ELECTROCHEMICAL AND METALLURGICAL BEHAVIOUR OF DUCTILE IRON IN ACIDIC, BASIC AND SALINE ENVIRONMENTS

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Abstract-
This research work presents the comparative study of the effect of some selected environments on the corrosion characteristics and accompanying changes in microstructure on ductile iron. In this study, the atmospheric corrosion of ductile cast iron immersed in acidic (2M H₂SO₄), basic (2M NaOH) and saline (3.5% NaCl) environments, which represents the major atmospheric environments in which metals are mostly subjected to while in service. The corrosion characteristics of ductile iron have been determined by current potential curves. To determine the corrosion rates, the anodic and cathodic Tafel regions extrapolating to corrosion potentials were used. The individual corrosion rates of ductile iron were evaluated for a time period of 600 seconds, 1mv/s scan rate and Tafel plot range of -250mv to 250mv. Each sample were dimensioned, polished, pickled in dilute HCL and rinsed with distill water, degreased with acetone followed by drying and then mounted for the potential dynamic tests. The results obtained reveal that corrosion of DI in 2M H₂SO₄ is (0.25699 mmpy), 2M NaOH is (0.025955 mmpy), 3.5% NaCl is (0.10396 mmpy) and distill water is (2.6447e-05 mmpy). The results obtained showed that corrosion rate in decreasing order is 2M H₂SO₄, 3.5% NaCL, 2M NaOH and lastly as expected distil water. The corrosion product morphologies of the DI showed the nodular matrix was gradually covered up as the corrosion rate increased. This work is important reference point for the corrosion effectiveness of ductile iron in major atmospheric conditions.

Key words: Salt, fog. chamber. materials testing, corrosion.

1. Introduction

Ductile iron, also known as nodular cast iron or spheroid-graphite (SG) cast iron contains nodules of graphite, embedded in a matrix of ferrite or pearlite or both, the graphite separates out as nodules from iron during solidification because of the additives like cerium (Ce) and magnesium (Mg) introduced into the molten iron before casting. These nodules act as crack arresters, thereby improving the mechanical properties of ductile iron. The formation of graphite nodules during solidification causes an internal expansion of ductile iron as it solidifies, and is responsible for the absence of shrinkage defects in most ductile iron castings [1-2]. The major difference in the structure of ductile and grey iron is the flaky and spheroid graphite in the grey and ductile iron respectively. However, the spheroid graphite in ductile iron does not weaken the matrix and hence
its mechanical properties are superior to those of grey iron and comparable to that of steel. Ductile iron has been widely used as a structural material across various sectors because of its better castability, workability, ductility, fluidity, strength and toughness over grey cast iron [3, 4].

The corrosion resistance of ductile cast iron is attributed to the formation of a thin passive barrier film of hydrated oxides of silicon on the metal surface. The film develops with time due to the dissolution of iron from the metal matrix leaving behind silicon which hydrates due to the presence of moisture. The passive hydrated silicon film is thought to bridge over and form an impervious barrier layer on a fine grained high silicon cast iron with spheroidal graphite areas much more readily than on a high silicon cast iron with coarse graphite flakes [5].

While a lot is known on the effect of alloyed elements on the mechanical properties of ductile cast iron, not much is known of the effect of microstructure, and the corrosion behavior of these materials, in natural and acidic environments. Hence the need to investigate the effect of heat treatment on the microstructure and corrosion resistance of as-cast ductile iron, in Sodium Chloride and Sodium Hydroxide solutions. This research work is based on an experiment to carry out a potentiodynamic study of the corrosion of ductile iron and stainless in three major applicable engineering environments; Acidic, basic and sea water environments.

2. Methodology

The process involves sample and surface preparation along sides with the simulation of environment. Thereafter, some characterizations were carried out.

2.1 Material Used

The ductile iron was dimensioned into 10cm × 10cm cylindrical shape with the aid of lathe machine and ark saw, surface treatment and cleaning of the metal coupons was then carried out using a silicon carbide abrasive paper of 60, 220, 400 and 800 grits. In order to ensure a rust-free surface, the coupons were pickled in dilute HCl and rinsed with distill water, degreased with acetone and dried. This is to remove organic matter on the surface of the metal and the make the surface ready and prepared for carrying out the surface morphological tests as well as the potentiodynamic polarization tests. The chemical analysis of ductile iron used in this study is shown in Table 1.

| Element     | Weight % |
|-------------|----------|
| Carbon      | 2.04     |
| Silicon     | 3.36     |
| Manganese   | 0.558    |
| Phosphorus  | 0.0290   |
| Cr2         | 0.0673   |
| Cr          | 0.119    |
| Sulphur     | 0.00529  |
| Fe          | Balance  |
A small cable wire was then connected on the rough surface of the coupons and sealed with aluminum tape, mounting the sample by centralizing it in the mold, then pouring a mixture of epoxy, activator and ADNA, and allowing it to solidify.

2.2. Corrosion test

The potentiodynamic experiments were conducted through a three-electrode cell connected to VersaSTAT 4 system furnished with a VersaStudio software for collection and analysis of results. A silver/silver chloride electrode was used as a reference to measure the potential across the electrochemical interface and a platinum sheet as counter electrode. The scan rate was taken as 1 mV s\(^{-1}\). Before carrying out this measurement, a stabilization period of immersion was decided on and its open circuit potential was recorded as a function of time for some minutes. All measurements were taken at room temperatures using the 2M H\(_2\)SO\(_4\), 2M NaOH, 3.5% NaCL solutions. The solutions for the study were prepared from analytical grade reagents and distilled water. After the experiment, polarization curves will be obtained by shifting the electrode potential automatically from +250mv to -250mv vs. OCP. The corrosion potential \(E_{\text{corr}}\), corrosion current potential \(I_{\text{corr}}\) and corrosion rate were measured afterwards.

2.3. Microstructural Analysis

Optical microscopy was carried out on all the metal samples after the polarization test has been carried out. This is done by the use of a metallurgical microscope to study the surface morphology of the corroded surfaces to compare the extent of corrosion that has taken place on the ductile iron in the selected environments. This was done by mounting the samples on the microscope and adjusting the eyepiece and objective to get an image magnification of 100μm micrograph.

3. Result and discussions

The morphology of the ductile iron is observed by an optical microscope shown in Fig. 1 at 100μm indeed show us evidence of the predominant nodular graphite structures that characterize ductile iron. Visual observation of the specimens exposed for the potentiodynamic tests, showed that the colour of the solutions remained colorless. The microstructural results also support the electrochemical results such that; the corrosion rates were higher in the H\(_2\)SO\(_4\) and 3.5% NaCl solutions. However, the corrosion appears to be uniform and there is no evidence of localized corrosion. The Result is in good agreement with Ogundare et al. (2012) [12].

The electrochemical results are plotted against each other in the Fig 2. From the results it is observed that the sample subjected to the sulphuric acid at room temperature corroded the fastest compared to the other Specimens (0.25669 mmpy). The sample subjected to corrosion in water had the lowest corrosion rate (2.6447e-05 mmpy).
Fig 1: Optical micrographs of DI in selected environments after respective electrochemical test
(a) 2M H₂SO₄ (b) 2M NaOH (c) 3.5% NaCl (d) Control
Material processing is technical knowledge are also factors responsible for processing risk and are due to lack of exposure.

Table 1: processing risks of cocoa in Ondo State using the kruskal-Wallis test.

| Factors responsible for processing risk | Ranking | Mean |
|----------------------------------------|---------|------|
| Material                               | 1       | 0    |
| Chemical                               | 2       | 6    |
| Metallurgy                              | 3       | 2    |
| Productivity                           | 2       | 71.5 |

4. **Conclusion**

From the electrochemical test results obtained, the highest corrosion rate was observed in sample tested in 2M Sulphuric acid and therefore the corrosion of ductile iron would be more rapid in this environment because of the aggressive nature of acid. 3.5% Sodium chloride environment also shows a high corrosion rate which is due to the presence of chloride ions which attacks the surface of metals which leads to pitting corrosion. Corrosion on ductile iron was less aggressive in the 2M Sodium hydroxide and almost minimal in distil water.

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