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Corrosion behaviour of thermal cycled aluminium hybrid composites reinforced with rice husk ash and silicon carbide

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Abstract The corrosion behaviour of aluminium hybrid composites reinforced with rice husk ash and silicon carbide subjected to thermal cycling has been investigated. Aluminium hybrid composites having 10 wt% reinforcement consisting of silicon carbide (SiC) and rice husk ash (RHA) in weight ratios of 1:0, 3:1, 1:1, 1:3, and 0:1 respectively were produced. The composites were subjected to varying thermal cycles of 6, 12 and 18 from room temperature to 200 °C repeatedly. Potentiodynamic polarization measurements were used to study the corrosion behaviour of the produced composites. The results show that the composites displayed similar polarization curves and passivity characteristics irrespective of the number of thermal cycles both in H_2SO_4 and NaCl solutions. No consistent trend of corrosion current density changes with increase in thermal cycling was established for composite grades 3:1, 1:1 in H_2SO_4 and 1:0, 0:1 and 3:1 in NaCl solutions. The hybrid composite grades with a higher RHA content generally exhibited a lower tendency to corrode compared to the other composite grades. Generally, the composites seemed to be structurally stable as they maintained their corrosion resistance levels even after exposure to thermal cycling.

1. Introduction

Aluminium matrix composites (AMCs) are a unique class of composite materials that are used for a wide range of applications. Their use pervades the aerospace, automotive, nuclear, biotechnology, sports, recreational and thermal management applications (Asif et al., 2011; Alaneme and Bodunrin, 2013; Alaneme et al., 2014; Mohan et al., 2014; Suresha and Sridhara, 2010). Its attraction is mainly due to its low cost of processing, and wide spectrum of properties which include high specific strength, high specific stiffness, low thermal coefficient of expansion, improved tribological and corrosion properties (Ramachandra and Radhakrishna, 2005; Alaneme, 2011; Prasad et al., 2014).

AMCs have are used in the design of specific aerospace and automotive components such as ventral fins, fuel access door covers, rotating blade sleeves, gear parts, crankshafts, and suspension arms. In the electronic industry they are used in the

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processing of integrated heat sinks, microprocessor lids, microwave, aircraft wings, fuselage frames and landing gears (Macke et al., 2012; El-Labban et al., 2016). In most of these applications the components undergo cyclic thermal exposures due to the operational mechanism of the engineering systems of which they are part. (Mallik et al., 2011; Alaneme et al., 2015).

The increasing service performance expected from materials utilized for thermal management applications has buoyed interest in the development of advanced aluminium matrix composites (AMC) with high thermal conductivity (TC) to effectively dissipate heat and low coefficient of thermal expansion (CTE) to minimize thermal stresses (Qu et al., 2011; Requena et al., 2012). This is of vital importance to enhance the performance, life cycle and reliability of AMCs utilized in environments where they are exposed to intermittent or constant elevated temperatures (Chen et al., 2009). Indeed several works have been conducted on the thermal management capabilities of AMCs (Qu et al., 2011; Requena et al., 2012; Chen et al., 2009; Daguang et al., 2013; Huber et al., 2006) but sparse literatures are available for AMCs reinforced with agro waste ashes. Also the effect of repeated or fluctuating thermal cycles on the engineering properties of agro waste reinforced AMCs has rarely received attention.

It is instructive to note that ashes derived from controlled burning of agro wastes (such as coconut shell, rice husk, bamboo leaf, and bagasse among others) have been used as reinforcements in AMCs with very promising results obtained (Alaneme et al., 2016; Bodunrin et al., 2015; Alaneme et al., 2013; Alaneme and Olubambi, 2013). These agro waste ashes have advantages of low densities and processing cost compared with common synthetic reinforcing ceramics such as silicon carbide and alumina (Saravanan and Kumar, 2013).

In this research work, the effects of thermal cycling on the corrosion behaviour of Al based composites reinforced with rice husk ash and silicon carbide are investigated. The microstructural features of these composite grades have been reported by Alaneme and Adewale (2013); and the mechanical properties of the composites under the influence of thermal cycling have been reported to be stable (Alaneme et al., 2015; Ekperusi, 2016). However there is currently no available study which has considered the corrosion behaviour of these composites using potentiodynamic polarization technique as basis for electrochemical studies. This work is aimed at comparing the corrosion properties of low cost processed Al based composite grades with conventional reinforced AMCs in environments where they are liable to undergo thermal cycling.

2. Materials and methods

2.1. Materials

Al–Mg–Si alloy (Si: 0.40, Fe: 0.22, Cu: 0.01, Mn: 0.01, Mg: 0.40, Cr: 0.03, Zn: 0.02, Ti: 0.01, Ni: 0.01, Al: 98.88 in wt. %) was used as the metal matrix for this research. Chemically pure silicon carbide particles having average particle size of 28 μm and rice husk ash were selected as hybrid reinforcements for the aluminium based composites to be produced.

2.2. Preparation of RHA

The rice husk ash was processed from rice husk following procedures reported in detail by Alaneme and Adewale, 2013. Rice husk ash was produced by burning rice husk completely with the aid of a metallic drum. The ash obtained from the process was conditioned in a furnace at a temperature of 650 °C for 180 min to reduce the volatile and carbonaceous constituents of the ash. Sieve size analysis was carried out on the conditioned ash using a digital sieve shaker. Particle sizes below 50 μm were selected for use as reinforcement in the composites to be developed. The chemical composition of the rice husk ash in wt.% is: silica (SiO_2): 91.59; carbon, C (4.8); calcium oxide, CaO (1.58); magnesium oxide, MgO (0.53); potassium oxide, K_2O (0.39); haematite, (Fe_2O_3); sodium, Na, (trace), and titanium, TiO_2 (0.20) (Alaneme et al., 2013).

2.3. Production of the Al based composites

Double stir casting process in accordance with Alaneme and Adewale, 2013 was adopted for the production of the composites. Charge calculation was used to determine the quantities of aluminium, rice husk ash (RHA) and silicon carbide (SiC) required to produce a hybrid composite of 10 wt% reinforcement consisting of RHA and SiC in weight ratios 0:1, 1:3, 1:1, 3:1, and 1:0. The rice husk ash and silicon carbide particles were initially preheated separately at a temperature of 250 °C to eliminate dampness and improve wettability with the molten Al–Mg–Si alloy. The Al ingots were charged into a gas-fired crucible furnace, and heated 30 °C above the liquidus temperature to ensure the alloy melts completely. The liquid alloy was then cooled in the furnace to a semi solid state at a temperature of about 600 °C. The preheated SiC and RHA were added at this temperature and stirring of the slurry was performed manually for 5minutes. The composite slurry was then superheated to 720 °C and a second stirring process performed using a mechanical stirrer. The stirring operation was performed at a speed of 300 rpm for 10 min to help improve the distribution of the SiC and RHA particles in the aluminium based composite. The molten composite was then cast into prepared sand moulds inserted with metallic chills to increase the composite solidification rate.

2.4. Thermal cycling

The thermal cycling procedure adopted is in accordance with Alaneme et al., 2015. The as-cast composite materials were subjected to repeat heating and cooling cycles of 6, 12 and 18 cycles to a maximum temperature of 200 °C to room temperature (25 °C). Control samples of the composites which were not subjected to thermal cycling were also prepared for experimentation. The thermal cycling process was performed by heating the samples in an oven to 200 °C and held for 45 min before removal from the oven and cooled in air to complete a thermal cycle. This procedure was repeated for the respective number of thermal cycles desired.

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