THE EFFECT OF INHIBITION ON CORROSION RESISTANCE OF AISI 1020 IN SEA WATER [+]

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Abstract :

This paper aims to study the effect of inhibitor addition to sea water on corrosion rates of St 1020 according to AISI . Many corrosion specimens were papered from the metal of dimensions of (15*15*3) mm according to ASTM G71-31 then Optical microscopy was used to observe the microstructure

Corrosion tests were investigated by electrochemical potential state cell in 3.5% NaCl salt water (sea water) where the test specimen represents the positive electrode (anode) pole while tungsten electrode represents the cathode, the voltage was determined by open circuit and compared with the positional of metal in the electrochemical series then voltage was increased ±100 mv, at each 10mv. then record the current causes the change of voltage which will called the corrosion current then calculating corrosion rate by using Tafel equation.

The inhibitors Sodium Nitrate ($NaNo_2$) and Sodium molybdate in the concentration of 5% in addition to a synergistic inhibition of the both inhibitors in equal percentage of 2.5% for each one were added to the prepared sea water to show the effect of these inhibitors on corrosion behavior, and then corrosion rate calculated using Tafle equation.

Results show that all the used inhibitors have contributed to reduce the corrosion rate while using the synergistic (blend) inhibitors gives the best results; this is due to the synergistic action of these inhibitors in reducing the anodic and catholic activities thus promoting a continuous and protective film on the alloy from corrosion.

Keywords Corrosion rate, inhibitor, carbon steel, sea water

تأثير المثبطات على مقاومة التآكل للفولاذ (AISI 1020) في ماء البحر

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المستخلص:

يهدف البحث الى دراسة تأثير اضافة المثبطات على مقاومة التآكل لفولاذ كاربوني (AISI 1020) في ماء البحر، اذ تم تحضير عينات اختبار التاكل 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 . تم اضافة المثبطات بنسبة تركيز 5% (نتريت الصوديوم، ،مولبيد الصوديوم، ونتريت الصوديوم ومولبيد الصوديوم معا الى ماء البحر ثم اجراء اختبار التاكل الكهروكيميائي باستخدام جهاز المجهاد الساكن اذ تم امرار تيار كهربائي في خلية تتألف من

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قطبين احداهما قطعة العمل والثاني قطب من التنكستن عند جهد حدد من دائرة مفتوحة حسب موقع المعدن في السلسلة الكهروكيميائية ، وبعدها تم زيادة الجهد ب (± 100) ملي فولت عند كل 10 ملي فولت ، وأن التيار الذي يؤدي الى تغير في الجهد يمثل تيار التآكل ، وتم حساب تيار التآكل اعتمادا على معادلة تافل . تم اضافة المثبطات بنسبة تركيز 5% لكل من نتريت الصوديوم، ،مولبيد الصوديوم،وكذلك اضافة نسب تراكيز 2.5% من نتريت الصوديوم و 2.5%مولبيد الصوديوم للحصول على تركيز 5% منهما معا) ووجد ان جميع المثبطات ساهمت في تقليل معدل التآكل وان استخدام مثبطين معا اعطى افضل النتائج اذ عمل على تقليل معدل التآكل للمعدن بنسبة 20% مقارنة للوسط بدون مثبط.،لأن استخدام المثبطات المتزامنة قلل من التفاعلات عند قطبي الكاثود والانود وبهذا تكونت طبقة حماية مستمرة فوق المعدن لحمايته من التآكل.

Introduction:

Corrosion of metals is a major industrial problem that causes a severe damage in various engineering fields and attracts a lot of investigations in recent years [1].
Most metals are inherently unstable and have the natural tendency to react with their environments to obtain lower energy by forming a chemical compound in a more stable state. Steel materials which are very susceptible to attack in aggressive media are the commonly exposed metals in industrial environments
Mild steel is particularly used in most structural shapes such as beams, plates, bars, and pipes used in seawater which contains chlorides
of corrosion cells resulting from the presence of an electric voltage between different regions of the metal surface, for that to reduce corrosion depends on preventing leakage of electricity from facilities to the surrounding soil or water, this can be achieved either by the separation of metal surfaces from corrosive environments or by changing the environment [2]
These various methods of corrosion prevention include
1- Cathodic protection (CP) which is a technique used to control the corrosion of a metal surface by making it the cathode of a cell. The simplest method to apply CP is by connecting the metal to be protected with a piece of another more easily corroded "sacrificial metal" to act as the anode of the electrochemical cell, then the sacrificial metal will corrodes instead of the protected metal [3]
2- Coating where a variety of different coatings substance can be applied to the metal to prevent oxidation by keeping the part from exposure to oxygen and water then the coating material will corrode instead of the protected ferrous metal part [4]
3- Anodic protection which is used in giant areas by applying a sacrificial anode; a block of metal of the sacrificial anode will be more reactive than the corroded metal (iron for example) and acts as a source of electrons for the iron, When oxygen takes electrons from the iron during the process of rusting iron atoms simply take electrons from the reactive metal as shown in the following equations [5].

$Fe \rightarrow Fe^{2+} + 2e^-$ ---------(1)
$O2 + 2H_2O + 4e^- \rightarrow 4OH$ ----------(2)
$Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$ ---------- (3)
$Fe(OH)_2 + O_2 \rightarrow 2H_2O + 2Fe_2O_3.H_2O4$ ---------- (4)

4- The use of corrosion inhibitors, which is a chemical compound added to the environment in order to reduce the rate of metal corrosion by forming a thin film onto the surface of corroding metal preventing by that any chemical reactions in the media, or change the

characteristics of the environment resulting in reduced aggressiveness as the National Association of Corrosion Engineers (NACE) editor describes, The common inhibitors are chromates, nitrates, benzoates, phosphates, silicate and molybdate [6]

Synergistic inhibition has been proved by several authors as an effective means to improve the inhibitive force of inhibitor .they obtained that Synergistic effect of inhibitors is a combined action of inhibitors greater in total effect than the sum of the individual effects.

Several studies have been carried out on these corrosion inhibitors

Braithwaite [7] used molybdenum as a corrosion inhibition in industry is important, for it is a non-oxidizing anodic inhibitor and the addition of sodium molybdate significantly reduces the nitrite requirement of fluids inhibited with nitrite-amine, and improves the corrosion protection of carboxylate salt fluids

Aramide [8] study the effect of applying sodium nitrate in different concentrations from 2-10% to sea water and by using the weight loss method to calculate corrosion rate, he found that for (120-264) hours of immersion the 4% inhabitation percentage gives no loose in weight and then the best corrosion resistance.

Afolabi [9] compare the inhibition performance of potassium chromate and sodium nitrite and investigate the synergistic effect of these inhibitors on mild steel immersed in chloride and sulphide media getting that, the combination of sodium nitrite and potassium chromate inhibitors produced an enhanced inhibition performance on the mild steel giving a better corrosion resistance results than individual effect in both medias.

The aim of this work is to study the effect of using 5% of concentration for synergistic inhibitors of (Sodium Nitrate, and Sodium molybdate) on the corrosion resistance of AISI 1020 .

Experimental work :

The experimental work is summarized as follows:-

1- Materials

Low carbon steel was chosen according to AISI 1020 the chemical composition was conducted by ARL Spectrometer (German source) in the specialized institution of engineering industries of Industry ministry and it is shown in Table (1).

Table (1) chemical composition of carbon steel AISI 1020

Element wt %	C	Mn	Si	Ni	Cr	Mo	S	P
Actual value	0.20	0.41	0.012	-	0.011	0.004	0.005	0.009
Standard value	0.18-0.23	0.3-0.6	0.001	-	-	0.05	0.04	0.04

2- Preparation of test specimen

Many specimens of the steel used were prepared according to standard specification testing ASTM (G71-31) in dimensions of (15, 15. 3) mm.

3- Categorization of specimen

The specimens which prepared categorized into groups as shown in **Table (2)**

Table (2) Categorization of specimens

Group symbol	State of specimen
A	immersed in sea water without inhibitors
B	immersed in sea water with 5% Sodium Nitrite
C	immersed in sea water with 5% Sodium molybdate
D	immersed in sea water with(2.5% of Sodium molybdate +2.5% of Sodium Nitrite)

4-Metallurgraphic Examination

Specimens were prepared as following for microstructure test

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

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.

Microstructures of specimens were examined with optical microscope provided with computer and digital camera (Metallurgical Microscope MTJ Corporation). The Microstructure of the alloy is shown in **Fig. (1)**

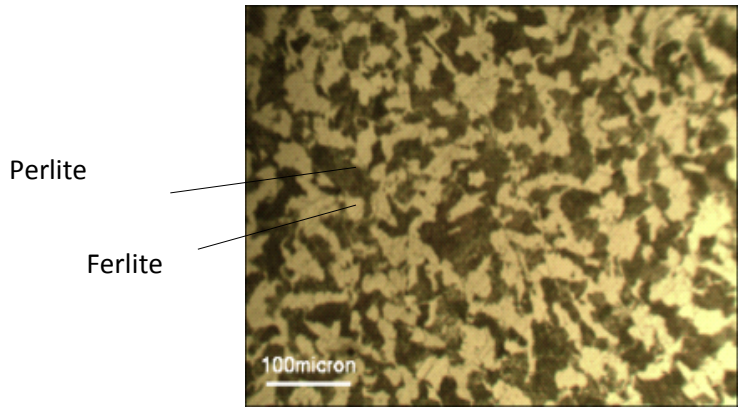

Fig. 1 Microstructure of (AISI1020)

5- Corrosion Test

Corrosion test carried out as follows

1- Preparation the Corrosion Solution

The corrosion solution is prepared, which is consists of: dissolving a 35 gm of sodium chloride (NaCl)with 1000 gm of distil water. The pH of the solution is measured by pH meter and it's found 6.9≅7

2- Preparation three corrosion solutions by adding the inhibitors mentioned in Table (2) to the prepared sea water

3- Electrochemical Corrosion Tests

The prepared specimen of area 10 x 10mm 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 (OCP) 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 (2**.)

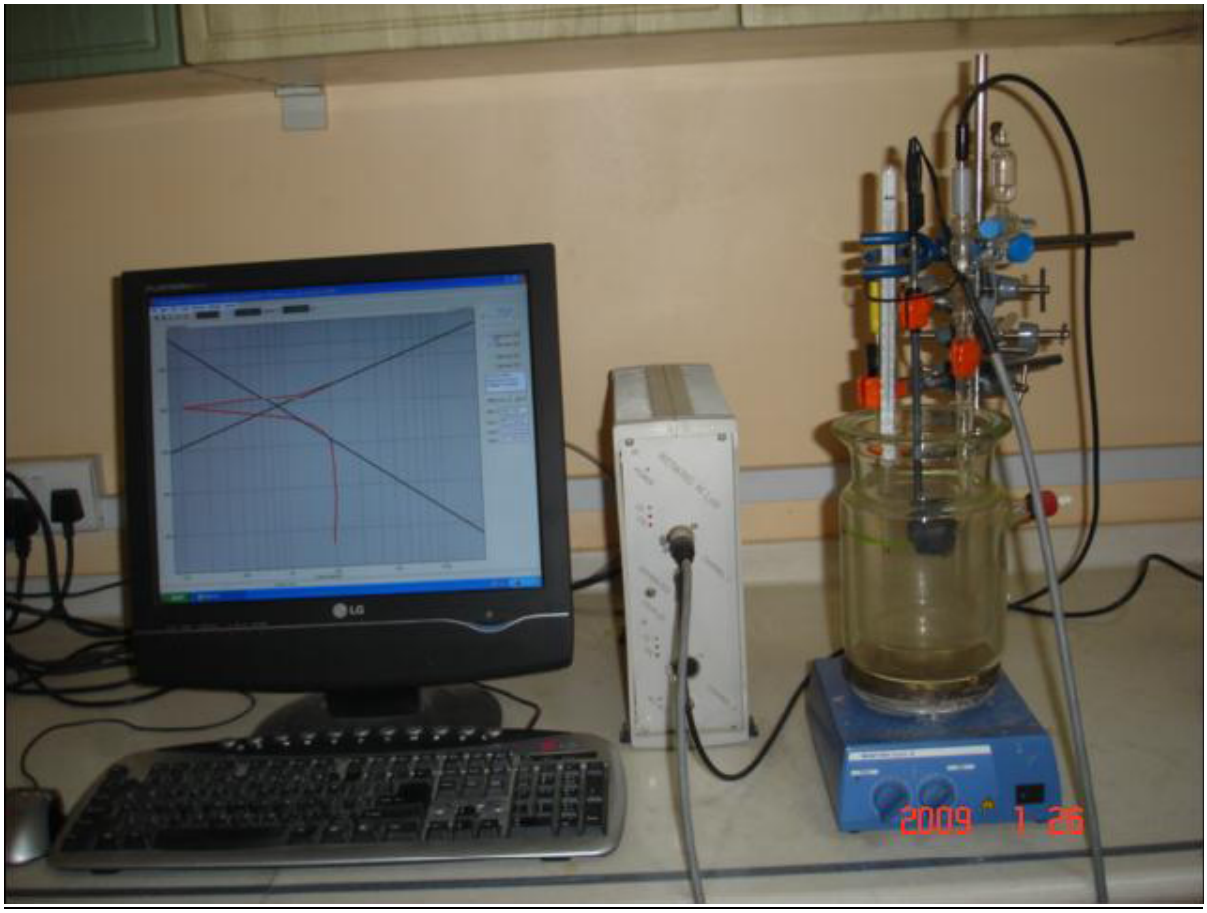

Fig. (2) Electrochemical potential state

Parameters, such as corrosion potential (Ecorr) and corrosion current (Icorr) as shown in **Tab.(3)**. These parameters will leads to calculate the corrosion rate according to Tafel equation below [10].

C.R (mpy) = 0.13 * Icorr * eq.wt / ρ (5)
Where

Icorr=corrosion current density (μAcm^2)
eq.w=equivalent weight of the corroding species,
ρ = density of the corroding species, (g/cm^3).

Table (3) electrochemical corrosion rate results for all specimens in Table (2)

Specimen	I core $\mu A/ cm^2$	E core (mV) SCE	Corrosion rate (mpy.)
A	12.03	-645.2	5.293
B	8.77	-649.4	3.858
C	8.06	-647.6	3.546
D	2.34	-560	1.0296

Results & Discussion:

The use of corrosion inhibitor, which is a chemical compound added to the environment in order to reduce the rate of metal corrosion by forming a thin film onto the surface of corroding metal preventing by that any chemical reactions in the media, or change the characteristics of the environments.
Table (3) shows the results of corrosion rate for all specimens and **Fig. (3)** represent the cathodic and anodic behavior of the used metal in sea water for all specimens, specimen A which represent the base metal gives the highest corrosion rate since corrosion occurs by the existing of ferrite phase which will combined with the dissolved oxygen producing iron oxide (rust) as shown in **Fig.(1)** which shows the microstructure of the metal containing the Ferrite and Perlite phases..
On the other hand using inhibitors in sea water lowered the value of corrosion rate of used metal, Specimen B which used Sodium Nitrite as an inhibitor gives a lower corrosion rate than speceimen A for Nitrite is considered as an anodic inhibitor which added to ferrous metals and oxides ferrous compounds to ferric Fe^{+2} to Fe^{+3} (equation1) with a concomitant rise in pH, so that the very sparingly soluble higher oxides or hydrous oxides arc readily precipitated at anodic places and stifle corrosion.
Specimen C used Sodium molybdate as inhibitor gives further reduction in corrosion rate since this inhibitor is known to be an effective oxidizing anodic inhibitor which maintains the steel in the passive state thus preventing breakdown of the passive oxide which can lead to localized corrosion in chloride media, is due to the molybdate adsorption on the surface in competition with negatively charged aggressive chloride ions by hydrogen bonding between the oxygen atom of the molybdate and hydroxyl hydrogen atom of the hydrous oxide layer on the surface. This makes surface negatively charged and prevent corrosion from the aggressive Cl^- attack
At the moment of immersion for Specimen (D) that uses both Sodium Nitrite and Sodium molbydait as inhibitors a potential of −150 mV was recorded. This potential moves fast toward negative values around −500 mV as a result of the breakdown of the molybdate layer formed on the steel surface. Simplistically, when iron corrodes, ions, in conjunction with other anions adsorb to form a nonprotective complex with Fe^{2+} ions. The result is a soluble and shallow protective film due to the poor oxidation ability of Na_2MoO_4. Because of dissolved oxygen or other oxidizers in the water, some of the Fe^{2+} ions are oxidized to the ferric (Fe^{3+}) state, and the ferrous molybdate is transformed to ferric molybdate, which is both

insoluble and protective in neutral and alkaline waters, this is well agreed with work [8] achieved in the success of using two inhibitors and its synergistic inhibition in reducing the corrosion rate in a noticeable way.

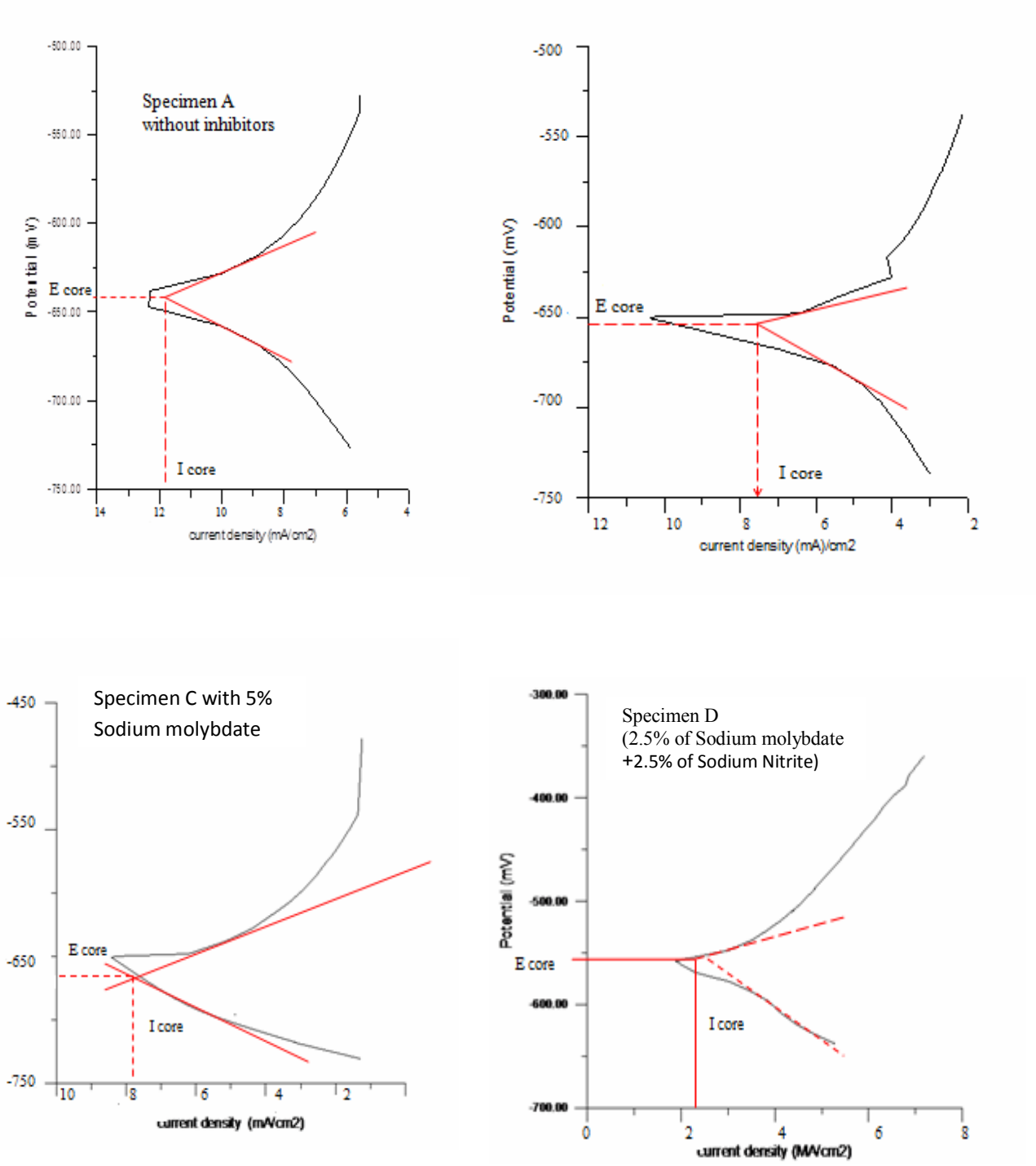

Fig. (3) Potential static polarization results for all specimens

Conclusions :

1-All inhibitors (Sodium Nitite, Soduim Molybdate) for carbon steel leads to reduce the corrosion rate by forming a film on the surface prevent chemical reactions for ferrite phases with oxygen.
2- Sodium molpydait gives the best reduction in corrosion than Sodium Nitrate using as individual
3- Combination of Sodium Nitite, Soduim Molybdate enhanced inhabitation performance on carbon steel giving low corrosion rate than individual effect in a percentage of 20%

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