible for decrease in corrosion rate [6]. Further it is observed that corrosion rate decreases with increase in time. The corrosion rate of AA6061-9%SiC at maximal condition (96 hours) is 0.019 mpy

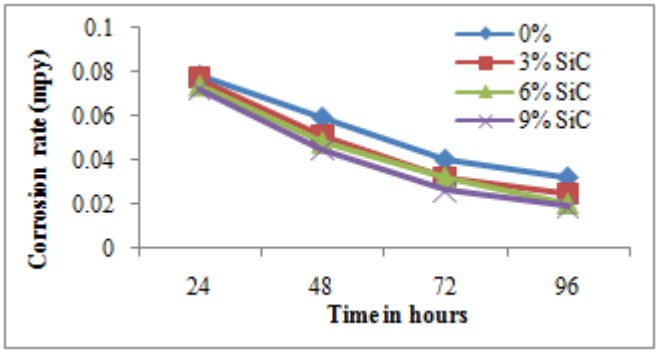

Figure.3. The percentage of SiC particle effect on corrosion rate of AA6061-SiC composites with 3.5% NaCl solution

3.2 Corrosion behavior of AA6061-4.5%Cu-SiC hybrid composites before FSW

Figure 4 presents the percentage of SiC particles effect on corrosion rate of AA6061-4.5%Cu-SiC hybrid composites with 3.5% NaCl solution, from the fig it is observed that corrosion rate decreases with increase in percentage SiC particles because with increase in volume fraction of SiC particles, the silicon carbide acts as physical barrier playing a secondary role and the formation of the corrosion pits will changes microstructure of the metal matrix which results in decrease of the corrosion rate [5] the corrosion rate of the AA6061-4.5%Cu- 9%SiC hybrid composites at extreme condition are 0.01 mpy.

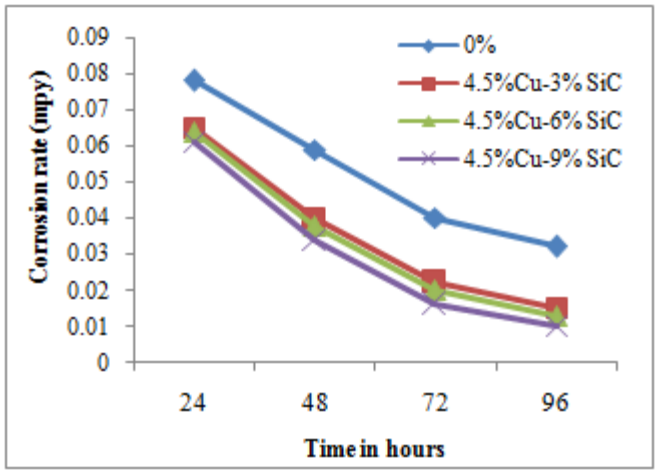

Figure.4. The percentage of SiC particles effect on corrosion rate of AA6061- 4.5%Cu-SiC hybrid composites before FSW with 3.5% NaCl Solution

3.3 Corrosion behavior of Cast AA6061, AA6061- 9%SiC composite and AA6061-9%SiC hybrid composite before FSW

Figure 5 presents corrosion rate of cast AA6061, AA6061-9%SiC composite and AA6061-9%SiC hybrid composite before FSW with 3.5% NaCl solution, from the fig it is observed that corrosion rate of AA6061-4.5%Cu-9% SiC hybrid composites exhibits lower compared with the cast AA6061 and AA6061-9%SiC composites because AA6061-4.5% Cu-9% SiC hybrid composites indicates the possible passivation of the matrix alloy, this layer protects further corrosion in corrosive media results in lower the corrosion rate[7]. The corrosion rate of AA6061-4.5% Cu-9% SiC hybrid composites at extreme condition (96 hours) are 0.01 mpy

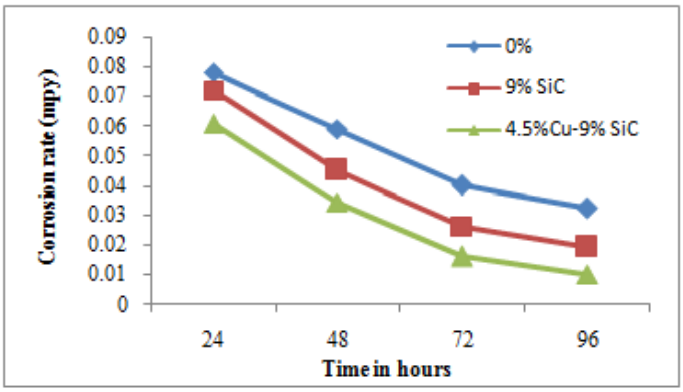

Figure.5. Corrosion rate of Cast AA6061, AA6061- 9%SiC composite and AA6061-9%SiC hybrid composite before FSW with 3.5% NaCl Solution

3.4 Corrosion behavior of AA6061-SiC composites after FSW

Figure 6 presents the effect of percentage of SiC particles on corrosion rate of AA6061-SiC composites after FSW at tool rotation 650rpm, welding speed 45mm/min, axial load-6KN, using square pin tool profile with 3.5% NaCl solution from the fig it is observed that corrosion rate decreases with increase in percentage SiC particles in AA6061-SiC composites because the decrease in corrosion rate gradually with increase in reinforcement content and exposure time is due to the formation of the protective layer which is stable and not attacked by neutral and alkali solutions [6] the corrosion rate of AA6061-9%SiC composite at extreme condition (96hours) are 0.007 mpy. The corrosion rate of AA6061-9%SiC composite lower compare with cast AA6061 before and after FSW

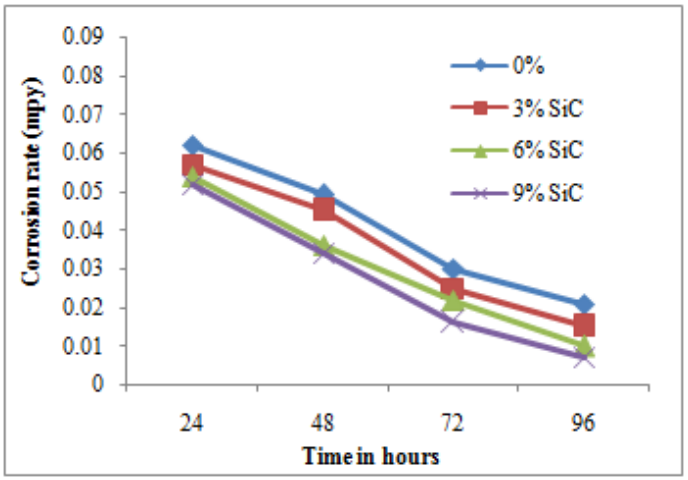

Figure.6. Effect of percentage of SiC particles on corrosion rate of AA6061-SiCcomposites after FSW with 3.5%NaCl solution

3.5 Corrosion behavior of AA6061-4.5%Cu-SiC hybrid composites after FSW

Figure 7 depicts the effect of percentage of SiC particles on corrosion rate of AA6061-4.5%Cu-SiC hybrid composites after FSW at tool rotation 650rpm, welding speed 45mm/min, axial load-6KN, using square pin tool profile with 3.5% NaCl solution, from the fig it is observed that the increased in percentage of SiC particles in hybrid composite decreases the corrosion rate because the passivation in the metal matrix alloy results in development of permanent layer which reduces the corrosion rate [5] the corrosion rate of AA6061-4.5%Cu- 9%SiC hybrid composite at extreme condition are 0.005 mpy.

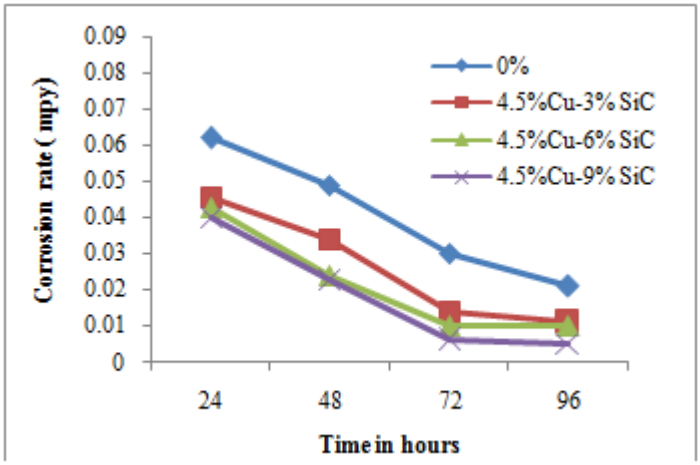

Figure.7. The percentage of SiC particles effect on corrosion rate of AA6061- 4.5%Cu-SiC hybrid composites after FSW with 3.5%NaCl solution

3.6 Corrosion behavior of cast AA6061, AA6061- 9%SiC composite and AA6061-9%SiC hybrid composite after FSW

Figure 8 presents the corrosion rate of cast AA6061, AA6061-9%SiC composite and AA6061-9%SiC hybrid composite after

FSW at tool rotation 650rpm, welding speed 45mm/min, axial load-6KN, using square pin tool profile with 3.5% NaCl solution from the fig it is observed that the corrosion rate of AA6061-4.5%Cu- 9%SiC hybrid composite is lower compared to the cast AA6061 and AA6061-9%SiC composites because copper and silicon carbide is acting as physical barrier playing as secondary role and the formation of corrosion pits changes the microstructure of metal matrix composite which results in decrease in corrosion rate [5] The corrosion rate AA6061-4.5%Cu-9%SiC hybrid composite is lower compare with cast AA6061 and AA6061-SiC before and after FSW.

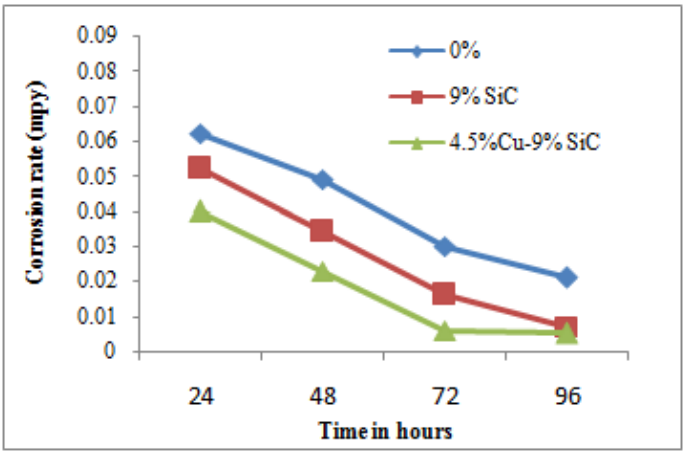

Figure.8. Corrosion rate of cast AA6061, AA6061- 9%SiC composite and AA6061-9%SiC hybrid composite after FSW with 3.5%NaCl solution

3.7 The effect of tool rotation on corrosion behavior of AA6061-4.5%Cu-9%SiC hybrid composites after FSW

Figure 8 presents the effect of tool rotation on corrosion behavior of AA6061-4.5%Cu-9%SiC hybrid composites after FSW with 3.5%NaCl solution, from the fig it is observed that as the tool rotation increased the corrosion rate of AA6061-4.5%Cu-9%SiC hybrid composites increases because increase in tool rotation increases frictional heat, reduces hardness and wear resistance of composites results in decrease in corrosion rate, the corrosion rate AA6061-4.5%Cu-9%SiC hybrid composites at extreme condition are 0.004mpy for 500rpm

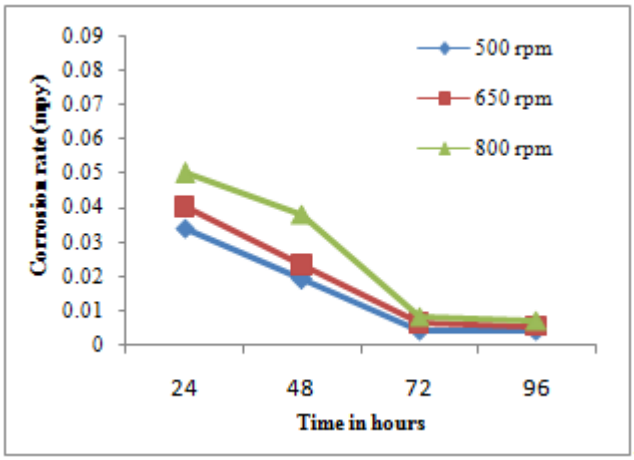

Figure.9. The effect of tool rotation Corrosion behavior of AA6061-4.5%Cu-9%SiC hybrid composites after FSW with 3.5%NaCl solution

IV. CONCLUSION

In the present research work AA6061 composites and AA6061-4.5%Cu hybrid composites containing SiC (0 to 9%) in a step of 3 % each were produced by stir casting technique and successfully friction stir welded, The results are summarized as follows.

1) Corrosion rate decreases for all materials after FSW
2) Before FSW the corrosion rate of AA6061-SiC composites AA6061-4.5%Cu-SiC hybrid decreases with increase in percentage SiC particles in composites, further it is noticed that the corrosion rate of AA6061-4.5%Cu-9%SiC hybrid composites are lower compared to the cast AA6061 and AA6061-SiC composites.
3) After FSW the Corrosion rate AA6061-SiC composites AA6061-4.5%Cu-SiC hybrid decreases with increase in percentage of SiC particles in composite further it is observed that Corrosion rate of AA6061-4.5%Cu-9%SiC hybrid composites are lower compared to the cast AA6061 and AA6061-SiC composites
4) The tool rotation increase the corrosion rate of AA6061-4.5%Cu-9%SiC hybrid composites increases
5) The corrosion rate decreases with increase in time before and after FSW.

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