Corrosion Rate Calculation of Carbon Steel (0.4%C) After Subjected to Thermal Cycling, Sea Water Cooled

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***Abstract*—Thermal cycling tests were carried out on carbon steel (0.4 C%). A single run was performed at upper temperature of 500°C and lower temperature of 32°C cooled in sea water. For several numbers of cycles up to 30 cycles for an accurate determination of heating and cooling times. The effect of thermal cycling on corrosion rate were evaluated.**

***The effect of thermal cycling* on the following properties were evaluated, corrosion rate.**

***From the obtained test results,* it was found that: the type of corrosion is uniform attack; corrosion rate of the first stage gradually increases with the number of thermal cycling up to 15 cycles, then it take steady state up to 30 cycles.**

Keywords—Thermal Cycling; Corrosion Rate; Heat Treatment Hardening; Carbon Steel; Sea Water.

I. INTRODUCTION

Plain carbon steels are emerging as backbone structural materials in high temperature applications such as spray towers turbine engine, missiles, etc.

Carbon steels have many advantages, high strength, and ductile materials and very easy to alloyed with other elements........ Etc. On the other hand its disadvantages are the high ability to corrosion. So, a lot of researches have been studied corrosion mechanisms through which a better understanding is obtained of the causes of corrosion and the available means for preventing or minimizing resulting damage. There are many factors which have a great influence on corrosion rate, Environments, metallurgical factors, effect of stress. Eg.Halyna Chumalo, et al [R.1] studied the resistance of new austenitic ferritic steels to stress corrosion While C.P.Atkins and J.D. Scantlebury [R.2]. et al studied the activity coefficient of sodium chloride in a simulated pore solution environment. S.H.Zhang, S.B. Lyon, et al [R.3] investigated the retention of passivity on iron after several months' atmospheric exposure.

Shin-ichi Komazaki et al [R.4] using six different steels. Slow strain rate tensile test and thermal disruption spectroscopic analysis were applied to specimens subjected to wet-dry cyclic corrosion tests in a NaCL solution. Hideki Katayama, et al [R.5] was conducted the corrosion simulation in a chamber to carbon steels in atmospheric environment by controlling the environmental factors such as temperature, relative humidity and temperature of carbon steels. Akira Tahara and Tadashi Shinohara, et al [R.6]. They found that there are two kinds of corrosion patterns were distinguished, uniform corrosion and local corrosion and the addition of Cu, Ni and Cr changed the form of the corroded surface from the uniform corrosion to the combined pattern (uniform corrosion + local corrosion) While M.Yamashita, et al., [R.7], studied the initial rust formation process on carbon steel under Na2SO4 and NaCL solution films with wet/dry cycles using synchrotron radiation X-rays. Robert E. Melchers, et al., [R.8] reported that, the corrosion loss vs. time behaviour is initially highly non-linear and then almost linear until corrosion product formation begins to control the rate of corrosion. On the other hand a mathematical modelling was carried out by Hiroshi Kihira, Et al., [R.9] to corrosion prediction for weathering steels.

II. Iron-Carbon Equilibrium Diagram

A study of the constitution and structure of all steels and irons must first start with the Iron-Carbon Equilibrium Diagram, the Iron- Carbon Constitutional Diagram should extend from 100 percent Iron to 100 percent cementite (6.67C%), the plain carbon steels (0.4%C) were used, shown in Fig.2.1.

III. Experimental Work:

A. *Materials*

In this work hypo-eutectoid carbon steel (0.4%C) has been used their chemical composition are given in Table I.

Table I. Chemical composition of the used sample

Carbon, C	**0.40 %**
Iron, Fe	98.51 - 98.98 %
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

B. *Thermal cycled experiments*

Thermal cycled experiments were conducted for:
To study the effect of thermal cycling [10, 20, and 30 times] on the corrosion rate.
The thermal cycling will be carried out in the Material Science Laboratory at [***The Bright Star University***], Thermal cycling were carried out in the material science laboratory at [The Bright Star University], the details of the furnace are: [Gallenhamp, Cat. No. (FSW - 670 - 010 J), APP. No. (7B9714 B)]. England, S302AU. For this furnace the heating and cooling rate were recorded as shown in Fig.3.1 and Fig.3.2 respectively:

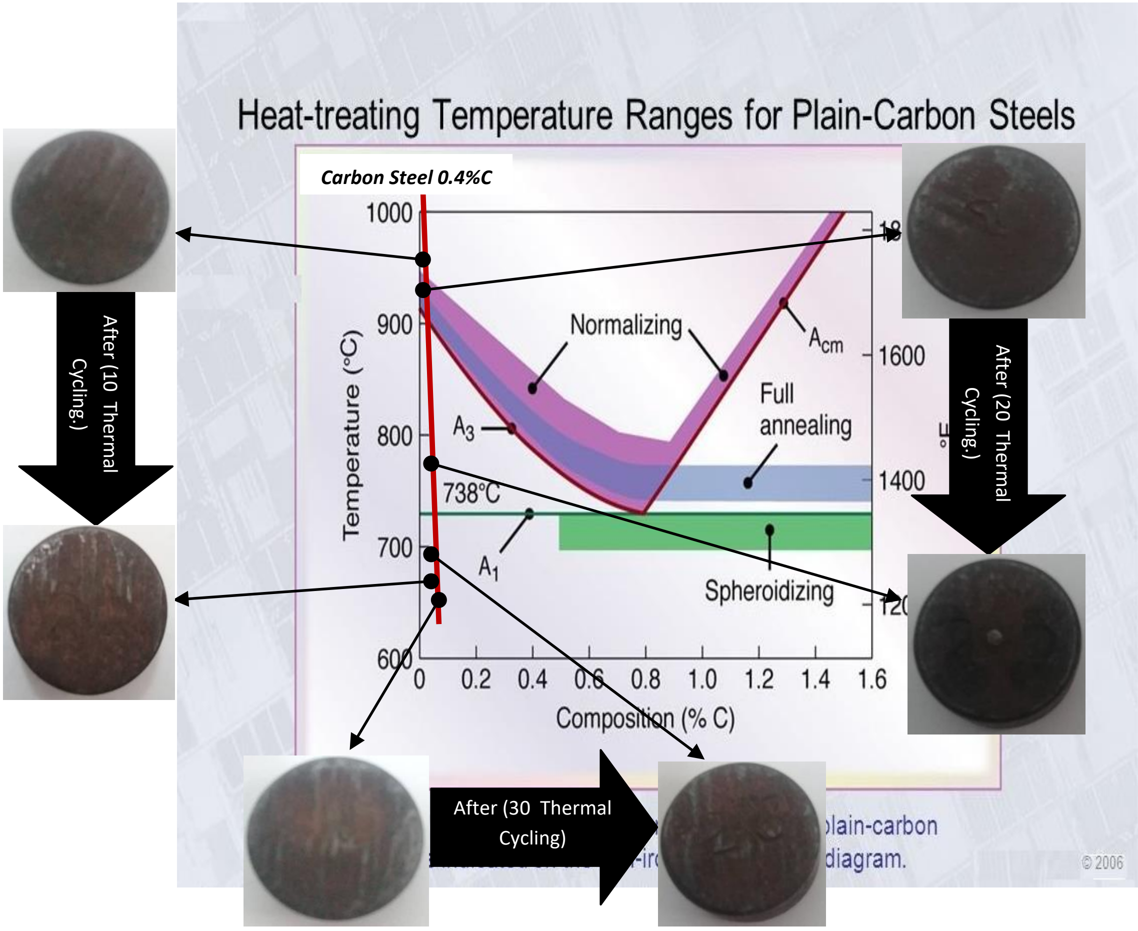
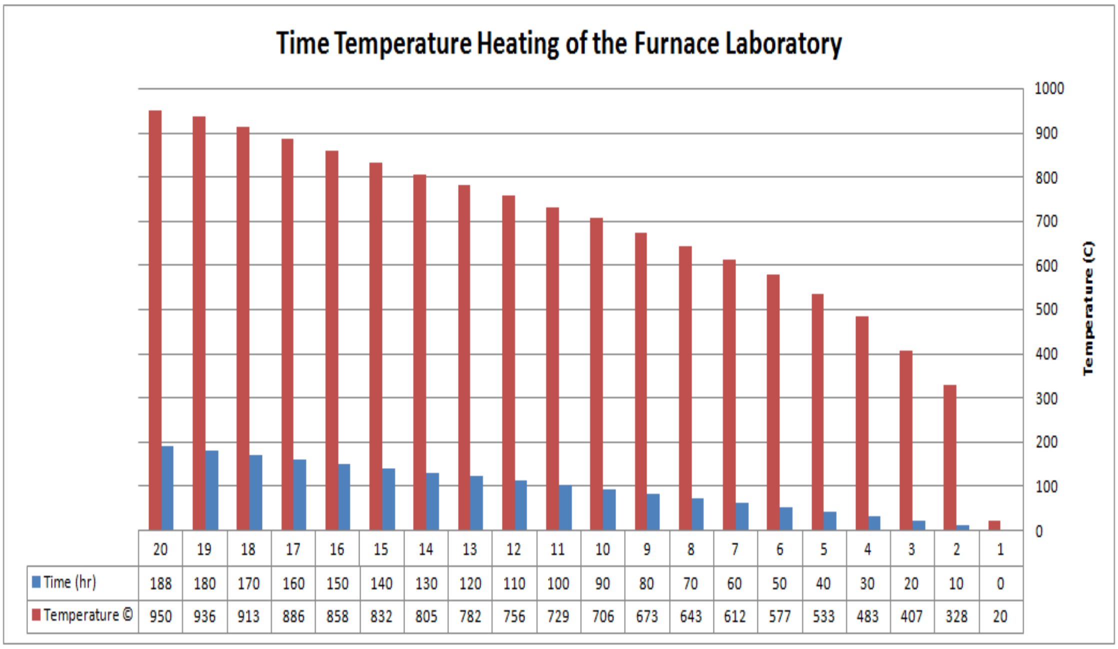
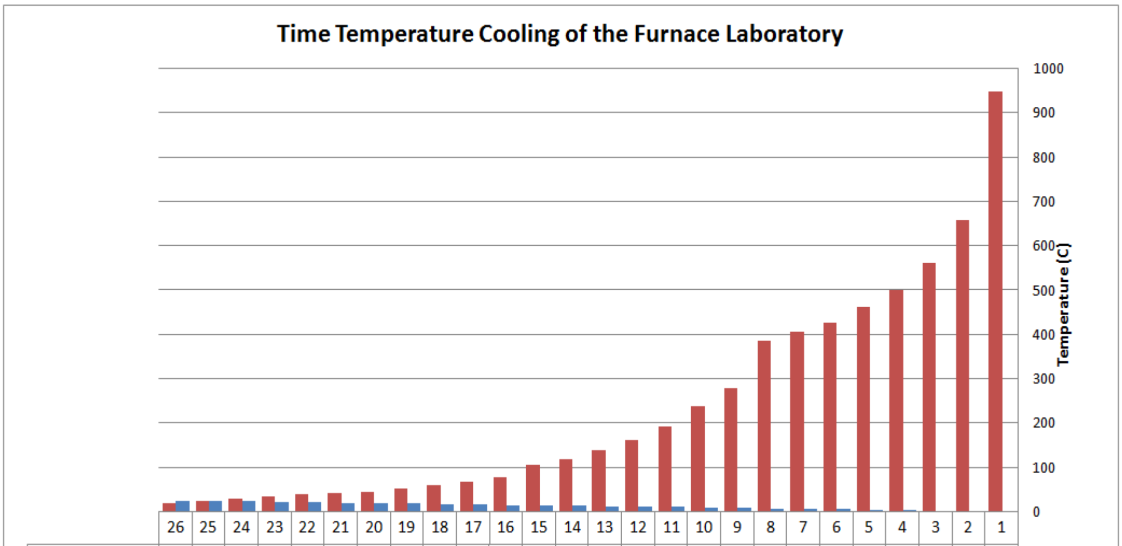


Fig.2.1. Iron-Carbon Equilibrium Diagram.



	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Time (hr)	188	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
Temperature ©	950	936	913	886	858	832	805	782	756	729	706	673	643	612	577	533	483	407	328	20

Fig.3.1. The furnace heating rate.



	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Time (hr)	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Temperature ©	20	25	30	35	41	43	47	53	60	68	80	108	120	140	163	193	240	280	387	406	427	463	502	563	658	950

Fig.3.2. The furnace cooling rate

The samples were each divided in to three groups, and each group were subjected to a different numbers of thermal cycling (10, 20, and 30 cycles). All samples were subjected to the same heating cycle, in which the samples were heated below A1 to 500oC and held in the furnace for 15 min. Three samples of each heating cycle were cooled in sea water. The total time of a single cycle was 40 min, as shown in Figs.3.3.

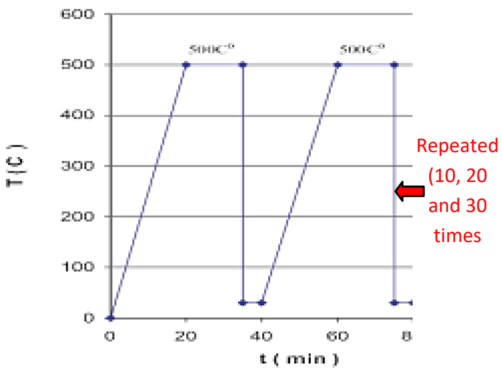


Fig.3.3. T.T. Diagram shows the [10, 20 and 30 cycled cooled in sea water].

C. *corrosion testing*

Thousand of corrosion tests are made every year. The value and reliability of the data Obtained depend on details involved. Unfortunately, many tests are not conducted or reported properly, and the information obtained is misleading. Corrosion rate has been measured by using the weight loss method for thus a [(Bulgur) calvarias (Varese) DEC.MIN.24-1-2003 N0 205295] were used. The difference between the weight sample after and before subjected it to thermal cycling then removal the corroded layer by a pieces of wood (more soft than steel).

This loss of weight (***ΔW***) is considered as weights of corroded materials were:

Losses of corrosion % = $\Delta W / W_0 * 100$

Where ΔW: losses of weight (mgr) due to thermal cycling.

W_0: original weight (gram).

IV. Results and Discussions

A. *The effect of thermal cycling on corrosion rate*

The samples subjected to a number of thermal cycling 10, 20, and 30 cycles then exposure to corrosion attack for (one week about 168 hr). We used sea water as a cooling media, Fig.4.1 shows the effect of thermal cycling on corrosion rate. The increasing of thermal cycling leads to increase the corrosion rate for carbon steel. This increase can be divided in two stages:

In the first stage the corrosion rate increases gradually with increasing thermal cycling up to 10 cycles. Above that (more than 10 cycles) the corrosion rate increasing slowly until 30 cycles. This behaviour can be attributed to the increase in the amount of residual stresses, this amount of residual stress increases with increasing cycles up to (10 cycles) and then there is slowly increasing in residual stresses after that. The lead to introduce residual stresses which have strong influence on corrosion rate.

Based on the above results, it can be safely concluded that thermal cycling introduced residual stresses which leads to increase in corrosion rate. Stages by increasing the number of cycles corrosion rate increases through two depending on amount of thermal cycling.

V. CONCLUSION

The results of this investigation show that:

- Thermal cycling causes uniform corrosion attack for plain carbon steel.
- Corrosion rate of the first stage gradually increases with the number of thermal cycling up to 15 cycles, then it take steady state up to 30 cycles.

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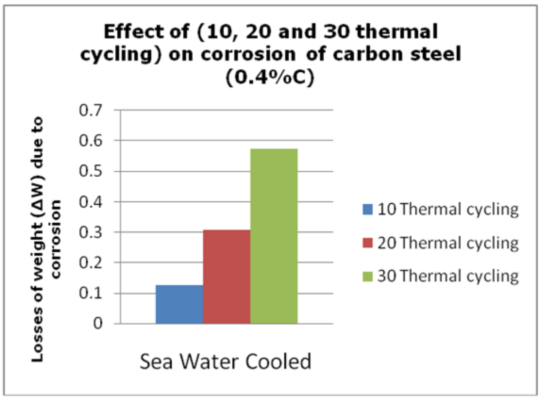

Fig.4.1. The effect of (10, 20 and 30 thermal cycling on corrosion rate, sea water cooled.

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