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Corrosion of Carbon Steel Pipeline in Flow System of water Sweetening Plant

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Abstract:

The electrochemical behavior of carbon steel in water sweetening station in Libya has been studied in the range of (293–333 °C) using weight loss technique. Measurements were carried out over a range of Reynolds number (5000 – 25000).An apparatus was designed for studying the corrosion process in the turbulent regime, which is of industrial significance. It was found that The corrosion rate of carbon steel in water sweetening station is under diffusion control and increases with increasing Reynolds number. On the other hand the variation of corrosion rate with temperature in the range of (293–333 °C) was found to follow Arrhenius equation and the activation energy approximately the same except at low Reynolds number.

Keywords :corrosion, sweeting, carbon steel.

Introduction:

Corrosion can be defined in several ways; it is the destructive attack of metal by a chemical or electrochemical reaction with its surrounding[1] ; or it is the interaction of material with its surrounding[2] .

Corrosion has been a serious problem in water sweetening stations for many decades, one of very common cause of corrosion is the presence of dissolved oxygen in water and the presence of chloride ions. The corrosion rate in water sweetening stations depend on many parameters such as; chemical composition of carbon steel, temperature, velocity of flow, salt concentration , oxygen concentration, carbon dioxide , and PH index.

Velocity primarily affects corrosion rate through its influence o diffusion phenomena. It has little or no effect on activation controlled processes. In addition the diffusion process is affected differently by velocity when flow conditions are laminar as compared to situation where turbulence exists[3].

For most conditions, the corrosion rate can be expressed by the equation[4]:

$$C.R.= k\,U^n \quad \ldots\ldots\ldots\ldots(1)$$

Where;

K is constant, and n is a constant for a particular system. Values of (n) vary from (0.2 - 1.0).Speller and Kendall[5] measured the effect of velocity of aerated water on corrosion of (1/2 in) iron pipe. The data were plotted and the constant, n, in this case turned to be 0.79.This value was similar to the results obtained by several other investigators[6].

The effects of temperature on corrosion rate may be represented by the Arrhenius equation:

$$K = A\,\mathrm{Exp}(-E_a / RT) \ldots\ldots\ldots\ldots\ldots(2)$$

So that ln (k) or Log(k) gives a straight line when plotted vs. (1/T) with a slope of ($-E_a/R$) or ($-E_a / 2.303R$), R is the gas constant. Many thermales processes behave in this way and an thermal Arrhenius plot enables to determine the activation energy[7].

For no heat transfer condition across the specimen / solution interface, increasing temperature (and therefore the specimen temperature) increases the corrosion rate.

The relationship is not linear, but follows the form[8]:

$$C.R. = A\ \mathrm{Exp}(BT) \quad \ldots\ldots\ldots\ldots\ldots(3)$$

Where A and B are constants.Skoulikidis and Vassilio[9] studied the electrochemical behavior of mild steel in 3.5 % NaCl solution at temperature between (20 to 60 °C). They found the applicability of Arrhenius plot with activation energy of 6 ± 2 Kcal / mole. Francis and Dolphin[10] studied the polarization of steel in saline solutions. They found that the C.R. increased with increasing temperature and was doubled when temperature was raised from ambient temperature to 80 °C.

The relationship between the limiting current(I_l) and corrosion rate for concentration polarization is given by[11]:

$$C.R = 0.0895 * I_l * M \quad \ldots\ldots\ldots\ (4)$$

Where, M, is equivalent weight.

The present study is a step to understanding the corrosion of carbon steel pipe lines in flow system of water sweetening station in Dranah city(Libya). In different flow conditions and different temperatures by using weight loss techniques.

Experimental Work:

Materials and Solution:

The materials used in this study is low carbon steel pipe, supplied by Dinah(Libya) Sweetening station. Cylindrical specimens having length about (10mm) and inside diameter about (30mm) were cut from carbon steel pipe. Water produced from station (PH = 6.8) was used as corrosive media with the following compositions:

Comp.	Cl^-	Ca^{++}	Mg^{++}	Ca-H	Mg-H	NH_4^+
Conc. (ppm)	2.6	1.6	0.5	4	0.5	Nil

Specimen Preparation:

Cylindrical specimens were cut from carbon steel pipe and they were washed and degreased with analr ethanol and acetone. They were annealed in vacuum at (600 °C) for one hours(to remove the effect of cold working[12])and then cooled under vacuum to room temperature. Specimen s were abraded in sequence under running tap water by using the following emery paper grades;240,320,420,and 600,washed with tap water followed by distilled water, dried with clean tissue paper, immersed in ethanol, dried with clean tissue paper, immersed in acetone, rinsed with acetone and dried with clean tissue paper. They were then left to dry for one hour over silica gel before use. The dimensions of specimens were measured by a vernier to the 2nd decimal of millimeter and accurately weighed to fourth decimal of gram.

Procedure:

Three specimens were used in each test, they were mounted axially in Teflon spacer made as part of the flow system as shown in Fig.(1).

The specimens were separated by Teflon washers in order to prevent galvanic contact[13]. Different Reynolds values (Re =5000 , 10000, 15000, 20000, and 250000) , different temperatures (T = 293, 313, 333 K) were used. Test duration was three days. Specimens after each test were visually observed,then washed with tap water, cleaned with brush to remove the weakly adherent corrosion scale, immersed in 5% hydrochloric acid containing hexamine,washed with tap water and rinsed with distilled water,dried and then rinsed with analar ethanol,dried ,rinsed with acetone and finally accurately weighed to the 4th deimal of gram the average corrosion ratewas calculated from the weight losses of three specimens .

Results and Discussions:

In this technique, three specimens were used in each run. The average corrosion rate was equal to arithmetical average of the three specimens, the method of calculation of corrosion rate is as follows;

$$C.R.=(\text{weight loss(gm)}*10^{-3})/(A(mm^{2})*\text{Time(day)}*10^{-4})$$

Or

$$C.R.=Dw/A*T \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

Where

C.R.(mdd), Dw = difference weight before and after duration(gm), A(area of specimen= 3.14*dL, where ; d, is the inside diameter, L, is the length), T is the time of duration.

Fig.(2) shows the variation of C.R. with flow rate at constant temperature.It is clearly influenced by the flow rate as the corrosion rate increases with increasing Reynolds number at constant bulk temperature of solution. This behavior is in accordance with previous investigations [14,15,16,17].This is attributed to the increase in mass transfer coefficient which will lead to the increase of oxygen flux arriving at the metal surface and the decrease in resistance that hinders the transfer of oxygen, especially the diffusion layer thickness.

Fig.(3) shows that the corrosion rate with temperature for different values of Reynolds number. It increases with increasing temperature. The slight influence of temperature on the C.R. in the interval of temperatures is due to the oxygen solubility decrease with the increasing temperature. The observation is in accordance with that observed by Parshin et. al.[18]. But the effect is clear for higher velocity (i.e. at Re greater than 25000) it is readily evident that the flow rates or Reynolds no. is more significant in fluencing the C.R. than the effect of temperature.

Several correlations have been predicted by the number of workers are available in literature, which are satisfactorily applied to electrochemical processes under laminar and turbulent conditions. The experimental results of Sherwood no. are presented in Fig. (4) as a plot of Sh no. versus Re no. with slop less than one[19,20].

Arrhenius plots Log (C.R.) against(1/T) for each Reynolds no. is shown in Fig.(5).The figure shows that the activation energy is approximately the same except at Re = 5000(i.e. at low rate of flow).

Conclusions:

The corrosion rate of carbon steel in water sweetening station is under diffusion control and the C.R. increases with increasing Reynolds number. On the other hand the variation of corrosion rate with temperature in the range of (293 – 333 K) is found to follow Arrhenius equation and the activation energy approximately the same.

Notations:

C.R. : Corrosion rate.
k : constant in eqn.(1).
n : constant vary (0.2 1).
K : reaction constant
A : Arrhenius constant.
Ea : activation energy.
R : gas constant.
T : temperature of electrolyte.
A : constant in eqn.(3).
B : constant in eqn.(3).
Il : limiting current density.
M : molecular weight.
A : surface area of specimen.
D : inside diameter of specimen.
L : length of specimen.
Re : Reynolds number.
Sh : sherwood number.
Dw : difference weight before and after duration.

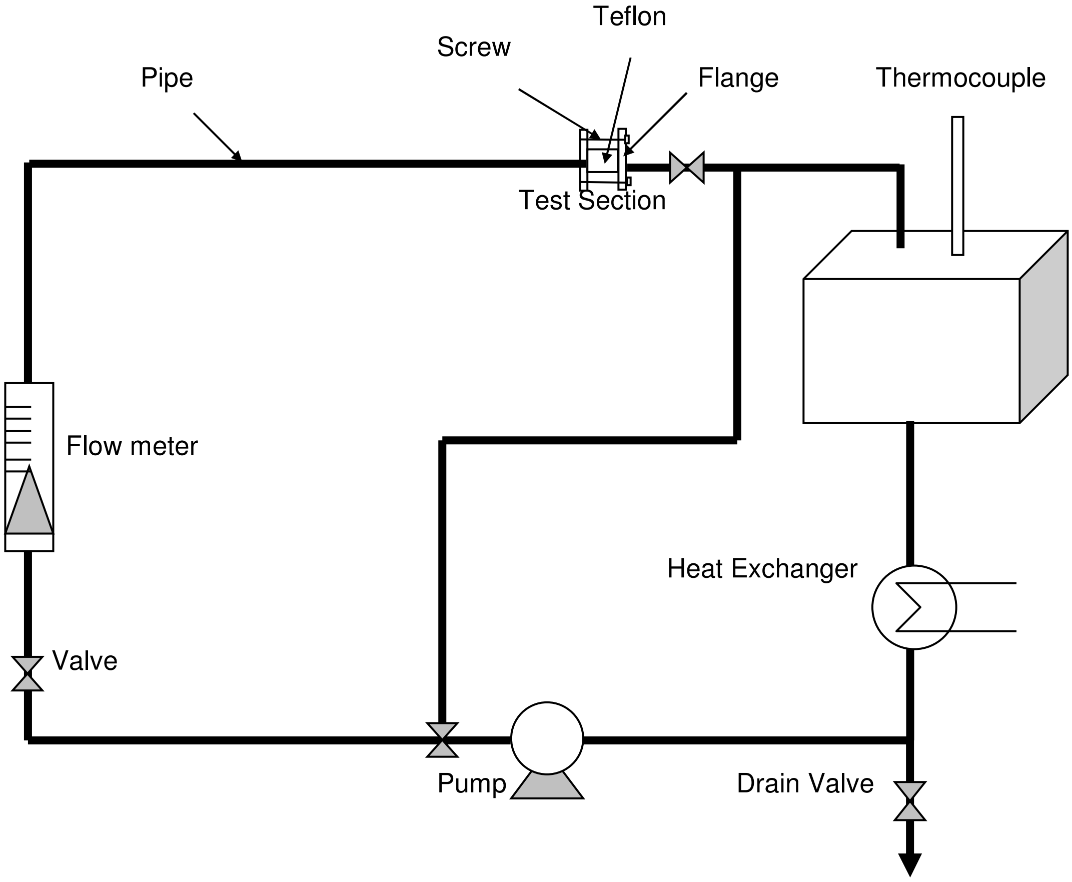

Fig. (1) Rig System.

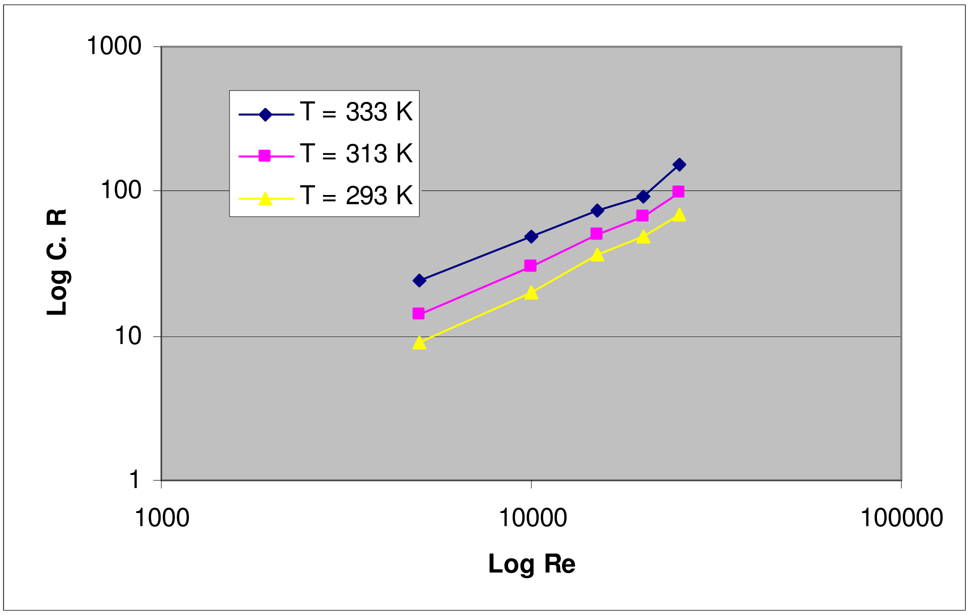

Fig.(2) Dependence of corrosion rate on the Reynolds number at different temperatures.

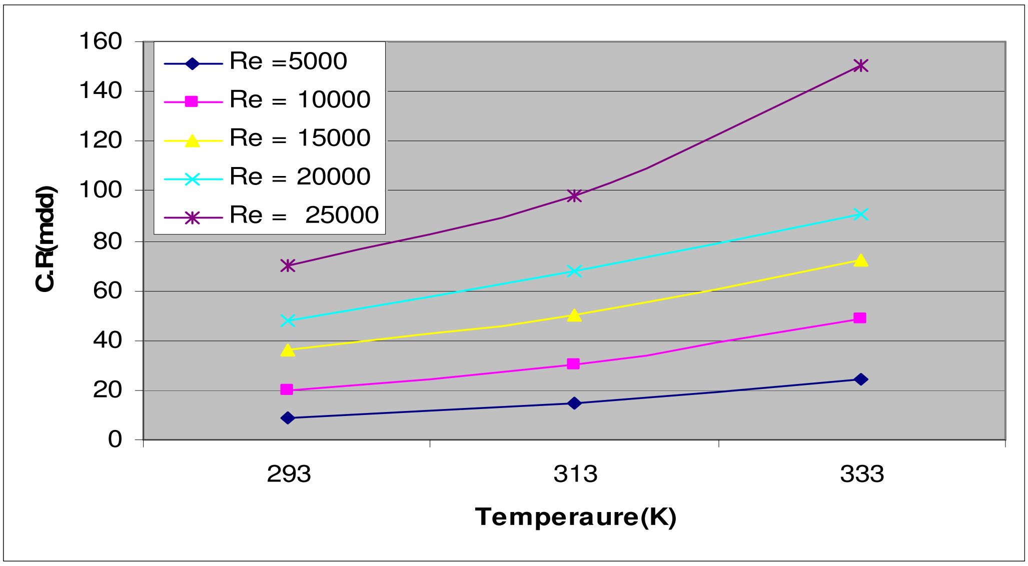

Fig.(3) Dependence of corrosion rate on the temperature at different Reynolds numbers.

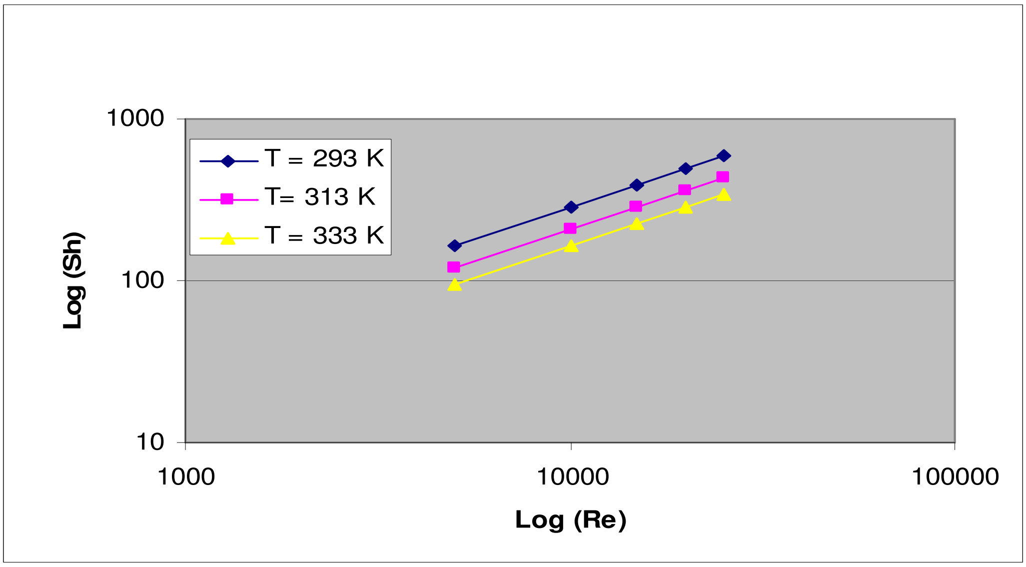

Fig.(4) Variation of Sherwood no. with Reynolds no. under different temperatures.

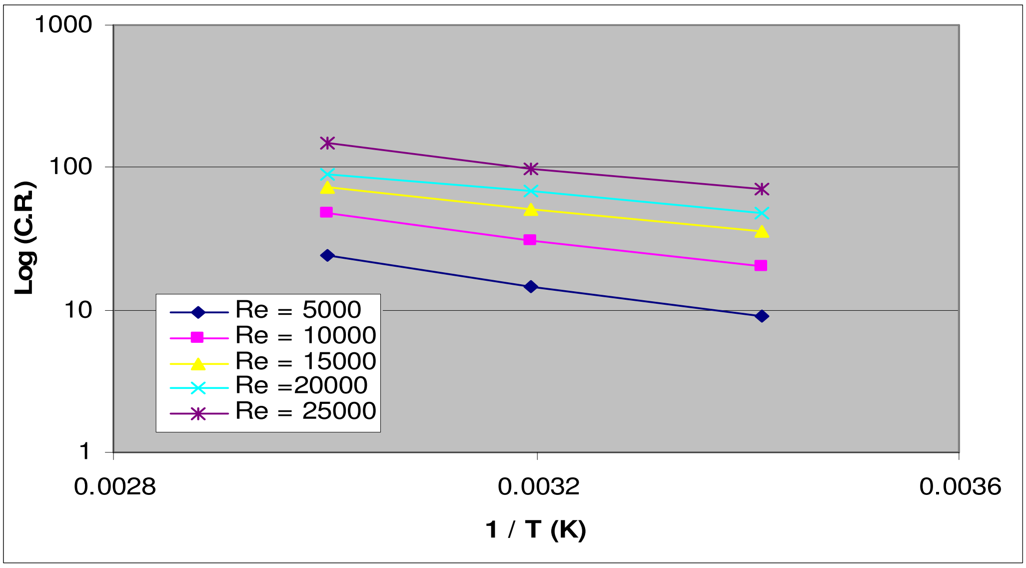

Fig.(5) Arrhenius plots of the of corrosion rate under different values of Reynolds numbers.

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تأكل أنابيب الصلب الكربوني في منظومة الجريان لمحطة تحليه المياه

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الخلاصة:

تم دراسة السلوك الكهروكيمياوي لمعدن الكربون ستيل في المحلول المائي في محطة التحلية في درنة / ليبيا، حيث تم دراسة تأثير درجة الحرارة وللمدى (٢٩٣ – ٣٣٣) درجة كلفن ، ومديات رقم رينولدز (الجريان) من (٥٠٠٠ – ٢٥٠٠٠) ، باستخدام تقنية الفقدان بالوزن. ولغرض انجاز هذه الدرسة تم تصميم منظومة تعمل تحت ظروف الجريان المضطرب وهو الظرف العملي في محطة التحلية.
من خلال الدراسة تبين إن عملية التآكل تحت سيطرة عملية الانتشار Diffusion Control ، هذا من جانب ومن جانب آخر فأن معدل التآكل يزداد بزيادة كل من درجة الحرارة والجريان(رقم رينولدز)،بالإضافة إلى ذلك لوحظ انطباق معادلة ارهينوس على القيم العملية وبتغير طفيف بأرقام رينولدز المنخفضة.