CORROSION BEHAVIOR OF GRAY CAST IRON IN SEA WATER AT DIFFERENT PARAMETERS [+]

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Abstract :

The corrosion behavior of gray cast iron in sea water at diverse temperatures (25, 50 and 75) °C and diverse velocity (1, 2 and 3) m/min was actualized. Many specimens were prepared in dimensions of (1.5* 1.5 * 0.3) cm according to ASTM G7-1-31then electrochemical potential state cell was used for corrosion tests, the positive electrode (anode) was signifies the test specimen while the cathode was made from tungsten metals, the voltage was determined by open circuit and associate with the positional of metal in the electrochemical series then voltage was increased + 100 mV, at each 10-mV increasing in the current and determine the corrosion current Sea water (3.5% NaCl in 1 litter distill water) temperature altered after each test then varying the velocity after each test (1, 2 and 3) m/min at stable temperature sea water 25 ^{o}C, calculating corrosion rate by using Tafel equation. Another test implemented such as microstructure examination using optical microscope. The results show that the corrosion rate increased with increasing solution temperature this is because of the prevention of oxygen from dissolving in water while the corrosion rate decreases by increasing velocity of sea water. Since the movement of the liquid avoids the formation of sums and ions gathering on cathode electrode where corrosion can simply improve.

Keyword: gray cast iron, corrosion, media temperature, media velocity.

سلوك التآكل لحديد الزهر الرمادي في ماء البحر عند متغيرات مختلفة

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المستخلص:

هدف البحث دراسة سلوك التآكل لحديد الزهر الرمادي في ماء البحر عند ظروف متغيرة من درجة حرارة وسرعة وسط، أذ تم تصنيع عينات أختبار التآكل من المعدن بأبعاد (1.5 x 0.3 1.5 x) وفق مواصفات القياسية ASTM G7-1-31 لأجراء أختبار تآكل كهروكيميائي بطريقة المجاهد الساكن أذ تم أمرار تيار كهربائي في خلية تتألف من قطبين أحدهما قطعة العمل والثاني قطب من تنكستن عند جهد حدد من دائرة مفتوحة حسب موقع المعدن في السلسلة الكهروكيميائية ،وبعدها تم زيادة الجهد بـ (100 +) ملي فولت عند كل 10 ملي فولت يزداد التيار، وأن التيار الذي يؤدي الى زيادة في الجهد يمثل تيار التآكل، وتم حساب تيار التآكل أعتماداً على معادلة تافل. في كل أختبار يتم تغيير درجة حرارة الوسط (25، 50 و 75) درجة مئوية وبعدها تم تثبيت درجةالحرارةعند 25 درجة مئوية وتغير سرعة الوسط (1، 2 و 3) م / دقيقة لتحقيق هدف البحث. تم أجراء فحص البنية المجهرية بأستخدام مجهر ضوئي ذو كاميرا للتعرف على التركيب الداخلي للمعدن وتأثيره على معدل التآكل. ومن النتائج التي تم الحصول عليها تبين أن بزيادة درجة

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الحرارة يزداد معدل التآكل بسبب منع الحرارة لذوبان الأوكسجين في الوسط بين ما يقل معدل التآكل بزيادة السرعة لدورها في منع تجمع الأيونات عند القطب الموجب الممثل للحديد.

Introduction :

Cast iron is generally used for water transport purposes in addition to mild steel and other metals. The degree and price of damage produced by leakage in domestic water pipes has been rising through new years. The use of cast iron notable water supplies in building is now essential limited to the incoming main water supplies [1]. Alloying elements can play a leading role in the weakness of cast irons to corrosion occurrence. Silicon is the most chief alloying element used to advance the corrosion resistance of cast irons. Silicon is usually not measured an alloying element in cast irons until heights exceed 3%. Silicon heights between 3 and 14% offer some rise in corrosion resistance to the alloy, but exceeding about 14% Si, the corrosion resistance of the cast iron rises intensely [2]. Corrosion behavior of metals in sea water is influence by many environmental parameters such as, dissolved oxygen content, water temperature and velocity of media. The influence of water velocity on metals corrosion conduct has got a great attention by researchers, the velocity uniforms the catholic and anodic zone by removing a possible local excess of H^+ and OH^+ ions in an open circuit. Convey saw that when increase the velocity cause an increasing in corrosion resistance since tribute to mend the oxide film in a closed circuit. The influence of water velocity on corrosion resistance of steel pipes resulting that the corrosion resistance reduced in low or medium flow media by a percentage between 20-50% than fast flow. The second factor, water temperature, avoid oxygen from dissolved inwater and thinning in the oxide film when automatically joint with oxygen and this film is never be jointed after 120 ^{o} C[3]. Many researchers study the subject as [2]who studied the differences with time in the corrosion rate and corrosion current density on a cast iron electrode in different aqueous salt solutions such as KCl and NaCl, finding that corrosion rate relies on salt concentration and immersion time. [4]studied Ni-resist cast iron corrosion behavior in sea water under different temperature resulting that maximum corrosion rate is shown in the temperature range of 40-60 °C.[5] studied the effect of various salt kinds on the corrosion rate of cast iron resulting that NaCl gives the highest corrosion rate. [6] studying the corrosion of cast iron which used in freely aerated stagnant Arabian Gulf seawater (AGS) at room temperature. Corrosion was occurred by using weight-loss (WL) containing immersion the specimens from tow –ten days and cyclic potential dynamic polarization (CPP) was also examined. The result specified that the weight-loss of cast iron increases with increasing the time of immersion. Corrosion current and corrosion potential increase causes increase in corrosion rate. This paper aims to study the effect of two factors temperature and velocity of sea water on the corrosion behavior for gray cast iron.

Experimental procedure

Experimental work includes many steps as follows

1-Metal used

Gray cast iron according to AISI was chosen with chemical analysis as indicated in Table (1) which was conducted by ARL spectrometer at the General Company for inspection and engineering orientation.

Table (1) Chemical analyses of the used metal gray cast iron

ElementWt. %	C	Mn	Si	S	P	V	Mo
Standardvalue	3.23	0.6	2.7	0.12	0.6	0.08	0.13
Actualvalue	3.20	0.7	2.36	0.2	0.3	0.05	0.01

2- Preparation of Specimens:

corrosion test specimens were prepared as (15* 15 * 3) mm according to ASTM G7- l - 31 which include cutting the specimens from metal with the dimensions of (20 x20 x4) mm using a cutting tool then fabricating it by a miller machine to the final dimensions.

3- Categorization of Specimens:

After completing the preparations of specimens, they were categorized to two groups as shown in Table (2).

Table (2) Categorization of specimens.

Specimens Symbol	State
A_1	At temperature 25 ^{o}C
A_2	At temperature 50 ^{o}C
A_3	At temperature 75 ^{o}C
B_1	At speed 1 m/min
B_2	At speed 2 m/min
B_3	At speed 3 m/min

4- Microstructure examination:

Many steps were achieved to microstructure test as follow:

1- Treated the specimens by emery papers No. (240, 400, 500, 800, 1000 and 1200).

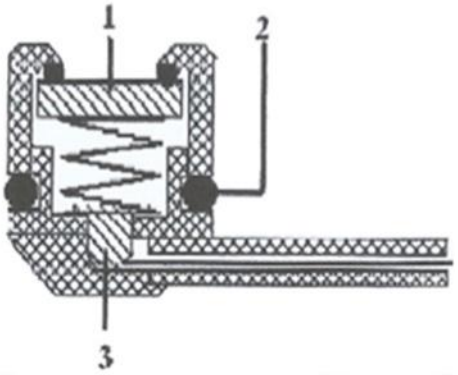
2- Polishing procedure was carried out using special polishing cloth with aluminum oxide (Al2O3) solution of grain size of 5μm.

3-To etch the structure (Nital) solution was used which consists of 2% of Nitric Acid and 98% of methyl alcohol.

4- A programmed microscope type advanced polarizing Dark-field metallurgical microscope MTJ Corporation in Ministry of Science and Technology was used to Photograph the microstructure. The photo is shown in Fig. (1).

5- Electrochemical Corrosion Tests:

The solution was prepared by dissolving 35 gm of NaCl in one liter of water thenmeasured its pH to be found equal to 6.8. The prepared specimen is fixed with in the holder revealed in Fig. (2).



1- Specimen 2-Seal 3- Electrical Connection.
Figure (1): Specimen holder.

The reference electrode was localized about (1mm) apart from the surface of the specimen to be examined. The reference electrode used in this paper was Saturated Calomel Electrode (SCE), while the auxiliary electrode was platinum type. The specimen holder (Working electrode), together with the reference and auxiliary electrode were inserted in their respective position in the electrochemical cell used for this purpose which can contain all these electrodes as shown in Fig. (3).

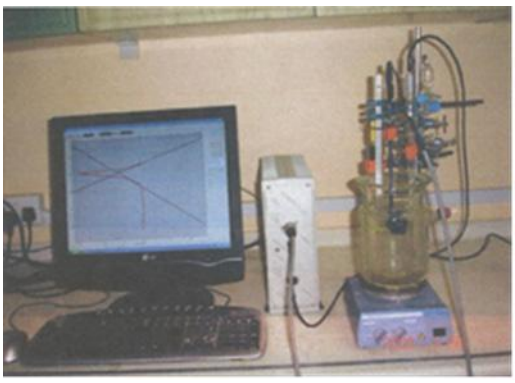


Figure (2): The electrochemical corrosion unit.

The cell used was made of glass. The potential change between the working and reference electrode and any current transient in the circuit of working electrode were auxiliary electrode can be determined by using the SCI Computer Software. The result and plots was recorded using window XP. Polarized resistance examinations were used to find the micro cell corrosion rates. In the examinations cell current analysis was taken through a short slow sweep of the potential. The sweep was occupied from (-100 to +100) mV relative to (OCP). Scan rate expresses the speed of potential sweep in mV/sec. In this series the current density versus voltage curve is nearly linear. A linear data fitting of the standard model provides an estimate of the polarization resistance, which used to determine the corrosion current density (icorr) and corrosion rate. The examinations were completed by using a WENKING MLab multi channels and SCI MLab corrosion gauging system from Bank Electronics-Intelligent controls GmbH, Germany 2007, as shown in Figure 3. The results of electrochemical corrosion rate are presented in Table (3) by using the following equation. [7].

C.R = 0.13* i cor * eq. wt / ρ (1)
mpy = mils per year.
i cor = corrosion current density (μA / cm2).
EW = equivalent weight of metal (g).
ρ = corroding species density (g/cm3).
C.R = corrosion rate (mpy)

Results and Discussion:

Fig. (3) Shows the microstructure of the used metal in this paper. The usual microstructure of gray iron is a matrix of pearlite with the graphite flakes dispersed throughout. The composition of gray iron usually contains 1 to 3% Si ,2.5 to 4% C, in addition to manganese, depending on the desired microstructure (as high as 1.2% in pearlitic and as low as 0.1% Mn in ferritic gray irons). Other alloying elements include nickel, copper,molybdenum and chromium where free graphite is the control phase in the matrix structure [7, 8], the existing ferrite has the role here to increase corrosion current density because it is combining with the oxygen which dissolved in sea water causing rust. This result gathered with temperature change in media in increasing corrosion rate which will be discussed as follow, finding the opposite effect velocity.

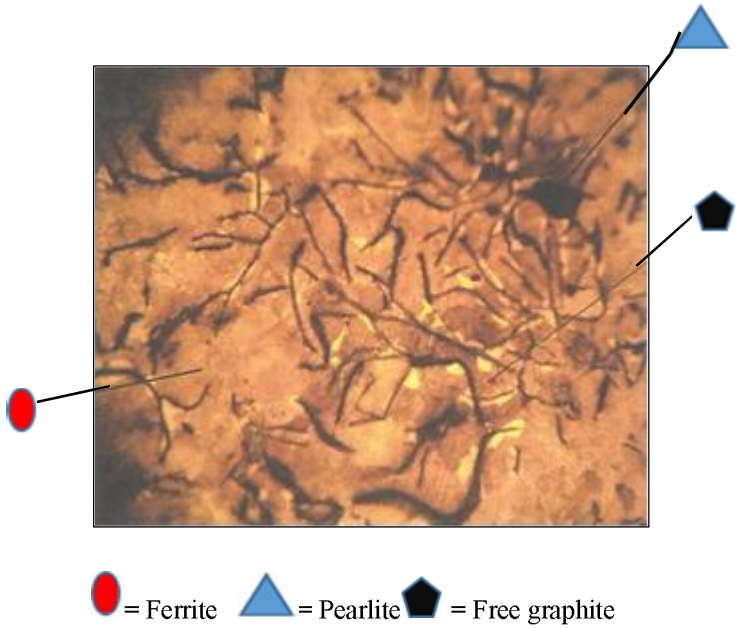


Figure (3): The microstructure of gray cast iron.

Fig. (4-1) to Fig. (4-6) shows the electrochemical polarization curves of cast iron in sea water 3.5% NaCl at various temperature and velocity that represented the corrosion behavior (cathode and anodic polarization curve) for all specimens that are categorized in Table (2). It can be seen different corrosion current density and potential for all specimens in Table (3) which shows the corrosion rate. In Fig. (4-1) to Fig. (4-3) It was observed that increasing in temperature 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 combined with water chloric ion to format an acidic media that contributed in increasing corrosion rate due to temperature contribute in increasing kinetic energy for molecule and increase(mass and charge) transfer from and

electrodes then increase cathodic and anodic reaction ,that is goes with specimen A3 comparing with the result of specimen A1 and in Fig. (4-4) to Fig. (4-6) we see the opposite effect of velocity on corrosion rate whereas increasing velocity there is a decreasing in corrosion rate because the movement of water prevent ions and reducing the chance for ion from combined with metal, this reduced corrosion rate and this from gathering on poles is obvious in specimen B3. also increasing velocity made to remove the passive layer from surface layer which before long formed again depending on kind of media and velocity [9].

Table (3) Results of Electrochemical Test.

Samples	State	i_{corr} $\mu A/cm^2$	EmV	C.R (mpy)
A_1	25°CAt 1m/min	111.51	-687.4	49.06
A_2	50°CAt1m/min	226.41	-750.8	99.62
A_3	75°C At 1m/min	242.41	-786.4	106.66
B_1	1m/minAt 25°C	157.5	-665.1	69.3
B_2	2m/minAt 25°C	91.1	-695.1	40.084
B_3	3m/minAt 25°C	89.93	-684.4	39.56

Conclusion:

1- Temperature increases corrosion because of increasing kinetic energy of particles and then increasing mass and charge movement from to poles of the electrical cell due to that the cathodic and anodic chemical reaction increases and the corrosion speed increased and the lowest corrosion rate is at media temperature for 25 C°.
2- Velocity have contrary effect on corrosion rate since it's reduce corrosion current density, by increasing corrosion speed media speed will erase prevented layers established on the metal surface, which means media speed involves in move foils to metal surfaceand create prevented layers.
3- The better obtained result for low corrosion rate was at temperature 25°C and velocity of 3m/min.

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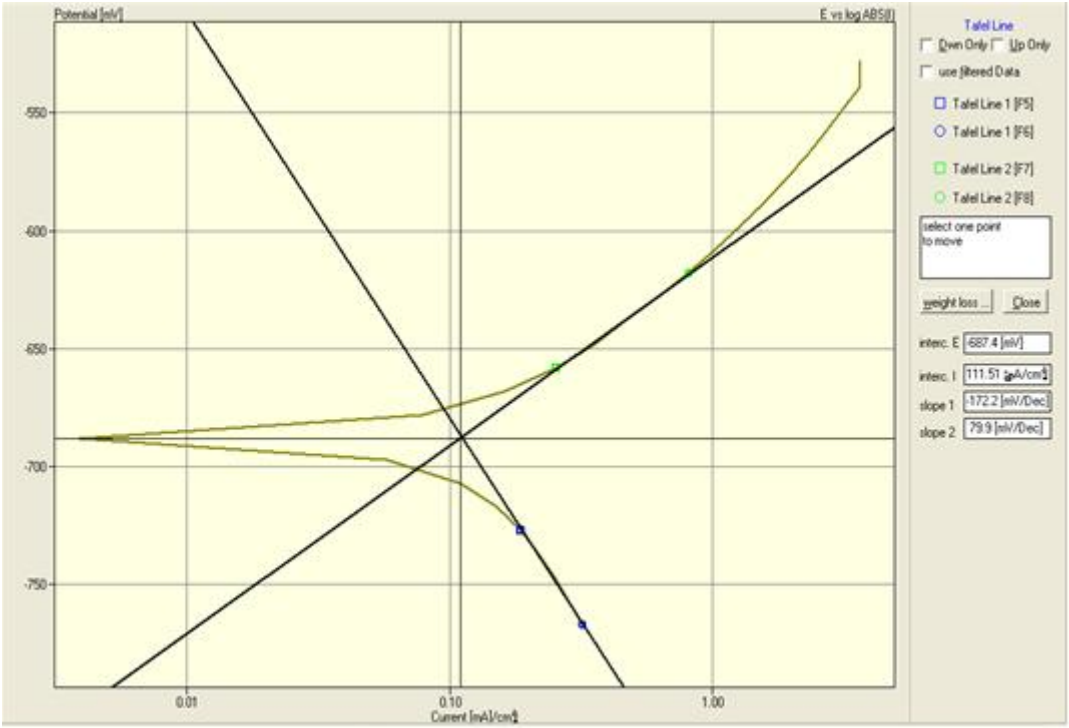

Figure (4-1): Electrochemical behavior of A_1 specimen.

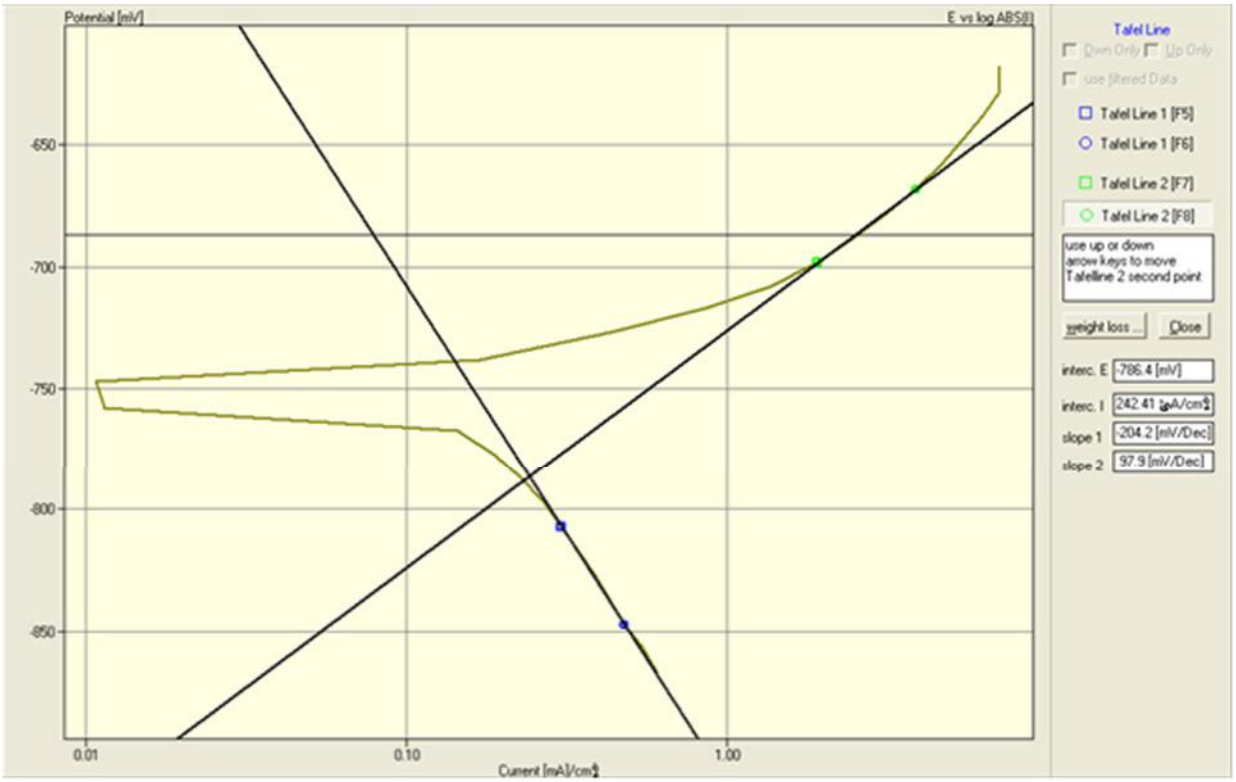

Figure (4-2): Electrochemical behavior of A_2 specimen.

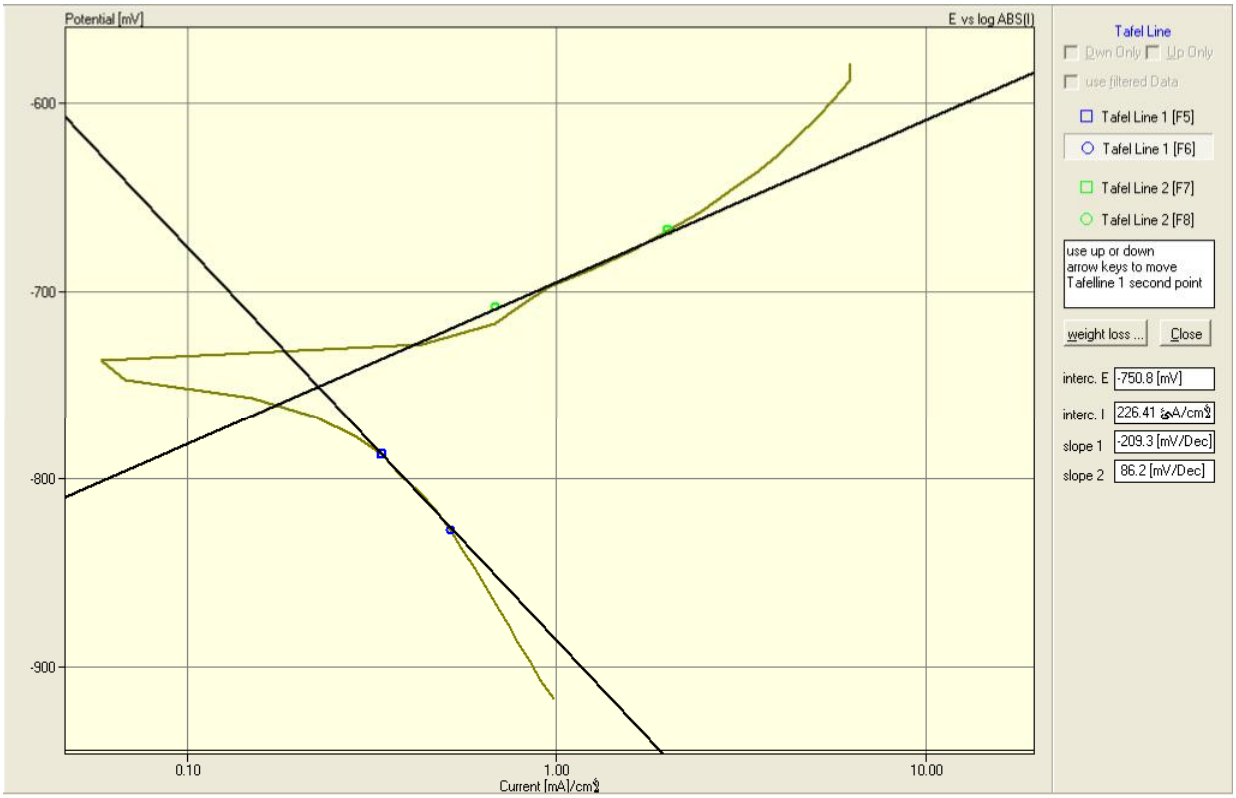

Figure (4-3): Electrochemical behavior of A_3 specimen.

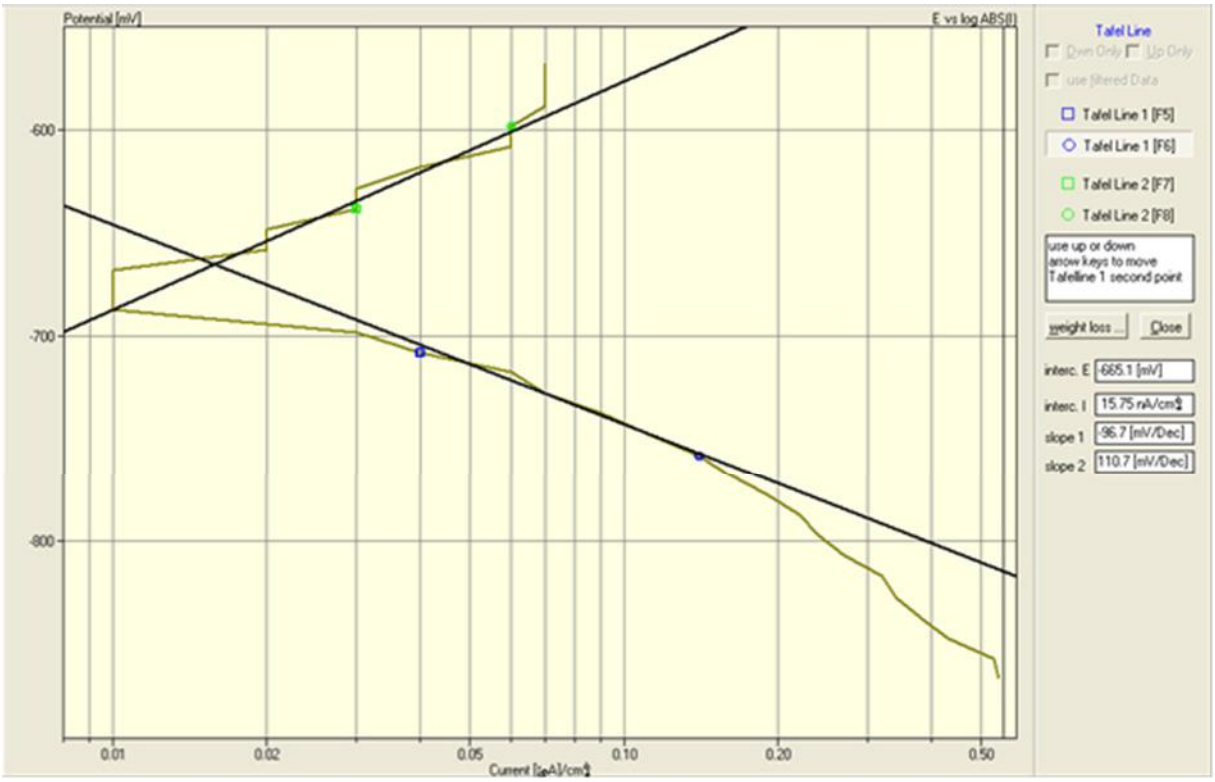

Figure (4-4): Electrochemical behavior of B_1 specimen.

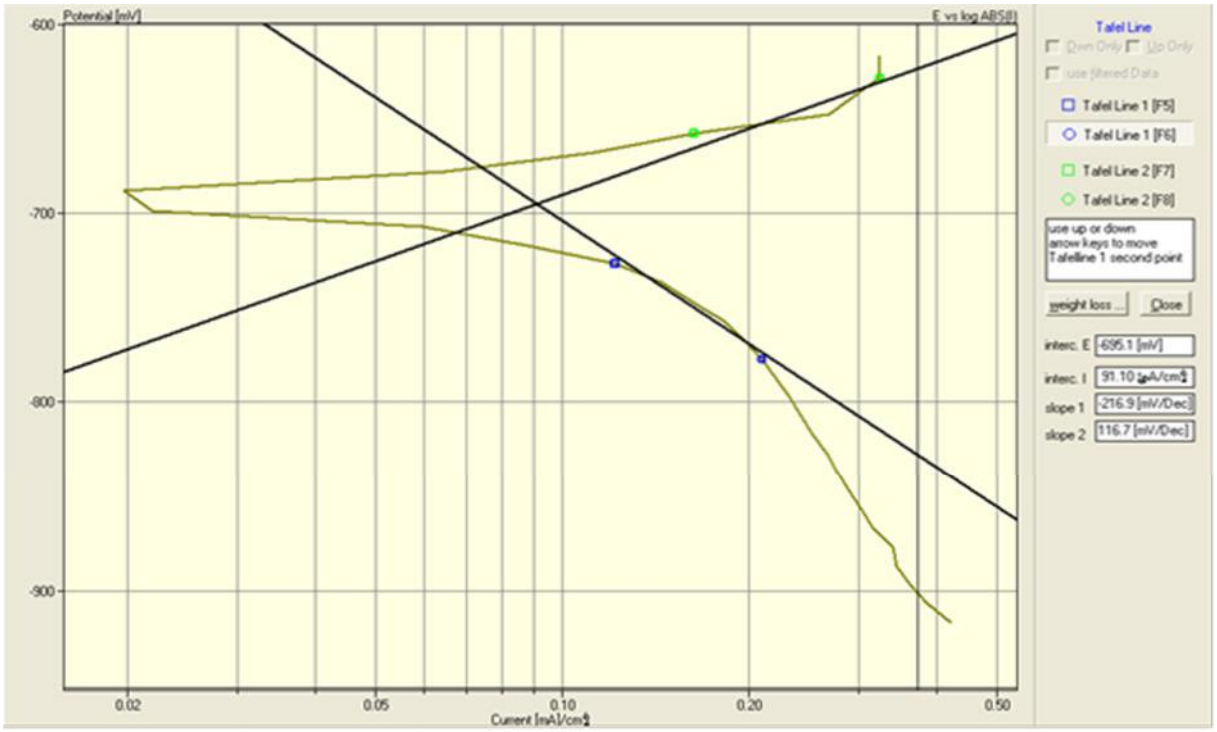

Figure (4-5): Electrochemical behavior of B_2 specimen.

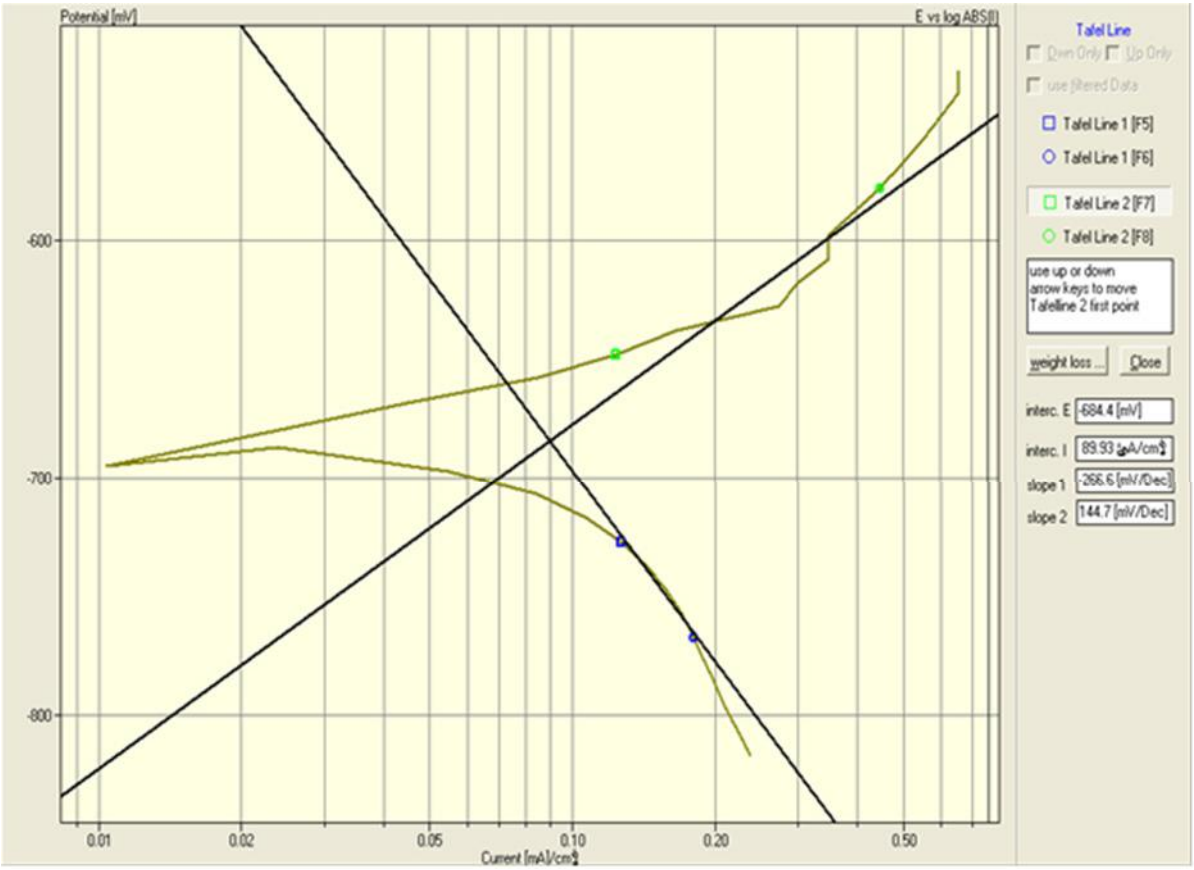

Figure (4-6): Electrochemical behavior of (B_3) specimen.