Corrosion Behaviour of Aluminium Alloy 7020-T6 welded Joint in Sea Water at Different Variables

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were welded by using inert gas metal arc welding method (MIG)to obtain butt joint with geometry of single V at 45^{0}with two pass.

The joints were tested by X-ray radiography and faulty pieces were excluded.and the indefectible joints were subjected to stress relief heat treatment including heating the joint to evaluating temperature 100 C^{0}for one hour and air cooling.Optical microscopy with camera was used to observe the welded joint microstructure.Micro hardness test were carried out using Vickers instrument to measure the hardness of the welded joint.

Corrosion behavior of welded jointspecimens in 3.5% NaCl solution at different media velocity (1, 2, 3) m/min and temperature of (25, 50, 75) ^{0} C for each velocitywas examined using Tafelpolarization measurements. It is determined byopen circuit potential (OCP) after that the cell's current is changed due to the increasing in potentialby ±100mV to calculate corrosion current then corrosion rate.

The results show that the corrosion rate is increased with increasing solution temperature. This is because of the prevention of oxygen from dissolving in water, while the corrosion rate decreases with increasing velocity of sea water since the movement of the liquid prevents the formation of deposits and ions gathering on cathode pole where corrosion can easily develop.

when comparing corrosion rate between the welded and unwelded samples, the welded samples gives more corrosion rate value since the cycle of heating and cooling that occurs during the welding process affects the microstructure of welds.

Keywords: Aluminum Alloys, MIG Welding, Corrosion Resistance

سلوك التآكللوصلات لحام تناكبية لسبيكة الالمنيوم 7020-T6 في ماء البحرعند متغيرات مختلفة

الخلاصة

ان المعدن المستخدم في البحث هو سبيكة المنيوم 7020-T6 اذ تم استخدام صفيحتين في لحام وصلة تناكبية تم لحامها بطريقة لحام القوس الكهربائي المحمي بغاز خامل بعد عمل زاوية تحضيرية من جهة

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واحدة مقدارها45درجة على شكل حرف V وبشوطين ,ودراسة تاثير عملية اللحام على مقاومة التاكل في ماء البحر عند سرع متغيرة(1و2و3) ملم/دقيقة ودرجة حرارة متغيرة (75و50و25) درجة مئويةمقارنة بالسبيكة الاساس.
بعد عملية اللحام والتاكد من خلو الوصلة من العيوب من خلال فحصها بواسطة جهاز X-ray radiography تم تحضير عينات اختبار التاكل بعد قطعها من الوصلة بابعاد 15*15*3 ملم وفق المواصفة القياسية ASTM G71-31 اتبعتها عمليات تحضيرمنتنعيم وصقل لاجراء فحص البنية المجهرية باستخدام المجهر الضوئي ذو كاميرا للتعرف على البنية المجهرية لمناطق اللحام والمعدن الاساس ثم اجراء اختبار الصلادة بواسطة جهاز فيكرزللتعرف على صلادة وصلة اللحام .
اجري اختبار تاكل كهروكيمياوي بطريقة المجهاد الساكن اذ تم حساب التيار الكهربائي المتولد في خلية تتألف من قطبين يمثل احداهما قطعة العمل والقطب الثاني قطب من البلاتين عند تسليط جهد يحدد حسب موقع المعدن في السلسلة الكهروكيميائية، ثم زيادته ب (±100) ملي فولت للتوصل الى قيمة تيار التآكل من خلال رسم منحنى تافل ثم حساب معدل التآكل.
ووجد من نتائج التاكل للعينات الملحومة والسبيكة الاساس عند درجات حرارة وسرع وسط مختلفة ان بزيادة درجة الحرارة يزداد معدل التآكل بسبب منع الحرارة لذوبان الاوكسجين في الوسط بينما يقل معدل التآكل بزيادة السرعة لدورها في منع تجمع الايونات عند القطب السالب.وعند مقارنة نتائج التآكل بين العينات الملحومة والسبيكة الاساس اعطت العينات الملحومة نتائج تآكل اكثر بسبب تأثر البنية المجهرية للوصلة الملحومة بدورة التبريد والتسخين الحادثة من جراء عملية اللحام.

INTRODUCTION

Al-Zn-Mg (7xxx series) alloys are getting more interest in Industry. It is widely used in welded engineering structural components, military applications and in aerospace applications. In space applications in addition to shipbuilding industry as these alloys allow a significant reduction in ship structure weight compared with the weight of steel structures where the use of aluminum reduces the weight by about half [1].

The disadvantage of the welded 7xxx series alloys is that they are prone to stress and layer corrosion, researcheshave shown that the resistance of these alloys to stress corrosion is influenced among other things by heat processing, chemical composition and welding technology for thatAA 7020,medium strength alloy, has been carefully designed to give good strength with reasonable freedom from cracking, and an alloy such as this would be the one normally recommendedand gives high strength of welded joints compared to all other weldable Al alloys [2,3]During corrosion of metals many parameters should be considered, fluid velocity is one of the most important parameters to be considered during corrosion of metals, since it is increased regularly eliminates corrosion products and uniforms the cathode and anodic zones by removing a possible local excess of H^+ and OH^- ions in an open circuit, moving water is aerated and oxygen up takes the mission in repairing the oxide layer in closed circuit the movement of the liquid prevents the formation of deposits under which corrosion can easily develop ,on theother hand the temperature of seawater has also affect corrosion resistance as decrease with arise in temperature because temperature prevents oxygen from dissolve in water and thinning the protective layer or removed[4].

Many studies have investigations on the corrosion resistance of aluminum alloy in seawater.

krzysztofdudzik [5] studied the influence of joining method of 7020- T6 aluminum alloy on corrosion properties where tests carried out on specimens of the native material, friction stir welded and MIGwelded 7020T6 aluminum alloys in 3.5%Nacl solution. He found that corrosion current density is lower for joints welded by FSW by about 35% relative to the native material and MIGwelded 7020 aluminum alloys

krzysztofdudzik[6] studied the stress corrosion for both the FSW and MIG welded 7020 aluminum alloys. Where the cracking was examined via the slow-strain-rate-testing (SSRT), where the results of the stress corrosion resistance of new method friction stir welded shows well and better results compared with traditional MIG method. The stress corrosion susceptibility of aluminum alloy 7020 welded sheets

M.C. Reboul [7] studied the stress corrosion susceptibility of aluminum alloy 7020-T6 welded sheets where they were prone to stress corrosion cracking (SCC) in a damp atmosphere. The cracks initiate at the root side of the weld in the finely recrystallized weld plate edge and propagate through the grain boundaries until failure.

Hani Aziz Amen [8] investigated the effect of temperature for specimens of 7020-T6 on corrosion resistance in sea water, he found that corrosion tendency increased with increasing temperature of heating and increasing time holding of heating.

The aim of this study is to study the effect of changing velocity and temperature of sea water on 7020 –T6 welded joint corrosion.

EXPERIMENTAL WORK

The experimental procedure was as follows:

METAL SELECTION

The chemical analysis of Aluminum alloy 7020 -T6 is indicated in **Table (1)**; it was conducted by ARL Spectrometer in the specialized institution of engineering industries of Industry Ministry.

Table (1) Nominal and Actual chemical Analysis of the used metalAA7020- T6.

Elements w%	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Al**
Nominal value	0.4-0.8	Max 0.7	0.15-0.4	Max 0.15	0.8-1.2	0.04-0.35	4-5	Rem.
Actual value	.17	.28	.15	0.12	1.5	0.2	4.1	Rem.

WELDING PROCESS

Two Pieces of 10mm thick plates of aluminum alloy 7020-T6were machined to the required dimensions (100 *30 *10) mm andwith geometry of single V at 45^{0}as shown in Figure (2).The plates were cleaned before the welding procedure with a scraper and acetone then they were butt welded (two pass for each side) using the MIG process.

In the MIG welding process, a suppermig-460 type semiautomatic welding machine was used for welding the plates withparameters of (200 A) current and (30 V) voltage using argon as shielding gasat a flow rate of (16L/min).And ER 5356of 1.2 mm diameter as a filler material its chemical composition is shown in Table (2).With a welding speedof (10 mm /sec) was used to carry out the MIGwelds.

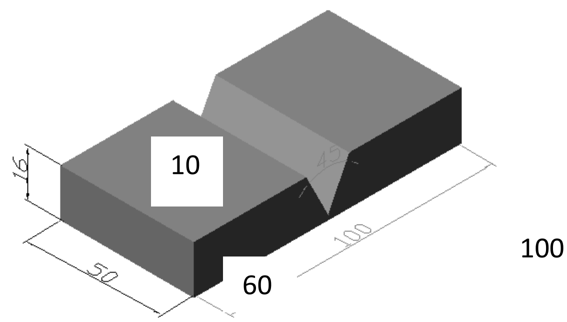


Figure (1) Design and dimensions of single V-butt joint.

Table (2) Nominal and Actualchemical Composition of ER5356 Welding Wire [9].

Elements w%	Mg	Mn	Si	Br	Ti	Cu	Cr	Zn	Fe	Al
Nominal value	4.5 – 5.5	0.05 –0.20	0.25 % Max	0.0008 Max	0.06 –0.20	0.10	0.05 – 0.20	0.10	0.4	BAL
Actual value	4.9	0 .1	0.22	0.0007	0.09	0.1	0.1	0.1	0.4	BAL

CATEGORIZATION OF SPECIMENS

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

Table (3)categorization of corrosion test specimens

Group	state	Sub group	Solution (speed and temperature)
A	As received	A_1	At 25 C° and velocity (1,2,3 m/min)
		A_2	At 50 C° and velocity (1 ,2 , 3/min)
		A_3	At 75 C° and velocity (1,2,3 m/min
B	As welded	B1	At 25 C° and velocity (1 ,2,3m/min)
		B2	At 50 C° and velocity (1 ,2,3m/min)
		B3	At 75 C° and velocity (1 ,2,3m/min)

Microhardness Test

Vickersmicrohardness test was performed on welded joint according to (ASTM E384) with (50 g) load to assess the hardness distribution of MIG welding.

MICROSTRUCTURES OBSERVATION

To execute the Microstructure examination of weld joints,a wet grinding with water was carried out for all the specimens by using SiC emery papers of grades 220,400,800, and1000 followed by a Polishing process using a special polishing cloth with aluminum oxide (Al_2O_3) solution of grain size of 5µm,after that an etching process was done by immersing each specimen in etching solution microstructure inspection by Keller's reagent consisting of 95 ml distill water, 2.5 m l HNO3, 1.5 ml HCl and 1 ml HF. Then washed with water and alcohol and dried in oven.

Microstructures of weld joint were examined with optical microscope provided with computer and digital camera type (Metallurgical microscope MTj Corporation). And the results of the weld metal and HAZ regions are shown in Figure (3).

X-RAY EXAMINATION

X-rays are electromagnetic waves, the waves lengths of 0.1 mm when a monochromatic-X-ray beam incidence on the surface of crystal, it is reflect this reflection is well defined by Bragg's Law for constructive interference which is $2dSin\theta = n\lambda$. The angle θ determined by Bragg's Law for a given interplanner distance (d) and X-ray wave length (λ) are the only angles at which reflection take place, The measurements include the specimen A, B and the results are shown in Figure(2).

Corrosion Test

The corrosion solution was prepared by adding A 35 gm. of sodium chloride (NaCl) to 1 liter of distill water, pH meter used to find the solution pH ratio which is found 6.9.

Polarization resistance tests were used to obtain the corrosion rates. In the test, cell current readings were 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 the potential sweep in 10mv/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 is used to calculate the corrosion current density (Icorr) and corrosion rate. The tests were performed by using a WENKING Mlab multi channels potentiostat and SCI-Mlab corrosion measuring system from Bank Electroniks-Intelligent control GmbH, Germany 2007, In this test, aluminum alloy (7020-T6) and MIG samples were used as working electrode (WE), a saturated calomel electrode (SCE) immersed in the prepared salt solution was used as reference electrode (RE), and a platinum electrode was used as auxiliary electrode (AE).

The potentiodynamic scan was performed at scan rate of (10mV/sec) by using potentiostat supported by corrosion measurement software.

The results of electrochemical corrosion rate are shown in Table (4) by using Tafel Eq.

$$C.R = 0.13 * l_{corr} * \text{ eq. Wt. } / \rho) \text{mpy} \quad [10] \quad \ldots(1)$$

i.e. Corrosion rate (C.R) = 0.43* l_{cor}r

Where

m.p.y = mill – inches per year

l_{corr} = corrosion current density ($\mu A / cm^2$)

ρ = density of corroding species (g/cm^3)

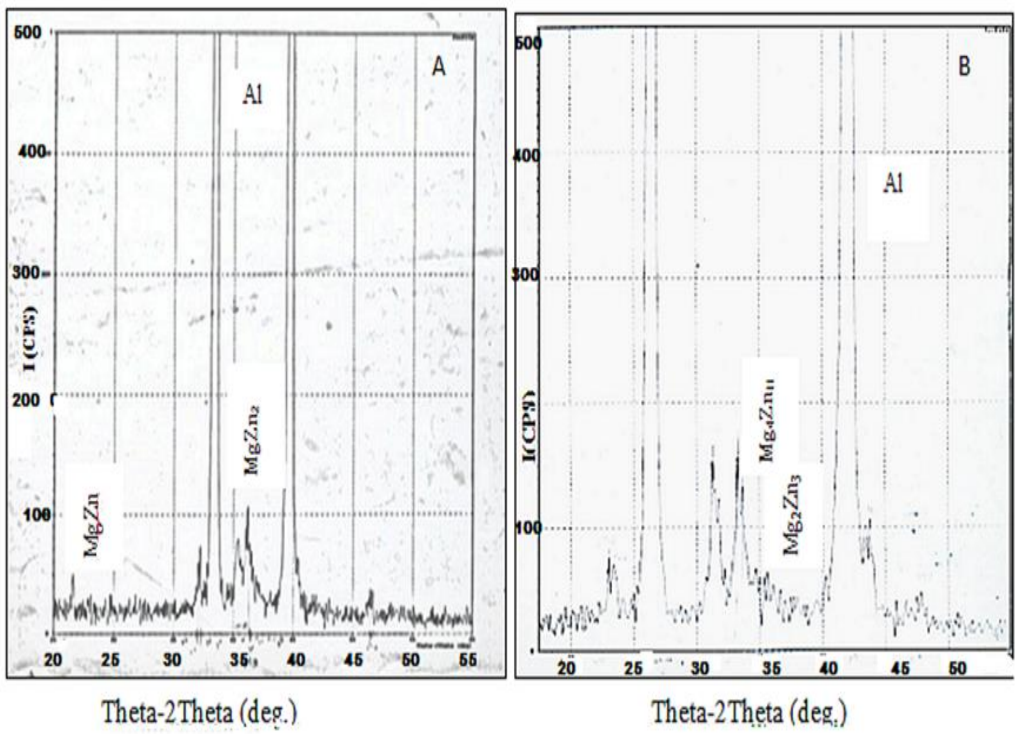
C.R= corrosion rate

wt. = weight

Results and discussion

X-Ray Diffraction Results

The result of x-ray diffraction is shown in **Figure (2)**; this test was carried out in Ministry of Scienceand Technology - Department of Materials, XRD Cu-Kα, wave length (λ) = 0.154nm, Philips



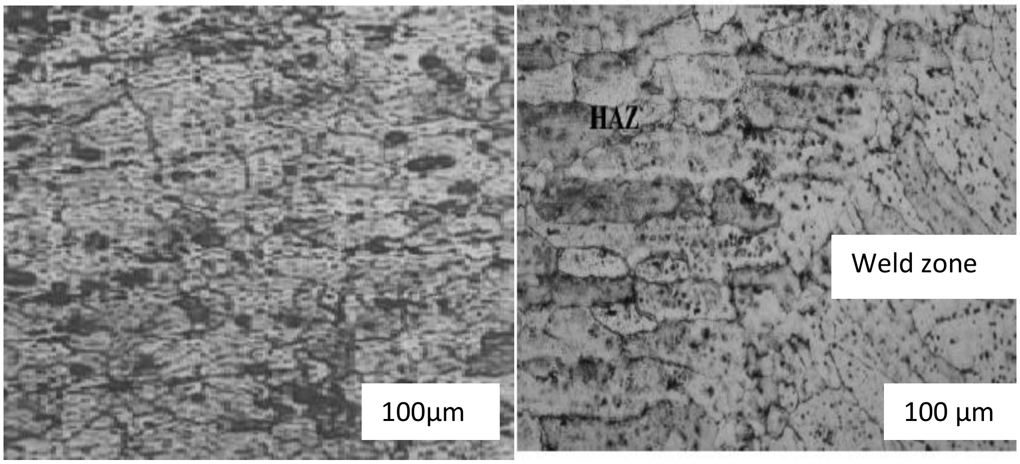
A: as received B: As welded

Figure (2) X-ray diffraction chart for Specimens (A) and (B).

Microstructure Examinations

Table (1) shows the chemical composition of Al-Zn-Mg (7020 –T6) alloy,which indicates that Zinc is the main alloying element and magnesium got the low percentage. Zinc in which it diffuses readily at normal homogenization temperature .This element has high diffusion rates and low solubility in aluminum resultingthe formation of (MgxZny) containing phases along grain boundaries and deletion of Mg and Zn in the area adjacent to the grain boundaries, as shown in the base metal microstructure Figure (3. A).

The microstructure examination in Figure (3.B) shows large variationsin grain size and geometry between the welding zones due to temperature comparing with the base metal microstructure **(A).** This figure shows that the grain in weld metal tended towards an equiaxed shape, while the grains in the fusion zone were generally columnarin shape due to growth from grains in the HAZ, coupled with direction and gradient of thermalconduction experienced. Grains in the HAZbecame more elongated as the distance from theweld increased and the influence of the heat wasreduced and grain sizes in the HAZ were bigger than that in the weld metaldue to heat reductionand that conform with ref. [11]



(A) Base alloy 7020-T6 (B) weld metal and HAZ

Figure (3) Microstructure of welded joint of Al 7020-T6

Hardness Profile

Figure (4) shows the distribution of hardness in the middle of the sample. The microhardness of MIG joint along the joint distance shows that the lowest hardness occurs in the weld zone to a value of 55 (HV.05) and it increases with increasing distance, from weld axis to hardness characteristic of the base metal due to very high arc temperature which increases the peak temperature of the molten weld. The weld metal created in the process of crystallization from the welding zone and exhibits a cast structure with lower hardness than that of the precipitation hardened base metal.

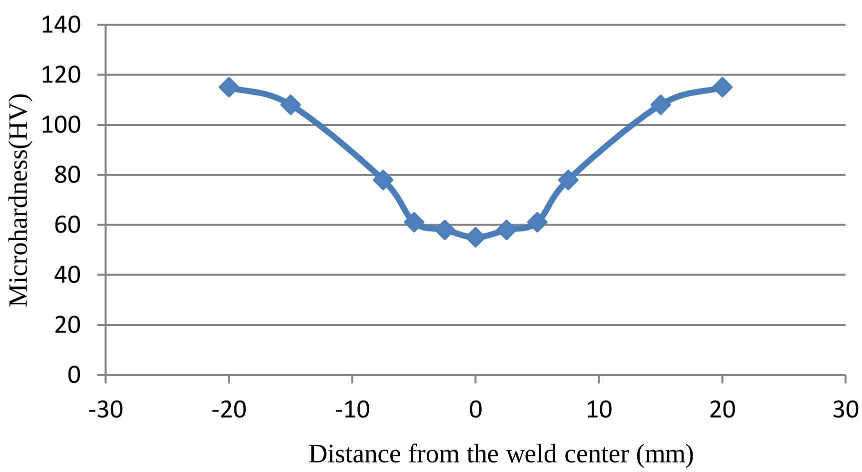


Figure (4)Microhardness distribution along distance from the middle of the weld.

Corrosion rate

Any aluminum surface exposed to corrosive media develops a thin oxide film from the combination of oxygen and the metal, which is hard, chemically stable and tightly keyed to the metal. Though very thin (typical thickness 0.005 mm), this layer prevents further oxidation when damaged, it immediately reforms, provided oxygen is available, which will gives aluminum its good durability.

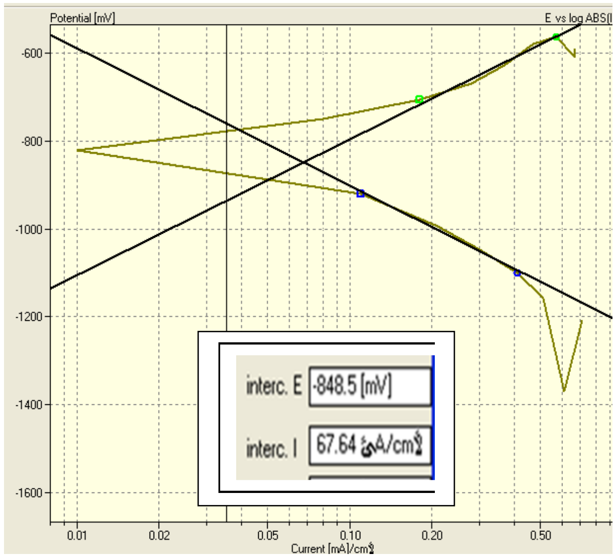
Figure (5) shows the polarization curve for aluminum alloy 7020- T6 in 3.5 % NaCl solution at constant speed and different solution temperature,it can be seen from these curves that as increasing solution temperature there is an increasing in I_{corr}value for all specimens. Corrosion rate calculations in Table (4) shows that, since the solubility oxygen required for repairing Al protective oxide films is reduced and the reactions that cause the films to break down are enhanced by the increased temperatures.

Corrosion becomes continually for all specimens in group (A) and (B), but when comparing these results between specimen B and A, [B] gives the lowest values because of the filler metal composition Table (2) which contain a lower percentage of zinc the responsible element of corrosion according to its position in chrochemical series.

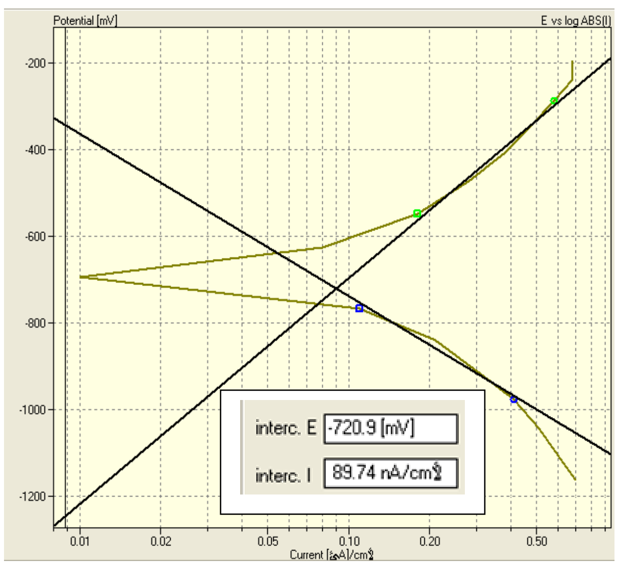
Figure (6),shows the polarization curve for aluminium alloy 7020- T6 in sea water 3.5 % NaCl at constant solution temperature and different solution speed and it can be seen from these curves that as increasing solution speed there is a decreasing in I_{corr}value for all specimens, It is also observed from corrosion rate calculations Table (4) this is due to the improvement of the passivation by the increase in the oxygen supply. Corrosion potentials were shafted toward the cathodic values and the magnitude of the resistance increased with solution velocities , movement of liquid prevents the formation of deposits under which corrosion can easing develop Al with a solution speed up to (1 - 3) m/s without any risk of corrosion and that conforms to [11] The proportion of zinc and magnesium elements in 7020-T6 alloy causes different soluble or insoluble compounds in solid state which effected on current and potential in cell test and then on corrosion rate, for that when comparing these results between specimen B and A we see that specimen B gives the lowest values because of composition of the filler metal [12].

Table (4) corrosion test result.

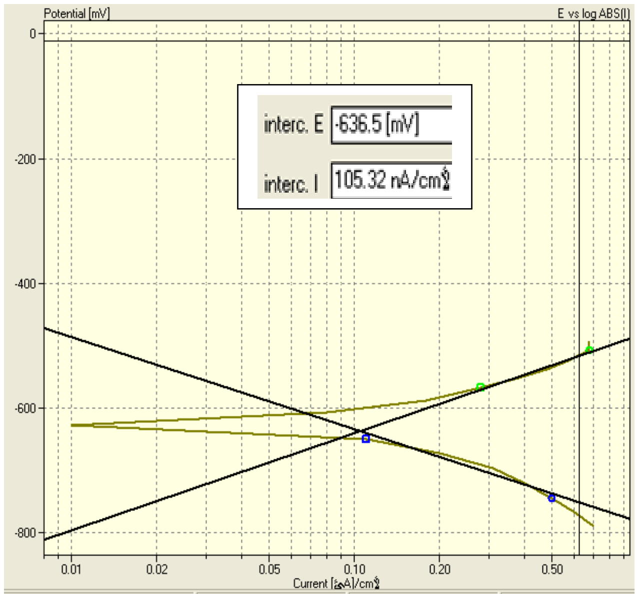
Sample		Corrosion rate (mpy)		
At temperature \ At velocity		1m/min	2m/min	3m/min
A	25 °C	29.08	25.42	17.33
	50°C	38.55	27.8	23.39
	75 °C	45.28	41.37	24.21
B	25 °C	18.22	11.53	8.99
	50°C	26.04	12.80	12.49
	75 °C	27.25	23.20	18.52



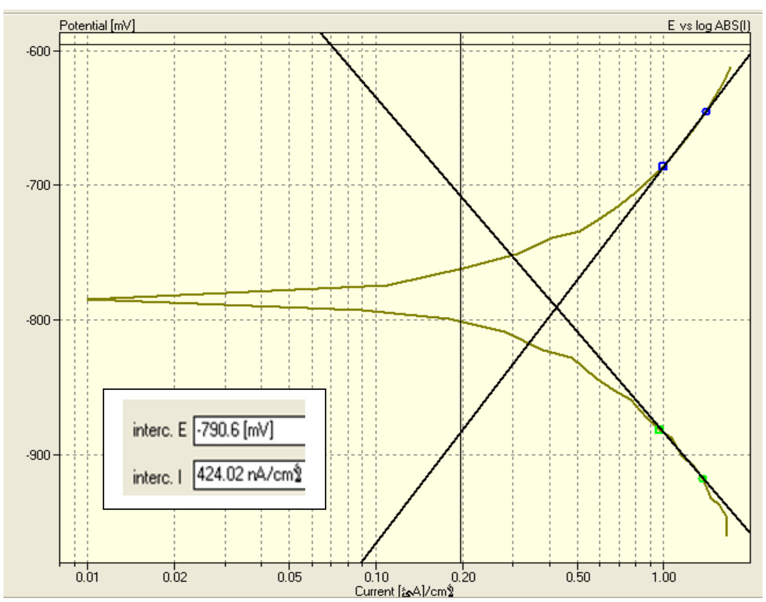
Speceimen A_1 at 1m/min



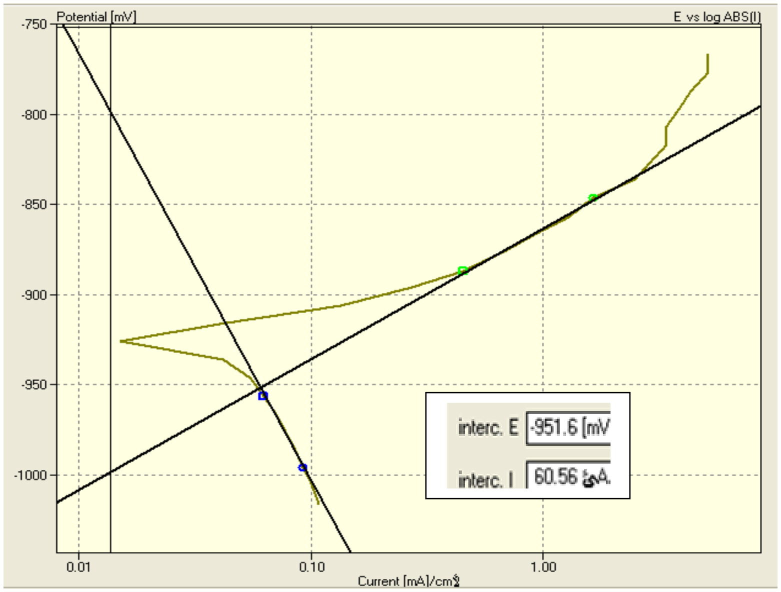
Speceimen A_2 at 1m/min



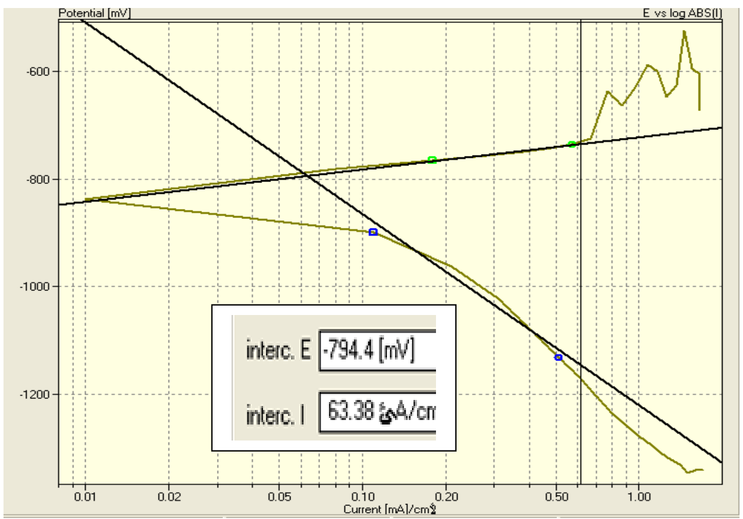
Speceimen A_3 at 1m/min



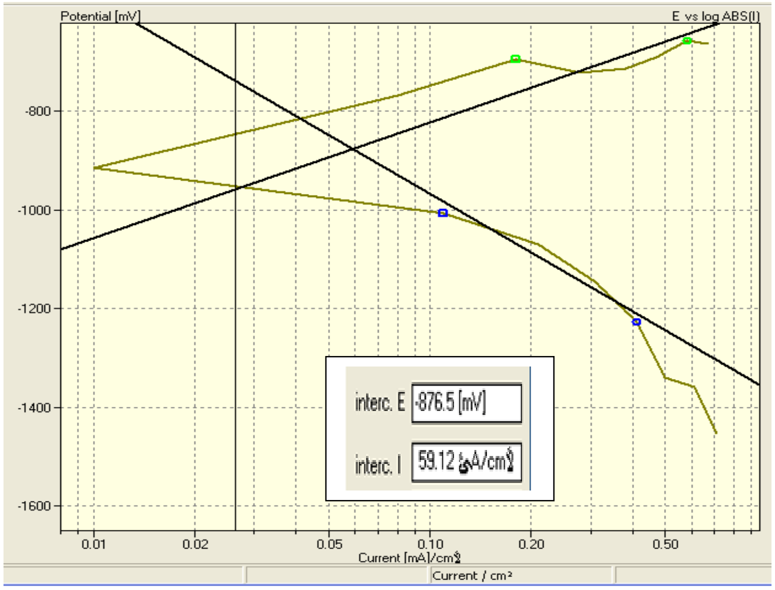
Speceimen B_1 at 1m/min



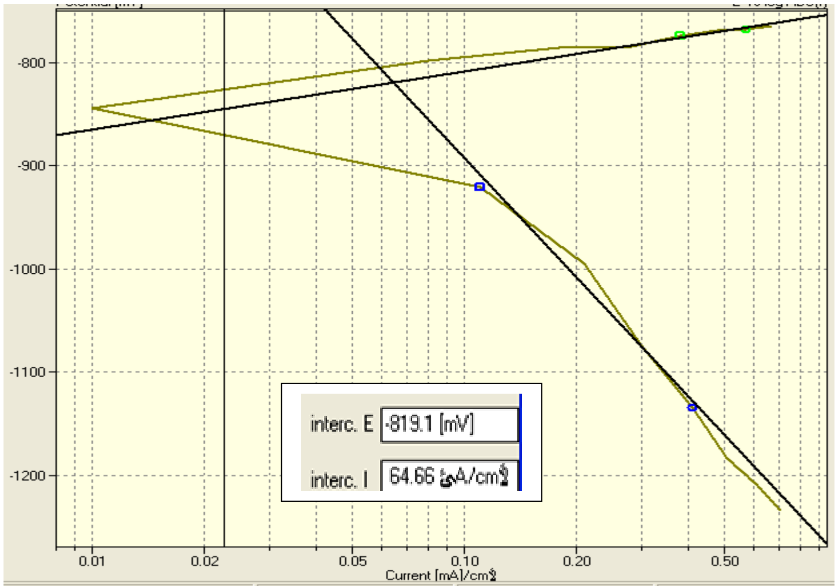
Speceimen B_2 at 1m/min



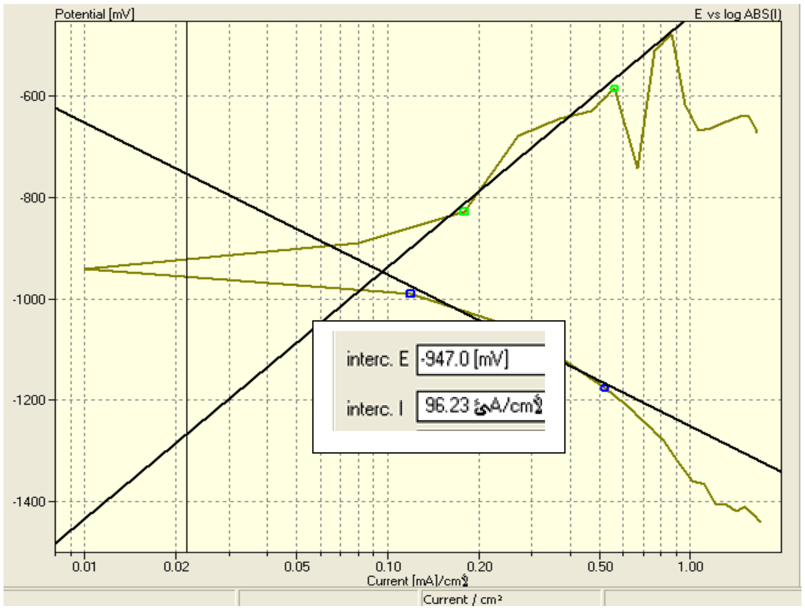
Speceimen B_3 at 1m/min



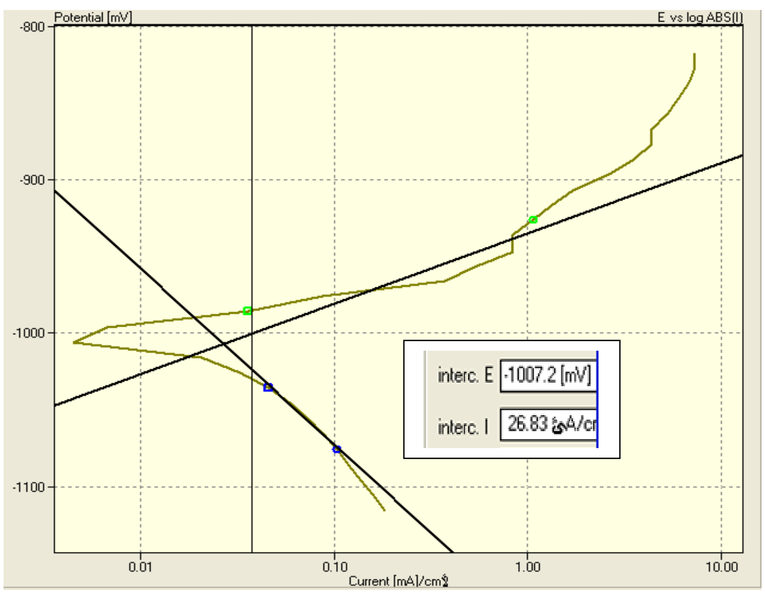
Speceimen A_1 at 2m/min



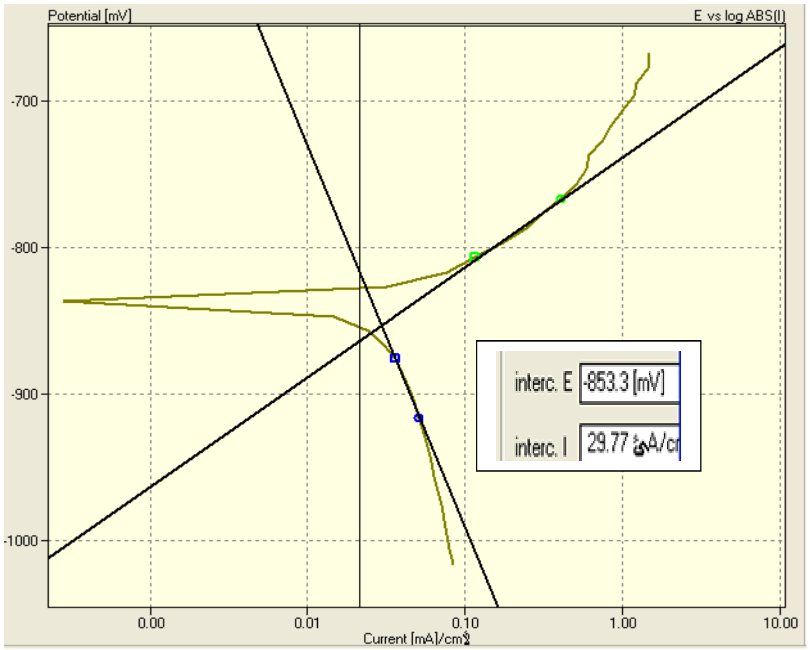
Speceimen A_2 at 2m/min



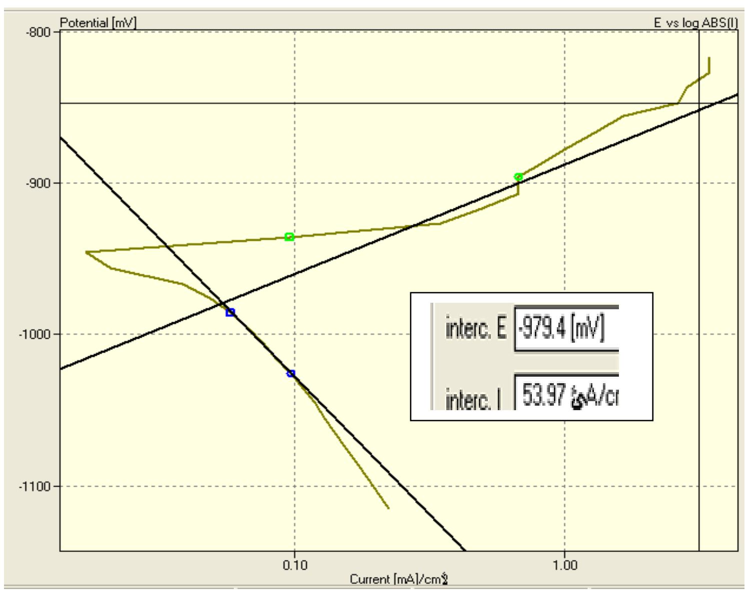
Speceimen A_3 at 2m/min



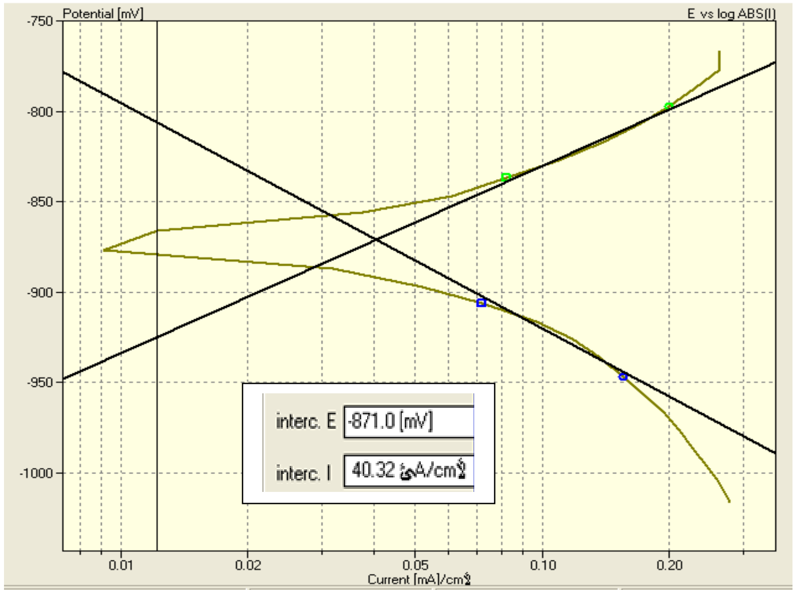
Speceimen B_1 at 2m/min



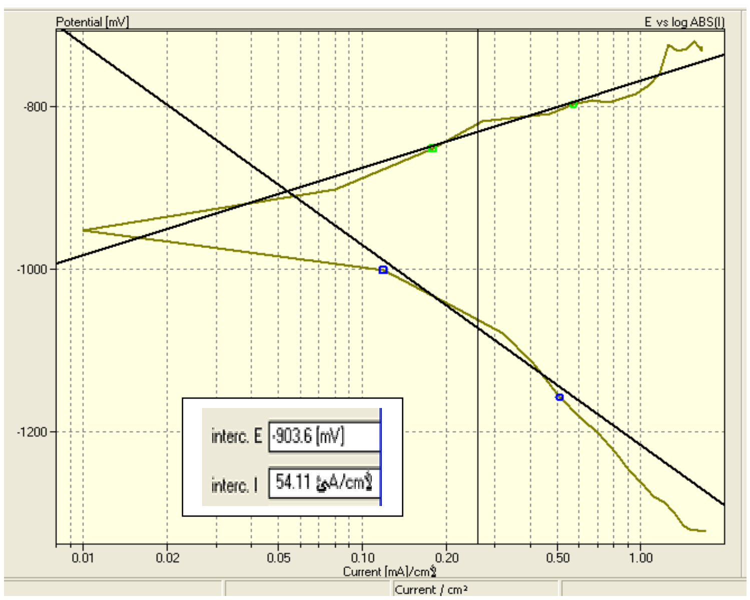
Speceimen B_2 at 2m/min



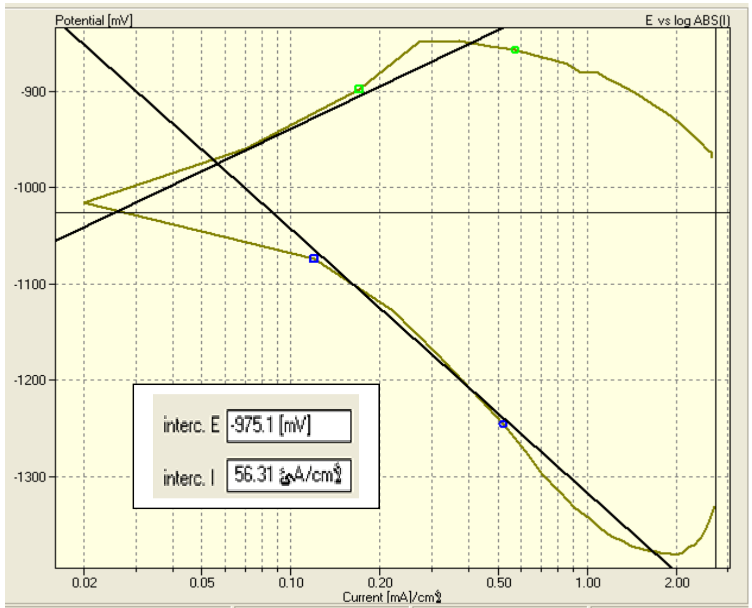
Speceimen B_3 at 2m/min



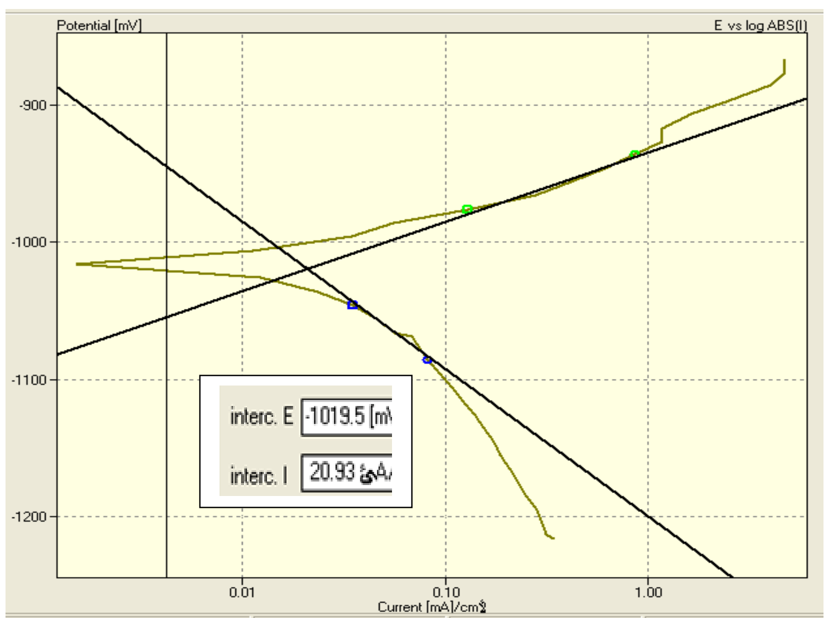
Speceimen A_1 at 3m/min



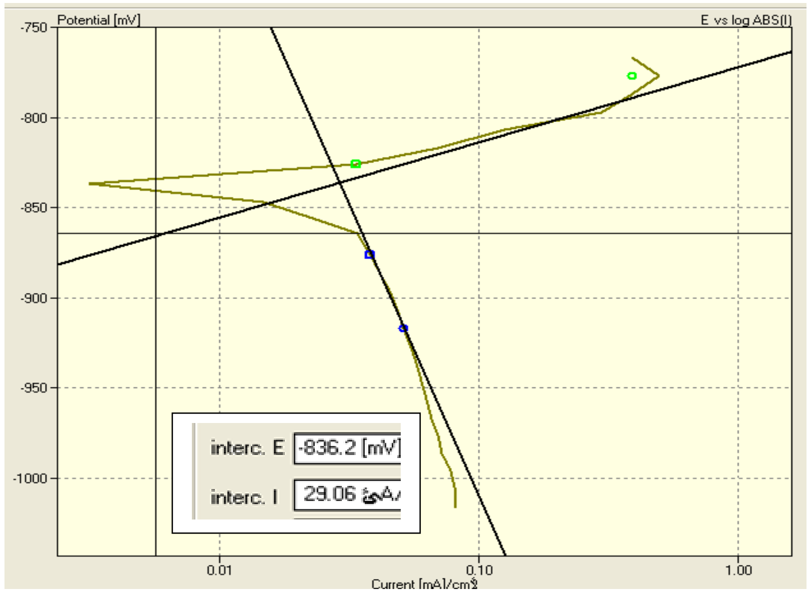
Speceimen A_2 at 3m/min



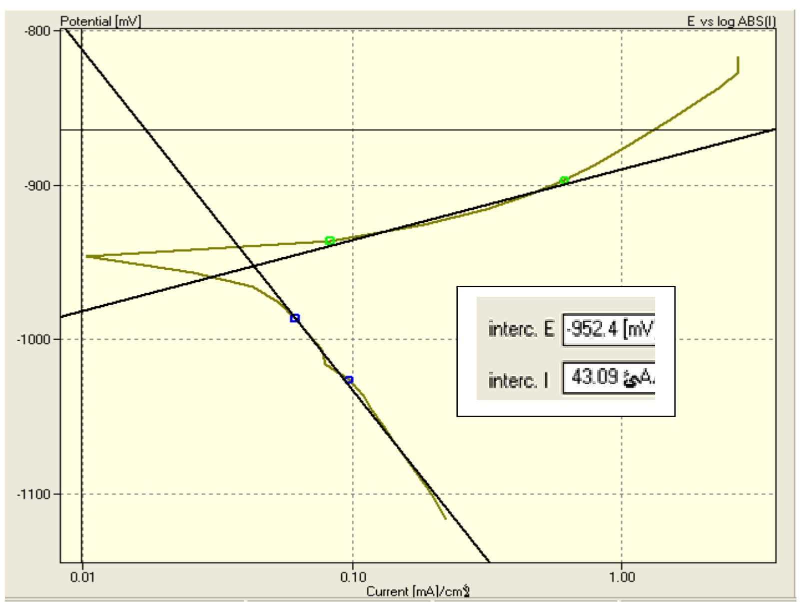
Speceimen A_3 at 3m/min



Speceimen B_1 at 3m/min

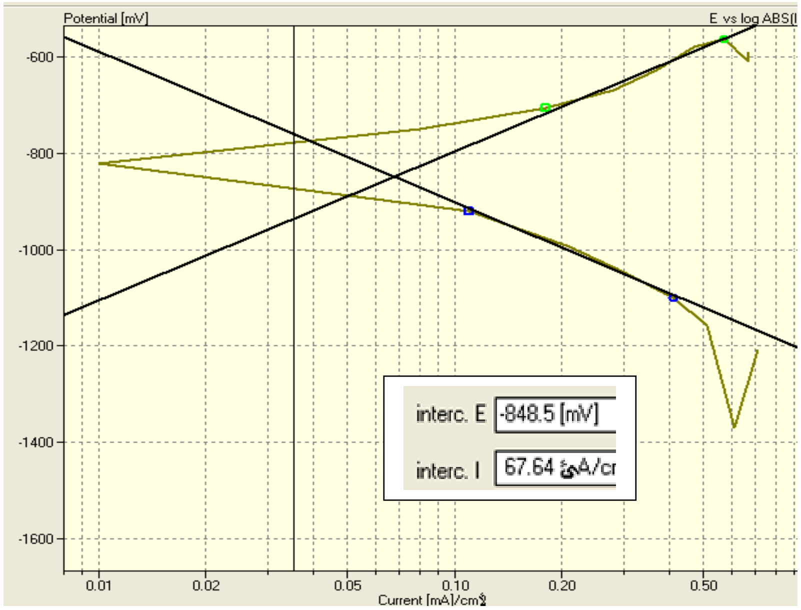


Speceimen B_2 at 3m/min

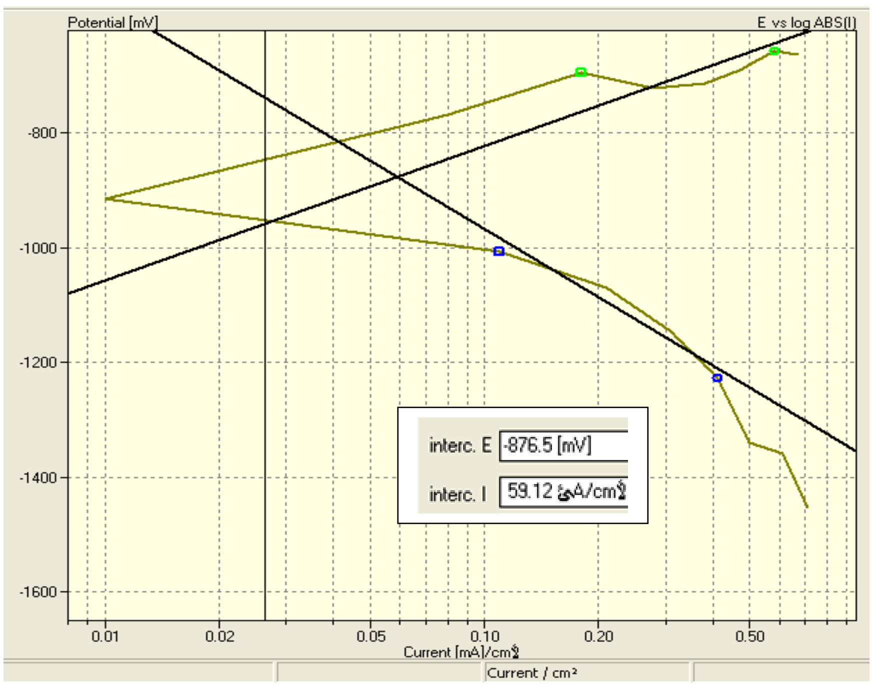


Speceimen B_3 at 3m/min

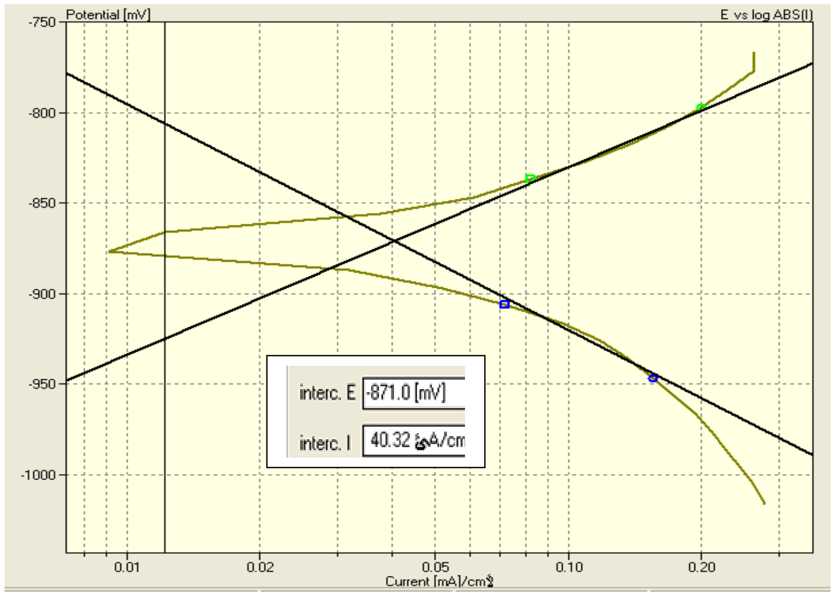
Figure (5) polarization curve for aluminum alloy 7020- T6 in sea water at constant water speed and different water temperature.



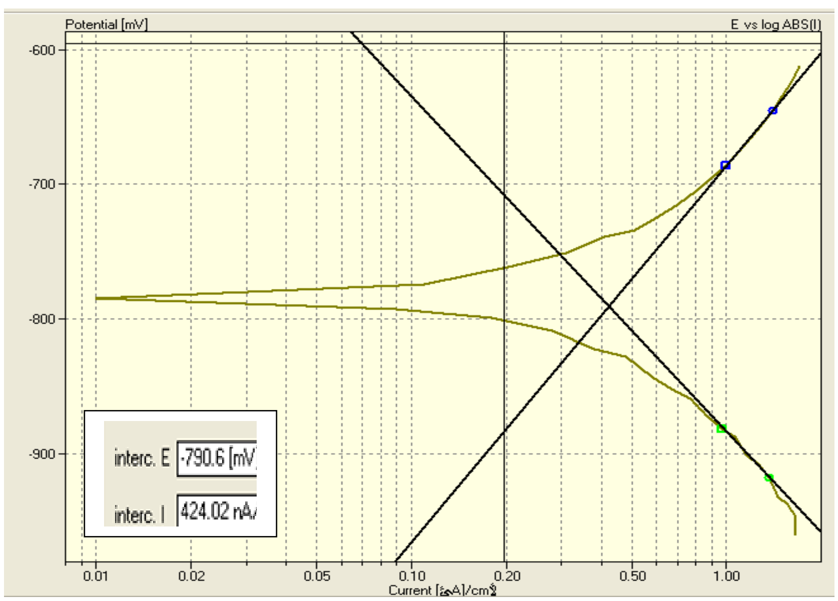
Speceimen A_1 at 1m/min



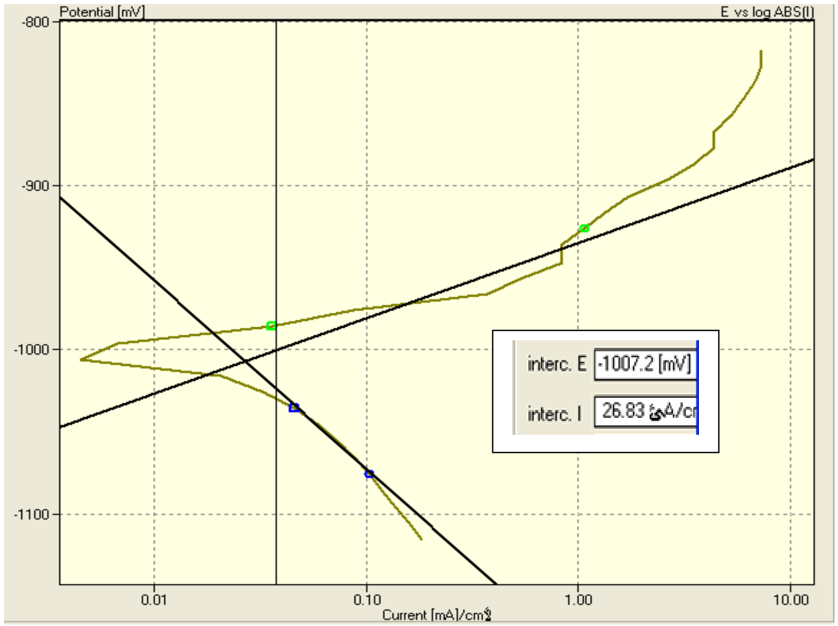
Speceimen A_1 at 2 m/min



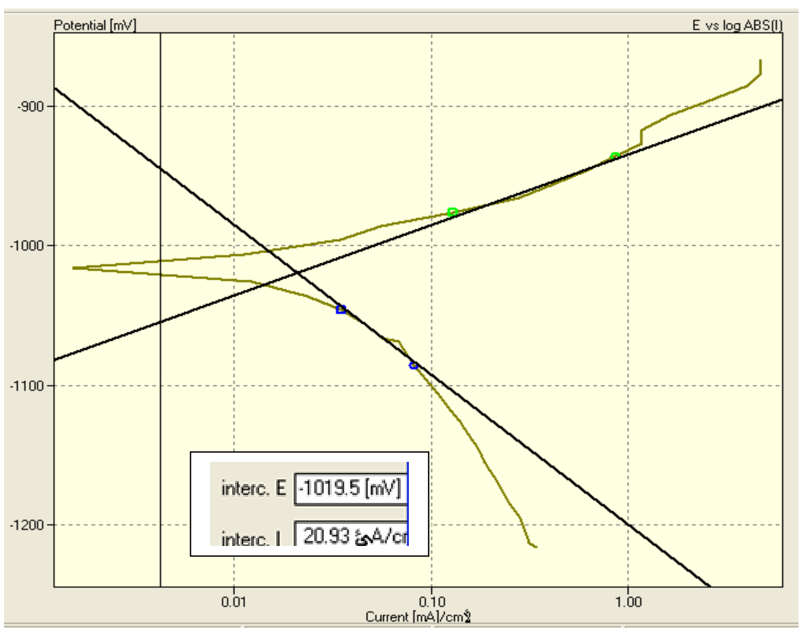
Speceimen A_1 at 3 m/min



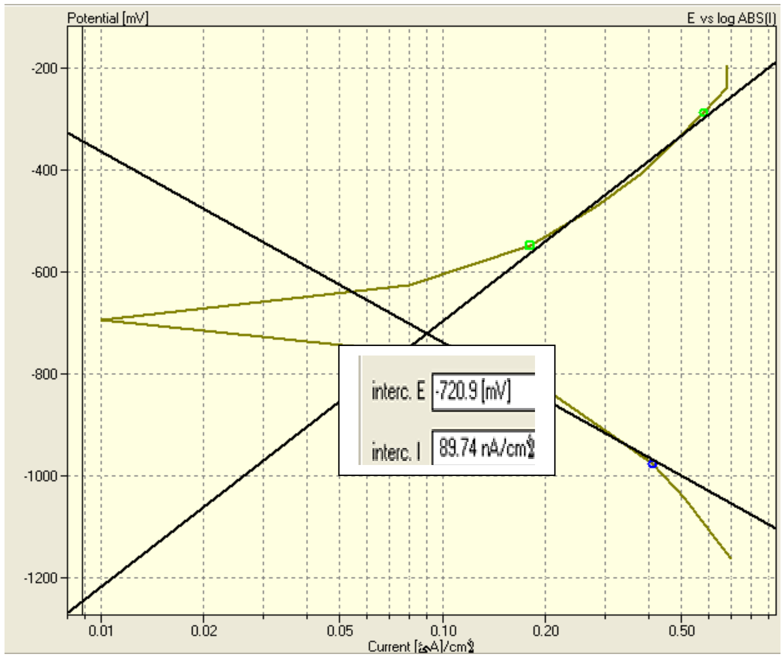
Speceimen B_1 at 1m/min



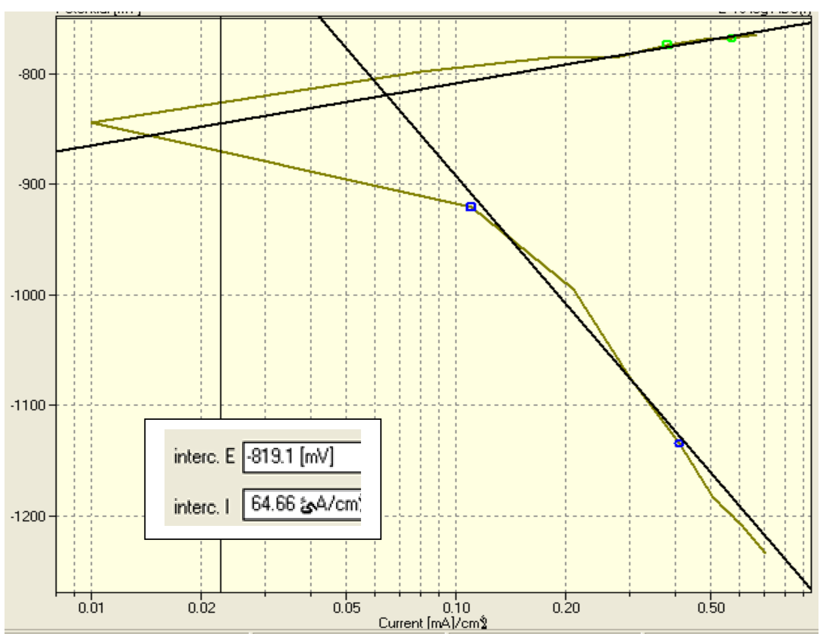
Speceimen B_1 at 2m/min



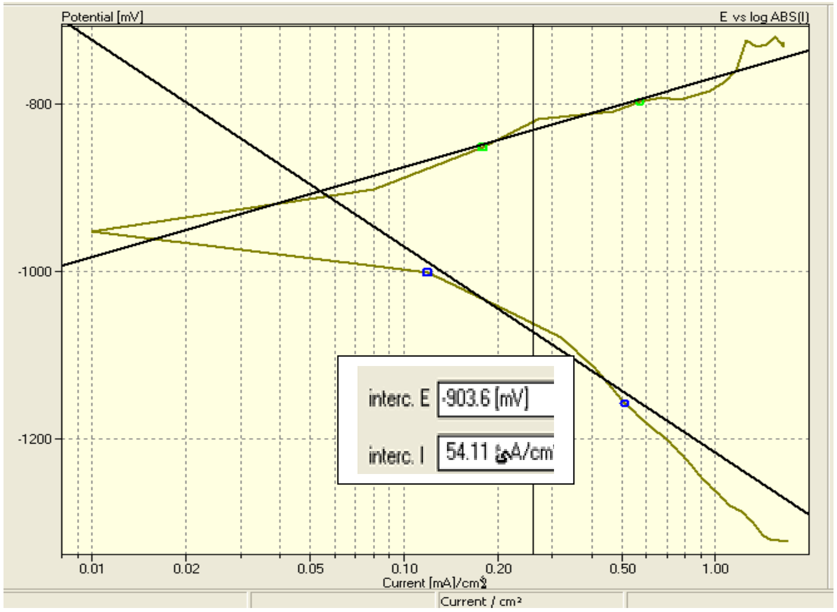
Speceimen B_1 at 3m/min



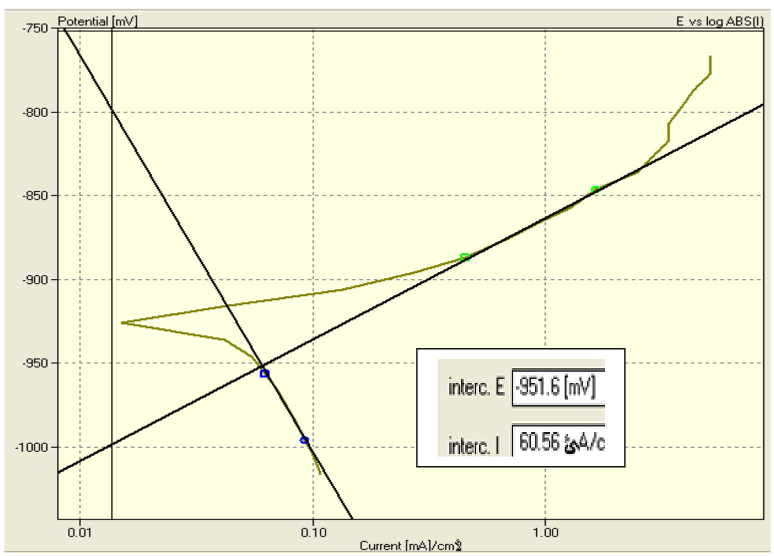
Speceimen A_2 at 1m/min



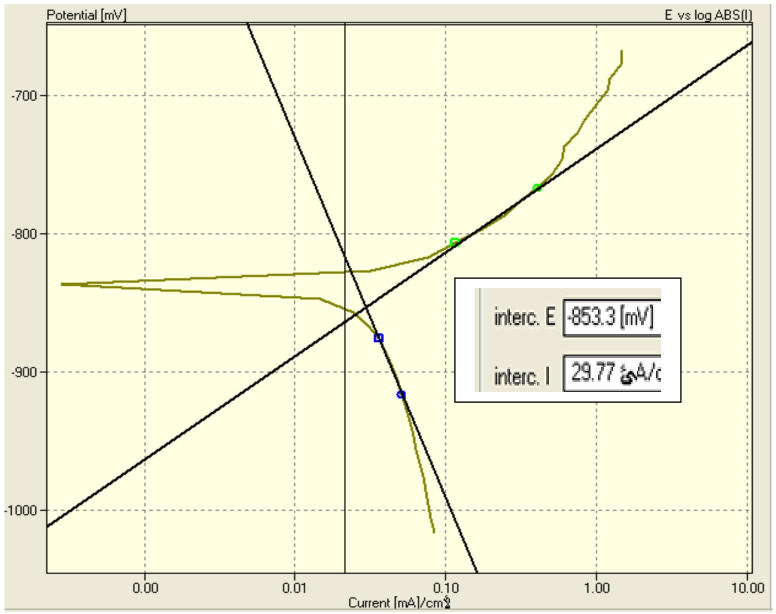
Speceimen A_2 at 2m/min



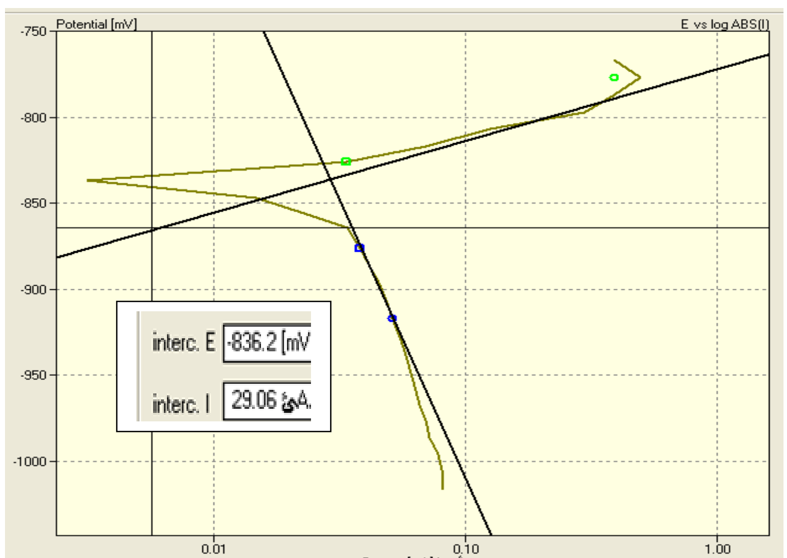
Speceimen A_2 at 3m/min



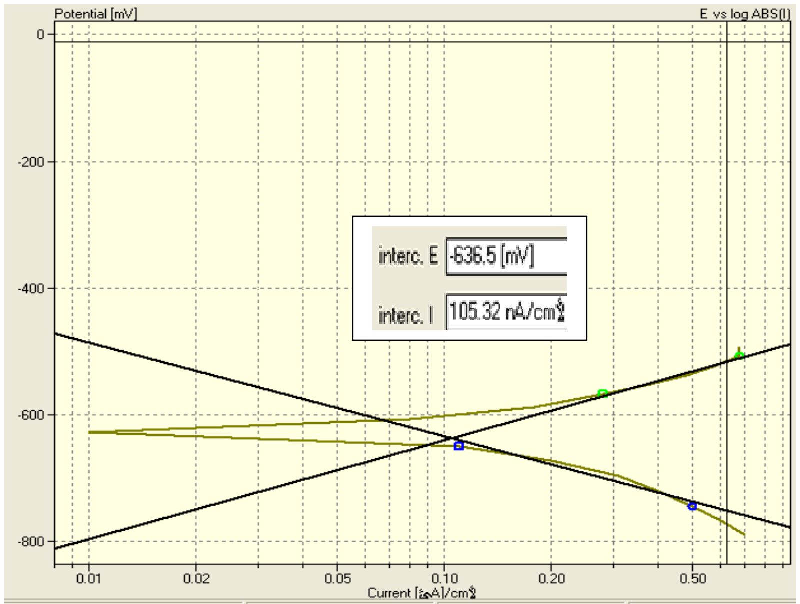
Speceimen B_2 at 1m/min



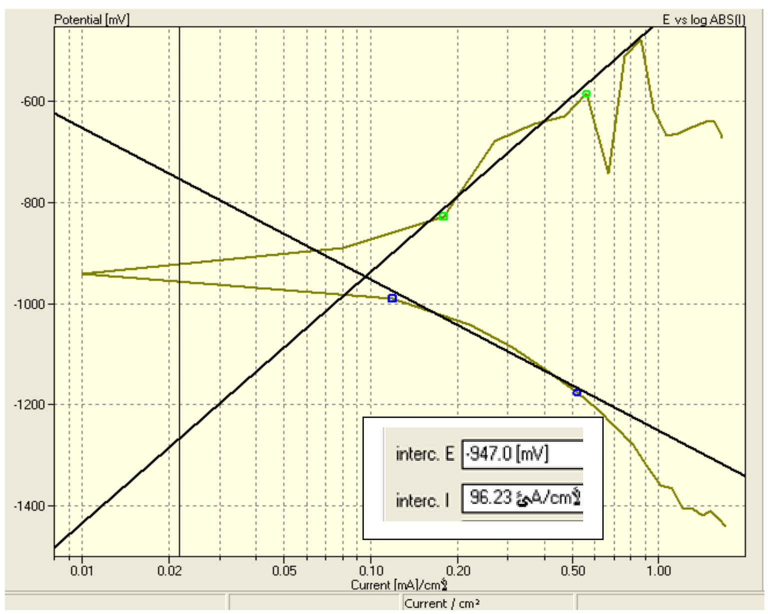
Speceimen B_2 at 2m/min



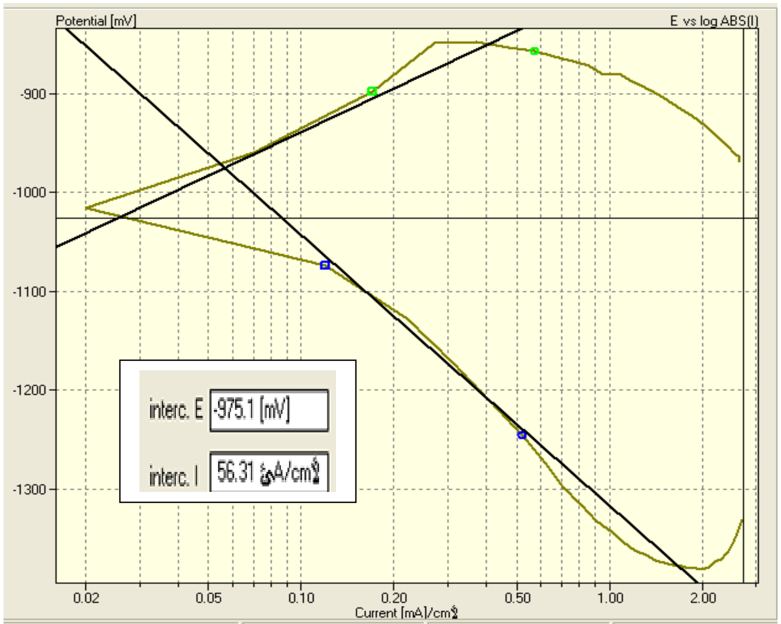
Speceimen B_2 at 3m/min



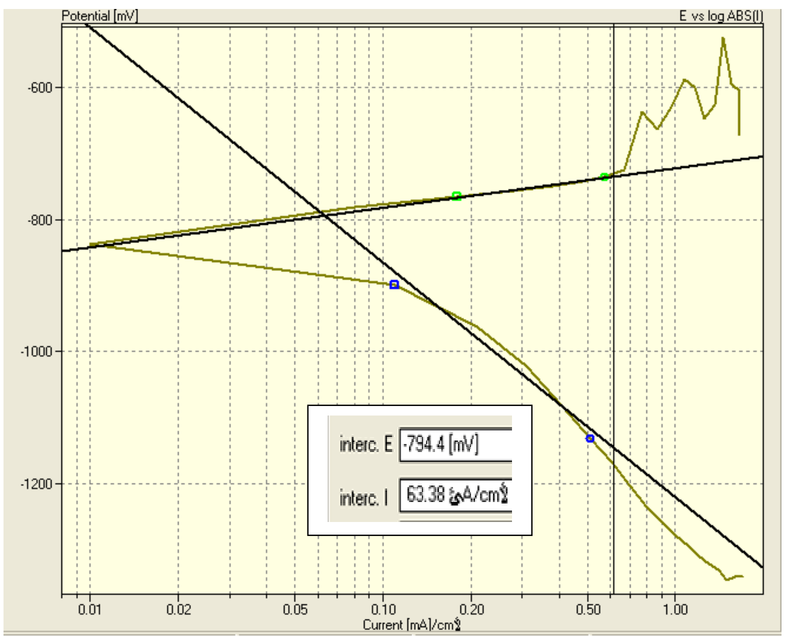
Speceimen A_3 at 1m/min



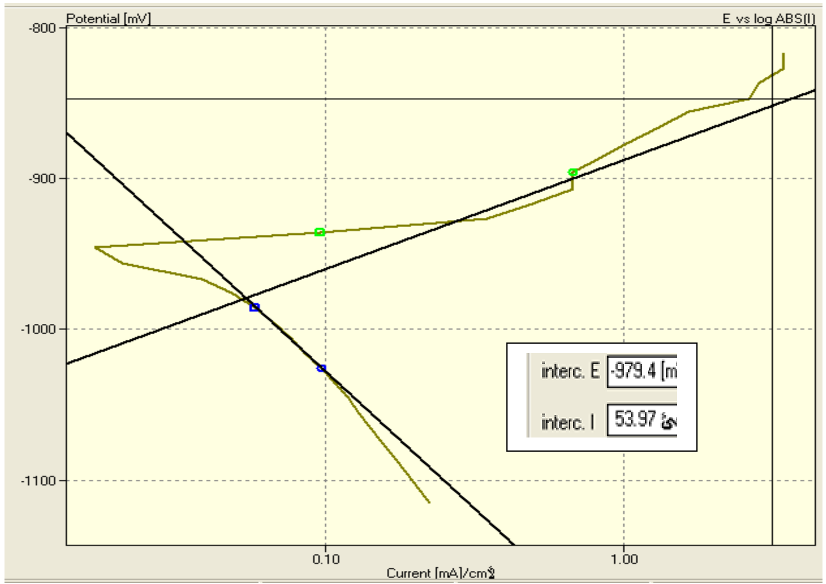
Speceimen A_3 at 2m/min



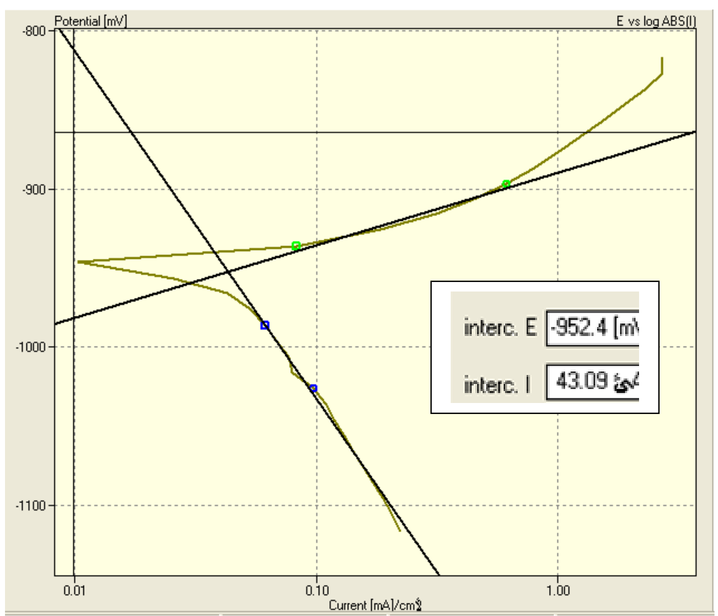
Speceimen A_3 at 3m/min



Speceimen B_3 at 1m/min



Speceimen B_3 at 2m/min



Speceimen B_3 at 3m/min

Figure (6)Polarization curve for aluminum alloy 7020- T6 in sea water at constant water temperature and different water velocity.

CONCLUSIONS

1-The filler metal contributed in decreasing corrosion rate because of its chemical composition containing Mg at high percentage and because of its position in cherochemical series under aluminum

2-Increasing solution temperatureincreases corrosion rate while increasing solution speed decreases corrosion rate.

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