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RELIABILITY AND PERFORMANCE EVALUATION OF STAINLESS AND MILD STEEL PRODUCTS IN METHANOLIC AND AQUEOUS MEDIA

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ABSTRACT

Reliability and performance of stainless and mild steel products in methanolic and aqueous sodium chloride media have been investigated. Weight-loss and pre-exposure methods were used. There was a higher rate of weight-loss of mild steels and stainless steels in 1% HCl methanolic solution than in aqueous NaCl solution. Solutions containing traces of sodium nitrite were found to enhance the reliability and performance of these steels. Mercuric and stannous chlorides were observed to reduce performance and reliability. Reliability and performance of these specimens decreased with continued exposure.

KEYWORDS: Reliability, performance, stainless steels, mild steels.

INTRODUCTION

Reliability can be defined as the ability of an item to perform a required function under stated conditions for a period of time. Mechanical and other engineering components and systems are designed and manufactured to possess excellent reliability and performance characteristics in their operational environments. Steel products in the form of stainless steels and mild steels are being used extensively in the production or manufacture of components and systems. The interaction of these products with various environmental conditions gradually or suddenly undermine the reliability of these components thereby leading to structural weakening and eventual failure. The major player to this reliability and performance weakening is corrosion. Other players include vibration, temperature and mechanical constrains.

Corrosion occurs in many areas of human activities. It occurs in all metal components depending on the environmental working conditions imposed on them. Thus when steel is exposed to an industrial environment, it reacts with the environment to form a product referred to as rust. Copper on the other hand forms an adherent green patina, which protects and isolates the metal from the atmosphere. Also chromium oxide is formed as a protective surface film on stainless steels.

Ovri (1998) studied the corrosion of steel reinforcements in concrete in sulphate, chloride nitrate and fresh water environments. He carried out the corrosion measurement at an interval of seven days using the potential and resistance methods for a period of six weeks. A low carbon steel was used as the reinforcement in the concrete. He embodied the steel in the concrete blocks and these blocks were immersed in the various environments. The results showed that the various environments have a devastating corrosion inducing effect, with the dilute sulphunic acid having the highest corrosion inducing effect, followed by the dilute HCl, the fresh water and finally the dilute HNO_3 environment.

Jombo and Okeke (1998) in their performance evaluation of cathodic protection for trans – Niger pipelines discovered that the older pipes attracted negative deviations from the potential criterion, while the newer ones showed attractive characteristics. They also discovered that the poor cathodic protection of a pipeline affects the (cathoditic protection) performance of other pipelines, if they are in the same environment. Umezurike (1998) studied the corrosion of oil field equipment and the integrated facilities with particular reference to offshore platforms, storage tanks, pumps, valves and compressors. He found out that the most severe damages occur in the splash zone of the platforms due to washing action of well-aerated warm salt water which keeps the metals wet. In the study of the effect of temperature on propagation of crevice corrosion of high alloyed stainless steels in Natural seawater, Steinsmo (1996) found that crevice corrosion of UNS S32750 and UNS S311254 (both rolled, welded and cast stainless steels) can propagate at low temperatures (15°C and 25°C) once initiated.

Shone and Idrus (1996) in their study on "The performance of selected stainless steels to tropical and temperate sea water", found out that the stainless steels were more prone to crevice corrosion in the tropical sea water and the rate of corrosion was significantly greater. This work according to them, shows that while selected

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stainless steels can be used with confidence in temperate sea water considerable caution must be exercised when considering these alloys for use in the tropics. In the present work, reliability and performance evaluation of stainless and mild steel products in methanolic and aqueous media has been carried out.

MATERIALS AND METHOD

Materials

The mild steels used for this work were obtained from the Oshogbo Steel rolling company, Oshogbo, Nigeria in the form of rolled rods of about 14mm diameter. Table 1 shows the composition of the mild steel.

On the other hand, type 316 austenitic stainless steel material was obtained in the form of shaft of diameter 30mm from a commercial steel stockist in Lagos, Nigeria. Its composition is shown in Table 2.

Table 1: Composition of mild steels

Element	% Composition
Carbon	0.006 – 0.12
Silicon	0.14 – 0.28
Manganese	0.40 – 0.60
Phosphonous	0.040 max
Sulphur	0.040 max
Copper	0.20 – 0.25

Table 2: Composition of the stainless steel

Element	% Composition
Carbon	≤ 0.08
Silicon	≤ 0.07
Molybdemum	1.00 – 2.5
Nickel	9.00 – 11.00
Chromium	18.00 – 21.00
Manganese	2.0 max
Phosphorus	0.04 max
Silicon	0.03 max
Copper	-

The major environments used for the work were methanol – HCl acid solutions and aqueous sodium chloride solution at room temperature. All tensile specimens were of gauge length 30mm and diameter 6mm and were all subjected to the same strain rate of 0.5cm/mm.

Experimental Methods

The mild steel and stainless steel specimens were prepared by turning to remove the mill scale and other dirt on the surface to expose the fresh steel to environment. They were given uniform surface finish by sanding with smooth emery paper. Each of them was cut to about 30mm of length and expose to the media, well covered for a variable length of time after being weighed. At the end of each exposure, three specimens were removed, cleaned and

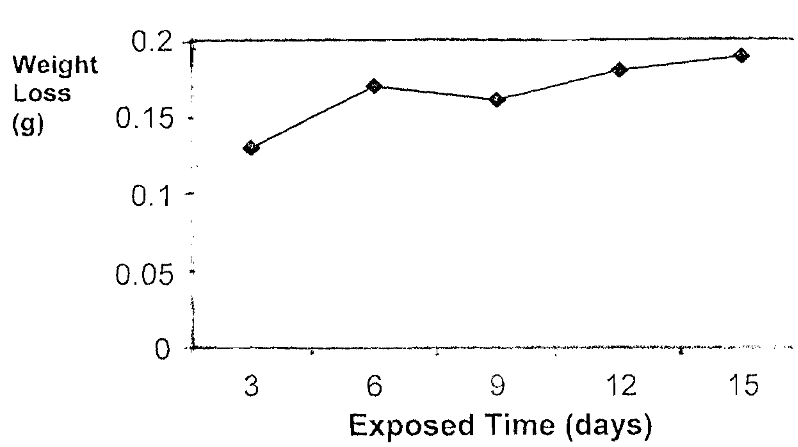

Figure 1: Mild Steel Exposed in Methanol-HCl

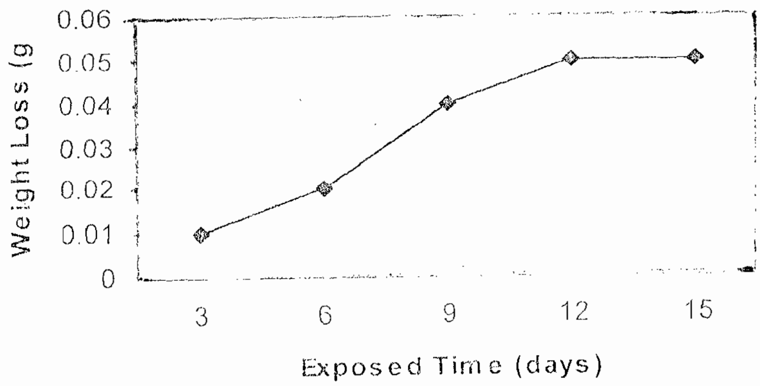

Figure 2: Mild steel in aqueous NaCl solution

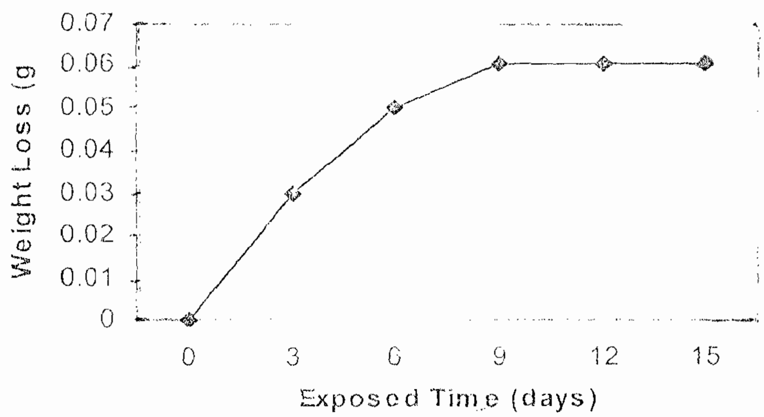

Figure 3: Stainless steel in Methanol – HCl Solution

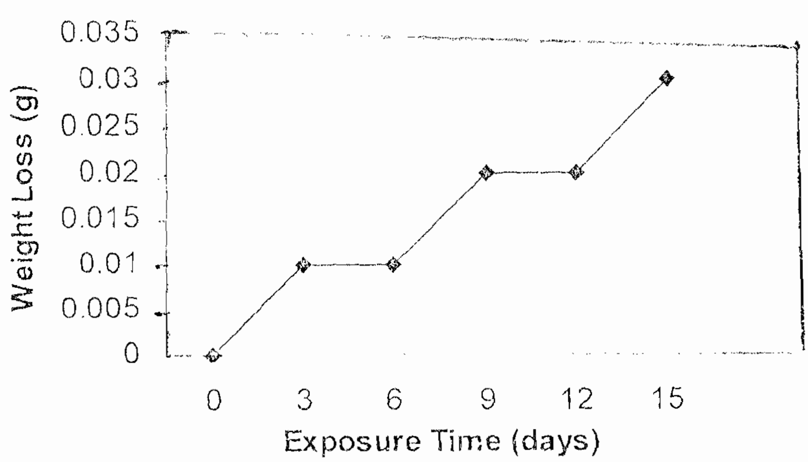

Figure 4: Stainless steel in aqueous NaCl solution

reweighed, to find the average weight-loss as a function of the exposure time.

In some experiments the tensile specimens were exposed for six days in separate solutions of methanol – HCl and aqueous solutions of sodium chloride containing extraneous additives (Sn^{2+} Hg^{2+} NO_2^- ions). At the end of the six days each of the specimens was removed and tensile tested with the tensometer to failure in air immediately to examine the effect of such additives on the strength of the test materials revealed by the time to fracture.

Tensile test specimens of the stainless steel and mild steels were exposed in the media (methanol – HCl and aqueous NaCl), covered to avoid contamination and evaporation. At different days some were removed from the solution, dried and immediately subjected to tensile testing in air.

The time to fracture was recorded.

The specimens not exposed to working media were also tensile tested as a reference in order to study the effect of the environment (media) on the performance and reliability of the material.

RESULTS AND DISCUSSION

Weight-loss measurements were carried out on the specimens exposed in both methanol – HCl and aqueous sodium chloride solution.

Massive evolution of gases was observed when the specimens were immediately exposed in methanol – HCl solution, but more in the aqueous sodium chloride. This evolution was suspected to be hydrogen and to be in accordance with the equation

$$Fe + 2H^{+} = Fe^{2+} + H_2 (g)$$

The results of the weight-loss measurements are shown in Figures 1 to 4. From the figures, it is evident that the weight-loss of the materials in the environments increased with exposure time showing that more corrosion damage occurs as exposure time increased. However, this corrosion damage is more aggressive in methanol – HCl solution than in aqueous sodium chloride solution.

Figures 5 and 6 show the effect of the extraneous additions to methanol – HCl and aqueous NaCL solution on the weight loss of mild steel after exposing the specimen for 4 days. From the figures, it is clear that sodium nitrite ($NaNO_2$) greatly reduced the weight-loss of the material in both solutions. On the other hand, the stannous chloride ($SnCl_2$) greatly enhanced the corrosion reaction.

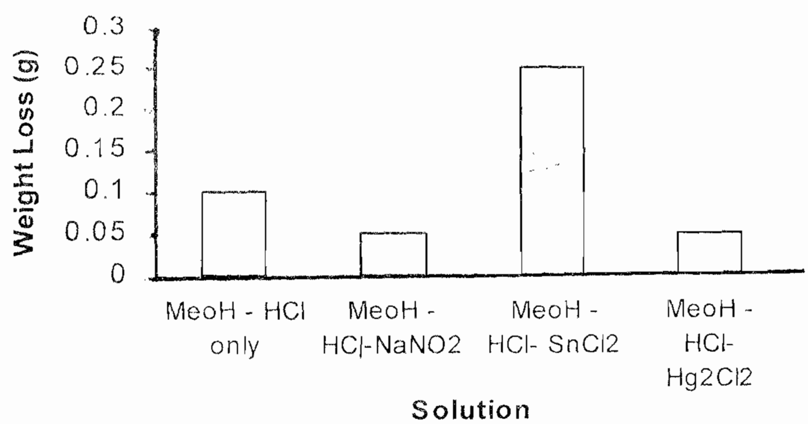

Figure 5: The effect of some extraneous additions to methanol – HCl solution on the weight loss of mild after exposure for 4 days.

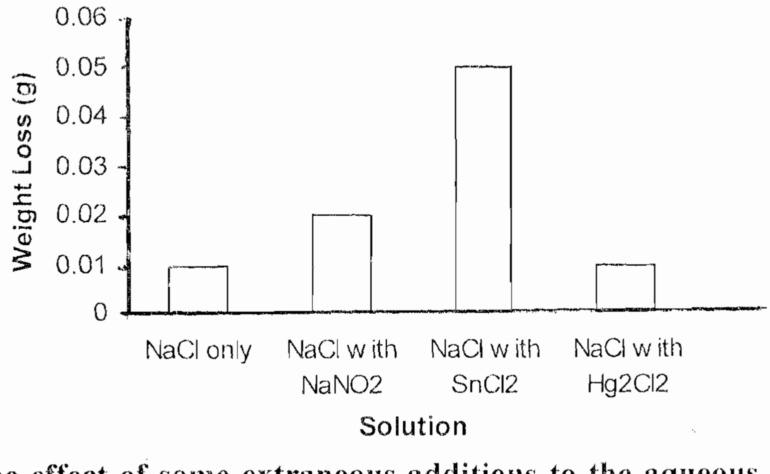

Figure 6: The effect of some extraneous additions to the aqueous NaCl on the weight loss of mild steel after 4 days.

Figures 7 – 10 show the graphs of time – to fracture against exposure time for each of them. From the graphs, it is noted that as exposure time to the media is prolonged, the time to fracture decreases. The longer the material stayed in the media, the more the corrosion reaction, and consequently weakening the materials leading to low performance and reliability. Thus, the reliability of the materials is seriously reduced with prolonged exposure to the media. The slope of the graphs involving aqueous NaCl is less than that of MeOH-HCl showing that the latter is more aggressive (damaging) in nature than the former.

2% by weight addition of stannous chloride ($SnCl_2$) in the MeOH-HCl was found to reduce the time to fracture of the stainless steel specimen

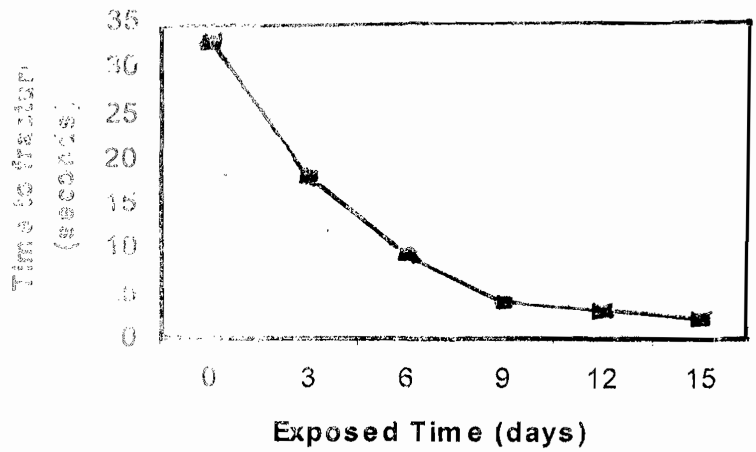

Figure 7: Stainless steel exposed in MeOH - HCl

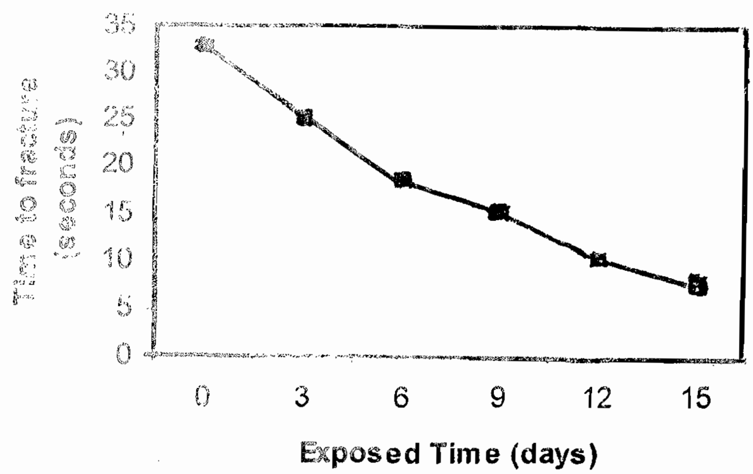

Figure 8: Stainless steel exposed in aqueous NaCl

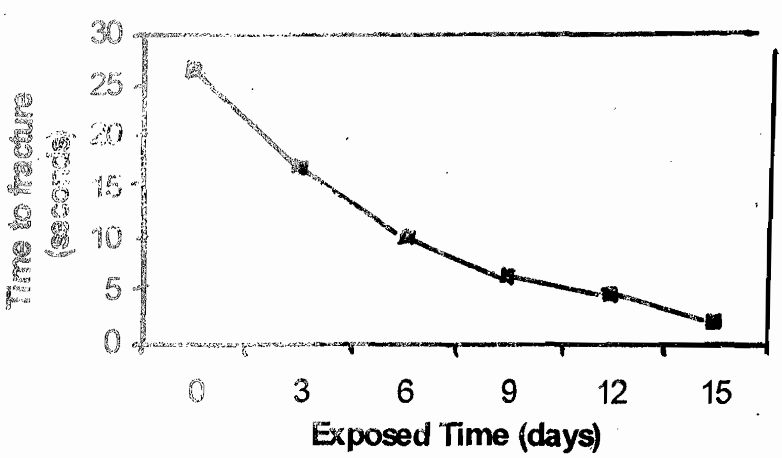

Figure 9: Mild steel exposed in methanolic – HCl solution

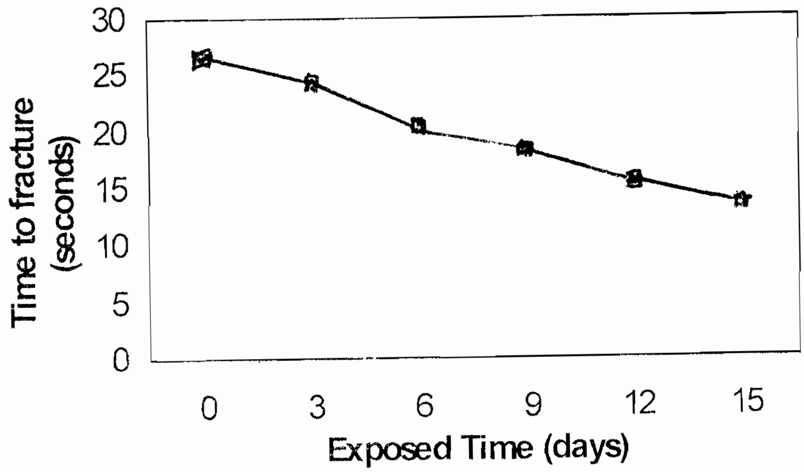

Figure 10: Mile steel exposed in aqueous NaCl solution

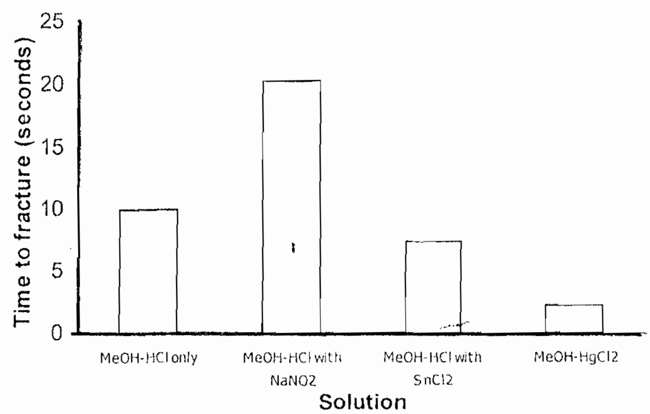

Figure 11: The effect of extraneous additions to methanol-HCl solution on the time to fracture of stainless steel exposed for six days at room temperature

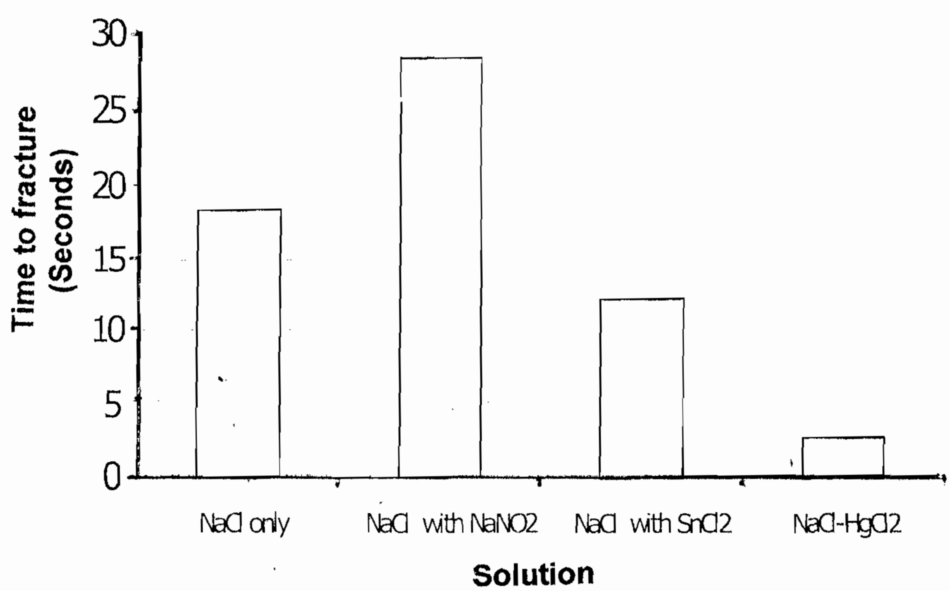

Figure 12: The effect of extraneous additions to NaCl on the time to fracture stainless steel exposed for six days at room temperature.

compared with MeOH-HCl solution alone. NaCl solution produced the same results. This is due to the fact that Sn^{2+} has a high hydrogen over potential. When plated out on the specimen, it permits the absorption of hydrogen into the material. It may also be thought as increasing the hydrogen absorption/hydrogen released ratio.

2% by weight of Hg^{2+} in the form of Hg_2Cl_2 was added to MeOH-HCl and aqueous NaCl solutions, where tensile specimens were exposed. It was found that Hg^{2+} greatly reduced the time to failure and therefore reducing the reliability and performance of the specimens below that obtained in the stress corrosion solutions without additive. The effect was more than that obtained with stannous chloride additions. This could be because mercury salts are readily reduced by local electrochemical actions resulting in the deposition of elemental mercury. The deposition permits hydrogen absorption into the material leading to hydrogen embrittlement and therefore cracking.

Addition of 2% by weight of $NaNO_2$ to MeOH-HCl and aqueous NaCl resulted in a very high increase in time to fracture of the specimens when compared with the ordinary environment. This inhibiting effect could be attributed to the passivating nature of the ion which makes use of its oxygen in firm formation and protection.

CONCLUSION

The weight-loss measurement with exposure to the environments reveals an initial high rate of weight-loss which decreases with passage of time. This suggests that as more corrosion products are formed on the surface of the materials (between the materials and environment) corrosion reaction rate is reduced. Additions of sodium nitrate to the media was found to reduce the weight-loss by corrosion on both materials, whereas mercuric and stannous chloride were found to increase the weight-loss of both materials in the media. It suggests that additions of mercuric chloride and stannous chloride led to rapid absorption of hydrogen whereas sodium nitrate led to a lower hydrogen absorption and passivation using the OH^- ion available Sodium nitrite has been found to be a very good corrosion inhibitor for both stainless and mild steel in the media. Therefore, it can be used to enhance performance and reliability of both products in the media.

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