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Improvement Properties of 7075-T6 Aluminum Alloy by Quenching in 30% Polyethylene Glycol and Addition 0.1%B

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Abstract

The 7000 series of aluminum alloys are primarily used in the aerospace industry as structural components and are strengthened by age-hardening especially 7075-T6 aluminum alloy. This study aims to improve properties of 7075-T6 such as impact toughness, thermal age hardening behavior and corrosion resistance in 3.5% NaCl solution by using quenching in 30% polyethylene glycol and addition alloying elements, i.e. boron (B) to this alloy. Results showed that the addition 0.1% B to the base alloy improves impact toughness by (30%) when quenching in water, and by (50 %) when quenching in 30%PAG corresponding to the base alloy at aging temperature 150ºC. Also results showed that the thermal age hardening behavior improved when we add0.1% B (b alloy) by (18%) at aging temperature 150ºC in comparison to the base alloy. An improvement of corrosion resistance in 3.5% NaCl solution when adding 0.1%B (b alloy) by (234 %) at aging time 150ºC in comparison to the base alloy.

Keywords: Improvement properties, aluminum, alloy by quenching, polyethylene glycol.

Introduction

Aluminum alloys fall into two general categories: heat-treatable and non-heat treatable. Series 7xxx alloys are considered the high strength aircraft alloy family, are heat treatable by solution and aging. Various aging cycles produce desired attributes such as maximum attainable strength (T6 temper) or stress corrosion resistance (T73 temper). Either way, the alloy must go through solution treatment, the goal of which is to complete dissolve into solid solution all alloy elements responsible for subsequent precipitation hardening. The 7075 wrought aluminum alloy is an Al-Zn-Mg-Cu alloy, has one of the highest attainable strengths of all aluminum alloys[1].

Adding trace elements to high-strength aluminum alloys can enhance their mechanical properties. It is found that trace elements and aluminum can form dispersoids to improve the recrystallization resistance of aluminum alloys, control the structure of grain boundary etc. These can stop cracks penetration along grain boundary[2].

Quenching of aluminum alloys includes heating to 465- 565 ºC and rapid cooling in order to obtain a supersaturated solid solution. Then the alloys are subjected to aging at different temperatures in order to obtain the requisite strength and plasticity. Minimum warping and minimum internal stresses are obtained by changing the cooling rate in quenching. By increasing the temperature of the quenching medium the temperature gradient in the quenched parts can be decreased while decreasing or eliminating the warping. It should be noted that parts produced from aluminum alloys often have a complex geometry[3].

Aqueous solutions of poly alkylene glycol (PAG) are used to improve the cooling characteristics of the quenching medium and to reduce the machining requirements after the heat treatment. PAG concentrations vary from 4 to 30%, depending on the type of product being processed. For the heat treatment of aluminum alloys, such polymeric solutions have been widely applied during more than 30 years[4].

Warpage is a major problem, which leads to laborious, expensive, and time consuming straightening operations and in some cases to scrapping of large expensive parts. Warpage can be minimized by adding polymer to water quenchants to reduce the convective or film coefficient between the parts and the water[5].

The reduction of warping in the process of quenching is important not only for rolled products but also for castings, finished parts, and semi finished products[6].

Heat treatable aluminum alloys are widely used in aircraft structural applications and are susceptible to localized corrosion in chloride environments, such as pitting, crevice corrosion, intergranular corrosion, exfoliation corrosion and stress corrosion cracking[7].

Metallic corrosion under wet conditions is generally electrochemical, occurring in corrosion cells at the metal surface. Being corrosion phenomena in aqueous environments generally of electrochemical nature they are dominated by the corrosion potential, Ecorr., of the metal[8].

In this work study the effect of trace alloying element (i.e. B) and media of quenching (i.e. water and 30% polyethylene glycol) on impact toughness, thermal age hardening behavior and corrosion resistance of alloys that used in this study.

Methodology

Chemical Composition of the Alloys: The Al-based alloys used in this research are shown in table 1.

Table-1
The composition of Al- alloys used in research

Element Wt% / Alloys		Zn	Mg	Cu	B	Al
a alloy	**Stand.**	5.6	2.5	1.6	_	Bal.
	Exp.	5.63	2.45	1.65	_	Bal.
b alloy	**Stand.**	5.6	2.5	1.6	0.1	Bal.
	Exp.	5.55	2.56	1.58	0.14	Bal.

The Table 1 appears that **a** alloy (base **alloy**) found in boundary of chemical composition of 7075 aluminum alloy [Al- (5.1-6.1)Zn –(2.1-2.9)Mg –(1.2-2)Cu ; %wt] that is known from Aluminum Association[9].

Sample Preparation: Specimens were prepared firstly, by casting process and then machined to the required dimensions. These ingots were prepared as follows:

Casting Process: Casting process includes die designing and manufacturing. Ingots as shown in figure-1 were prepared by melting aluminum at 675 ºC then remain for 5 minutes after each element addition and then cast in especially design. Steel die which is designed and manufactured with dimension and tolerance with respect to the required ingot.

Figure-1
Rod ingots

Specimen Machining: Heat treatment of specimens: Heat treatment usually includes three main stages namely:

Solution Heat Treatment: Heating alloys into solid solution at 482°C for two hours[9], then the specimens quenched by different ways of cooling.

Quenching: Water, and polymer solutions are common quenching mediums for aluminum alloy are used in this studied. The mediums differ in the rate at which they dissipate heat out of a quenched part. Medium of polyethylene glycol have [30%PAG + 70% water].

Aging: The final stage to optimize properties in the heat treatable aluminum alloys was aging. Artificial aging at temperature 150 ºC for 5 hour is used only.

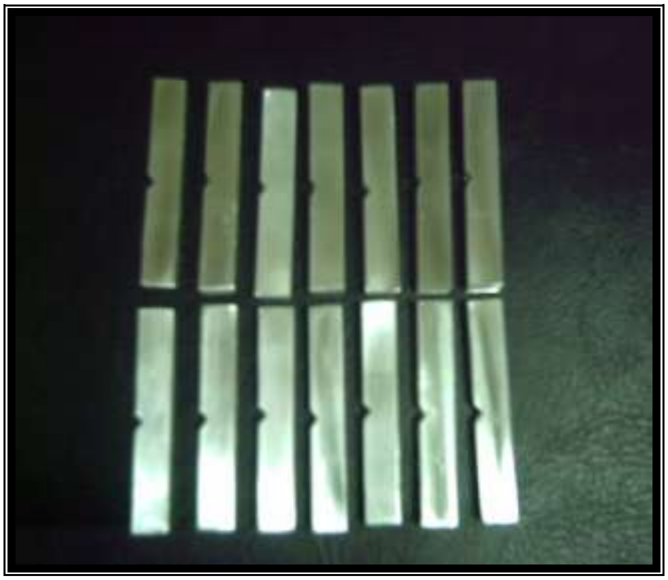
Mechanical Testing: Many mechanical testing have been done.

Hardness Test: Appropriate grinding and polishing were done before subject specimens to hardness tests.

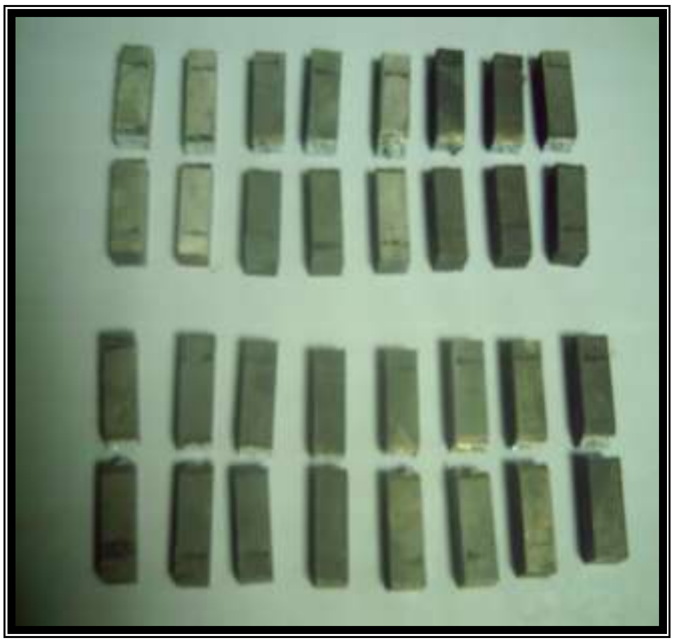
A Vickers micro hardness testing machine type [TH-717, Digital Micro Vickers Hardness Tester] used to conduct the test with a load of 100g for 20 sec. as shown in figure-2.

Figure-2
The digital micro Vickers hardness tester was used to conduct the test with a load of 100g for 20 sec

Impact Test: Impact testing was performed on Charpy testing machine using 55mm length with 45° V notch, 2mm deep with 0.25 mm root radius. The number of specimens of impact test shown in figure-3.



A



B

Figure-3

The specimens of impact test, a: before fracture, b: after fracture

Corrosion Test: Calculated current of corrosion in this study depends on electrochemistry route.

Linear Polarization: The tester consists of electrochemical corrosion test cell and electrodes as shown in figure-(4).

In this study was used (3.5% NaCl) solution, with specimens dimensions (diameter = 8 mm, thickness = 2 mm) and aged at temperature 150 ºC.

Figure-4

The cell of electrochemical corrosion test

Results and Discussion

The results are presented and discussed under various aspects difference between quenching in two mediums (polyethylene glycol and water) and note the difference by compared the results obtained in each parts of work such as corrosion resistance, and mechanical properties (impact toughness and micro hardness properties).

Thermal Stability Test: The little change in hardness at different temperatures with time indicates to thermal age hardening behavior at these temperatures.

The relationship between Vickers hardness and exposure time at aging temperature 150 ºC appears in figures- 5 and 6.

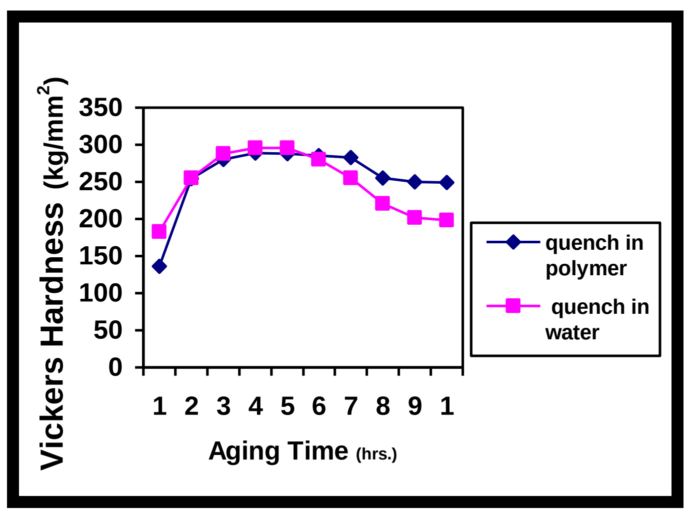


Figure-5

Variation of hardness of (a alloy) sample (quenching in a: water medium, b: 30% polyethylene glycol medium) with ageing temperature at 150°C

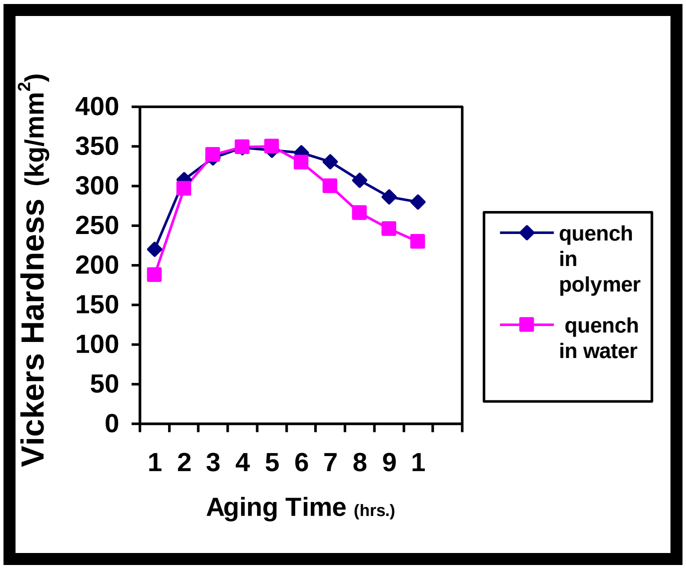


Figure-6
Variation of hardness of (b alloy) sample (quenching in a: water medium, b: 30% polyethylene glycol medium) with ageing temperature at 150°C

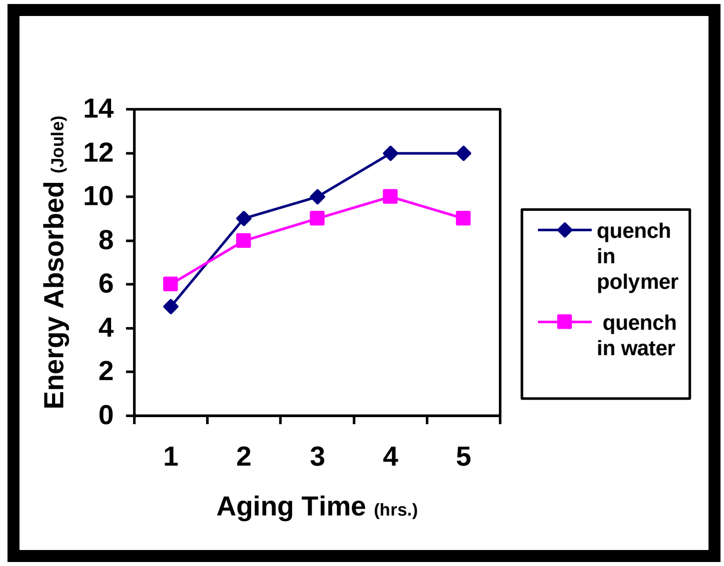


Figure-7
Variation of energy absorbed of (a alloy) sample (quenching in a: water medium, b: 30% polyethylene glycol medium) with ageing temperature at 150°C

From figure-(5) concluded a alloy (quenched in 30% PAG) have maximum value of hardness (at aging time 4 hr.) was 288.7 kg/mm^2, and the same alloy (quenched in water) have maximum value of hardness (at aging time 4 hr.) was 295.7 kg/mm^2 because the medium of water was faster quenching than PAG, and grain size in a alloy (quenched in water) become very small, these reasons cause high hardness.

From figure (5) and (6) concluded b alloy (quenched in 30% PAG) caused an increase in thermal age hardening behavior by (21 %) than a alloy (quenching in 30% PAG) because the element of B (in b alloy) done really fine grain causes thermal age hardening. Alloys that quenched in PAG remain have best thermal age hardening behavior from these quenched in cooled water.

Impact Toughness Tests: The relationship between energy absorbed and exposure time at aging temperature (150 ºC) appears in figure [(7) and (8)].

From figure-(7) found that the impact toughness of a alloy (quenching in 30% polyethylene glycol) increased by (20%) in comparison to the a alloy (quenching in water) because when quenched a alloy that cause the reduction of residual stresses and producing uniform in precipitate along grain size.

From figure (7) and (8) obtained that the impact toughness at 150 °C of b alloy (quenched in water) increased by (30 %) in comparison to the base alloy because found the element of B in b alloy, that element work to product really fine grain size to aluminum matrix with dispersoids and precipitate these dispersoids on dislocations and grain boundary.

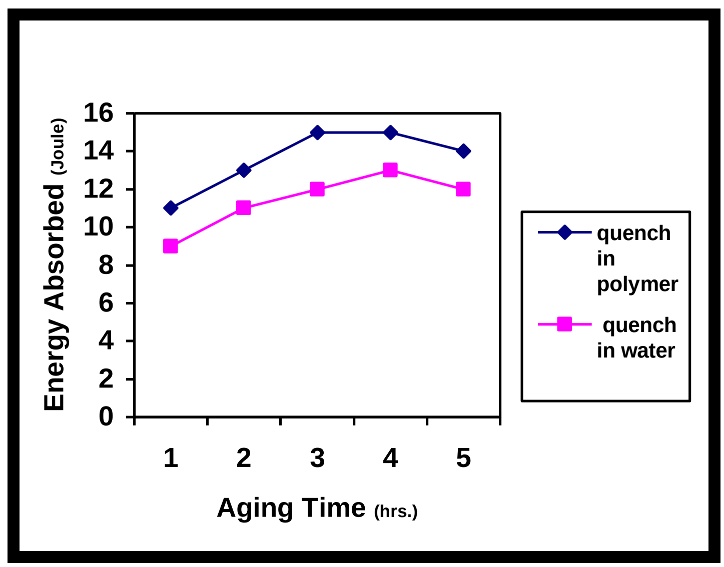


Figure-8
Variation of energy absorbed of (b alloy) sample (quenching in a: water medium, b: 30% polyethylene glycol medium) with ageing temperature at 150°C

All figures appears alloys that quenched in PAG have maximum values from energy absorbed and these values have long stable than when it quenched in water, because these alloys quenched in 30% PAG that concentration reduce residual stresses and it produced alloys have uniform and fine grain from dipearsoids in ductile matrix of aluminum.

The Corrosion Test by Electrochemical Method: This method which used to calculate corrosion rates in (3.5% NaCl) solution. The samples of test quenched in two medium (water and 30% polyethylene glycol) and aged at 150 ºC.

Figure-9 shows that a alloy (quenched in water) have: I corr. = 338 µA/cm^2, E corr. = - 727.1 mV

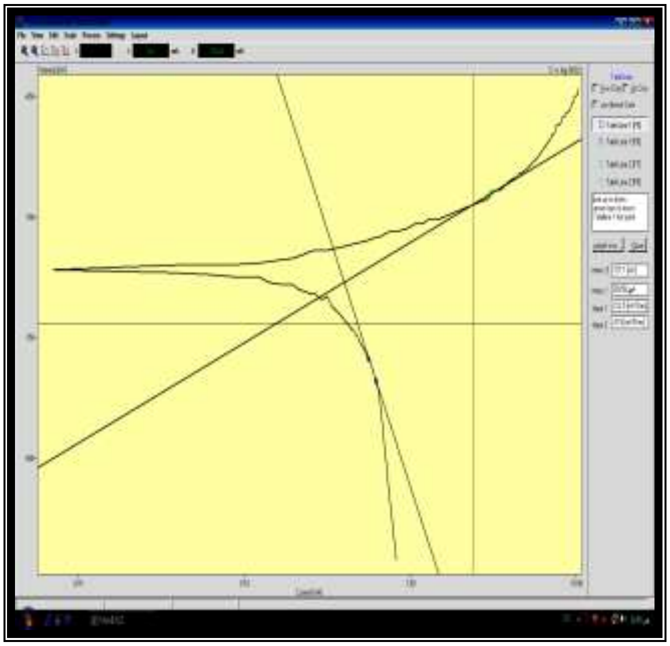


Figure-9
Tafel curve for a alloy (base alloy) that quenched in water.

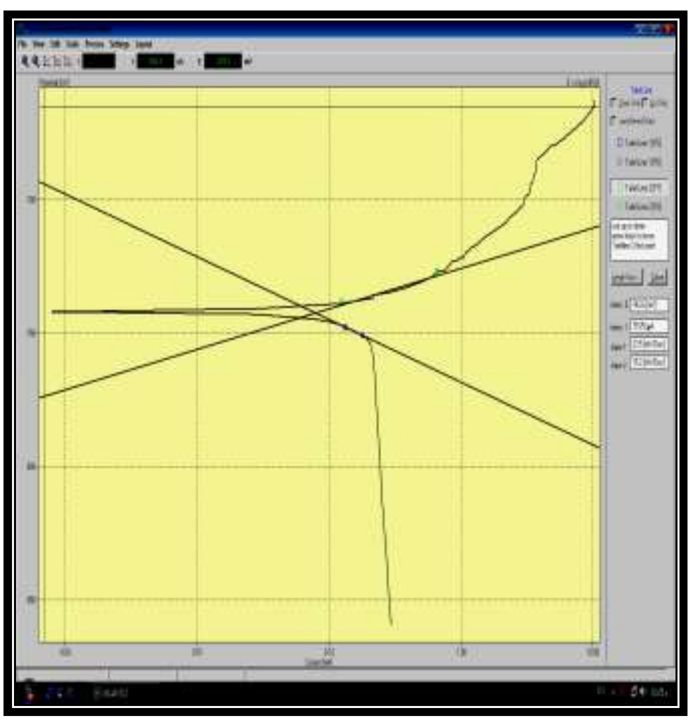


Figure-10
Tafel curve for a alloy (base alloy) that quenched in 30%PAG.

The values of corrosion current density above indicates that a alloy have low resistance to corrosion.

Figure-10 shows that a alloy (quenched in 30% PAG) have:
I corr. = 79.25 µA/cm^2, E corr. = -742.6 mV

From Figure-9 and 10 obtained that value of corrosion current density at 150 °C of a alloy (quenched in 30% polyethylene glycol) was decreased by (326 %) in comparison to the base alloy (quenching in water)

Figure-11 shows that b alloy (quenched in water) has:
I corr. = 101.23 µA/cm^2, E corr. = - 789.2 mV

Above values of corrosion current density indicates that a alloy (base alloy) have corrosion resistance less than b alloy because the element of B (in b alloy) was produce more fine grain from dispersoids that works to prevent corrosion.

Figure-12 shows that b alloy (quenched in 30% PAG) has:
I corr. = 71.15 µA/cm^2, E corr. = -743.3 mV

From figures. (11) and (12) obtained that value of corrosion current density at 150 °C of b alloy (quenched in 30% polyethylene glycol) was decreased by (42 %) in comparison to the b alloy (quenching in water). b alloy (quenched in 30%PAG) have high corrosion resistance than b alloy (quenched in water) because the precipitates in alloy are uniformly distributed and have higher efficiencies to prevent corrosion when quenching in 30% PAG.

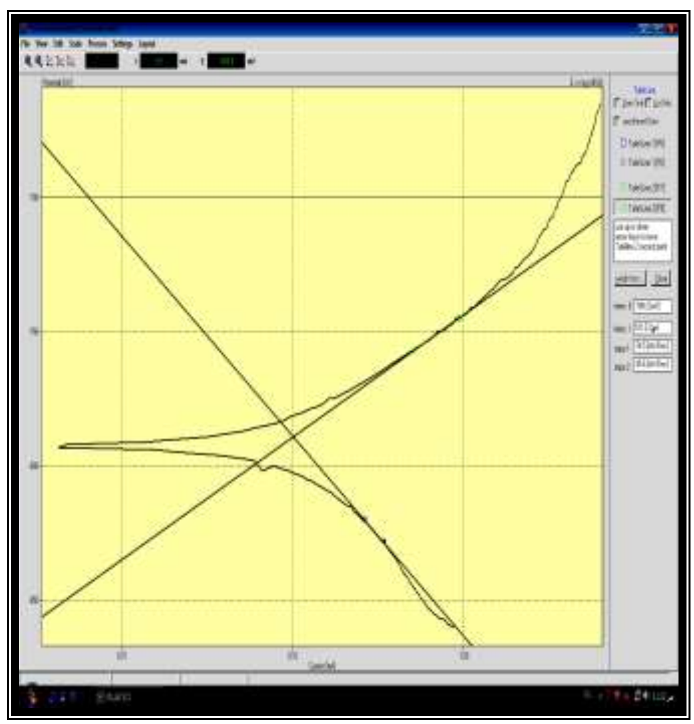


Figure-11
Tafel curve for (b alloy) that quenched in water

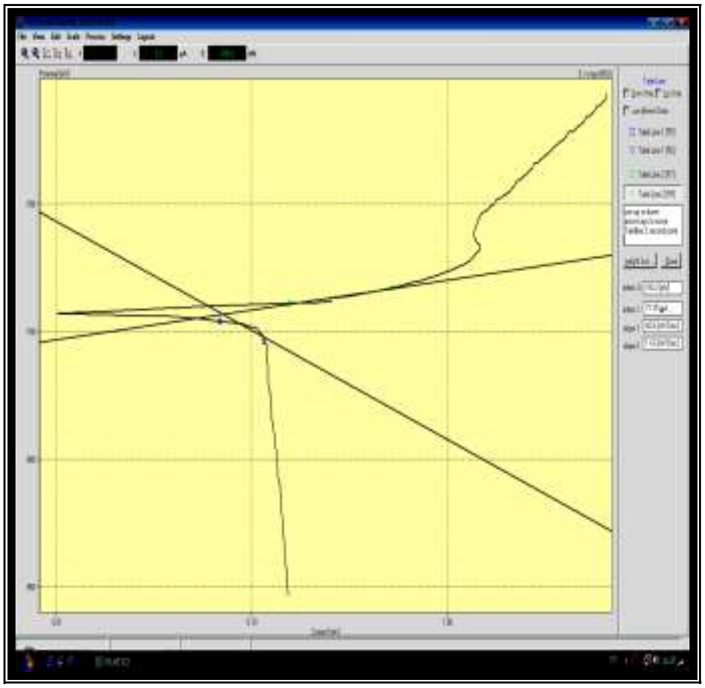


Figure-12
Tafel curve for (b alloy) that quenched in 30%PAG

Conclusion

According to results of present work, the following can be concluded:

Quenching in medium of 30% polyethylene glycol improves most of properties of alloy that used in this study such as compression resistance, microstructure and thermal stability for alloy at the most aging times especially at 150 ºC.

Addition 0.1% B to the base alloy improves impact toughness by (30%) when quenching in water, and by (50 %) when quenching in 30%PAG at aging time 150ºC corresponding to the base alloy.

Thermal stability improved when adding 0.1% B (b alloy) by (18%) at aging temperature 150ºC in comparison to the base alloy.

Corrosion resistance in 3.5% NaCl solution improved when adding 0.1% B (b alloy) by (234 %) at aging temperature 150ºC in comparison to the base alloy.

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