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Erosion-corrosion behaviour of aluminum alloy 6063 hybrid composite



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ABSTRACT

Aluminum alloy 6063 (AA6063) composite with varying proportion of snail-shell-ash (SSA) and silicon carbide (SiC) reinforcement has been developed by stir-casting. Hardness and erosion-corrosion characteristics of the composite were studied. Erosion-corrosion behaviour of the composite was studied in a mono-ethylene glycol (MEG)-water environment with 20% v/v of ethylene glycol and 0.1 g/L silica sand particles using a re-designed miniature submerged impinging jet rig. SEM-EDX of the as-cast composites showed the presence of the particulates distributed in the matrix. The hardness of the aluminum alloy was enhanced up to a maximum value (with the addition of 7.5 wt % SiC+7.5 wt % SSA). However, hardness values declined when (10 wt % SSA+10 wt % SiC) was used as reinforcing phase. Erosion-corrosion studies showed that erosion component dominates the total material loss and the composite with highest hardness displaying better erosion-corrosion resistance. Also, addition of MEG to the slurry resulted in lower erosion-enhance corrosion and total material loss due to erosion-corrosion. SEM images of the damaged composite showed that the damage mechanism is dominated by ploughing and indentation.

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1. Introduction

Aluminum matrix composites find applications in aerospace and automobile manufacturing because of the several advantages they offer [1–3]. These advantages include high strength to weight ratio, elevated temperature toughness, low density, high stiffness and high strength compared to its monolithic counterparts [4,5]. However, application of this class of composite has been hindered by the high cost of producing components of complex shapes [4]. Techniques used for the development of these composites include stir casting [6], powder metallurgy [7,8], spray atomization and co-deposition [9], plasma spraying [10], squeeze-casting [11] and compo-casting [4,12]. However, casting technology seems a preferred method with stir casting and compo casting receiving more attention [4]. The commonly used metallic matrices for composite production include Aluminum, Magnesium, Titanium, Copper and their alloys. Reinforcements commonly used include fibers, whiskers and particulates of SiC, Al₂O₃, B₄C and TiC [4,8,13,14]. However the use of agro and industrial wastes as single or complementary reinforcement to the more conventional reinforcing materials such as alumina and silicon carbide is attracting much attention [15,16]. One reason for this choice is cost reduction as a

result of reducing the use of the more expensive traditional reinforcements [4,14].

Alaneme and his co-workers [15,16] reinforced AA6063 with rice husk ash and alumina. Corrosion rate of the hybrid composite was found to increase with increase in the volume fraction of rice husk ash [16]. Emenike [17], investigated the corrosion behaviour of cast Al-Mg alloy A535 composites containing fly ash reinforcement using weight-loss and electrochemical corrosion tests in NaCl solution at room temperature. The findings showed that unreinforced A535 alloy has lower corrosion rate in fresh water and seawater environments than the composites at all the tested pH values. It was concluded that the corrosion rate of the composites increased with increasing fly ash content [17]. Erosion-corrosion performance of metal matrix composites is linked to the hardness of the matrix phase and the capacity to absorb impact energy. However, microstructural constituent of the composite respond to the erosion-corrosion process in a different ways. Erosion has been reported to produce materials loss in MMCs as a result of plastic deformation and mechanical removal of the matrix and by brittle fracture of the unprotected reinforcing phase [18].

Al alloys have been widely use in the production of heat exchangers, radiators, engine and transmission oil coolers [1,2,19]. However, Al alloys are relatively soft metals and can be susceptible to erosion-corrosion in the automotive cooling system, where ethylene glycol has been used as a coolant. Moreover, coolant in aircraft heat exchanger is said to be contaminated with chloride [20,21] and when such occurs the erosion-corrosion of the alloy

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Table 1
Chemical composition of the AA6063.

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Ni	Sn	Pb	Ca	Cd	Na	V	Al
Wt%	0.400	0.222	0.010	0.068	0.400	0.039	0.211	0.0120	0.010	0.001	0.001	0.002	0.0005	0.0007	0.001	98.62

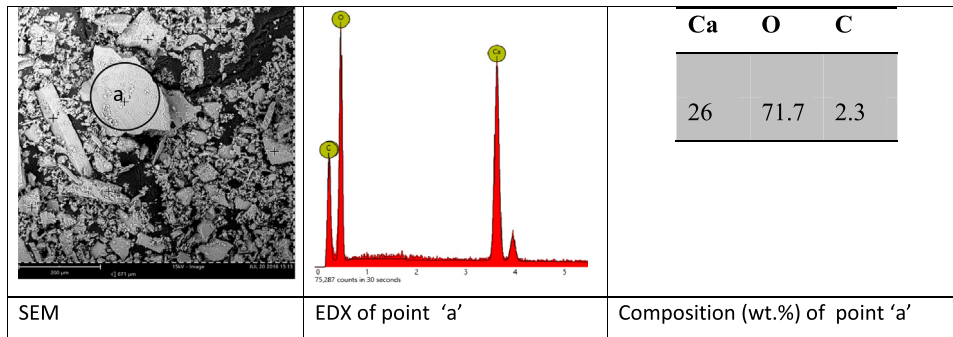


Fig. 1. SEM-EDX and point analysis (composition) of the snail shell ash.

become more complex. It has also been reported [22] that Aluminium alloy experiences erosion–corrosion in the presence of inhibited ethylene glycol coolants, especially when the coolant is contaminated with solid particles from the corrosion product. Moreover, erosion–corrosion of an aluminium alloy composite is expected to be more complex than that of a monolithic alloy. Even so, the hybrid system employed for this research has an agro based additive that may change the erosion–corrosion characteristic of the aluminium alloy. This research will therefore investigate the erosion–corrosion characteristics of Al alloy matrix composite reinforced with SiC and snail shell ash– an agro based reinforcement.

2. Experimental

2.1. Materials and equipment

AA6063 with chemical composition shown in Table 1 was used for this research. Silicon carbide and snail-shell ash particles were used as the reinforcing phase. The snail shell was burnt into ashes in the presence of air in accordance to the work of Alaneme et al., [16]. The ashes were then conditioned at a temperature of 650 °C for 3 h in an oven to reduce the carbonaceous and volatile constituent of the ash [22]. Ash obtained was ground and sieved to obtain ashes with size below 50 μm. SEM-EDX and point analysis (composition) of the snail shell ash is shown in Fig. 1.

2.2. Composite development

The AA6063 was melted in a gas-fired crucible furnace at a temperature of 750 °C. The liquid melt was then cooled to about 600 °C (semi-solid state) and the reinforcing phase added and stirred manually for 5 min. Meanwhile, the mixture of the reinforcing phase was pre-heated to 250 °C to eliminate dampness and to improve wettability. The composite slurry was then superheated to 780 °C and the second stirring was performed with a mechanical stirrer at a speed of 300 rpm for 10 min. The mixture was then poured into the prepared mould and allowed to solidify. Four volume fractions of the reinforcing phase were employed (Table 2).

2.3. Erosion–corrosion

Erosion–corrosion tests were carried out in a submerged

Table 2
Designation of the different volume fractions of cast composites.

Al	2.5/2.5-Al	5/5- Al	7.5/7.5- Al	10/10-Al
Monolithic Al 6063	2.5 wt% SiC+2.5 wt% Snail shell ash	5 wt% SiC+5 wt% Snail shell ash	7.5 wt% SiC7.5 wt% Snail shell ash	10 wt% SiC+10 wt% Snail shell ash

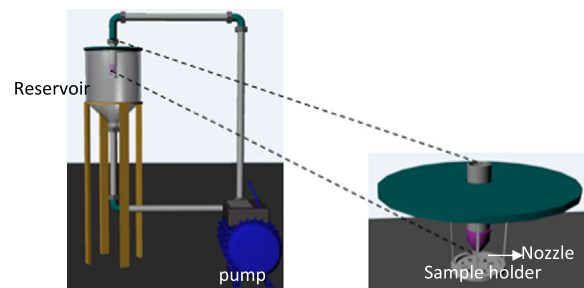


Fig. 2. Submerged Impinging Jet (SIJ) Rig.

impinging jet rig shown in Fig. 2. The rig has a glass-reservoir of 1.5 l capacity and powered with a 0.5 Hp water-pump. This is a miniature rig with a single nozzle modified based on the rig used by Aribo et al., [23]. Speed of the pump is controlled by varying the input voltage into the system. The impinging speed was calibrated before the experiment was carried out. Meanwhile, variable speeds of 2 m/s and 3.5 m/s were used for the experiment while a sand loading of 0.1 g/L was adopted for the total weight loss and erosion–enhanced corrosion characteristics. Erosion–corrosion was carried out in aerated conditions with 20% (v/v) mono-ethylene glycol+80% (v/v) tap water. A set of experiment was also conducted with 20% (v/v) mono-ethylene glycol+80% (v/v) distilled water+1 wt% of NaCl. Also, some experiments were carried out in pure tap water and a mixture of tap water+0.1 g/L silica sand. Silica sand of average particle size of 200 μm and particle size distribution shown in Fig. 3 was adopted for the experiments. All experiments were carried out at ambient temperature of (approximately 25 °C) and open to air. The weight loss was taken after 1 h of each experiment and each set of experiment was repeated three times.

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