



## Original Research Article

### Microstructure and Corrosion Behaviour of ZA-27/ B<sub>4</sub>C Particulate Composite

\*<sup>1</sup>Saliu, A.M., <sup>2</sup>Onimisi, Z. and <sup>3</sup>Ubandoma, P.Z.

<sup>1</sup>Department of Metallurgical and Materials Engineering, Kogi State Polytechnic Itakpe, Nigeria.

<sup>2</sup>Department of Mechanical Engineering, Kogi State Polytechnic, Itakpe, Nigeria.

<sup>3</sup>Department of Mechanical Engineering, Niger State Polytechnic, Zungeru, Nigeria.

\*mumeensaliu5@gmail.com

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#### ABSTRACT

*The corrosion behaviour of ZA27/B<sub>4</sub>C particulate composites in an aerated sodium chloride solution was studied. ZA-27/B<sub>4</sub>C particulate composite at different weight percentage (2.5%, 5%, 7.5%, 10%) of B<sub>4</sub>C particles were produced using the stir casting method. The corrosion behaviours of both unreinforced alloy and reinforced composites were examined using potentiodynamic test in a salt solution (3.5 wt.% NaCl). Optical microscopy was used to examine the microstructure of the composites produced. The results showed improved corrosion resistance for metal matrix composites compared to corrosion resistance of the matrix in 3.5 wt.% NaCl solution. Increasing the weight percentage of the reinforcement particulates decreased the corrosion rate of the composites.*

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## 1. INTRODUCTION

Zinc-Aluminum (ZA-27) alloy was originally designed as a high strength gravity casting alloy and is extensively being utilized as bearing and bushing materials for high load, low speed applications in automobiles, drive trains, wear plates and thrust washers (Sharma *et al.*, 2008; Bobic *et al.*, 2014). ZA-27 alloy has the highest strength and the least density of the ZA alloys and provides the highest design stress capability of all the commercially available zinc-based alloys (Sharma *et al.*, 2008).

Commercially available ZA based cast alloys have recently become an alternative material, primarily for aluminum cast alloys and bearings, by virtue of their excellent castability, wear resistance, corrosion resistance and good mechanical properties (Babic and Ninkovic, 2004; Babic *et al.*, 2005). The popular members of ZA alloy family are ZA-8, ZA-12, and ZA-27. The letter Z and A refer to zinc and aluminum respectively, while the preceding numbers 8, 12, and 27 refer to the corresponding weight percentage of aluminum in each alloy. The corrosion behaviour of a metal matrix composite (MMC) in various environments is one important consideration when choosing a suitable material for particular purpose. The processing techniques associated with MMC's fabrication can cause accelerated corrosion of the metal

matrix alloy (Hihara, 2005). However, corrosion behaviour of these composites has not been studied on a large scale (Bobic *et al.*, 2015).

Corrosion characteristics of metal-matrix composites are deeply influenced by the microstructure of metal matrices (Shreir *et al.*, 2000). The ZA27 alloy is highly corrosion resistant in atmospheric conditions and natural waters (Porter, 1994). In comparison with the already studied reinforcements, boron carbide (B<sub>4</sub>C) particulates possess a superior and unique combination of high corrosion resistance, low density, elastic modulus, chemical and thermal stability (Auradi *et al.*, 2014). Seah *et al.* (1997) investigated the corrosion characteristics of ZA-27 alloy reinforced with graphite particles in HCl solution and SAE 40 oil respectively which was aimed at exploring the possibility of using the composite in such acidic environments and also to evaluate the composite as a bearing material. The results however showed that the ZA-27/graphite particles composites corrode in HCl solution but not in SAE 40 oil.

The most common form of corrosion in these environments is general corrosion. The aim of this work is to study the microstructure and influence of corrosion processes on the surface appearance of ZA27/B<sub>4</sub>C composites. Corrosion resistance of the composites was evaluated after the immersion of composite samples in the aerated sodium chloride solution.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The matrix materials used in this research were Zinc and Aluminium ingots, while the reinforcement material is boron carbide (30  $\mu\text{m}$ ) which was procured from China.

### 2.2. Methods

#### 2.2.1. Production of composite

The ZA-27 alloy matrix composites reinforced with B<sub>4</sub>C particles was produced using stir casting process (Fatile *et al.*, 2017). The quantitative amounts of B<sub>4</sub>C required to produce 2.5, 5, 7.5 and 10 wt % reinforcement were determined by charge calculations. The B<sub>4</sub>C particles were preheated in a heating furnace separately at a temperature of 250 °C for an hour in order to eliminate moisture/ volatile matter and improve wettability with the molten ZA-27 alloy. A crucible furnace was used to completely melt the alloy by firing to a temperature of 690 $\pm$ 30 °C (above the melting temperature of the ZA-27 alloy). Manual stirring was performed at this temperature before charging the preheated B<sub>4</sub>C particles into the vortex and the stirring was continued for about 2 minutes to ensure homogeneity in the composite. After removing the slag, the molten composite was poured into the permanent mould and allowed to cool and solidify. Finally, the castings were removed from the mould and machined into the desired test samples. The same procedure was followed to produce composites of different weight percent of reinforcement

#### 2.2.2. Microstructure examination

Microstructural examination of the composites produced was performed using a Zeiss Metallurgical Microscope for image analysis. The samples for the examination were metallographically ground, polished and etched using Keller (H<sub>2</sub>O-95 ml, HNO<sub>3</sub>-2.5 ml, HCl-1.5 ml and HF-1.0 ml) solution before the microstructural investigation was carried out.

### 2.2.3. Corrosion analysis

The corrosion analysis was investigated using potentiodynamic polarization electrochemical methods in accordance with ASTM G59-97 (Owoeye and Folorunsho, 2019) in 3.5 wt. % NaCl solution at room temperature (25 °C). The experiments were performed using a three-electrode corrosion cell set-up comprising the sample as the working electrode, saturated silver/silver chloride as reference electrode, and platinum as counter electrode. The samples were rinsed in distilled water before immersion in the prepared solution of 3.5 wt. % NaCl, and then exposed to atmospheric air. After each experiment, the electrolyte and the test samples were replaced. The results of the corrosion tests were evaluated by Tafel plot extrapolations of the corrosion rate, corrosion current densities ( $I_{\text{corr}}$ ) and corrosion potentials ( $E_{\text{corr}}$ ). Potentiodynamic polarization measurements were carried out using a scan rate of 0.16 mV/ s at a potential initiated at -200 mV to +250 mV (Owoeye and Folorunsho, 2019).

## 3. RESULTS AND DISCUSSION

### 3.1. Microstructure Analysis

Several inclusions can be noticed on the surface of the composite sample, but also mechanical damages on the edge of the sample (Plate 1). The microstructure of the composite sample was revealed by etching (Plate II). It can be seen that  $B_4C$  particles are distributed in the regions of the  $\eta$  phase and regions of the phase mixture  $\alpha+\eta$  (Bobić *et al.*, 2015). Several clusters of  $B_4C$  particles can be seen in the composite microstructure (Plate III). Voids, due to the fallout of  $B_4C$  particles from the composite matrix, are not visible. This indicates good bonding between particles and the matrix alloy. In Plates IV and V, main microconstituents in the composite matrix ( $\alpha$  phase,  $\eta$  phase and  $\alpha+\eta$  phase) can also be noticed. The microstructure of the metal matrix is non-dendritic, with large primary particles. The primary particles consist of a core (rich in aluminium) and a periphery (composed of the phase mixture  $\alpha+\eta$ ). Interdendritic  $\eta$  phase (rich in zinc) can be seen between the primary particles (Bobić *et al.*, 2015).

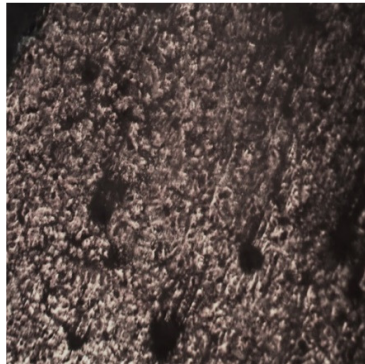


Plate I: ZA-27 alloy

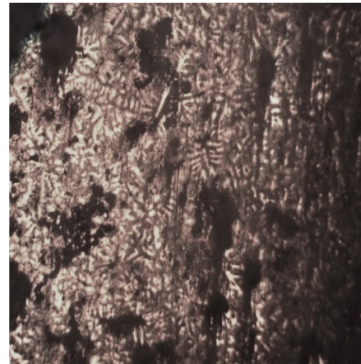
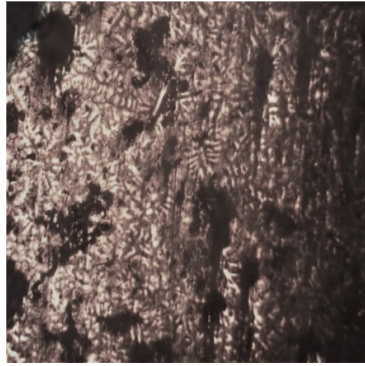
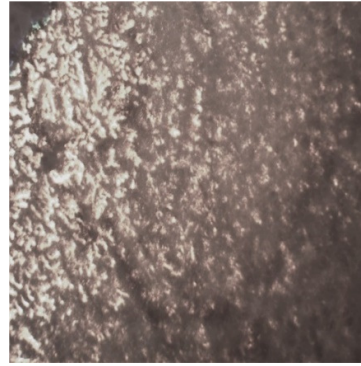
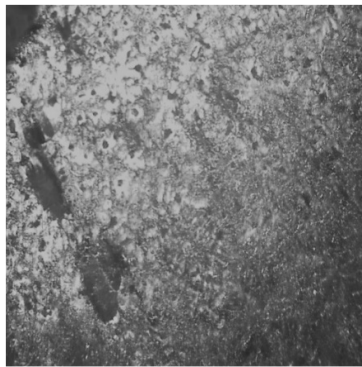


Plate II: ZA27/ 2. 5%B<sub>4</sub>C

Plate III: ZA27/ 5%B<sub>4</sub>CPlate IV: ZA27/7.5%B<sub>4</sub>CPlate V: ZA27/ 10%B<sub>4</sub>C

### 3.2. Corrosion Behaviour in 3.5% wt NaCl Solution

The corrosion parameters of ZA-27/B<sub>4</sub>C composites in 3.5% wt NaCl solution are shown in Table 1. The composites exhibited similar polarization and passivity characteristics. For 10wt% B<sub>4</sub>C, it was observed that the reinforced composites designate B4 series showed better corrosion resistance in the salt environment compared with the unreinforced ZA-27 alloy (A0) having corrosion rate of 1.8534 mmpy. However, composites designated A2, A3 and B2 (corresponding to 2.5wt% B<sub>4</sub>C, 5wt% B<sub>4</sub>C and 7.5wt% B<sub>4</sub>C respectively) displayed superior corrosion resistance which might be attributed to the corrosion products forming a tenacious protective layer on the samples (Constantinescu *et al.*, 2014).

Table 1: Electrochemical data of ZA -27/B<sub>4</sub>C composites in 3.5 wt. % NaCl solution

ZA27/B <sub>4</sub> C particulate	I <sub>corr</sub> (A/cm <sup>2</sup> )	E <sub>corr</sub> (mV)	Corrosion rate (mm/y)
ZA-27 Alloy	176.37	-926.183	1.8534
ZA-27/ 2.5% B <sub>4</sub> C	114.53	-847.656	1.1357
ZA-27/ 5% B <sub>4</sub> C	82.19	-821.481	0.7956
ZA-27/ 7.5% B <sub>4</sub> C	57.64	-952.25	0.4570
ZA-27/ 10% B <sub>4</sub> C	32.48	-829.13	0.3232

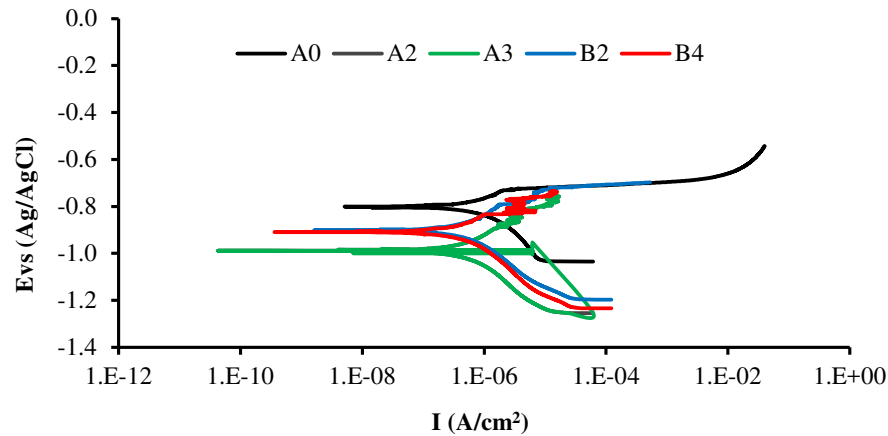


Figure 1: Polarization curve of ZA27/B<sub>4</sub>C composite in saline (3.5% NaCl Solution)

However, there is difference in the corrosion behaviour from the Tafel plot extrapolations of the corrosion current densities ( $I_{corr}$ ) and corrosion potentials ( $E_{corr}$ ) between the un reinforced ZA-27 alloy and the reinforced composites (Table1). It was observed that the corrosion current density is more intense for the unreinforced ZA-27 alloy designated as A<sub>0</sub> (176.37 A/cm<sup>2</sup>) in comparison with the composites containing B<sub>4</sub>C particulates. This shows that the composites containing B<sub>4</sub>C particles are more resistant to corrosion in 3.5 wt. % NaCl solution. The corrosion current densities ( $I_{corr}$ ) values were decreasing with increase in %B<sub>4</sub>C content. However, it is observed that the corrosion rate of both the B<sub>4</sub>C reinforced composites and the unreinforced alloy were generally low. This shows that the passive films formed on the surface of both the unreinforced alloy and the composites are stable and immune to attack when immersed in 3.5 wt. % NaCl environment. The composites will be suitable for use in saline environments (Adhan *et al.*, 2019).

#### 4. CONCLUSION

The following conclusions have been drawn:

- The microstructure of ZA-27 alloy reinforced with B<sub>4</sub>C particles is uniformly distributed and strong interfacial bonding between the matrix alloy and reinforcement.
- Corrosion current density values ( $I_{corr}$ ) decrease with increase in reinforcement content in the composites
- The corrosion behaviour for both unreinforced alloy and composites show that all the composites have superior corrosion resistance when compared with unreinforced alloy in 3.5 wt% NaCl environment.

#### 5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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