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CORROSION BEHAVIOR OF GALVANNEALED STEEL SUBSTRATE IN SALINE ENVIRONMENT

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Abstract: In this research, low carbon steel and Al-1200 series was used in the development of galvanneal steel; hot dip technique was adopted for the immersion at varied time ranging between 0 and 60 seconds. Muffle furnace was used for the annealing operation which precedes the corrosion experiment where weight loss technique was adopted. From the result, it was observed that the sample hot-dipped and held for 30 seconds gives better adhesive property between Al-Zn and Fe substrate thus indicating that it is feasible to develop galvanneal steel using low carbon steel. Aluminium (1200 series) and zinc was generally found to improve the corrosion resistance of the steel, thus galvanneal steel has better corrosion resistance in simulated sea water to represent the saline environment.
Keywords: Annealing, In-line annealing, Galvannealing, retention time

INTRODUCTION

Corrosion is a natural phenomenon, which converts refined metal to their more stable oxide. It is the gradual destruction of materials (usually metals) by chemical reaction with their environment. To avert this phenomenon, different routes or technique have been adopted to improve on the sustainability of the unstable and thermodynamically stable materials.

The developments of new and improved materials as an 'underpinning technology', which is one of the implored techniques, have been well regarded by most industrial nation (Small and Bishop, 1999). This is because it enhances innovation in all branches of engineering. One engineering material that has greatly explored a wide range of application is ferrous materials. The versatility application of ferrous materials is attributed to its amenability to alloying and heat-treatment which makes it possible to modify its properties to site specific service requirements (Momoh and Alaneme, 2015). One of such application is in the development of galvanneal steel that has final use in areas where high corrosion and reasonable wear resistance is required (Abdulhameed, 2005).

Developed galvannealed low carbon steel has been widely used in chemical plant in order to improve the corrosion resistance of vessels or section call units or lines that are interconnected by metal piping. Such material streams can include fluids (gas or liquid carried in piping) or sometimes solid or mixture such as slurries. Galvannealed steel provides corrosion protection without affecting the integrity of the steel. It has been observed that galvannealed steel exhibited excellent durability despite the harsh industrial and coastal environment or pH environment; this is due to its high resistant to corrosion (Max *et al.* 2003).

Galvannealed or galvanneal is the result from the combined process of galvanizing and annealing to produce specialized sheets of steel. The galvanization is made through the hot – dipping (hot – dip galvanizing) process and immediate in–lines annealing and gives a very fine greyish matter finish. Galvanneal does not flake of its galvanized coating when formed, stamped, and bent. The very fine malte finish acts like a primer, allowing paint to adhere easily, and is very rust proof; only white to dark grey marks appear if it comes in contact with water.

Galvannealed sheet is carbon steel sheet coated with zinc on both sides by the continuous hot–dipped process. Immediately as the stripe exits the coating, the zinc coating is subject to an in–line heat treatment that converts the entire coating to a zinc iron alloy (Hambidge and Krebs, 2007). Conversion to the alloy results in a non–spangle finish which makes the sheet suitable for painting after fabrication (Sere *et al*, 2015). This research is to generate a high adhesive Fe-Al-Zn ternary structure intermetallic compound on the corrosion resistance and investigate the feasibility and reliability of indigenous produced low carbon steel.

MATERIALS AND METHOD

— Materials and Equipments

Materials used for this project includes; low carbon steel plate of chemical composition shown in Table 1, zinc (Zn) and (Al). The equipment used for this research includes; metallurgical microscope of varied magnifications for microstructural view/examination. Muffle furnace was used for heat treatment operation (annealing) during the research. Micro hardness tester also used to determine the thickness of the coated steel. Digital weighing balance of 0.1g accuracy was used in the corrosion experiment to determine the weight lost and the corresponding rate.

— Method

The specimen was delivered in smooth 5 mm thickness form and some preparations need to be carried with the chemical composition as shown in Table 4.1. The sample was prepared by sourcing of low carbon steel which was machined into corrosion coupons. By using hack saw to cut it into a size of 2.8 x 1.8 x 0.5 cm. A binary Al-Zn phase was formed by the melting of 99.7 % Zn was melted in 0.3 % Al at 660oC, stirred to ensure thorough homogeneity. A hot dip approach was adopted in coating the substrate in the Al-Zn molten solution. And each sample was immersed in the melt and allowed to soak for 0, 30 and 60 seconds. This is followed by *annealing* operation in a muffle furnace maintained at 400°C and allowed to soaked again for 45 minutes.

The produced GA-steel were later immersed in a simulated saline environment by dissolving 3.5g NaCl in 500ml distilled water to form the desired environment. The weight was measured at a regular interval of 3 days, before calculating the metal loss and the corrosion rate of the samples using equation (i) and (ii) as adapted from ASTM G1-G4 standard (Momoh, 2012).

$$\text{Metal Loss} = \frac{\text{Weight Loss (g)} * \text{K}}{\text{Alloy Density (gcm}^{-3}) * \text{Exposed Area (A)}} \quad \text{(i)}$$

$$\text{Corrosion Rate} = \frac{\text{Weight Loss (g)} * \text{K}}{\text{Alloy Density (gcm}^{-3}) * \text{Exposed Area (A)} * \text{Exposure Time (hr)}}. \quad \text{(ii)}$$

RESULTS AND DISCUSSION

The results of the experiment before and after corrosion are shown thus.

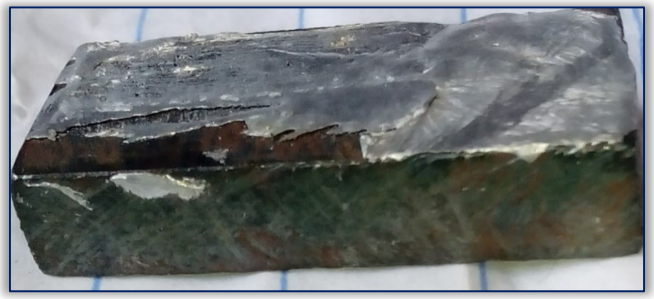

Figure 1: Picture of developed GA-steel (at 0 seconds retention)

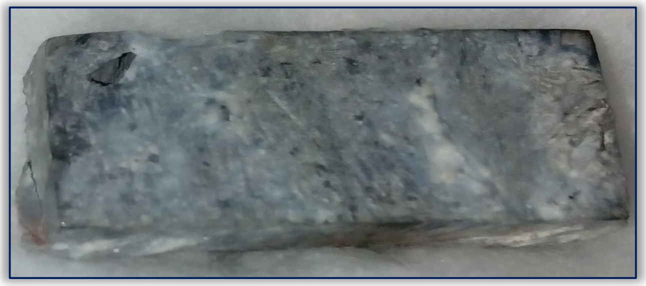

Figure 2: Picture of developed GA-steel (after 30 seconds retention)

Figure 3: Picture of developed GA-steel (at 60 seconds retention)

Table 1: Chemical composition of the steel

Element	Composition (wt.%)
C	0.0407
Si	0.1129
S	0.0004
P	0.0052
Mn	0.6122
Ni	0.1320
Al	0.0147
Fe	98.5323

Table 2: Sample designation

S/N	Sample	Soaking time (Seconds)
1	A	Control
2	B	0
3	C	30
4	D	60

Figure 4: Picture of corrosion setup

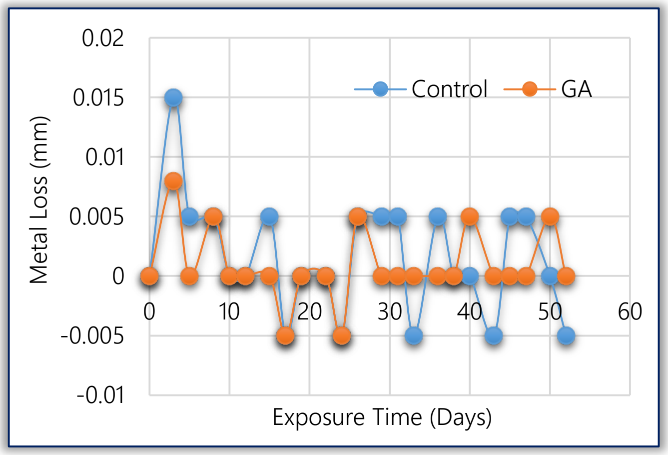

Figure 5: Variation of weight loss against Exposure time

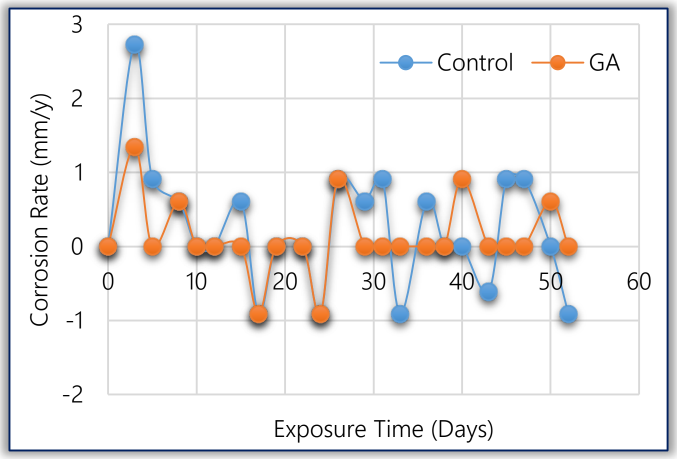

Figure 6: Corrosion rate versus Exposure time (in days)

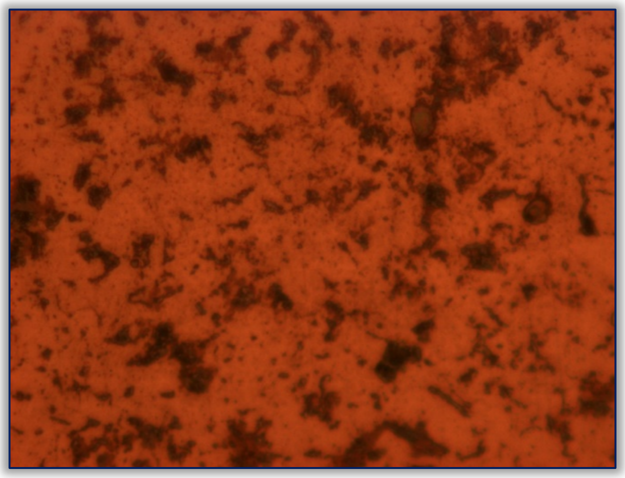

Figure7: Micrograph of the as-received steel (Sample A, X200)

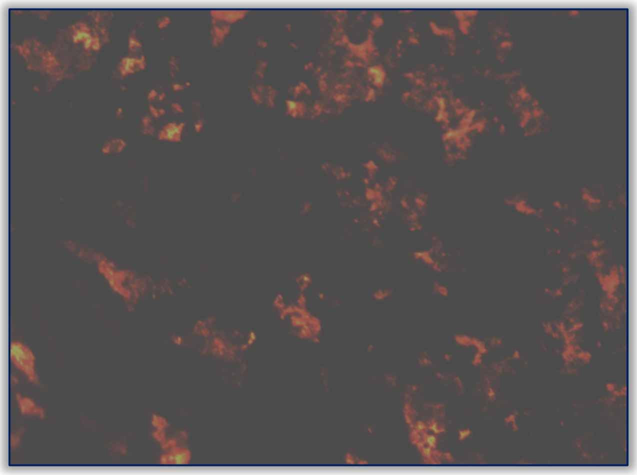

Figure 8: Micrograph of sample A after 52 days of immersion displaying predominantly corrosion products (dark phases), X200

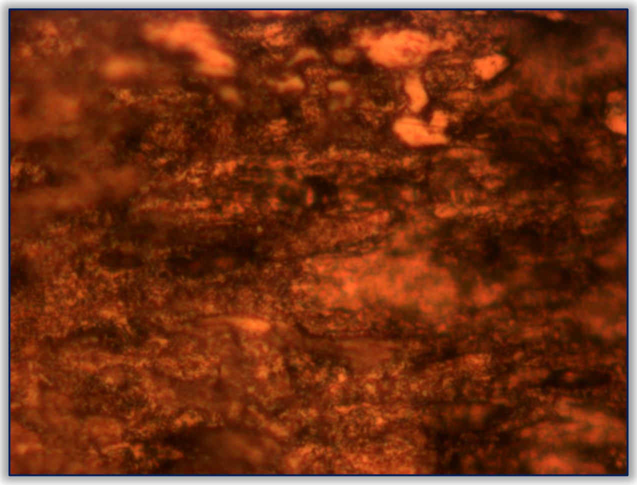

Figure 9: Micrograph of the developed GA steel after 52 days of immersion showing slight corrosion products (dark phases) on the exposed area, X200

This project has made a tremendous attempt to develop the same galvanneal steel with a different aluminum grade (1200 series). The results are as shown in Figures 1–9.

From the results, it was observed that the Fe-Al-Zn ternary phase formed on the surface of sample B and D (i.e at 0 and 60 seconds retention time as shown in Figure 1 and 3) has a very poor adhesive property. Wherefore, sample C with 30 seconds retention time (Figure 2) before annealing operation was found to possess a better adhesive property as it stocked to the steel surface.

After 52 days of immersion in the prepared NaCl environment, Figure 5 shows the metal or mass loss of the sample C (which has a better adhesion). Here, it was observed that the developed GA-steel, in most of the time spent in the environment, was immune to the attack as it maintains stability. The initial loss experienced by the sample could be as a result of the of the expose area since the coating was not homogenously distributed over the sample surface. This is further explained in the corrosion rate plot in Figure 6, where the sinusoidal trend of the sample A (control sample) is clearly shown.

Figure 7–9 show the microstructures of the samples before and after immersion in the prepared simulated sea water environment.

Figure 7 shows the conventional ferrite/pearlite in the microstructure of the low carbon steel. After a total 52 days of immersion, the resulting structures were also viewed and as shown in Figures 8 and 9 for the control and the GA steel respectively, the GA-steel was observed to have been able to resist the attack of the environment; wherefore the blank shows different dark spots indicating corrosion products.

CONCLUSIONS

In the development of galvanneal steel, low carbon steel and Al-1200 was selected alongside zinc granules, and hot-dip galvanizing method was adopted which precedes the simultaneous annealing operation prior to microstructural examination and which was done before and after corrosion experiment. And from the result, the following were observed:

— Development of GA-steel using low carbon steel is feasible with Al-1200 to improve on the adhesive property
— Al-1200 and Zn granules can form a ternary phase which improves the corrosion resistance of low carbon steel, and
— Galvanneal steel has better corrosion resistance in marine environment.

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