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EFFECT OF TEMPERATURE ON CORROSION OF CARBON STEEL BOILER TUBES IN DILUTE SODUIM CHLORIDE SOLUTION

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Abstract

The corrosion behavior of carbon steel at different Temperatures and in water containing different sodium chloride concentrations under 3 bar pressure has been investigated using weight loss method . The carbon steel specimens were immersed in water containing (100,400,700,1000PPM) of NaCl solution and under temperature was increased from (90-120ºC) under pressures of 3 bar. The results of this investigation indicated that corrosion rate increased with NaCl concentrations and Temperature.

***Keywords*:** Oil Corrosion, boiler tubes NaCl solution

Introduction

The corrosion of carbon steel occurs in neutral, slightly alkaline, high temperature water in boilers. The boiler steel itself will not normally be contact with the boiler water, because it quickly becomes covered with a layer of magnetite [1]. The formation of this magnetite layer is believed to take place in two stages. In the first stage, the steel reacts with the water, liberating hydrogen and forming ferrous hydroxide in absence of O_2 according to the equation:

$$Fe + 2H_2O \longrightarrow Fe(OH)_2 + H_2 \quad (1)$$

This reaction is known to take place at 100ºC between steel and the water containing little or no dissolved oxygen. At temperature below about 570 ºC the ferrous hydroxide converted into magnetite [2].

$$3Fe(OH)_2 \Leftrightarrow Fe_3O_4 + 2H_2O + H_2 \quad (2)$$

The over all reaction in boiler may be written as:

$$3Fe + 4H_2O \Leftrightarrow Fe_3O_4 + 4H_2 \quad (3)$$

In water containing CO2 a reaction take place between CO2, calcium carbonate and water to form calcium bicarbonate which has solubility of a proximately 300-400 ppm at 25 ºC [3].

Pitting corrosion of iron in alkaline solution occurred at definite potentials depend upon Cl- content of the medium. Similar to the behavior in acid solution ,gelatin in small concentration was effective in preventing pit formation .Large concentration of additive promoted localized attack ,though to a lesser extent than in its absence [4] .There are many factors effect pitting such as: Impurities ,stress, dissolved oxygen, copper impurities in water ,deposits [5].

EXPERIMENTAL PROCEDURE

A schematic diagram of the autoclave used in this investigation is shown in Fig.(1).The cylindrical shape autoclave, had a wall thickness of approximately 12mm, heating tape surrounded the outside the autoclave, temperature controller, pressure gauge recorder, N2 gas cylinder, sensor record temperature and control valve to get rid of excess steam.

Maximum capacity of the autoclave is 1700 ml of solution.

The carbon steel specimen materials used in this investigation has the chemical composition shown in Table (1):

Table 1 the chemical composition analysis of carbon steel

Fe	70.2
Si	1.8
Mn	9.2
Cr	2.1
Ni	1.7
Mo	2.8
Cu	1.2
Co	2.6
Al	3.8
C	3.0
S	1.6
HB*	3.5
Total elements%	100

Where *HB: Hardness Brinle

The rectangular carbon steel alloy specimens of dimensions about (10 x 3 x 0.2 cm) have been used in this investigation; their surfaces were abraded by using emery paper of different grade numbers 220, 320, 400, 600. After abrasion the surfaces were cleaned with running tap water , followed by acetone rinse for 5 minutes and were dried in discator.

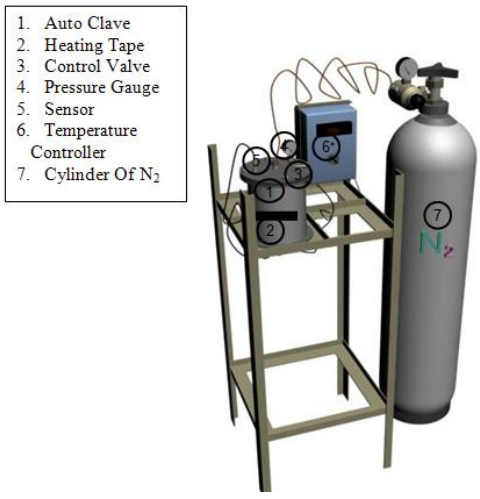

Fig. 1: Schematic Diagram of the experimental apparatus.

Different NaCl solutions were prepared using 2000 mg of dried cooled NaCl dissolved in one liter of distilled water to obtain 2000 ppm of NaCl. This concentrated stock solution was diluted with deionized water to obtain (100ppm, 400ppm, 700ppm, 1000ppm), taking 65ml, 260ml, 455ml, 650ml, of 2000ppm of stock solution and diluted with deionized water to obtain 1300ml of above NaCl concentration.

After specimen's preparations, weighing the specimen and record (W1), the specimen was clamped and immersed in NaCl solution in the autoclave, N2 gas cylinder with heating was used till the gauge pressure read 3 bars. These specimens were immersed in between 2 to 3 hours, after that, heating was cut off and then specimens were removed and cleaned by washing with running tap water and brushing them with bristle brush. Then the specimens were immersed in benzene for 5 minutes to ensure removal of corrosion products from the metal surface. The specimens were immersed in ethanol and dried, then kept in discator, and then the dried sample weighed as (W2).

Corrosion rate was expressed by weight loss per unit area per unit time in (gmd). The surface area of the three specimens evaluated and founded to be about 65cm2.

Results and Discussion

1. Temperature effects:
The effect of temperature in the range (90-120oC) indicates that higher temperature increase the electrochemical reaction and hence increase corrosion rate of carbon steel. But at low about 100 ppm NaCl concentrations the effects of temperature is slight as shown in Table (2) and Fig. (2).

2. Soduim chloride concentration effects:
The results indicate that sodium chloride concentration greatly increase the Electro- chemical reaction between carbon steel specimen and sodium chloride solution. Therefore it can be observed that concentration of NaCl is greatly affects electrochemical reaction. As shown in the following equation and Figs. (3and 4).

$$Fe + 2NaCl + 2H_2O \rightarrow 2NaOH + FeCl_2 + H_2$$

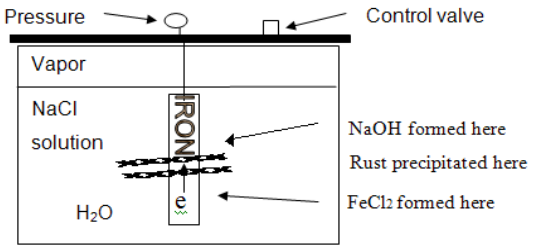

Fig. 2: Rusting of iron immersed in salt solution in autoclave

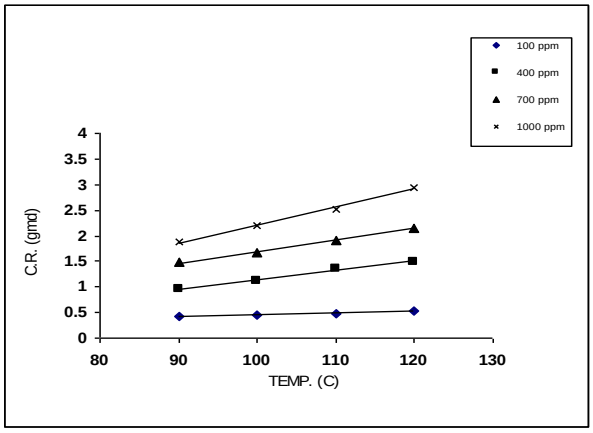

Fig.3: Corrosion rate/ temp. relationship for carbon steel in different NaCl conc. and at 3 bar.

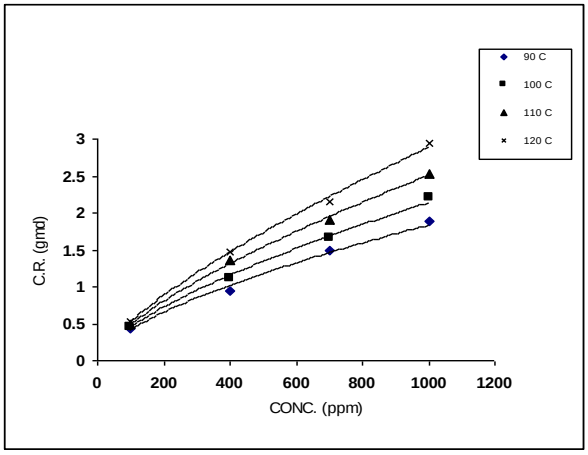

Fig.4**:** corrosion rate/ conc. relationship for carbon steel at different temp. And at 3 bar

Run No.	NaCl Conc.(ppm)	Temp. C0	C.R. (gmd)	C.R. mm/y
1.	100	90	0.44	0.0205
2.	100	100	0.47	0.0218
3.	100	110	0.49	0.022
4.	100	120	0.53	0.024
5.	400	90	0.96	0.044
6.	400	100	1.10	0.051
7.	400	110	1.31	0.06
8.	400	120	1.47	0.068
9.	700	90	1.52	0.070
10.	700	100	1.66	0.077
11.	700	110	1.91	0.088
12.	700	120	2.14	0.099
13.	1000	90	1.89	0.087
14.	1000	100	2.21	0.102
15.	1000	110	2.52	0.117
16.	1000	120	2.94	0.136

Where mm/y : millimeter per year.

CONCLUSIONS

Corrosion rate increases rapidly with NaCl concentration in all different temperature at 3 bar i.e. corrosion rate increase from 0.44 to 2.94 gmd when NaCl concentration from 100 up to1000 ppm. Corrosion rate increases with temperature linearly at 700 ppm NaCl concentration .i.e. Corrosion rate increases from 1.52 up to 2.14 gmd when temperature increases from 90 to 120oC at 3 bar. Therefore is recommended to operate the boilers with NaCl concentration up to 700 ppm before shut down and removing salts concentration will greatly damage metallic boilers.

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