



Study of the Corrosion Behavior of Zinc-Aluminum Alloy Matrix Composite Reinforced with Nanosilica Produced by Stir Casting

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ABSTRACT

In this investigation, Zn-Al alloy metal-matrix nano composites that reinforced via various weight percentages (2%, 4%, 6%, and 8%) of nanosilica (SiO₂) particles were fabricated applying the technique of stir casting. Behaviors of the corrosion of the unreinforced alloy and reinforced composites were measured utilizing a potentiostat test in a (3.5 wt.% NaCl) salt solution. The optical microscopy was employed to investigate the surface microstructure of the composite. Microstructure analysis manifested that the uniform distributions of the reinforcing particles in the composites are alike, consisting of a dendritic structure of the zinc alloy matrix with an excellent reinforcing particles steady dispersion. The improved results of the corrosion resistance for the metal matrix composites showed an excellent resistance to corrosion than the matrix in the (3.5 wt.% NaCl) solution. Raising the weight percentage of the reinforcement particulates of nanosilica (SiO₂) reduced the composites rate of corrosion.

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1. Introduction

High zinc-aluminum alloy (ZA alloys) have been of interest both research and industrial field, as a considerable potential tribo-material for the last little decades. It can be said that, at this time, due to the perfect castability and individual compound of characteristics, ZA alloys are commercially available and become the substitutional material firstly for numerous aluminum cast alloys, plastic materials, bearing bronzes, and even for steels, which work under the requirements of high mechanical burdens and moderate sliding speeds. Attention is in the prolonging the functional

utilization of such materials, in addition to the ecological, economic, and tribological character. Such alloys are known as a poor material treated efficiently, actively, and with no risk to environment [1]. The excellent mechanical and physical properties, unique properties of finishing, and atmospheric corrosion resistance have assisted the zinc alloys die casting to withstand the time tests after being utilized in a great number of uses with a substantial fame [2]. They let for a more significant difference in the design of section and the closer dimensional tolerances maintenance [3].

Zinc-aluminum alloy is the special Zn alloys strength. It's a sprightly alloy and gives superior bearing resistance, the more upper contents of Al and Cu impart them various clear benefits from the conventional zinc alloys which include less densities, excellent creep and wear resistance and higher strength,. Nevertheless, if the characteristics of wear resistance are required, Zn-Al alloy has revealed superior performance [4].

Due to the special characteristics of Zn-Al alloy, many researchers have reinforced it with ceramic particles to get more improved mechanical and tribological properties [5].

In actual casting requirements, the Zn-Al alloys possess a distinctive dendritic structure that relies upon on various factors, namely the rate of cooling exerts a vigorous effect upon the fineness of structure [6].

Seah et al. [7] presented that the hardness of the as cast is reduced when reinforcing the graphite particles in a ZA-27 alloy and simultaneously, it raised for the aged samples after comparing the as-cast hardness. In addition, the synthetic aged samples of (Zinc-aluminum-27/Gr) have an influence on the matrix. Babic et al. [8] showed that the results decreased in the ultimate tensile strength and hardness with a rise in the elongation of the alloy when compared with the casting and the heat treatment of the ZA-27 alloy reinforced with Gr.

Ranganath et al. [9] investigated the mechanical characteristics of (Zinc-aluminum-27) that reinforced with various percentages by weight of (TiO₂). It was concluded that the reinforced particles inclusion enhanced the hardness, modulus of elasticity, yield strength, and ultimate tensile strength of the composites, whereas the ductility decreased.

Prasad et al. [10] performed tests at different temperatures and stain values. The evolution of tensile properties was observed with an increment in the rate of strain, nevertheless, at more elevated temperatures, an opposite shift attended.

The work of the present investigation aims to evaluate the corrosion behaviour and microstructure of Zinc-aluminum alloy via utilizing alloys made via stir casting and study influence of adding various percentages of Nanosilica (SiO₂) particles upon the Znic alloy.

2. Methods and Materials

I. Materials Selection

Matrix Materials

In this research, zinc-aluminum alloy was used as a matrix material that possesses unique characteristics with a broad extent of uses. The chemical analysis of this material is depicted in the Table 1.

Table 1: The chemical analyses of zinc-aluminum alloy

Element	Al%	Cu%	Mg%	Fe%	Cd%	Pb%	Zn%
Chemical composition of zinc alloy	8.34	5.14	0.013	0.014	0.0015	0.0009	Rem

Nano Silica as Reinforcing Materials

Ceramic powder (nano SiO₂) was used as reinforcement for zinc alloy. The Granularity Commutation Distribution of the reinforcing powders was analyzed using AFM, as shown in Figure 1. It is observed that powders are with nanoscale. Figure 2 reveals the 2 D and 3D images of AFM for nano powders.



Granularity Commutation Distribution Report

Sample:1	Code: Sample Code
Line No.: lineno	Grain No.:227
Instrument: CSPM	Date:2018-10-07
Avg. Diameter:57.43 nm	<=10% Diameter:35.00 nm
<=50% Diameter:55.00 nm	<=90% Diameter:75.00 nm

Diameter(nm) <	Volum e (%)	Cumulatio n (%)	Diameter(nm) <	Volum e (%)	Cumulatio n (%)	Diamete r (nm)<	Volum e (%)	Cumulatio n (%)
25.00	2.20	2.20	50.00	9.69	32.60	75.00	8.37	83.70
30.00	4.85	7.05	55.00	10.13	42.73	80.00	7.93	91.63
35.00	2.64	9.69	60.00	10.13	52.86	85.00	8.37	100.00
40.00	3.96	13.66	65.00	12.78	65.64			
45.00	9.25	22.91	70.00	9.69	75.33			

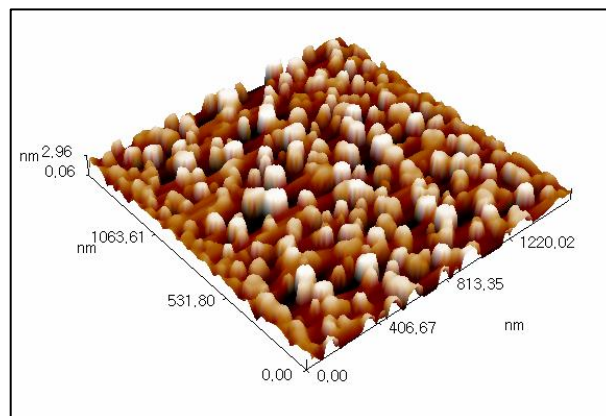


Figure 1: 2 D and 3D images of AFM for nano SiO₂ powders

II. Production of Matrix Material and its Composite

Zinc and aluminum alloys were melted in a graphite crucible applying an electric furnace to around (700°C) (above the melting point) to secure complete melting [11]. The mechanical stirrer was used to mix the molten material to ensure the mixture homogeneity. Flux cleansing (KCl- NaCl- NaF) with a weight percentage of (0.25%) was utilized which is normally more abundant in chlorides for facilitating the wetting of oxide additions for more natural disintegration from the melt that was degassed utilizing hexachloroethane for obtaining it free of gases impurities [12]. Nanoparticles (SiO₂) used in various by wt. % were added as reinforcement beyond packaged in the aluminium foil to the melted matrix with continuous stirred utilizing the mechanical stirring for (2-3) times and a speed of 1000-1200 rpm. To obtain the homogeneity between the matrix materials and the reinforced particles, slag was taken away, and molten alloy was then placed into a cylindrical permanent casting mold made from graphite, and the temperature was slowly reduced. Figures 3 and 4 depict the manufacture of mold and mold design with the dimensions, sequentially.

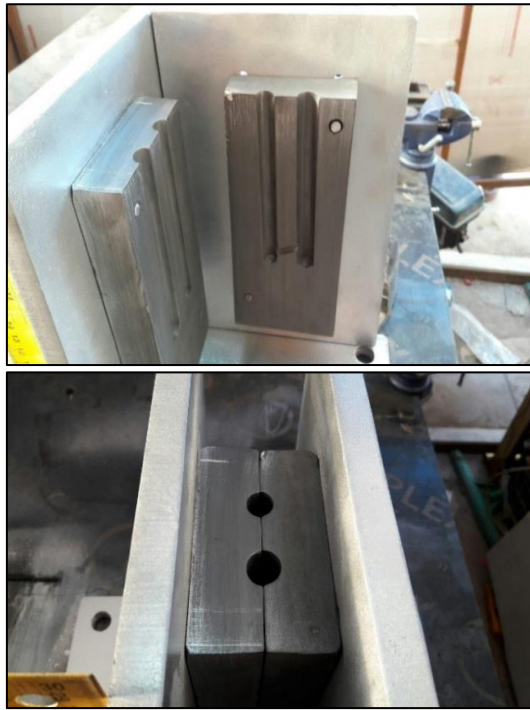


Figure 2: Mold preparation

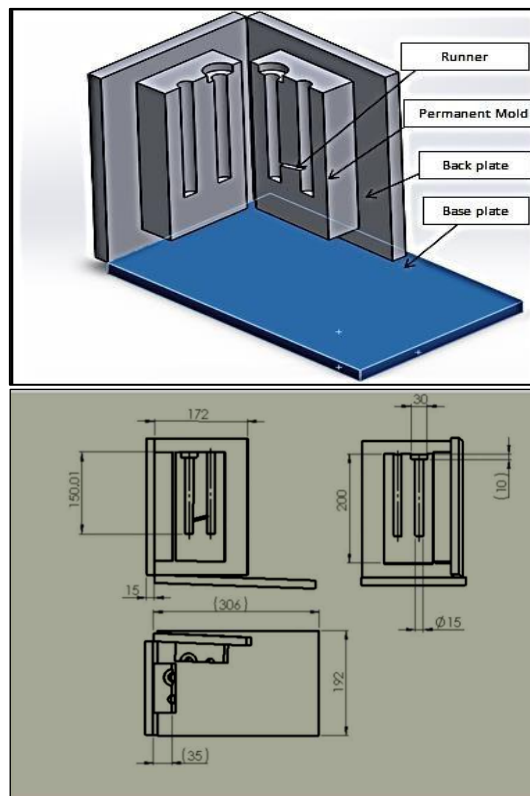


Figure 3: The mold sketch with the dimensions
(Dimensions are in mm)

The analyses were conducted using a three electrodes cell. It was immersed in 500 ml test solution (sea water). The ZA alloy and its composite sample were exposed to corrosion medium, where they created a steady-state open circuit potential that followed via the polarization measurements at scan rate (3) mV/s for the Tafel plots. Figure 4 reveals the used setup for the electro-chemical measurements.



Figure 4: The used setup for the electrochemical measurements

The values of (i_{corr}) were obtained by the junction point of each of the anode and cathode polarization linear parts, with the stationary corrosion potential (E_{corr}).

The corrosion rate can be calculated by the following equation [13]:

$$\text{Corrosion rate} = \frac{3.27 \times 10^{-3}}{\rho} \times i_{\text{corr}} \times EW \quad (1)$$

Where:

i_{corr} : The current density of corrosion in $\mu\text{A}/\text{cm}^2$

EW: The corroding species equivalent weight in gm.

ρ : The corroding species density in g/cm^3 .

3. Results and Discussion

1. Rate of corrosion in a salt solution

Table 2 gives the corrosion information for (ZA) alloy with its composites in the (3.5%) NaCl solution. The corrosion rate of the reinforced alloys is lower than the unreinforced alloys due to nano particles that are barely influenced via the salt medium and are not affected by the mechanism of the composite corrosion.

Figures 5 to 9 gave the polarization data of all samples and obtained the corrosion current density (I_{corr}). Table 2 indicated the values of the corrosion rate for the alloy and all composites. The corrosion rate values were decreased by increasing the wt. % of nano particulates. During the corrosion testing, the corrosion rate of composites was higher than the base alloy. The ceramic particles additives for alloy matrix exhibited good physical properties of additives and better corrosion rate due to the homogeneity of the inert ceramic additives in the alloy matrix. Therefore, it is noted that there is no interaction between the additives particles and alloy matrix during the preparation of the composite that enhanced the corrosion resistance because of the possible passivation of the matrix alloy.

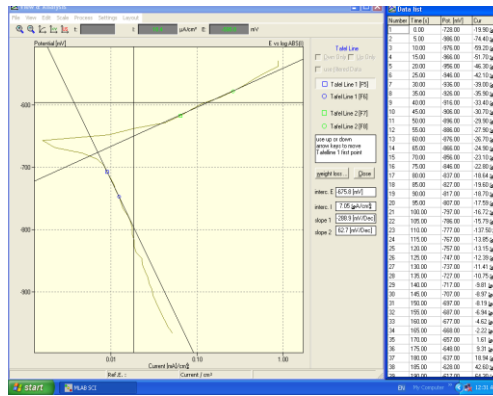


Figure 5: Tafel Plot for ZA alloy in a salt solution

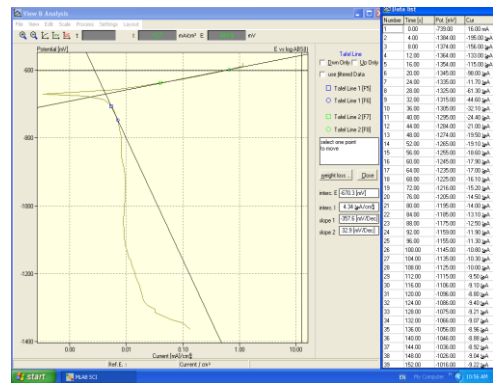


Figure 6: Tafel Plot for (Zn-Al alloy with 2%SiO₂) composite in a salt solution

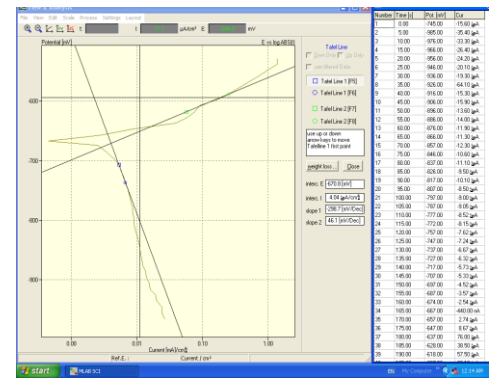


Figure 7: Tafel Plot for (Zn-Al alloy with 4%SiO₂) composite in salt solution

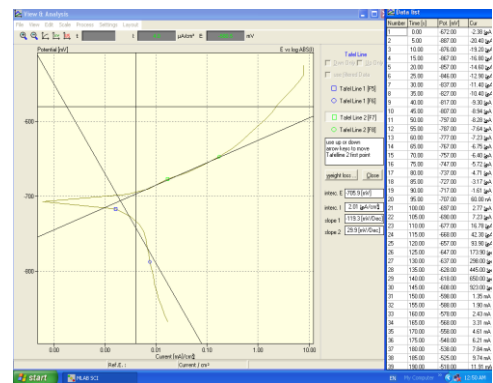


Figure 8: Tafel Plot for (Zn-Al alloy with 6%SiO₂) composite in a salt solution

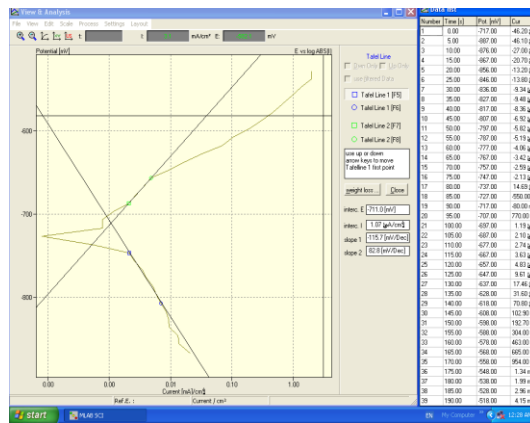


Figure 9: Tafel Plot for (Zn-Al alloy with 8%SiO₂) composite in a salt solution

II. Microstructure analysis

The microstructure illustrated a better reinforcement dispersion in matrix. When the nano particles weight percentage raises in the matrix, particles of the reinforcement raise, while inter- particle region reduces. No reinforcement agglomeration is indicated in the matrix. Microstructure being dendritic and initial dendrites are broken as fragments due to the mechanical stirring that depicts the enhancement in the capability to incorporate and entrap the nano-sized particles in the inter-dendritic interface that develops during the dispersed alloys solidification, as manifested in Figure 10.

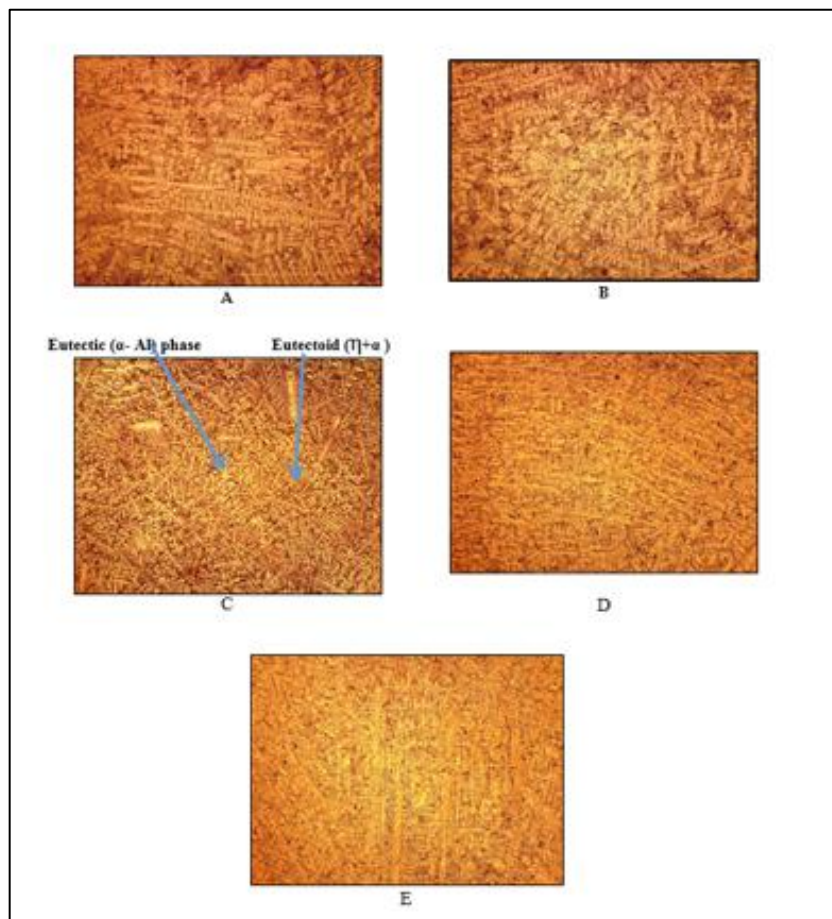


Figure 10: The (Zn-Al alloy-matrix) microstructure with nanoparticles at various percentages: (A) Zn-Al alloy, (B) Zn-Al alloy with 2%SiO₂, (C) Zn-Al alloy with 4%SiO₂ (D) Zn-al alloy with 6%SiO₂, and (E) Zn-Al alloy with 8%SiO₂

4. Conclusions

The following conclusions of the research:

- The composites that reinforced by the nanoparticles additives revealed a higher resistance to corrosion in the salt solution than the base material.
- Values of the current density (i_{corr}) of corrosion reduces with the increment in the content of nanoparticles in composites for the (3.5% NaCl) solution.
- Reinforcement with (8%) SiO₂ nanoparticles was the best nano composites for resistance to corrosion.
- The good distribution and vigorous interfacial bonding between reinforcement and matrix elucidated in microstructure of the reinforced alloy. Hence, increasing the nanoparticles with **% by wt.** raises the composite resistance to corrosion.

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