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Original Article

Corrosion and wear behaviour of Al–Mg–Si alloy matrix hybrid composites reinforced with rice husk ash and silicon carbide

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ABSTRACT

The corrosion and wear behaviour of Al–Mg–Si alloy matrix hybrid composites developed with the use of rice husk ash (RHA) and silicon carbide (SiC) particulates as reinforcements were investigated. RHA and SiC mixed in weight ratios 0:1, 1:3, 1:1, 3:1, and 1:0 were utilized to prepare 5, 7.5 and 10 wt% of the reinforcing phase with Al Mg Si alloy as matrix using double stir casting process. Open circuit corrosion potential (OCP) and potentiodynamic polarization measurements were used to study the corrosion behaviour while coefficient of friction was used to assess the wear behaviour of the composites. The corrosion and wear mechanisms were established with the aid of scanning electron microscopy. The results show that the effect of RHA/SiC weight ratio on the corrosion behaviour of the composites in 3.5% NaCl solution was not consistent for the different weight percent of reinforcement (5, 7.5, and 10 wt%) used in developing the Al–Mg–Si based composites. It was evident that for most cases the use of hybrid reinforcement of RHA and SiC resulted in improved corrosion resistance of the composites in 3.5% NaCl solution. Preferential dissolution of the more anodic Al–Mg–Si alloy matrix around the Al–Mg–Si matrix/RHA/SiC particle interfaces was identified as the primary corrosion mechanism. The coefficient of friction and consequently the wear resistance of the hybrid composites were comparable to that of the Al–Mg–Si alloy matrix reinforced with only SiC.

1. Introduction

The development of Aluminium based composites using agro-based wastes as sole or complementary reinforcement to the more conventional reinforcing materials such as alumina and silicon carbide is attracting much attention from researchers [1,2]. Aluminium based metal matrix composites (MMCs) are highly acclaimed for the attractive property combinations which they possess, making them very popular and top choice candidate material for a wide range of engineering applications [3]. The properties of aluminium matrix composites

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Table 1 – Elemental composition of Al–Mg–Si alloy.

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
wt%	0.4002	0.2201	0.008	0.0109	0.3961	0.0302	0.0202	0.0125

Element	Ni	Sn	Pb	Ca	Cd	Li	Na	V	Al
wt%	0.0101	0.0021	0.0011	0.0015	0.0003	0.0000	0.0009	0.0027	98.88

(AMCs) which have been explored for varied technical uses are: high specific strength and stiffness, good wear and corrosion resistance, low thermal coefficient of expansion, good high temperature mechanical properties, and excellent thermal management potentials among others [4–6]. Aluminium based matrices are also noted to be the cheapest among other common metallic matrix materials (copper, titanium, magnesium) for metal matrix composites (MMCs) production [7]. They can also be processed easily using similar techniques adopted for the production of metals and alloys [8]. Currently, AMCs are being reinforced using waste products derived from industrial processes (red mud, fly ash) and agro based materials (rice husk ash, bamboo leaf ash, ground nut shell ash, bagasse, among others) [9,10]. All the enumerated advantages have made AMCs become very popular and among top choice materials for a wide range of engineering applications by virtue of its excellent combination of material properties, ease processing, reduced cost, and accommodation of waste materials as reinforcement resource materials.

The development of reliable material property database for AMCs newly developed with the use of agro wastes as hybrid reinforcing materials (to either alumina or silicon carbide) is highly imperative. This is of vital importance in the area of materials selection to determine the most suitable areas and limits of application of these AMCs reinforced with agro based wastes. To this end, there have been efforts to generate material properties data for a number of AMCs developed with the use of agro waste based reinforcements [11–13]. From the results generated, a fairly consistent trend in mechanical behaviour has been observed for the different agro wastes used as hybrid reinforcements in AMCs [10,14]. But in the case of corrosion and wear properties, the results have not been as consistent as the observations recorded for mechanical properties [15].

Corrosion behaviour of AMCs in particular has been acknowledged to be difficult to comprehensively predict as shown by the wide variation and not too infrequent contradicting results reported by researchers for different AMC systems [16–18]. A measured forecast of the corrosion behaviour of AMCs in different environments is very helpful as part of assessments required in establishing its performance and suitability in a number of service environments. This is of paramount importance in AMCs developed with the use of agro wastes as hybrid reinforcements, since little corrosion data are currently available to understand its mechanisms of corrosion. Wear assessments are also very crucial where AMCs developed with the use of hybrid reinforcements are to be considered as replacement for the conventional AMCs (reinforced with Silicon carbide or alumina solely) for tribological applications [19].

There is currently no work available which has studied the corrosion and wear behaviour of Al–Mg–Si alloy matrix composites reinforced with rice husk ash and silicon carbide. The interest in studying the corrosion and wear behaviour is motivated by the promising mechanical properties of these Al–Mg–Si alloy based hybrid composites which have shown comparable strength characteristics and improved fracture toughness over the single reinforced Al–Mg–Si alloy/SiC composites [20]. The output from this research will be helpful in understanding the corrosion and wear behaviour of these peculiar AMCs. It would also serve as resource information in building a database of material properties for Al–Mg–Si alloy/RHA–SiC hybrid composites.

2. Materials and methods

2.1. *Materials*

Al–Mg–Si alloy was selected as aluminium alloy matrix for the investigation. The alloy was obtained in form of billets and its chemical composition determined using spark spectrometric analysis (Table 1). Silicon carbide (SiC) and rice husk ash (RHA) were selected for use as hybrid reinforcement for the composites to be developed. For this purpose high purity silicon carbide with average particle size of 28 μm was procured. The rice husk ash (with mesh size under 50 μm and chemical composition as presented in Table 2) was prepared from complete burning of the rice husks, thermal processing, and sieving following procedures in accordance with Alaneme [10]. Magnesium was selected as wetting agent to improve wettability between the Al–Mg–Si alloy and the reinforcements.

2.2. *Composites production*

The Al–Mg–Si alloy matrix composites reinforced with RHA and SiC were produced using double stir casting process [21]. The quantitative amounts of rice husk ash (RHA) and silicon carbide (SiC) required to produce 5, 7.5, and 10 wt% reinforcement consisting of RHA and SiC in weight ratios 0:1, 1:3, 1:1,

Table 2 – Chemical Composition of the Rice Husk Ash.

Compound/element (constituent)	Weight percent
Silica (SiO_2)	91.56
Carbon	4.8
Calcium oxide CaO	1.58
Magnesium oxide, MgO	0.53
Potassium oxide, K_2O	0.39
Haematite, Fe_2O_3	0.21
Others	0.93