EROSION - CORROSION BEHAVIOUR OF ANTIMONY MODIFIED CARBIDIC AUSTEMPERED DUCTILE IRON USING A DESIGNED SLURRY POT

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Abstract

This study involves erosion corrosion behaviour of CADI using slurry pot containing mixture of silica sand and 3.5 wt. % NaCl solutions. The slurry pot was controlled by a horse power electric motor which caused the rotation of the stirrer, leading to agitation of the mixture. 110 V resulting in rotational speed of 1100 rpm was applied for the erosion-corrosion test. Hardness values obtained from the un-heat treated samples ranged from 30 to 43.8 HRc. While that of heat treated samples ranged from 28.5 to 55.2 HRc. Erosion corrosion rates of $6.8E^{-4}$ to $8.3E^{-4}$ g/cm²/hr were obtained for the un-heat treated samples while the corrosion rates of the heat treated samples ranging $6.2E^{-2}$ to $3.8E^{-4}$ g/cm²/hr were recorded. It was observed that as hardness increased, there was reduction in weight loss index. For the un-heat treated samples, sample with 0.5 wt. % Sb had the least erosion corrosion rate of $8.3E^{-4}$ g/cm²/hr, among the heat treated samples; sample with 0.3 wt. % of Sb had the least erosion corrosion rate of $7E^{-4}$ g/cm²/hr. It was concluded that Sb addition improves erosion-corrosion resistance of CADI and also, the heat treatment improved the resistance of carbidic ductile iron to erosion-corrosion.

Keyword: Antimony, CADI, NaCl solution, Erosion-corrosion.

1. INTRODUCTION

Erosion corrosion is a complex material degradation mechanism, arising from both chemical and mechanical interactions [1, 2]. Mining, Agriculture, hydropower and oilfield environments are among the areas where this materials degradation mechanism is prevalent [3, 4].

Slurry erosion pot is one of the numerous methods that can be used to study erosion corrosion. The slurry pot has an advantage of a simple arrangement for potentiometric control of the specimens as well as ability to attain higher rotational speed. This experimental rig is also recommended for the understanding of the mechanism of erosion- corrosion interaction for dilute slurry [5, 6]. The presence of retained austenite in such matrix also makes such alloy strain hardenable due to the metastable phase of austenite (martensite)[7-10]. Many attempts have been made in the past to relate the volume fraction of martensite in such alloy to its tribological behavior [11-13].

However, little information is available to correlate the microstructure properties of CADI with the slurry erosion properties [14], though some claimed it's insignificant. High hardness has been reported to result in low erosion rate for ductile metals [15]. This research is an attempt to expand the data base on the erosion – corrosion characteristics of CADI.

2. MATERIALS AND METHODS

Equipment used was slurry pot which outer shell pot is made of mild steel while the inner part is made of high density polyethylene; for the purpose of reducing corrosion of the inner wall. Inner diameter of the pot has a depth of 35 cm and diameter of 29 and total capacity was evaluated to be 23 litres in volume. The sample holder was made of Perspex with a centre hole of diameter 2 cm to fit the shaft. Material used were heat treated and unheat treated samples of Sb-CADI with varied antimony (Sb) content of 0 wt. %, 0.096 wt. %, 0.192 wt. %, 0.288 wt. %, 0.384 wt. % and 0.48 wt. %.

2.2 Experimentation of Erosion – corrosion

Erosion – corrosion test was carried out using the designed slurry pot. The test solution used in this study contains 3.5 wt. % NaCl and 500 mg/L silica sand with particle distribution in accordance with Aribo *et al.* [16]. Prior to immersion, the test samples were grounded to a surface finish of 1200 grit using silicon carbide paper, polished with 15um diamond paste, degreased, washed in distilled water and dried in air. The slurry pot was operated at an average speed of 1100. Each experiment was performed for 1 hour and the weights before and after the experiment were measured and recorded. Six samples were tested and their results obtained were recorded. The erosion- corrosion rate was calculated using equation 1;

$$\text{Erosion – corrosion rate} = \frac{\text{Weight loss}}{\text{Surface area (cm}^2\text{)} \times \text{time (hr)}} \quad (1)$$

2.3 Hardness Test

The hardness test for the produced samples was conducted using Digital Rockwell hardness tester on scale C, in accordance with ASTM E18-08 [17] (standard test method for Rockwell hardness of metallic materials). The hardness value was then displayed on the machine. Four point's hardness values were measured and average of the four measurements was taken.

3. Result and Discussion

Fig 1: Variation of the hardness value of the (a) heat treated and (b) unheat treated CADI

Fig 2: variation of the hardness value of the (a) heat treated and (b) unheat treated CADI

Fig. 3: Optical micro-image of samples exposed to erosion-corrosion showing (a) (b) ploughing, (c) low ploughing and (d) scratching.

Erosion – corrosion Properties

Figs. 1 and 2 also showed that increase in hardness of the CADI resulted in higher resistance to erosion – corrosion. It will be recalled that higher hardness was recorded. The results of the erosion- corrosion tests performed on Sb - CADI samples are as shown in Figs. 4a and 4b. Good repeatability is seen in all the experiments conducted as shown by the deviations from the mean values illustrated by the error bars in Fig. 4.

Fig 4: Variation of the hardness value of the heat treated and unheated treated CADI

Relationship between the Microstructure and Erosion – corrosion Resistance

There is a direct relationship between carbide size and the erosion corrosion resistance of both unheated treated and heat treated CADI. As the carbide size reduces from coarse to granular, as a result of Sb modification of the CADI, erosion corrosion resistance increases. In the heat treated samples, ausferrite formed led to further improvement in the erosion corrosion resistance. Hence, Sb addition improves erosion-corrosion resistance of CADI and also, the heat treatment improved the resistance of carbidic ductile iron to erosion-corrosion.

This is in line with previous studies which reported the effects of phase's volume fractions in assessing the mechanical properties of ferrous metals [18]. The results obtained in this study tend to be more supportive of the work of Tekeli and Gural [19].

Degradation Mechanism

Degradation mechanism shows both scratching and ploughing (Fig. 3a, b, c and d). Scratches and ploughing from the sand is expected at that rotational speed and high volume fraction of sand particles. This is a classical mode of degradation in a slurry erosion. There is effect of the corrosive medium on the heat treated CADI. With general and localized corrosion seen on the steel surface. It can therefore be deduced that there is a form of synergy between erosion and corrosion although the extent has not been quantified in this study.

Conclusion

Results on heat treated and un-heat treated CADI samples show different hardness values. It was observed from the results that higher hardness value resulted in higher erosion corrosion resistance while higher slurry speed resulted in higher material loss due to erosion corrosion.

Degradation of the alloy combines both erosion and corrosion with ploughing and pitting dominating the degradation mechanism.

Model Summary

Regression Equation

Erosion corrosion ($\text{g}/\text{cm}^2 \text{ hr.}$) = $0.0554 - 0.1341$ (wt. % antimony content)
 $S = 2.3416$, $R^2 = 0.88$

Regression Equation

Hardness (HRc) = $27.82 + 30.66$ (Erosion corrosion rate ($\text{g}/\text{cm}^2 \text{ hr.}$))
 $S = 0.0139$, $R^2 = 0.80$

Regression Equation

Erosion corrosion rate ($\text{g}/\text{cm}^2 \text{ hr.}$) = $0.0554 - 0.1341$ Hardness (HRc)

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