EFFECT OF HEAT TREATMENT FOR SUBMERGED ARC WELDING ON CORROSION RESISTANCE IN SEA WATER AT DIFFERENT TEMPERATURE

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ABSTRACT

This paper is aimed to study the effect of heat treatment for submerged arc welding joint in the dimension of 100*50*16 mm on corrosion resistance in sea water at different temperatures.
Submerged arc welding is carried out for Low carbon steel St37 under welding conditions of 750 Amper DC current straight polarity (DCSP) and 32 volt, welding wire type EM12K.70-18 in diameter of 4mm and wire speed of 4.2m/min with Flux . A joint geometry of single V at 45^{o} butt joint welded two passes was adopted. The welded pieces were tested by X-ray radiography and faulty pieces were excluded.
After welding, the joints without defects have be submitted to heat treatment including quenching where the joint heated to 900 C^{0} for one hour then water cooled and followed by normalizing heat treatment by heating to 900 C^{0} for one hour then air cooled. Corrosion specimens prepared from the weld joint with the dimensions of (15*15*3) mm according to ASTM G71-31 then optical microscopy was used to observe the welded joint microstructure.
Corrosion tests were investigated by electrochemical potential state cell in a prepared salt water (sea water) at different temperatures (25, 50.75) C^{0}. Tafle equation was adopted to calculate the corrosion rate.
Results show that heat treatment contributed in reducing corrosion rate and normalizing gives better results than quenching but the effects of media temperature give the opposite
Keyword: submerged arc welding SAW, heat treatment, corrosion resistance

الخلاصة :

يهدف البحث الى دراسة تاثير المعاملات الحرارية لوصلات لحام تناكبية بالابعاد 100*50*16 ملم تم لحامها بطريقة لحام القوس الكهربائي المغمور على مقاومة التاكل في ماء البحر عند درجات حرارة مختلفة لفولاذ كربوني St 37
تم اللحام عند ظروف لحام من تيار 750ملي امبير و فولتية 32 فولت وسرعة 4.2 م\ دقيقة باستخدام سلك لحام نوع EM12K.70-18 وقطر 4 ملم مع وجود Flux كمادة عازلة و بعدد اثنان من التمريرات باستخدام تيار (DCSP) للحصول على وصلة لحام تناكبية وعمل زاوية لحام تحضيرية من جهة واحدة مقدارها 45 درجة .
بعد عملية اللحام والتاكد من خلوها من العيوب من خلال فحصها بواسطة جهاز X-ray radiography اجريت معاملة حرارية (تقسية) اذ تم تسخين الوصلة الى درجة 900 درجة مئوية ثم التبريد السريع بالماء اتبعتها عملية معادلة حيث قمنا باعادة التسخين الى نفس الدرجة والتبريد البطيء بالهواء تم تحضير عينات اختبار التاكل بعد قطعها من الوصلة بابعاد 15*15*3 ملم وفق المواصفة القياسية ASTM G71-31 اتبعتها عمليات تحضير من تنعيم وصقل لاجراء فحص البنية المجهرية باستخدام المجهر الضوئي ذو كاميرا . ولإجراء اختبار تآكل كهروكيمياوي في وسط ماء البحر عند درجات حرارة متغيرة 25,50,75 درجة مئوية فيمثل تيار التآكل ، وتم حساب معدل التآكل اعتمادا على معادلة تافل في وسط ماء البحر .من النتائج التي تم الحصول عليها وجد ان مقاومة التاكل تزداد مع المعاملة الحرارية وان المعادلة اعطت افضل النتائج ولكن على العكس فقد اعطت درجة حرارة الوسط نتائج عكسية

INTRODUCTION

During the fabrication process, welding is the most commonly used method of joining items together. The welding process SAW involves formation of an arc between a continuously-fed bare wire electrode and the work piece. The process uses a flux to generate protective gases and slag, and to add alloying elements to the weld pool. A shielding gas is not required. Prior to welding, a thin layer of flux powder is placed on the work piece surface. The arc moves along the joint line and as it does so, excess flux is recycled via a hopper. Remaining fused slag layers can be easily removed after welding. As the arc is completely covered by the flux layer, heat loss is extremely low. This produces a thermal efficiency as high as 60% (compared with 25% for manual metal arc). There is no visible arc light, welding is spatter-free and there is no need for fume extraction (A.Wahid,1993), SAW procedure is shown in **Fig.(1).**
The result of this thermal cycle is distortion if the welded item when it is free to move, or residual stress if the item is securely held. There comes a point when the amount of residual stress can create potential problems, either immediately or during the life of the welded structure, and it needs to be reduced or removed.
Post weld heat treatment is the most widely used form of stress relieving on completion of fabrication of welded structures approaching or even exceeding the yield stress is possible when welding thick sections like high quality of submerged-arc welds, which include high deposition rates, the deep penetration, the adaptability of the process to full mechanization, and the comfort characteristic (no glare, spark, spatter and smoke) make it a preferred process in steel fabrication. It is used in ship and large building, pipe manufacture, railways, car structure and fabrication structure beams.
Heat treatment is also considered to be very important tool of the metallurgist by which he can alter the properties of steel easily. The same steel can have a very wide range of mechanical properties if subjected to different heat treatment (A.V. Adedayo ,2012).
Corrosion resistance of steels is strongly connected to their microstructure obtained after heat treatments that are generally performed in order to achieve good mechanical properties. For that reason, there is currently a strong interest in the effect of the heat treatment on the corrosion resistance which is affected by the changes in the microstructure (Alstom,2000),(Article,2003)
Many studies investigate the corrosion behavior of welded joints. (A. Vargas-Arista ,2011) who studies the corrosion in API5L-X52 pipe steel aged at 250 °C at different times under electrochemical technique like tafel polarization. The electrochemical study which were performed in a solution of brine containing hydrogen sulfide at 25 ºC, revealed an increase of the general corrosion rate in the weld bead, the heat affected zone and the base metal as the aging time was elapsed.
(Dr.Abbas Sheyaa Alwan,2011**)** studied the effect of normalizing on mechanical properties of steel welded joints resulting that normalizing causes high decrease in the tensile properties specially the yield strength. (Dr.Shantharaja.M,2009) study the effect of post heat treatment for weld joint on mechanical properties emphasizing that the residual stresses obtained from welding process have the main effect on improving these properties. (A.V. Adedayo,2012) study, the effects of quenching heat treatment on mechanical properties and microstructure of different grades of carbon steel (0.16 wt% C to 0.33 wt % C) welded by fusion arc welding observing that quenching significantly affects the microstructure and thus the mechanical properties of the weld giving different properties at different zones. (A. Wahid, 1993) studied the corrosion in welds ,he saw that weldments can experience all the classical forms of corrosion, but they are particularly susceptible to those affected by variations in microstructure and composition. Specifically, galvanic corrosion, pitting, stress corrosion, intergranular corrosion, and hydrogen cracking must be considered when designing welded structures. (Khairia Salman Hassan, 2011) study the influence of the joint design of Tungsten Inert Gas welding (TIG) on the

corrosion resistance of low carbon steel (type St-37). Corrosion rate increases as preparation angle of single V butt joint increased because of increasing of filler metal which is deposited in the weld zone. The effect of heat treatment on corrosion resistance in sea water at different temperatures was investigated in this paper

EXPEREMENTAL WORK

1- Material selection

A low carbon steel type St37 is chosen according to the Russian Standards (Gost) . Its chemical analysis is shown in **Table 1.**

2- Preparation of welding pieces

Low carbon steel St37 plates of dimensions of16 mm thick 50 mm long and 50 mm wide are selected for submerged arc welding. Two pieces are prepared with making of single V- butt joint with angle of 45°. As shown in **Fig 2.**

3- Weld process

Two weld joints were made with submerged-arc welding, and the adopted welding procedure was according to AWS A.5.17-69 [11]. Consumables of as-deposited weld metal obtained by applied double-pass, it was used a neutral flux and wires. Of type EM12K.70-18 with chemical composition detailed in **Table (2)**

4- Preparation of specimens:

After the welding process, the welded pieces were tested by X-ray radiography. Faulty and poor welded pieces were excluded from the group , the Welded pieces without defects or faults used to prepare the corrosion specimens test in the dimensions of (1.5*1.5*3) cm according to the ASTM G 71 -31

5- Categorization of specimens

After completing the preparation of specimens, it is categorized as in **Table 3.**

6- Heat treatment

Heat treatment involved two steps , first welding joint was heated to 900 C^0 for 1 hour then water quenched and after that normalizing heat treatment was made by heating the welding joints to 900C^0 and remained at this temperature for 1h. Afterwards, they were removed from the furnace and air cooled up to the ambient temperature.

7- Microstructure test

Specimens were prepared as following:

1- Wet grinding with water was carried out for all the specimens by using SiC emery papers of grades 220,400,800, and 1000.

2- Polishing process was carried out by using special polishing cloth with aluminum oxide (Al_2O_3) solution of grain size of 5µm.

3- Etching process was done by immersing each specimen in etching solution (Nital solution) which consists of 98% Methyl alcohol and 2% Nitric acid for 30sec .Then the specimen was washed with water and alcohol and dried in oven.

4- Microstructures of specimens were examined with optical microscope provided with computer and digital camera.

8- Corrosion Test

Corrosion test carried out as follows

1- Preparation the Corrosion Solution

The corrosion solution is prepared, which consists of:

A 35 gm of sodium chloride (NaCl)with 1000 gm of distilled water. The pH ratio is measured by pH meter and its found 6.9.

2- Electrochemical Corrosion Tests

The prepared welded specimen of area 1cm x 1cm was fixed in the holder**.** The reference electrode was fixed about (1 mm) apart from the surface of the specimen to be tested. The reference electrode used in this study was saturated calomel electrode (SCE). The auxiliary electrode used in the electrochemical cell was platinum type. The specimen holder (working electrode), together with the reference and auxiliary electrode were inserted in their respective positions in the electrochemical cell used for this purpose that can fit all these electrodes. The cell used was made of glass. Constant potentials (anodic or cathodic) can be imposed on the specimen, by using the potentiostat (Mlab200 of Bank Eleck .Germany). This potentiostat is able to induce a constant potentials ranging from (–1 to + 1V) the potentials of the standard reference electrode used in this study (SCE). The potential difference between the working and the reference electrode (WE - RE) and any current passing in the circuit of working electrode were the auxiliary electrode can be measured by using the SCI Computer Software. Any potential difference between the working and reference electrodes and also any current in the working electrode circuit can be automatically recorded. The results and plots were recorded using window XP. The scan rate can be selected also. Polarization resistance tests were used to obtain the micro cell corrosion rates. In the tests, cell current reading was taken during a short, slow sweep of the potential. The sweep was taken from (–100 to +100) mV relative to OC (Kalpakjian, Serope 2006), **(Richard S.Sabo1999)**. Scan rate defines the speed of potential sweep in mV/sec. In this range the current density versus voltage curve is almost nearly linear. A linear data fitting of the standard model gives an estimate of the polarization resistance, which used to calculate the corrosion current density (I_{corr}) and corrosion rate. The tests were performed by using a WENKING MLab multi channelsWENKING MLab multi channels and SCI-Mlab corrosion measuring system from Bank Electronics- Intelligent controls GmbH, Germany 2007. as shown in **Figure 4**.

RESULTS and DISCUSSION :-

From **Fig. 3** we see the microstructure of a cross-section of the welded joint and its adjoining region in which is manifested the thermal influence of the weld. The weld structure consists of columnar grain region "weld zone " of large grain size cast structure which is a characteristic of the alloyed metal between filler metal (welding electrode) and base metal. This region is followed by the grain growth region of excess heating in HAZ adjacent to weld zone, this is due to influence of high temperature excess heating greatly lowers the plasticity and shock resistance. It forms in the fine grain region or tempered region in HAZ which is heated to a little higher temperature than line GS (i.e. line between two regions) upon air cooling. Gradually, this region shifts to region of phase recrystallization which is heated to a temperature below line GS. Upon slow cooling, this leads to incomplete plasticizing. In base metal region the temperature of the heated metal does not reach to the region of phase recrystallization of low carbon steel. Thus, the structure of the base metal in it is not influenced by the heating due to welding. So, the weld creates different structure in the adjoining its regions causing great degradation of its properties. Shifts in the structures of regions (Weld zone, AZ zone and Base metal) help at generation of internal stresses in it. Evidently good welding quality would be better as the region adjacent to the seams of the weld is smaller.

The microstructure of weld metal consists of austenite (γ) as light, which is primary solidification phase and ferrite phase (α –ferrite) as matrix particles formed between the primary arms during the terminal stage of solidification. The columnar grains are in direction perpendicular to the interface between weld metal and heat affected zone (HAZ). The amount of austenite and ferrite phases depends on the welding parameters such as welding current, welding speed, composition of filler metal, etc. (Dr. Muna Khethier Abbass ,2012).

From Fig.(3) we can see the effect of this microstructure on corrosion behavior with the chosen parameter we see that specimen (A_1) give the highest corrosion rate because of the ferrite and its chance to combined with oxygen and when comparing with specimen (B_1,C_1) we saw an decreasing in corrosion rate which emphasize the heat treatment role in computing combined phases which mainly decrease the corrosion rate

Fig. 5 Shows the electrochemical behavior of welded joint in 3.5% NaCl at various temperature that represented the corrosion behavior [cathode and anodic polarization curve] for all specimens that are categorized in **Table 2.** We see different corrosion current density and potential for all specimens which show the corrosion rate calculated by using Tafel equation. It has been observed that increasing in temperature media causes an increasing in corrosion rate since by raising temperature oxygen will be prevented from dissolving in water giving it an opportunity to combined with iron of the metal forming iron oxide which called rust or combined with water chloric ion to format an acidic media that contributed in increasing corrosion and it is obvious at 50,75 C^o where it is obvious where corrosion results of specimen A gives the highest result in comparing with specimens (B)and (C),this is agree with(**Edna Keehan** ,2004).and this is clear for the effect of the applied heat treatment in reducing corrosion rate for the planes of the grains Further the corrosion behavior of welds largely depends on heterogeneity of their microstructures. The submerged welding process induces dramatic changes in microstructures which are changed from coarse cast structure in the weld zone to fine recrystallized structure in HAZ and wrought structure in the base metal

normalizing heat treatment contributed in achieving this heterogeneity of the microstructures comparing with the metal joint without heat treatment in quenching we obtained the martinsied phase from the combined of ferrite and cementite which reduce the opportunity to ferrite to combined with oxygen reducing by that corrosion rate .

CONCLUSIONS :

1- Homogeneity in grain size gives the best results in corrosion resistance which was achieved by normalizing

2- Increasing in Solution media temperature cause decrease in corrosion resistance.

3- Quenching has an effective role in reducing corrosion rate but in less value from normalizing.

Table 1 the chemical composition of the used metal

Element	Nominal value	Actual value
C	0.2	0.18-0.23
Si	0.009	0.05
Mn	0.65	0.03-0.6
Cr	0.011	-
Mo	0.04	-
Cu	0.041	-
Co	0.04	-
V	0.09	-
W	0.03	-
S	0.05	0.05
Ni	0.017	-
Ti	0.01	-
P	0.04	0.04

Table 2 chemical composition of the weld wire EM12K.70-18

Element	C	Mn	Si	P	S
Wt. %	0.1	1	0.25	0.03	0.03

Table 3 categorization of specimens

Specimen symbol	state
A	As received
B	Quenching heat treatment
C	Normalizing heat treatment

Table 4 the corrosion results of all specimens

Samples	I $\mu A/Cm^2$	Emv	C.R (mpy)
A1	16.29	-655.9	7.61
A2	63.31	-694.2	27.85
A3	75.44	-688.1	33.19
B1	13.34	-522.5	5.86
B2	72.25	-681.8	31.79
B3	85.4	-727.0	37.57
C1	3.29	-498.9	1.44
C2	1.6	-488.5	7.04

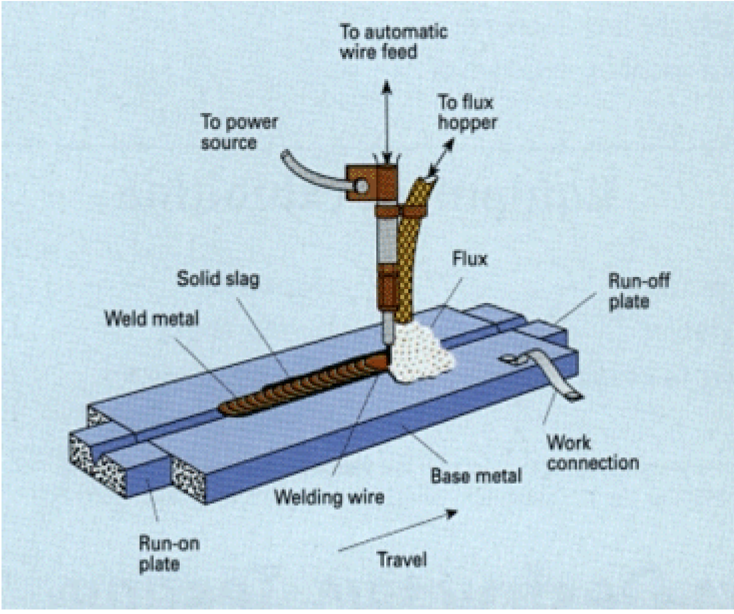


Fig. 1 Submerged-arc Welding process

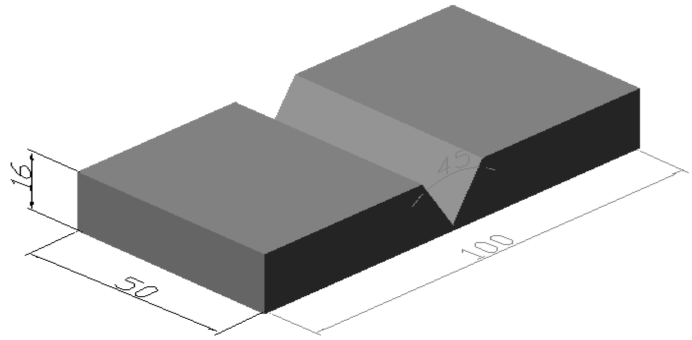


Fig. 2 The design and dimensions of single V-butt joint

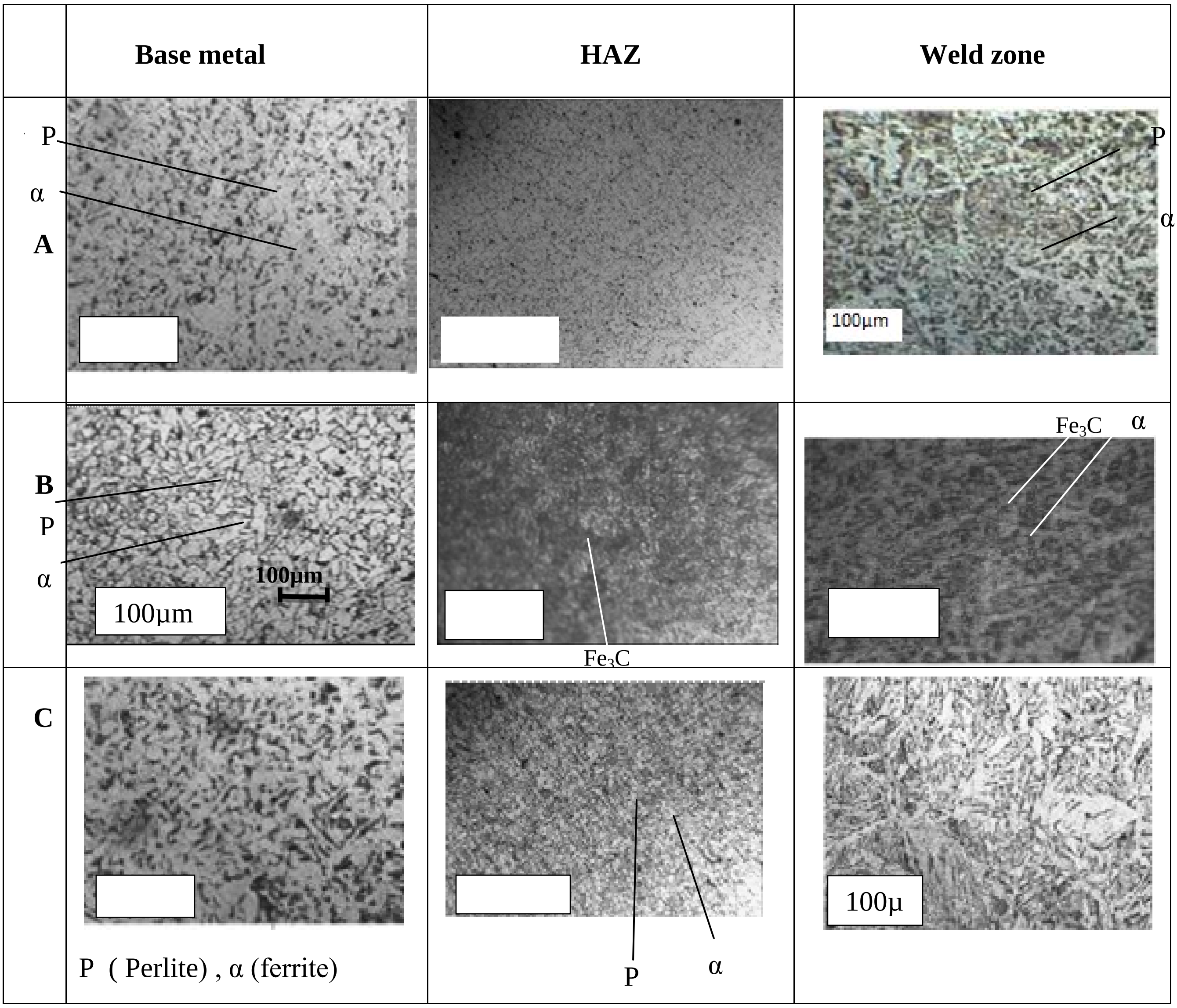


Fig. 3 microstructure of all speceimens which are catogized in **Tab. 3**

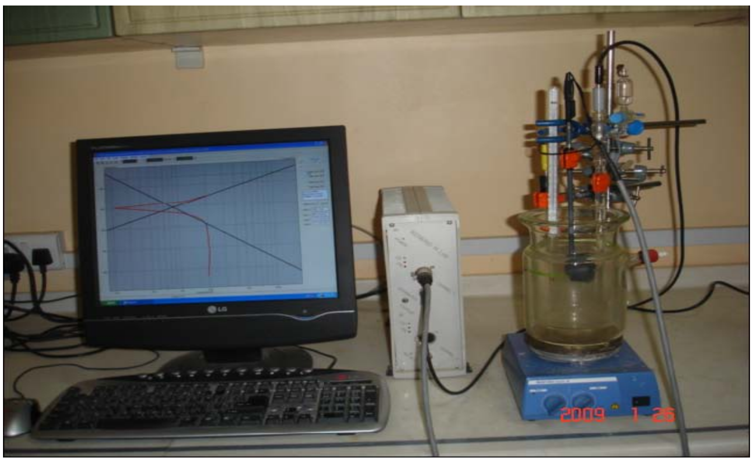
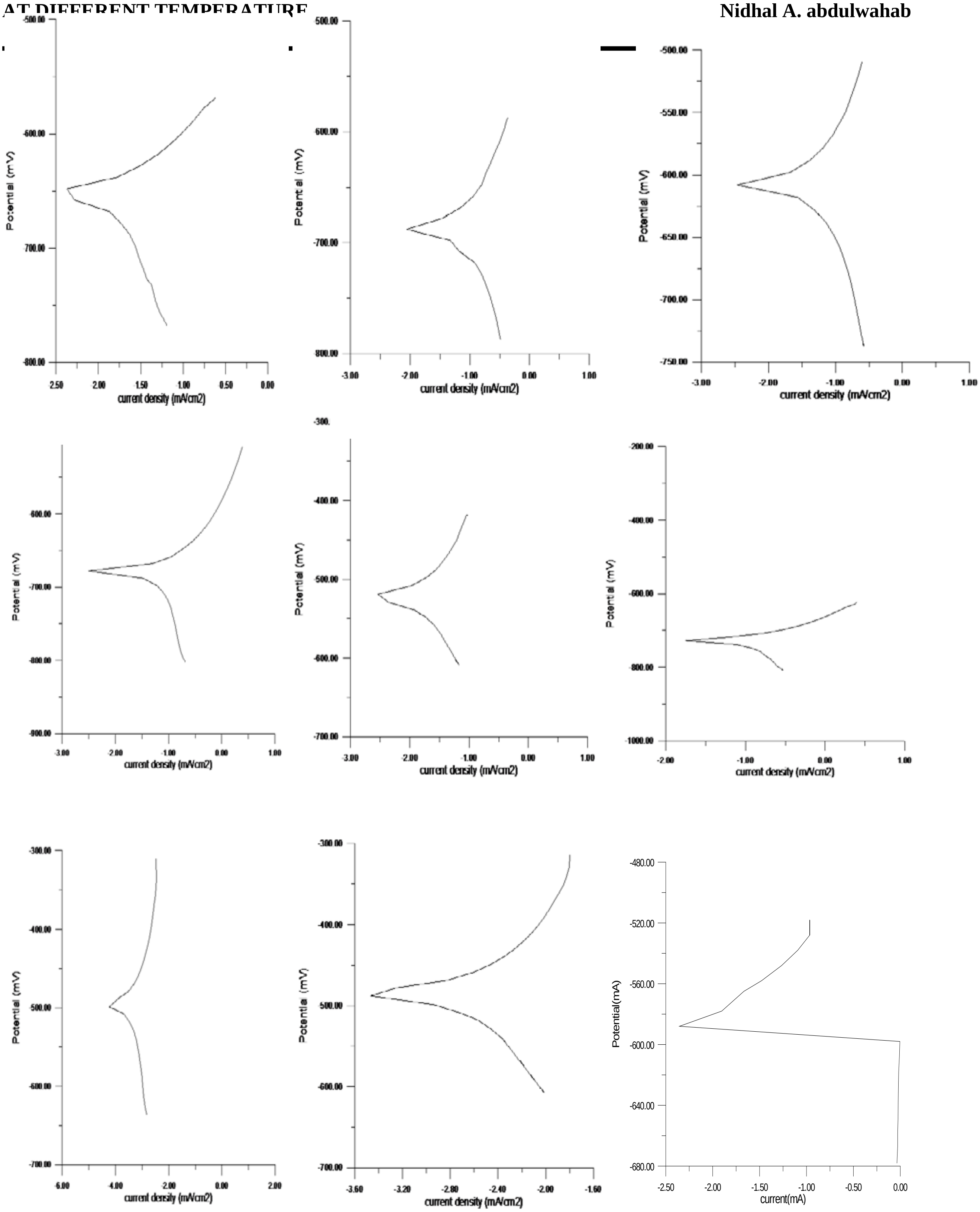


Fig. 4 The electrochemical corrosion unit



Pol-C_3-75

Fig.(5) the electrochemical behavior polarization for all specimens

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