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Corrosion behaviour of austempered ductile iron produced by forced air quenching method in a simulated mine water

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Abstract

The production of austempered ductile iron (ADI) with uniform microstructure and properties is constrained by the austempering process vis-à-vis the quenching medium. This is as a result of the stringent operating parameters with costly facilities. This limitation has restricted the application of ADI, despite its inherent mechanical and chemical properties. An emerging technology channelled towardsovercoming this limitation is by austempering with forced air cooling equipment, which is accessible, available and cost-efficient. This work characterizes the behaviour of the forced air cool ADI in simulated mine water due to the strategic importance of the mining industry in the global economy. The study establishes the influence of sample section thickness (5, 15, and 20 mm) on corrosion performance. Electrochemical experiments were performed on the forced air cooled ADI at atmospheric pressure and room temperature with methods such as open circuit potential (OCP) and anodic polarisation. The post-corrosion characterizations were performed using field emission scanning electron microscopy (FESEM) equipped with energy dispersive spectroscopy (EDS). The research highlighted that small section thickness has a more favourable performance compared with larger section. Consideration is also accorded to the capability of the ADI in the studied environment.

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Keywords: Austempering process, forced air cool quenching, austempered ductile iron, simulated mine water

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1. Introduction

Production of austempered ductile iron lead to the development of unique microstructure capable of offering excellent toughness and wear resistance and has been shown to have superior fatigue properties as well [1]. The production process consists of two different stages, namely; casting and heat treatment. The latter is the dominant process which will determine the possibility of producing good engineering parts. The heat-treatment facility's capacity, defects free casting, and optimization of heat-treatment parameters are some of the limiting factors [1-2]. However, an emerging technology of overcoming this limitation is by austempering with force air cooling equipment [3], which is accessible, available and cost-efficient. The performance of tempered parts is a function of the section thickness, which significantly affect its industrial applications. There is a paucity of information on the corrosion behaviour of forced air austempered ductile iron in the mining industry and this has prompted the attempt to explore the chemical stability of this material in this environment.

Hence, this study considered the corrosion behaviour of austempered ductile iron produced using forced air as a quenching medium in simulated mine water with a view to assess the impact of the sample thickness. The goal does not capture the effect of austempering parameters such as temperature and time on the performance of the ADI in the studied environment.

2. Experimental procedures

This study involves production of austempered ductile iron (ADI) of various section thicknesses due to the limitation associated with thickness and microstructure during quenching process. The ADI was thereafter investigated for their corrosion resistance in stimulated mine water. Ductile iron used as the starting material was manufactured at Nigerian Foundries Limited, Sango-Ota, Nigeria using medium frequency (3000 Hz) coreless induction furnace with melting capacity of 500 Kg. The charge composition consists of 15% pig iron, 20% ductile iron return and 65% steel scrap while 75wt. % FeSi, 70wt. % FeMn and graphite were added as modifiers. The charge was superheated to 1550 °C to ensure homogenization and it was subsequently tapped at 1450 °C onto 5.5wt. % of Fe-Si-Mg and post inoculation treatment was carried out with 75wt. % Fe-Si. After post inoculation, the melt was cast at 1440 °C into keel Y-blocks inside the green sand mould which ensured a sound casting. Thereafter the samples were austenitized at 820 °C for an hour, forced air cooled in an air quenching chamber to an austempering temperature of 300 °C and rapidly transferred into another muffle furnace maintained at 300 °C in order to austempered them for a fixed period of 2 hrs. Finally the samples were air cooled to room temperature.

Prior to corrosion tests, an electrical wire was fastened to one side of the samples with conductive aluminium tape to ensure electrical connection, and thenthe samples were mounted in epoxy resin. The exposed samples surface were wet-ground with SiC grit sizes ranging from 240 to 1200, polished with 15 μm diamond suspensions, degreased with acetone, washed in a stream of water and dried in air. Simulated mine water with chemical composition; $NaSO_4$ (1237 mg/L), $CaCl_2$ (1038 mg/L), $MgSO_4$ (199 mg/L) and NaCl (1380 mg/L) and the measured pH was 6.0.

The corrosion tests were open circuit potential and anodic polarization measurements. The sample was the working electrode, graphite as the auxillary electrode, (AE) and a 3 MKCl saturated Silver/Silver Chloride electrode (Ag/AgCl) acted as reference electrode (RE) to complete the three electrode cell. The surfaces of the specimen were polarized from –1 V below OCP to + 1.2 V above OCP at a scan rate of 0.25 mV/s and the test was carried out using an AUTOLAB PGSTAT 302N at room temperature (22°C).

3. Results and discussion

The possibility of the degradation process taking place is examined using open circuit potential, the corrosion rate was examined by tafel plot, while the capability of the fabricated austempered ductile iron is assessed using the hardness values and lastly, the microstructural behaviour were reported. Figure 1 presents the open circuit potential for the samples after two hours and the OCP for 5, 15, and 20 mm are –0.684, –0.624, and –0.634 V respectively. Generally, the OCP first decreased cathodically and then stabilised after about 2500/3500 seconds. There is an average of 40 mV difference between the initial OCP and the OCP after 2 hours for 15 mm diameter, 20 mV