VOL. 7, NO. 5, MAY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

STUDY OF CORROSION AND SYNERGISTIC ACTIONS OF INHIBITORS ON THE FATIGUE PROPERTIES OF MILD STEEL RODS

Adebayo A.[1] and Aremu B.[2]
[1]Cranfield University, Cranfield, Bedford-MK43 0AL, England, United Kingdom
[2]The Polytechnic, Ibadan, Nigeria
E-Mail: a.adebayo@cranfield.ac.uk

ABSTRACT

This paper is an outcome of the investigation of the effects of corrosion and synergistic actions of inhibitors on the fatigue properties of mild steel rods. The corrodents are saltwater and sulphuric acid while the inhibitors used are potassium chromate and 0.5M zinc oxide. The saltwater is sodium chloride solution containing approximately 3.5% weight of solute, prepared from 97.5% table salt; this approximates to the average salt concentration in quiet seawater. Mild steel water corroded in 0.5M H_2SO_4 was found to have shorter fatigue life (measured by number of cycles-to-failure) from those corroded in saltwater. Moreover, the fatigue life of specimens soaked in the corrodent in which both ZnO and $K_2Cr_2O_7$ (of equal proportion) were added was observed to have a longer fatigue life than the sample soaked in the corrodent with only $K_2Cr_2O_7$. However specimens with the corrodent of only ZnO displayed the least fatigue life. These findings therefore, shows that sulphuric acid has more corrosive action on mild steel than salt water and the corrosion inhibitor ability of $K_2Cr_2O_7$ (for mild steel) is more than that of ZnO while the mixture of $K_2Cr_2O_7$ and ZnO produce best corrosive inhibitor compared to those of the individual inhibitors.

Keywords: mild steel rods, corrosion, inhibitors, fatigue property.

1. INTRODUCTION

The phenomenon of stress corrosion cracking of metallic or alloy material occurs under the combined actions of stress and corrosive environment. The stress can either be applied mechanically or can occur as a residue within the material that has undergone cold working or shaping process such as forging, rolling, extrusion etc. or can result from hardening process e.g. quenching of steel. Several data are available in the steel corrosion cracking behavior of steel in several aqueous systems Oni (1997).

Synergistic effect is defined as a combined effect that is greater than the sum of individual effect. Hosary and Saleh (1985), showed that the inhibitive action of coal tar fraction/halide mixtures are better than that of the halide or tarn base products used alone in sulphuric acid.

Combined effect of two or more inhibitors in a corrosive environment reduce rate of corrosion considerably as shown by Oni (1997). Although the individual constituent of the additive mixture achieved little inhibition, the sum of the effects achieved by each of the constituents is by far, less than the overall effects produced by the mixture of the constituents. Thus effective inhibition was due to synergistic property of the additive mixture. The mechanism of action of mixture synergism involves the massive reduction of Fe^{2+} activity in the solution (Baroux, 1995). Although inhibitors can be used to great advantages to suppress corrosion of metals in many environments, there are certain limitations of this type of corrosion prevention which must be recognized. First, it may not be possible to add inhibitors to all corrosive system because they may contaminate the environment. Further, many inhibitors are toxic and their application is limited to those medium which will not come in contact with humans.

Oni (1991) distinguished fatigue corrosion from stress corrosion, corrosion fatigue cracking which is caused by alternating or cyclic stress in a corrosive medium.

Many research works had been carried out on corrosion fatigue of metals especially mild steel. Among such is the work done by Odebisi (1991). He studied the corrosion fatigue behavior of ST60Mn steel in cassava juice; he observed that the forms of heat treatment will enhance the fatigue strength of ST60 Mn steel in a corrosive environment. Also Adepoju and Odeshi (1996) studied the effect of cyanide on fatigue strength of ST 60Mn steel and showed that normalized ST60Mn steels has enhanced corrosion fatigue strength in a cyanide environment. Oni (1997) worked on the effect of heat treatment on the damage rate of corroded ST60Mn; it was observed that fatigue strength of annealed ST 60Mn steel prior to usage is higher than water quenched specimen but lower than as received sample. In another work by Kamma and Anagbo (1989), the micro structural and surface finish effect on corrosion rate of mild steel, he found that the tempered martensite structure has the highest practical mechanical properties.

According to Oni (1997), the use of inhibitors for the prevention of corrosion is however limited as compared to the other forms of corrosion attack. The reason for this is lack of complete clarity on the mechanism of interaction between the metal under the stress and corrosive medium and more particularly for the process taking place at the crack top in the presence of the additives in the solution, rendering the forecasts for the efficient inhibitors rather difficult.

In this work, corrosion fatigue was not investigated but the effects of corrosion and synergistic action of inhibitors on the fatigue properties of mild steel rods. The corrosive media used are salt water and 0.5M sulphuric acid, while the inhibitors are 0.5M potassium chromate and 0.5M zinc oxide.

2. EXPERIMENTATION

2.1 Methodology

The material used is mild steel rod of the same batch, cut and faced to a length of 55mm. With the aid of a table lathe machine, the specimen was machined to ASM Standard of fatigue test specimen for AVERY 7305 fatigue testing shown fatigue specimen (Figure-1).

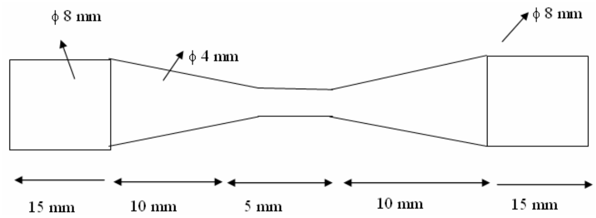

Figure-1. Fatigue test sample.

Some of the samples were retained as non-corroded by placing them in a case after wrapping them with cotton wool to prevent them from moisture. The corrosive media (corrodents) are $0.5MH_2SO_4$ and saltwater while the inhibitors used were 0.5ZnO and $0.5mK_2C_2O_7$. The mild steel specimens were corroded for thirty days. The samples used were categories and immersed in various corrosive media as highlighted below:

i Non corroded
ii 0.5 MH_2S0_4 with no inhibitors
iii $0.5MH_2S0_4$ + 0.5MZnO
iv $0.5MH_2S0_4 + 0.5MK_2Cr_20_7$
v $0.5MH_2S0_4$ + 0.5MZnO + 0.5 $MK_2Cr_20_7$
vi Saltwater with no inhibitor
vii Saltwater + 0.5MZnO
viii Saltwater + 0.5 $MK_2Cr_20_7$
ix Saltwater + 0.5ZnO $K_2Cr_2O_7$

Experimental fatigue test was carried out on the specimen after 21 days using the AVERY 7305 fatigue testing machine. The machine is designed to apply reverse loading, with or without initial static load. Grips were provided on the specimens. The result was then analyzed for each of the specimen.

2.2 Results

The variations of fatigue stresses, S (MPa) with the logarithms scale of the no of cycle-to-failure (LogN) for the (H_2S0_4) corroded mild steel specimen, are shown in Table-1 and Figure-2. However, Table-2 and Figure-3 shows, respectively the variation of fatigue stress with the logarithmic scale of the number of cycle-to-failure for saltwater-corroded specimen.

Also, Figure-4 shows the fatigue stress against the logarithm scale of the number of cycle-to-failure for both H_2S0_4 and saltwater specimen with no inhibitors. While Figures 5, 6 and 7 show the graphical representation of fatigue stress with the logarithmic scale of the number of cycle-to-failure for both H_2S0_4 and saltwater specimen with zinc oxide inhibitor and potassium chromate inhibitors separately, and the addition of both zinc oxide and potassium chromate, respectively.

3. CONCLUSIONS

Mild steel suffer greater corrosion in H_2S0_4 than in saltwater under any condition. The fatigue strength of the non-corroded specimen is higher than that of corroded specimen of the same batch of mild steel. It can be concluded that potassium chromate is better inhibitor with greater inhibitive power than zinc oxide. Therefore, the synergistic effects of the inhibitors surpasses the individual inhibitive power of each inhibitors used. The increase in fatigue stress reduces the no of cycles-to-failure.

Table-1. Variation of fatigue stress, S with logarithmic scale of the number of cycles to failure (Log N) for sulphuric acid corroded mild steel specimens.

Fatigue stress (MPa)	**Non corroded**		**H_2S0_4 corroded specimens**							
			No Inhibitor		**ZnO Inhibitor**		**$K_2Cr_20_7$ Inhibitor**		**ZnO + $K_2Cr_2O_7$**	
	No. of cycles (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**
50	-	-	6.2×10^2	2.7924	1.2×10^3	3.0792	4.6×10^3	3.6628	1.4×10^4	4.1461
100	-	-	1×10^2	2.000	2.5×10^2	2.3979	8.0×10^2	2.9031	4.8×10^3	3.6812
150	6.5×10^5	5.8129	38	1.5798	79	1.8976	158	2.1988	562	2.7497
200	4.0×10^5	5.6021	20	1.3010	37	1.5682	71	1.8512	316	2.4990
250	9.7×10^5	4.9868	16	1.2041	32	1.5051	63	1.7993	166	2.2201
300	4.0×10^5	4.0021	13	1.1139	22	1.3424	54	1.7323	126	2.1004

Table-2. Variation of fatigue stress, S with logarithmic scale of the number of cycles to failure (Log N) for salt water corroded specimen.

Fatigue stress (MPa)	Non corroded		Salt water corroded specimens							
			No Inhibitor		ZnO Inhibitor		$K_2Cr_2O_7$ Inhibitor		$ZnO + K_2Cr_2O_7$	
	No. of cycles (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**	**No. of cycles** (N)	**Log N**
100	-	-	1.25×10^6	6.0969	1.86×10^6	6.2695	2.8×10^6	6.4471	4.46×10^6	6.6493
150	6.5×10^5	5.8129	3.7×10^5	5.5682	4.0×10^5	5.6021	4.5×10^5	5.6532	5.2×10^5	5.7160
200	4.0×10^5	5.6021	1.1×10^5	5.0414	2.4×10^5	5.3802	2.9×10^5	5.4624	3.5×10^5	5.5441
250	1.7×10^4	4.9868	6.2×10^4	4.7924	7.12×10^4	4.8524	8.1×10^4	4.9085	9.0×10^4	4.954
300	4.0×10^4	4.8021	1.4×10^4	4.1461	2.1×10^4	4.3222	2.4×10^4	4.3802	3.1×10^4	4.4914

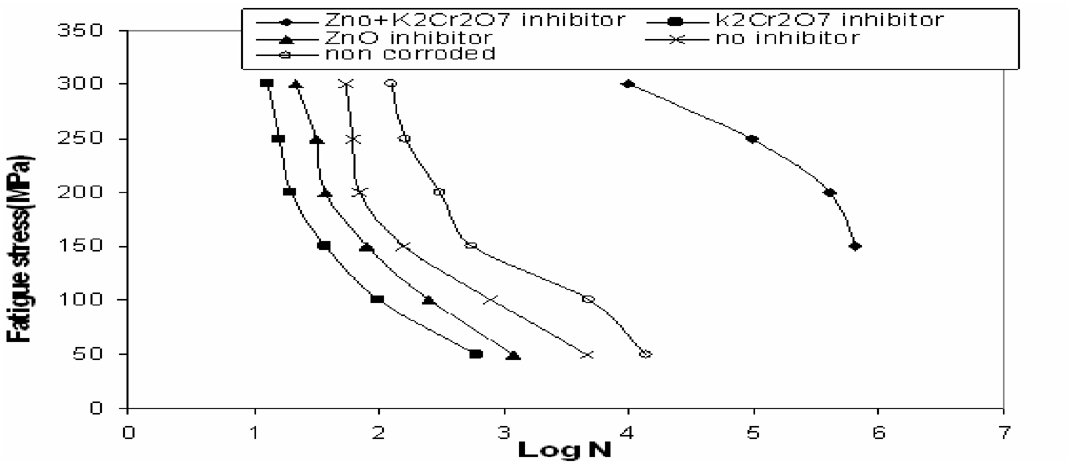

Figure-2. Fatigue stress against log N sulphuric acid corroded.

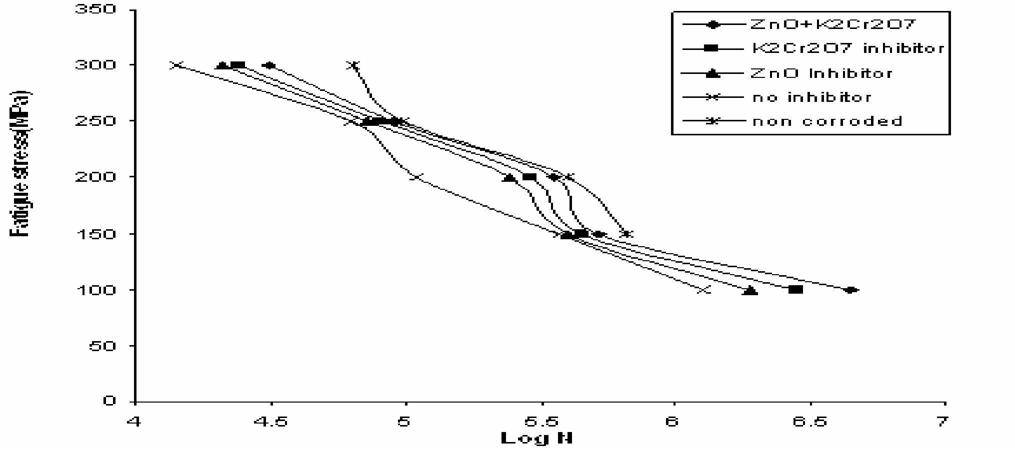

Figure-3. Fatigue stress against log N salt water corroded.

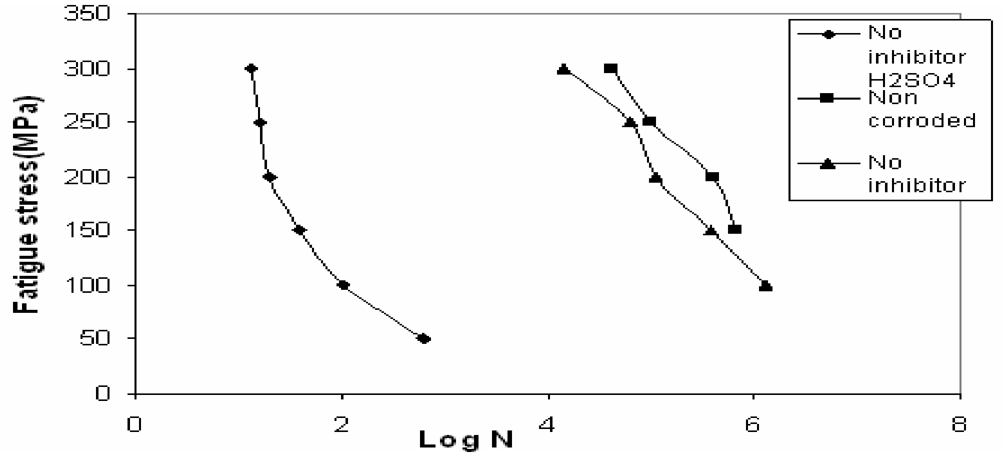

Figure-4. Fatigue stress against log N for acidic and salt water corroded with no inhibitor.

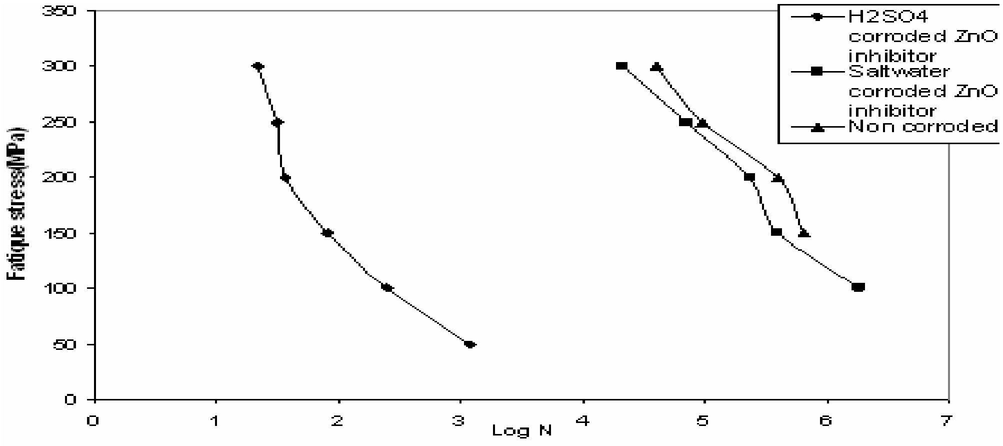

Figure-5. Fatigue stress against log N for acidic and salt water corroded with ZnO inhibitor.

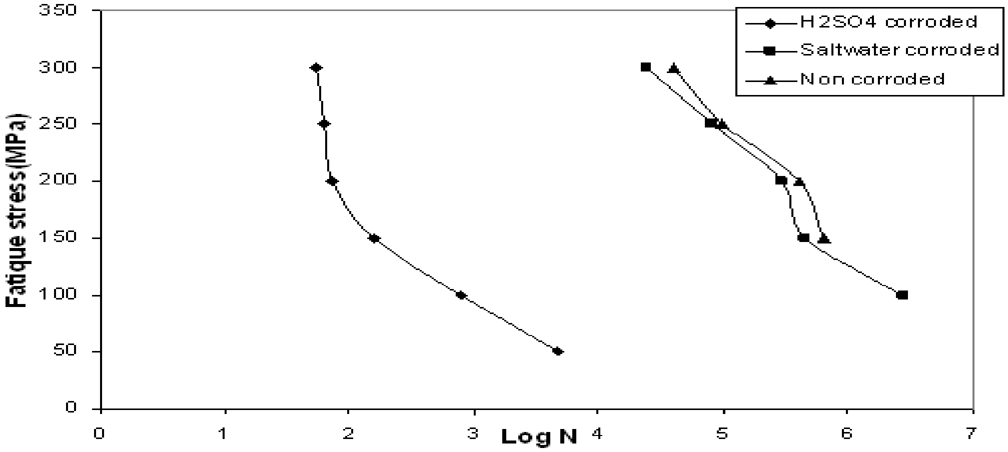

Figure-6. Fatigue stress against log N for acidic and salt water corroded with $K_2Cr_2O_7$

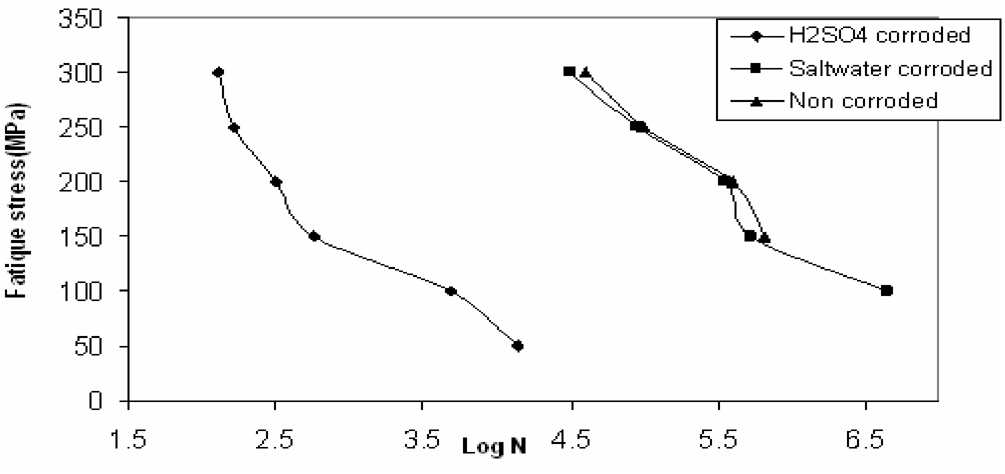

Figure-7. Fatigue stress against Log N for acid water corroded with both ZnO and $K_2Cr_2O_7$

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