THE EFFECT 0F HEAT TREATMENTS, POLYMER QUENCHING AND ADDITIONS (Zr AND Ag) ON MECHANICAL PROPERTIES OF (6061) ALUMINUM ALLOY

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ABSTRACT

Aluminum alloys (6XXX series) are widely used in the structural components of automotive and construction industries as they show a good combination of formability, corrosion resistance, weldability, and final mechanical properties.

The objective of this work was to introduce improve properties of 6061-T6 aluminum alloys such as impact energy, thermal age hardening behavior, thermal stability and corrosion resistance in 3.5%NaCl solution by using quenching in 35% polyethylene glycol and addition alloying elements, i.e. Zr with Ag together to this alloy. And to determine the effects of artificial ageing on the properties. The precipitation hardening usually undergoes a thermal treatments, which consists of a solution heat treatment (530ºC for 1 hour) this temperature was selected among three temperatures that used to solid solution treatment, quenching (in water, in 35% PAG polymer solution) and artificial ageing. The experimental study is focused on artificial ageing upon that the temperatures is varying from 160ºC - 180ºC - 200ºC at different periods of time. Several tests were carried out to evaluate the performance of alloys before and after ageing, such as Vickers hardness, impact, thermal stability(DSC), metallographic examination, corrosion resistance in 3.5%NaCl solution and X-Ray diffraction (XRD).Results showed that the hardness of the base alloy(A) as homogenized was 48.7(kg/mm^2) whereas to alloy with additions from (Zr and Ag)(B) alloy was 50.7,the hardness at solid solution treatment was in alloy that quenched in water higher than these quenched in polymer

Addition of 0.03% Zr with 0.18% Ag to the base alloy improves thermal age hardening behavior by (17.3%) when quenching in water, and by (17.1%) when quenching in 35%PAG at ageing temperature 180 ºC in comparison to the base alloy.

The addition of 0.03% Zr with 0.18% Ag together to base alloy improves impact energy by (25%) when quenching in 35%PAG corresponding to the base alloy when aging at 180 ºC

From DSC curves could conclude the alloys that quenched in polymer solution have been higher thermal stability than these quenched in water.

An improvement of corrosion resistance in 3.5% NaCl solution when the alloys quenched in polymer solution have been higher corrosion resistance than these quenched in water at aging temperature 180ºC.

Keywords: **Aluminum Alloys, Corrosion Resistance, Heat treatments, Polymer Quenching, Mechanical Properties**

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تأثير المعاملات الحرارية، الإخماد بالبوليمير والمضافات (Zr, Ag) على الخواص الميكانيكية لسبيكة الألمنيوم (6061)

الخلاصة:

تستخدم سبائك الألمنيوم ذات السلسلة 6XXX بصورة واسعة في تراكيب الهياكل للسيارات والصناعات الإنشائية كما توفر قابلية تشكيل و مقاومة تآكل جيدة وقابلية لحام جيدة وتحسن في الخواص الميكانيكية.

الهدف من هذا البحث هو تحسين الخواص لسبائك الألمنيوم 6061–T6 مثل متانة الصدم، سلوك الإصلاد بالتعتيق الحراري، الأستقرارية الحرارية ومقاومة التآكل في محلول NaCl 3.5% باستخدام الإخماد في محلول البوليمير بنسبة 35% PAG وأضافة عناصر سبك مثل Zr مع Ag معاً لهذه السبيكة. ولإيجاد تأثيرات التعتيق الاصطناعي على الخواص. الإصلاد بالترسيب عادةً يخضع لمعاملات حرارية، التي تتكون من المعاملة الحرارية المحلولية (530°C) لمدة ساعة واحدة اختيرت هذه الدرجة الحرارية من بين ثلاثة درجات حرارية التي استخدمت للمعاملة الحرارية المحلوليه، الأخماد (في الماء، في محلول البوليمير بنسبة 35% PAG) والتعتيق الاصطناعي. أما التعتيق الاصطناعي فقد أجري في درجات حرارية تتفاوت من (200°C – 180°C – 160°C) عند فترات زمنيه مختلفة. أجريت عدت اختبارات لتقييم الأداء للسبائك قبل وبعد التعتيق، مثل صلادة فكرز، الصدمة، الأستقرارية الحرارية (DSC) ، فحص البنية المجهرية، مقاومة التآكل في محلول (3.5% NaCl) وحيود الأشعة السينية(XRD) .

بينت النتائج ان صلادة السبيكة الأساس (A) عند المجانسة كانت (48.7(kg/mm^2) بينما للسبيكة مع مضافات من Zr مع Ag كانت 50.7، الصلادة عند المعاملة المحلوليةكانت أعلى في السبيكة التي أخمدة في الماء منها في البوليمير وأضافة Zr 0.03% مع Ag 0.18% للسبيكة الأساس تحسن سلوك الأصلاد بالأزمان الحراري بنسبة (17.3%) عند الأخماد بالماء، وبنسبة (17.1%) عند الأخماد في محلول البوليمير (PAG 35%) بعد أجراء التعتيق عند درجة حرارة 180°C بالمقارنة مع السبيكة الأساس.

أما الإضافة Zr 0.03% مع Ag 0.18% للسبيكة الأساس فهي تحسن متانة الصدم بنسبة (25%) عند الأخماد في محلول البوليمير(PAG 35%) بالمقارنة مع السبيكة الأساس عند أجراء التعتيق عند درجة حرارة 180°C.

من خلال منحنيات DSC يمكن استنتاج أن السبائك التي أخمدت بمحلول البوليمير تمتلك أستقرارية حرارية أعلى من تلك التي أخمدت بالماء.

مقاومة التآكل تحسنت هي الأخرى في محلول NaCl 3.5%، عندما أخمدت السبائك بمحلول البوليمير وامتلكت مقاومة تآكل أعلى من تلك التي أخمدت بالماء.

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1- INTRODUCTION

The relatively low density of aluminum makes it beneficial in comparison with other metals for numerous civilian and military applications. Aluminum has been used for packaging, electrical, automotive, and aerospace applications. Its high strength makes it suitable for shock loading, and its energy at different temperatures makes it beneficial for aerospace applications Aluminum is not as conductive as copper, but it has a low density, which is attractive for aircraft electronics and applications (e.g., laptop computers) which require low weight, it is the most dominant matrix for metal-matrix composites for both structural and electronic applications. This is because of its low cost and low melting point (660°C). Iron, silicon, and copper are the principal impurities in commercially pure aluminum; Alloying aluminum with various elements markedly improves mechanical properties, strength primarily, at only a slight

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sacrifice in density, thus increasing specific strength, or strength-to-weight ratio. Aluminum used up to 260℃**[G. S. brady et al.2002].**

There are several investigations and peer-reviewed publications devoted to tribological and mechanical properties of strengthening aluminum alloys. **[M. Cabibbo, et al. 2006]** studied a TEM study of the combined effect of severe plastic deformation and (Zr), (Sc+Zr)-containing dispersoids on an Al–Mg–Si alloy. by microstructural evolution with strain was investigated in a Zr-modified 6082 Al–Mg– Si alloy and in the same alloy added with 0.117 wt.% Sc, subjected to a multi-pass equal-channel angular pressing, up to a true strain of ~12. **[K. M.C. Wong et al. 2007]** studied microhardness and tensile properties of a 6XXX alloythrough minor additions of Zr. The alloy used in this study contained excess Si, and it had been reported elsewhere that such alloys do not show positive response to the pre-aging process. The present work is aimed to study the microhardness and tensile strength of the Al-1.2Si-0.5Mg-0.25Fe wrought alloy through Zr additions between 0.02 and 0.30 wt.%. **[V. Sudarshan 2008]** studied effect of trace additions of cadmium, silver and zirconium on the precipitation hardening behavior of aluminum 6061 alloy. In this research Age hardening response was investigated in Aluminum 6061 alloy to determine the influence of trace additions of 0.01 and 0.1 % of cadmium, 0.01, 0.1 and 0.5% of silver, 0.05 and 0.1% of zirconium, as well as 0.1% each of Cd + Zr and Ag + Zr. Thermo-mechanical stabilization treatment followed by artificial aging of these alloys were carried out at 313 K, 353 K, 393 K and 453 K. Vickers hardness was used to monitor the progress of age hardening. **[T. Ogura, et al in 2010]** studied effects of microalloyingSn and (Ag+Sn) on precipitation in the vicinity of grain boundaries in Al-Zn-Mg alloys. In the Sn-added alloy, TEM observation showed that some precipitates were sparsely formed within the region of precipitate free zones (PFZs) of an Al-Zn-Mg ternary alloy. The EDX analysis showed that Sn was incorporated in the precipitates, indicating that Sn accelerate the nucleation in the vicinity of grain boundaries. The aimes of this study is to Improving the properties(impact , microhardness) of alloys that used in this study by using polymer quenching, studying the difference between quenching in polymer and in water on properties of alloys that used in this study and Studying the effect of trace elements additions such as [Zr with Ag] on mechanical properties (impact , microhardness) of alloys.

2- EXPERIMENTAL WORK

A- Used Materials:

The materials investigated in this work were used to preparation wrought aluminum alloy 6061. All the material used in ingots were received from the Iraqi local markets. All The elements subjugate to chemical analysis in the Ministry of The Environment /management bureau of Al-diwaniyah Environment/Iraqin order to insure their purity, by using the device (Atomic Absorption Spectrophotometer, made in Japan, model 2000) to examination of all elements exclusive of silicon examination by (SBECTROPHOTOMETER, made in Germany, model 2002) as following (Al-99.8%, Mg-99.36%, Si-99.999%, Cu-99.8%, Zr-99.95%, Ag-99.5%). The shape geometry to these elements were (Al-wires, Si- target disc, cu-small rods, Zr-powder, Ag-wires). The chemical composition of 6061 Aluminum alloy samples obtain examination in the Ministry of The Environment /management bureau of Al-diwaniyah Environment by using the same equipment that is used to examination purity above the result as following shown in (**Table 1**).

The average chemical composition of 6061 Aluminum alloy samples that used in the study corresponding with composition the aluminum alloy 6061 that composed of 97.5% aluminum, 0.8-1.2% magnesium, 0.6% silicon, 0.34% iron, 0.15-0.4% copper by weight**[B. Banerjee, et al 2008].**

For the quenching processes when used two different media (distil water, PAG polymer solution in water type polyethyleneglcol 200/ packed in Switzerland).

B-Alloys Preparation

The ingots produced by permanent mould casting. Steel moulds were prepared, first mould for casting rods of 15mm in diameter and 150mm high to made the hardness and corrosion specimens and the second mould for produced casting plates with dimensions (L=120,W=39,T=13) in mm to made the impact specimens, from the molten Aluminum charge with alloying elements in percentage required, that surround by aluminum foil to immersed in melting and flux used type NaCl, the melting was mixed by ceramic mixer inside the electric resistance furnace, it poured in the especially design moulds. After solidification, the moulds were open to obtain the products rods and plates.

The rods and plates were taken to the machine shop for preparation into hardness and impact specimens test. The specimens were prepared according to the ASTM standard **[ASTM standards pt. 31, designation E23-82].**

C-Heat Treatment

-Homogenization:

The aluminum alloys is "homogenized". During this homogenization process the aluminum alloys are annealed for a three hours at temperature 415$°C$ as recommended by The Aluminum Association **[ASTM Designation: B 918 – 01].** Later, Slow cooled to prevent any possibility of partial solution heat treatment of the alloy **[H. Johansen 2008]** in a furnace type (**box-type resistance furnace, model: SRJX-2007**), accurate furnace temperature and special temperature variation must be controlled to within a range of ±5°C.

-Solution Treatment

There were three degrees of temperature used to solution heat treatment applied on the alloys samples(515$°C$,530$°C$,545$°C$) **[M. R. said, et al. 2009]** for one hour in order to selected one among these degrees which obtained good mechanical properties, After that treatment quenching in two different media quench (water, polymer solute in water).

-Quenching

The solid solution alloys were cooled rapidly to retain the high temperature single-phase supersaturated solid solution at room temperature. When quenching implement by investigated two difference quenching media water, and polymer solution (35% PAG + 65% water),

-Aging:

Only artificial age hardening applied in this study by holding the quenched alloys at elevated temperatures (160°C, 180°C and 200°C) in different times(2-4-6-8-10)Hr., to achieve better mechanical properties in these alloys**.**

D-Thermal Stability Analysis of Alloys:

The thermal stability measurement implemented on the solid solution alloys as quenched as well as aged alloys. It achieved by differential scanning calorimeter (DSC-60) (SHIMADZU, japan) .The temperature range for all the samples was from room temperature to 450$°C$ and the heating rate was 20$°C$/min.

E-Mechanical Tests :

Mechanical tests including micro hardness and impact test have been done for homogenization, solid solution, and age hardening heat treated samples.

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-Microhardness Measurements:

Hardness is a measure of a material's resistance to localized plastic deformation. Early tests were based on natural minerals with a scale constructed solely on the ability of one material to scratch another that was softer**[W. D. Callister 2007]**.The samples grinding and polishing were done before its subject to hardness tests.MicrohardnessVickeres tester type (Microhardness Tester Hv-1000) is used to measure hardness with 200g load and holding time of 20 seconds.

-Impact Test:

Impact testing was performedby Charpy testtype, the Charpy V-notch (CVN) specimens used in this test The notch is located in the center of the test specimen, which is supported horizontally at two points. The specimen receives an impact from a pendulum of a specific weight on the side opposite to that of the notch. The specimen fails in flexure under impact. The specimens dimension 55mm length, 10 mm cross-section with 45° V notch, 2mm deep with 0.25 mm root radius**[ASTM standards pt. 31, designation E23-82].**

F-Corrosion Tests:

The Corrosion test was achieved in electrochemistry route. The metal specimens were polished in the same manner as mentioned above. The polished specimens were used to plot polarization curves. An electrochemical cell, consisting of an electrolyte, a calomel reference electrode, a platinum counter electrode and the specimen as the working electrode were used for this purpose. A software program (**Bank-Elechtionies**) was used to plot the polarization curves anodic and cathodic . Electrolytes were prepared from 3.5% sodium chloride salt and distilled water.

G-Light Optical Microscopy (LOM):

Optical microscopy was used to provide information about the microstructure of alloy samples before and after exposure for age hardening with magnification (800X) by using (SIMRAN optical microscope made in USA). The samples have been wet ground using 1200 grit aluminum oxide paper and 2000 grit carbide tungsten(cc-CW) .The specimen surface was etched with a solution containing 95% H_2O, 2.5% HNO_3, 1.5% HCl and 1%HF**[ASTM standards Designation: E 407 – 99]** commonly known as Keller's reagent.

H-X-Ray Diffraction Tests :

All X-ray diffraction tests to alloys are carried out at specialized institute for engineering industries (S.I.E.I)/ Baghdad. Low angle X-ray diffraction is performed. X-ray generator with Cu Kα radition at 40 Kv and 20 mA is used.

3-RESULTS AND DISCUSSION

A-Mechanical Properties Tests:

-Hardness Tests:

The hardness tests achieved on the alloys at different conditions as following:

- Hardness Tests at Homogenization:

The hardness evolution foralloys that homogenized for three hours at 412 °C and slow cooled to room temperature to prevent any possibility of partial solution heat treatment of the base alloy(A) was 48.7(kg/mm^2)and B alloy was 50.7(kg/mm^2).

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- Hardness Tests at Solid Solution:

The hardness evaluation for alloys which solid solution treated for (1) hour at three suggested solid solution temperatures (515, 530 and 545)$°C$ and used two different quenching media. The purpose for these to determine preferred selection of time and temperature to achieve solid solution treated dependent on investigation of hardness values.

The relationship between Vickers hardness and exposure solid solution temperatures for two different quench media appears in **(Fig. 1)**.

From three temperature in **(Fig. 1)** concluded the better solid solution temperature was 530$°C$ due to this temperature give high solubility for elements with in solid solution(α-Al). 515$°C$ not give full solubility for elements with in solid solution (α-Al). 545$°C$ give full solubility for elements with in solid solution (α-Al) but produce grain growth for (α-Al) and the average size of the remand precipitated particles increases with temperature **[E. Tan and B. Ögel 2007]**, and the total number of particles in the system decreases because larger particles tend to grow at the expense of the smaller ones, which shrink and disappear. result the decrease in hardness. That is similar with another researcher which studied aluminum alloy material for forging and continuous casting process therefor **[Touma 2006]**.

- Hardness Tests at Aging Behavior:

The variation in hardness at different temperatures with time indicates to precipitation sequences behavior at these temperatures.

The relationship between Vickers microhardness and exposure time at aging temperature 160 $°C$ appears in **(Fig. 2)**.

From **(Fig. 2A)** it is concluded that alloy (quenched in water) have maximum value of hardness (at aging time 9 hr.) was 145 kg/mm^2 , and the same alloy (quenched in 35% PAG) have maximum value of hardness (at aging time 9 hr.) was 122 kg/mm^2 because the medium of water was faster quenching than PAG. Therefore, grain size in alloy (quenched in water) become very small, this cause high hardness.And noted increase in aging behavior to this alloy started from 4 hr. to 10 hr., these behavior indicated on the precipitate resultant completed at these stages of aging.

From **(Fig. 2B)** At early aging stages (1,2)hours of aging, the hardness of sample dropped until 88.9, 107.6 HV for polymer and water medium respectively, the reason of this as the solute is removed from solution. Increase in aging behavior to this alloy started from 3 hr. to 10 hr., these behavior indicated on the precipitate processes occurred at these stages of aging. Noted B alloy (quenched in water) have maximum values of hardness (at aging time 6, 10 hrs.) were 167, 174 kg/mm^2 respectively, and the same alloy (quenched in 35% PAG) have maximum value of hardness (at aging time 6, 10 hrs.) was 143, 158 kg/mm^2 respectively, this behavior because the medium of water was faster quenching than PAG. **[L. Runxia, et al. 2010].**

From **(Fig. 2 A and B)** it is concluded that B alloy (quenched in water) caused an increase in hardness value by (20%) than A alloy (quenching in water) because the elements of Zr and Ag (in B alloy) have been affects on precipitation modifiers.

The relationship between Vickers microhardness and exposure time at aging temperature 180 $°C$ appears in **(Fig. 3)**

From **(Fig. 3A)** it is noted microhardness of alloy increase occurred from (1 to 3) hours aging time, which was followed by a plateau of contrast strength after which there was a second rise to a slightly higher hardness of 150 kg/mm^2 and 136 kg/mm^2 at aging time (6)hours for water and polymer quenching respectively. This comparison with **(Fig. 6A)** for the same alloy which treated at aging temperature 160$°C$ that achieved aging peak at 9 hour, from this concluded that in 180 $°C$ aging temperature could achieved aging peak higher and faster than that

achieved in 160$°C$ aging temperature. Alloy that quenched in PAG remain have best thermal age hardening behavior from these quenched in cooled water.

That is similar with another researcher when studied Influence of Heat Treatment on the Mechanical Properties of AA6066 Alloy **[E. Tan and B. Ögel 2007]**.

From **(Fig. 7A and B)** it is concluded B alloy (quenched in water and 35% PAG) caused an increase in thermal age hardening behavior by (17.3% and 17.1 %) respectively than A alloy (quenching in water and 35% PAG) because the elements of Zr and Ag (in B alloy) done really fine grain. Furthermore, microalloying of Ag is quite effective to improve mechanical properties because Ag increases the density of nucleation sites in the vicinity of grain boundaries.

That is similar with other researchers which studied Effects of MicroalloyingSn and (Ag+Sn) on Precipitation in the Vicinity of Grain Boundaries in Al-Zn-Mg Alloys **[T. Ogura, et al. 2010]**.

The relationship between Vickers microhardness and exposure time at aging temperature 200 $°C$ appears in **(Fig. 4)**.

From **(Fig. 4A)** In general, the growth of precipitate is the platelet shaped Mg2Si (β) phase that caused an increase in the hardness of the specimen were(154 kg/mm^2 and 135 kg/mm^2) for alloy as quenched in water and polymer media respectively. Aging for 1 hour at 200$°C$ led to the increment of hardness greater than other same specimens at 160$°C$ and 180$°C$ for the same time. Besides, the value of hardness for 1 hour, 200$°C$ aging are also inaccurate compare with other results. The values of hardness obtained is only (67.4 kg/mm^2 and 83.1 kg/mm^2)for alloy as quenched in water and polymer media respectively until 10 hours aging time, it can be concluded that over aged region was reached at 10 hours, 200$°C$ aging. But noted the alloy which quench in polymer have been thermal stability at ageing behavior higher than which quench in water medium.

That is similar with other researchers which studied the tensile strength effects on precipitation heat treatment of 6061-T6 aluminum alloy especially at aging temperature195$°C$**[M. R. said, et al 2009]**.

From **(Fig. 4A and B)** it is concluded B alloy (quenched in water and 35% PAG) caused an increase in thermal age hardening behavior by (79%, 54.7%) respectively than A alloy (quenching in water and 35% PAG) because the elements of Zr and Ag (in B alloy), whereas Zr has been serve to retard recrystallization and grain growth during processing and heat treatment of the alloys concerned due to dispersoids that form during homogenization of the ingots by solid state precipitation of compounds (Al_3Zr) and the Ag containing alloy responds to age-hardening at elevated temperatures due to the formation of a finely dispersed precipitate($AlAg_3$)**[I. J. Polmear 2007]**. Therewith the two elements eliminated or lowed the alloy to happen over aging at elevated temperature aging.

B-Impact Tests :

The impact tests also achieved on the alloys at the same different conditions that hardness tests applied as following:

-Impact Tests at Homogenization Treatment:

The impact energy evolution for alloys that homogenized for three hours at 412 $°C$ and slow cooled to room temperature was 12.5(Joule) to A alloy and 12 (Joule) to B alloy .

-Impact Tests at Solid Solution Treatment:

The impact energy measurements for alloys(A, B)which solid solution treated for (1)hour at three suggested solid solution temperatures (515, 530 and 545)$°C$ and used two different quenching media. As shown in **(Fig. 5)** the relationship between energy absorbed and exposure solid solution temperatures for two different quench media.

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From **(Fig. 5)** appears the impact energy increases display at 530°C but disparity in values comparison to the base alloy (A) whereas B alloy contains Zr and Ag these elements enhanced the impact energy about (10%) in comparison to the base alloy and an increase in impact energy befall for all alloys that quenched in 35% polyethylene glycol because low deformation and residual stresses result through quenched in contrast to water quench medium.

-Impact Tests at Aging Behavior:
The impact energy measurements for alloy achieved at three different aging temperatures (160, 180 and 200)°C at different times in these temperatures.
The relationship between energy absorbed and exposure time at aging temperature (160°C) appears in **(Fig. 6)**.
From **(Fig. 6)** it is found that the impact energy of A alloy (quenching in 35% polyethylene glycol) increased by (71%) in comparison to the A alloy (quenching in water) at four hours because when quenched A alloy in polymer solution cause the reduction of residual stresses and producing uniform in precipitate along grain boundary. And noted increase in impact energy in two aging time(4, 8)hours that concomitant to GPZs and intermediate phases formation**[R. E. Smallman, R. J. Bishop 1999]**.
From **(Fig. 6A and B)** it is obtained that the impact energy at 160 °C of B alloy (quenched in water and polymer solution) an increase by (20 %) in comparison to the base alloy, because B alloy contains Zr and Ag. Whereas the element of Zr work to prevent the processes of recrystallization. Furthermore, Ag cause formation of a finely dispersed precipitate **[I. J. Polmear 2007]**. The addition Ag to Al-Mg-Si alloys decreases the width of PFZs and increases the total elongation of the alloys **[T. Ogura, et al. 2010, E. P. Kwon, et al. 2010]**.
The relationship between energy absorbed and exposure time at aging temperature (180°C) appears in **(Fig. 7).**
From **(Fig. 7)** it seems that the impact energy at 180°C of Aalloy (quenched in 35% PAG) caused an increase in impact energy by (45.4%) than alloy that (quenching in water).
From **(Figs. 7A and B)** it seem that the impact energy at 180 °**C** of **B** alloy (quenched in 35% PAG) caused an increase in impact energy by (25%) than A alloy (quenching in 35% PAG). That enhanced in impact energy correlated to coexist the Zr and Ag elements, where these elements caused refine grains, the aging temperature (180°*C*) that effected to complete precipitates compared with aging temperature (160°*C*).
The relationship between energy absorbed and exposure time at aging temperature (200°C) appears in **(Fig. 8)**.
(Fig. 8) it is shown that the impact energy at 200 °**C** of A alloy (quenched in water and 35% PAG) decreased in comparison to the alloy that aged hardening in (160, 180)°*C*. This behavior was because over-ageing occurs at high temperature; the quick drop in the curve was an indication of the fast overaging due to high diffusion rates at high temperatures.
(Fig. 8A and B) it is shows that the impact energy at 200 °**C** of B alloy (quenched in 35% PAG) enhanced by (62.5%) in comparison to the base alloy. That enhanced correlated to the microalloying element these present in this alloy.
That is similar with other researchers which studied Influence of Heat Treatment on the Mechanical Properties of AA6066 Alloy**[E. Tan and B. Ögel 2007].**

C-Thermal Stability Tests :
A thermal stability tests achieved on alloys at various conditions i.e (solution heat treatment at different quench media and aging heat treatment).

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- Thermal Stability Tests at Solid Solution:

The DSC curves obtained at a heating rate of 20°C/min for alloy that used in this work after solid solution treatment in 530°C and quenching at two different media (water and 35% polyethylene glycol) appears in (Figs. {(9) , (10), (11) and (12)}).

(Fig 9) it is shows DSC curves of the as-quenched (A) alloy in water obtained at a heating rate of 20°C /min. The exothermic reaction peaks corresponding to the precipitation of β" and β' in (A) alloy were observed. The DSC curve of alloy shows three exothermic peaks. The first peaks have resulted from the formation of GP zones and/or Si/Mg-vacancy clusters. Recent studies have found that GP zones or Si/Mg-vacancy clusters (cluster II) are transformed to β" phase [E. P. Kwon, et al. 2010], the small peak (3) at around 262.50°C was attributed to the precipitation of β' phases. and the formation of equilibrium β (peak 4) occurs at the range of 342.99–386.93°C. Whereas the endothermic peak 2 (253.24–258.61 °C) may be attributed to the dissolution of the preformed GP zones/ β'.

In (Fig. 10) it is noted that the temperatures corresponding to the exothermic peak 1 obviously decrease with 0.35% PAG quenching, the exothermic peaks 2 and 3 nearest from each other comparison with water quenching. And notes the exothermic peaks in DSC curve for 0.35% PAG seems less sharply from these in water. That indicated on stability of precipitate in alloy that quench in 0.35% PAG.

That is similar with other researchers when were studied Effect of annealing on precipitation, microstructural stability, and mechanical properties of cryorolled Al 6063 alloy [S. K. P. R. Jayaganthan 2010].

(Figs. 11and 12) the DSC curves, for samples (B), obtained at a heating rate of 20°C /min before ageing treatment, which shows four exothermic peaks and two endothermic peaks. The endothermic peak 1(250.31-261.15°C and 125.72-134.32°C) represent the dissolution Mg and Si/clusters and exothermic reaction peak 2 at a temperature range of 254.24–268.04°Cand 128.88-143.49°C for alloy quench in water and 0.35% PAG respectively, represents the formation of solute-rich clusters. From two figures above noted acceleration to formation clusters in quenching by 0.35% PAG. Because relatively low cooling rate through a quench in polymer that tend to some solute atoms go out from solution it do as a nucleation of clusters. The formation of GP-zones or Si– Mg-vacancy clusters (peak 3) is observed at a temperature range of 318.63–363.56°C and 195.36-204.52°C for alloy quench in water and 0.35% PAG respectively; the endothermic peak 4 (207.08°C)in polymer quenching may be attributed to the dissolution of the preformed GP zones/ β' phases. The formation of incoherent precipitate β' and equilibrium precipitate β {are observed at the peak temperature range of 302.94-365.92°C for alloy quench in water and 217.23–251.45 °C for alloy quench in 0.35% PAG) (peak 5) and at the peak temperature range of 368.85-371.78 °C for alloy quench in water and 293.12–364.71°C for alloy quench in 0.35% PAG (peak 6)}, respectively. The dissolution peak of β (peak 7) occurred at the range of 340.69 -433.47°C and 369.72–418.79°C for alloy quench in water and 0.35% PAG respectively.

In DSC curves for 6061 aluminum alloy with trace addition from Zr and Ag together were showed obviously appearance all stages of precipitation sequences in 6xxx aluminum alloys. From this concluded the additions from Zr and Ag to 6061 aluminum alloy acceleration or increase its ability on precipitation and increase the thermal stability of this alloy [V. Sudarshan 2009].

- Thermal Stability Testsat Aging Treatments:

The DSC curves obtained at a heating rate of 20°C/min for alloys that quenched in two different media(water and 35% polyethylene glycol) then age hardening at 180°C(at this temperature obtained best mechanical properties). Appears in {Figs. (13) and (14)}.

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AND ADDITIONS (Zr AND Ag) ON MECHANICAL PROPERTIES   Mr. Haydar S. Rahi
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The precipitate evolutions after the ageing treatment at *180°C for alloy* were studied in detail by DSC and shown in (**Fig. 13**). The peak3 corresponding to stable β precipitate is clearly observed in 357.64°C. A small intensity peak of β' precipitate is also observed.

That is similar with other researchers which studied Effect of annealing on precipitation, microstructural stability, and mechanical properties of cryorolled Al 6063 alloy **[S. K. P. R. Jayaganthan 2010]**.

From (**Fig. 14**) it is noted the peak3 corresponding to stable β precipitate is clearly observed in 420.19°C. This mean the alloy (B) has been higher thermal stability than alloy (A) by 17.4%.

From (**Fig. 15**) it is concluded that the alloy quenched in polymer has been higher thermal stability than these alloy that quenched in water because no beak appears in alloy that quenched in polymer.

From (**Figs. 15 and 16**) it is noted the peak2 corresponding to stable β precipitate is clearly observed in 271.96°C for (A) alloy and in 296.74°C for (B) alloy. This mean the alloy (B) has been higher thermal stability than (A) alloy.

D-The Corrosion Test by Electrochemical Method:

The potentiodynamic polarization curves of 6061Al alloy in 3.5% NaCl solution These samples were quenched in two media (water and 35% polyethylene glycol) and aged at 180 °C (at this temperature obtained best mechanical properties). The corrosion current densities (i_{corr}) obtained by the Tafel extrapolation technique, its variation with different in quench medium for sample .

(**Fig. 17**) Shows that A alloy (quenched in water) have :

I corr. = 0.960 µA/cm^2

E corr. = - 765.3 mV

(**Fig. 18**) Shows thatAalloy (quenched in *35%PAG*) have :

I corr. = 0.798 µA/cm^2

E corr. = - 724.5mV

From (**Figs. 17 and 18**) it are obtained that value of corrosion current density values of alloy (quenched in 35% polyethylene glycol)then aged at 180 °**C** indicate that undergoes lower corrosion than the alloy that quenching in water.

(**Fig. 19**) Shows that B alloy (quenched in water) have :

I corr. = 1.06 µA/cm^2

E corr. = - 755.6 mV

From (**Figs. (17), (18) and (19)**) it can be obtained that value of corrosion current density values of B alloy (quenched in water)then aged at 180 °**C** indicate that undergoes higher corrosion than the base alloy that quenching in water and 0.35% PAG. This because high deformation in lattice due to precipitates and high cooling rate. And from anodic reaction in (**Fig. 19**) it could be indicated the B alloy has been higher corrosion resistance than A alloy, this com from the addition Zr and Ag to B alloy.

(**Fig. 20**) Shows that B alloy (quenched in *35%PAG*) have :

I corr. = 0.665 µA/cm^2

E corr. = - 760.1 mV

From {**Figs.(17), (18), (19)}** and (20) it can be obtained that value of corrosion current density values of B alloy (quenched in 0.35% PAG)then aged at 180 °**C** indicate that undergoes smaller corrosion than the base alloy and B alloy that quenched in water. This because low deformation in lattice due to precipitates and relatively slow cooling rate. And from anodic reaction in (**Fig. 20**) it could be indicated the B alloy has been higher pitting corrosion resistance than A alloy, this com from the addition of Zr and Ag to B alloy. This is due to precipitation of phases and intermetallic compounds **[A. M. A. Alsamuraee, et al. 2011]**.

E-Optical Microscope Testing:
From **(Fig. 21 and 22)** it is noted that the precipitates were distributed in structure , the grains sizes homogenizing and no found any cracks in alloys that quenched in polymer compared with alloys that quenched in water

F-X-Ray Diffraction Analysis:
X-ray diffraction patterns, as shown in **(Figs.(23) and (24))** trace the properties of crystalline peaks on Al 6061. Spectra show sharp peaks in alloy for 2theta around 38.26°, 44.42°, 64.74°, 77.92°, 82.2° corresponding to α-aluminum and very few diffuse diffraction peaks of varying phases of (Al_2Mg, $Al_7Cu_3Mg_6$). There is a possibility that other reflections were present in minor proportions that were not detected because the precipitates were too thin. It has been widely observed that fresh bath precipitates have either microcrystalline or fine crystalline structures **[E. Khan, et al. 2007]**. Whereas the (B) alloy were appears new intermetallic precipitates ($Al_3Zr, Ag_3Mg, AlAg_3$) moreover the previous precipitates in A alloy.

4- CONCLUSIONS

1- The better solid solution temperature was $530^\circ C$ due to this temperature give high solubility for elements with in solid solution (α-Al).
2- Addition of 0.03% Zr with 0.18% Ag to the base alloy improves thermal age hardening behavior by (17.3%) when quenching in water, and by (17.1%) when quenching in 35%PAG at 180 $^\circ C$ in comparison to the base alloy.
3- The addition of 0.03% Zr with 0.18% Ag together to base alloy improves impact energy by (25%) when quenching in 35%PAG corresponding to the base alloy when aging at 180 ℃.
4-The trace additions from Zr and Ag together were showed obviously appearance all stages of precipitation sequences in 6xxx aluminum alloys.
5- The thermal stability improved when added 0.03% Zr with 0.18% Ag (B alloy) by (17.4%) at aging temperature 180℃ in comparison to the base alloy.The alloys that quenched in polymer solution have been higher thermal stability than these quenched in water
6- An improvement of corrosion resistance in 3.5% NaCl solution when the alloys quenched in polymer solution have been higher corrosion resistance than these quenched in water.

(Table 1) The chemical composition of aluminum alloys that used in study.

Alloy	Al wt.%	Mg wt.%	Si wt.%	Cu wt.%	Zr wt.%	Ag wt.%	Fe wt.%
A	97.87	0.836	0.62	0.1522	-------	0.0022	0.0617
B	97.77	0.758	0.594	0.139	0.0395	0.189	0.0601
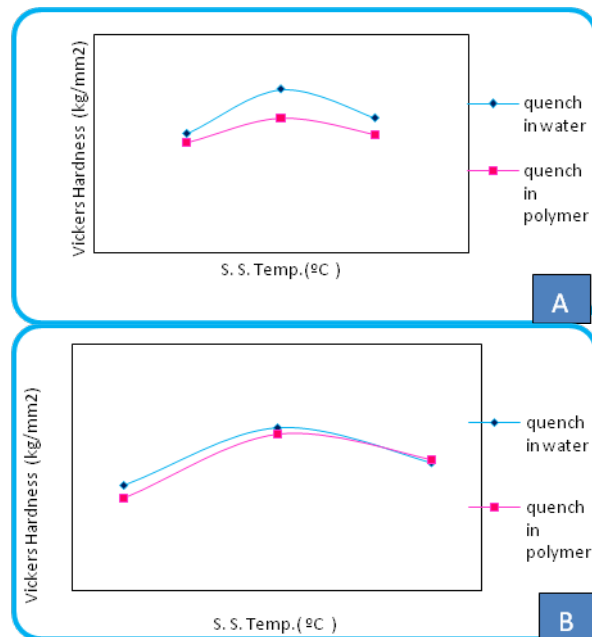
Fig.(1) Variation of hardness of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with solid solution temperatures for A and B alloys.
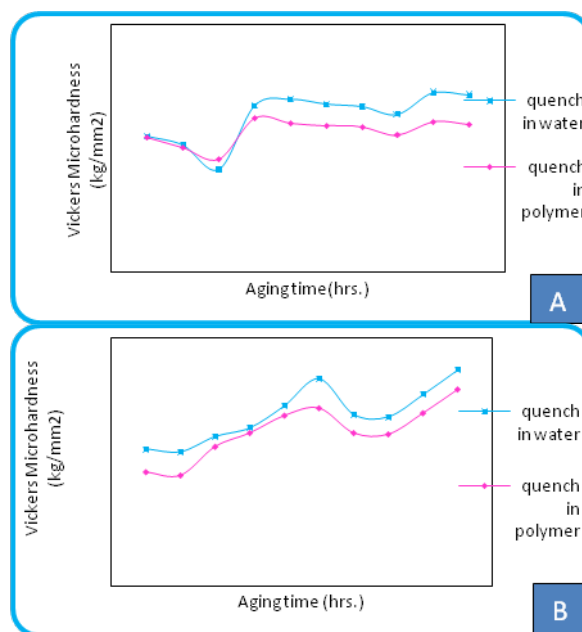

Fig.(2) Variation of microhardness of alloy samples (quenching in water medium and 35% polyethylene glycol medium) with aging time at 160°C aging temperature for A and B alloys.
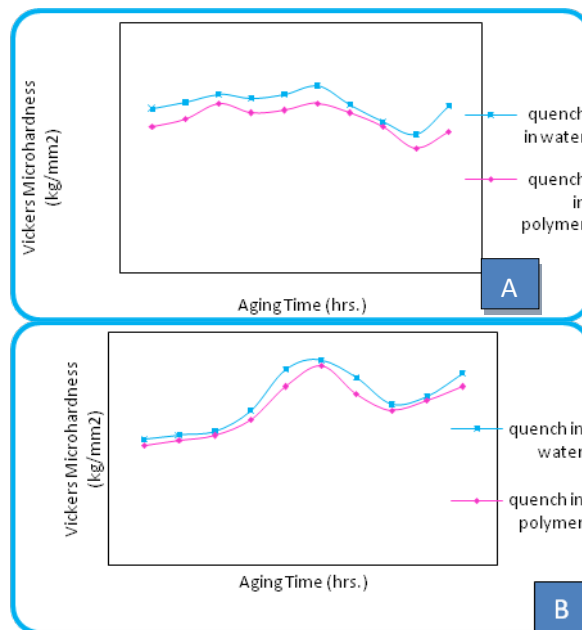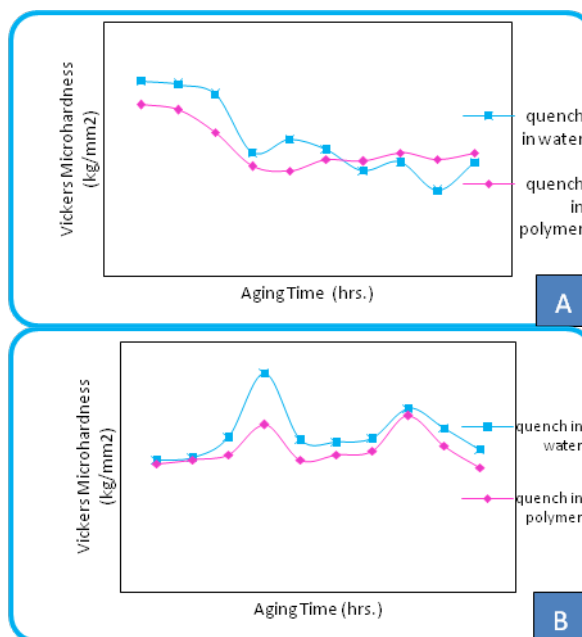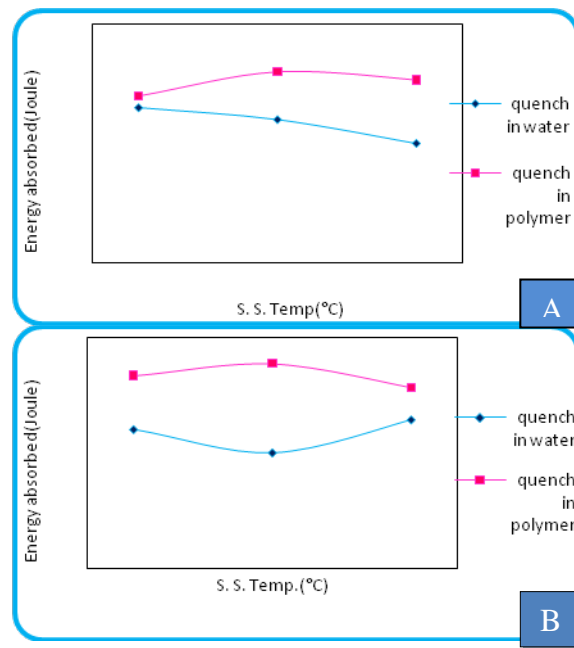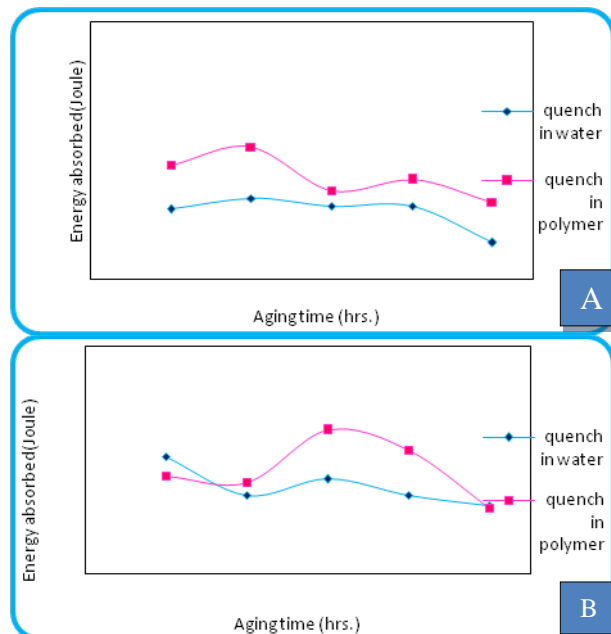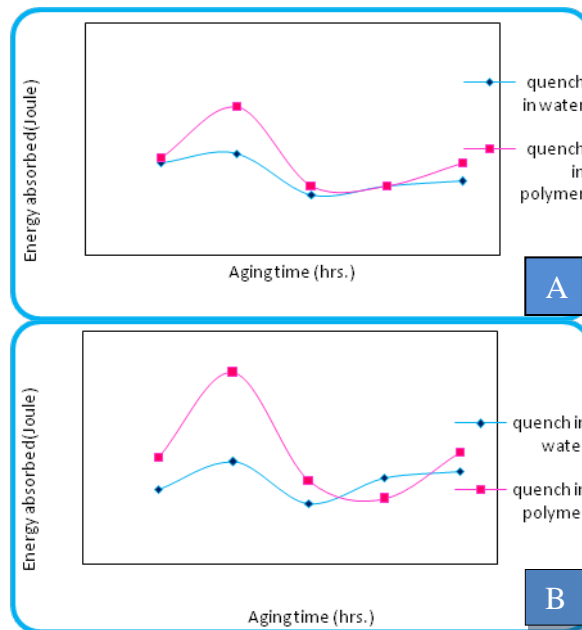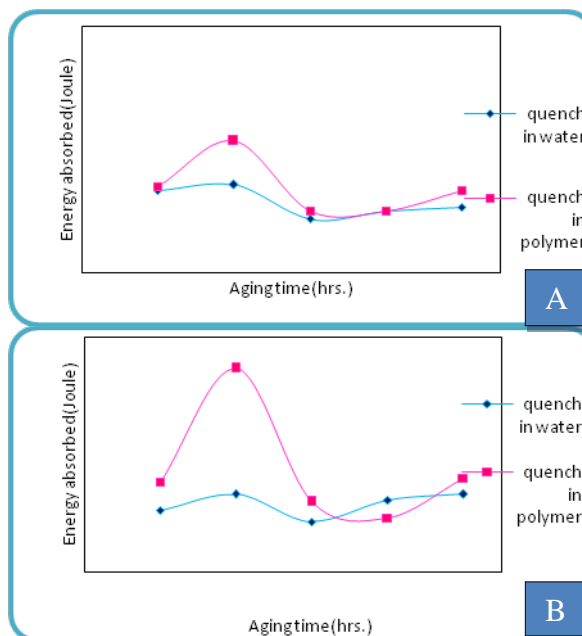
Fig.(3) Variation of microhardness of alloy samples (quenching in water medium and 35% polyethylene glycol medium) with aging time at 180°C aging temperature for A and B alloys.

Fig.(4) Variation of microhardness of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with aging time at 200°C aging temperature for A and B

Fig.(5) Variation of energy absorbed of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with solid solution temperatures for A and B alloys.

Fig. (6) Variation of energy absorbed of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with aging time at 160°C aging temperature for A and B alloys.

Fig.(**7**) Variation of energy absorbed of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with aging time at 180°C aging temperaturefor A and B alloys.

Fig. (8) Variation of energy absorbed of alloy sample (quenching in water medium and 35% polyethylene glycol medium) with aging time at 200°C aging temperature for A and B alloys.
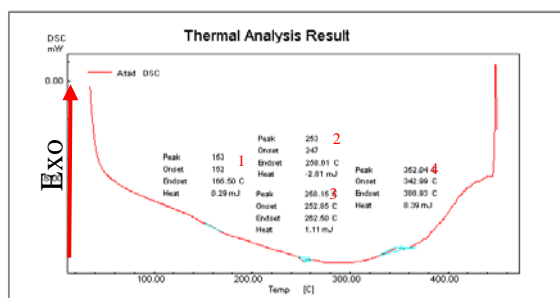
Fig. (9) DSC curve of the A alloy as-quenched in water.
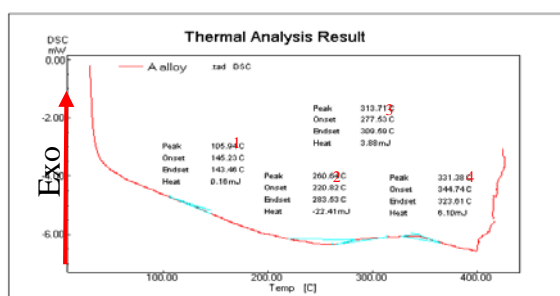
Fig.(10) DSC curve of the A alloy as-quenched in 0.35% PAG
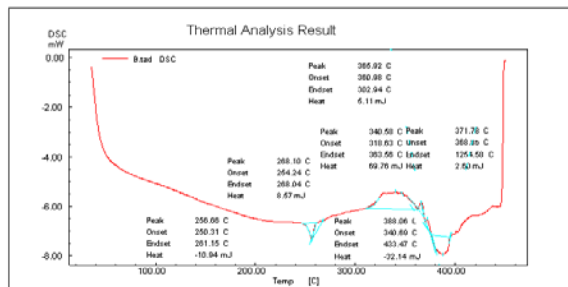
Fig.(11) DSC curve of the (**B**) alloy as-quenched in water.
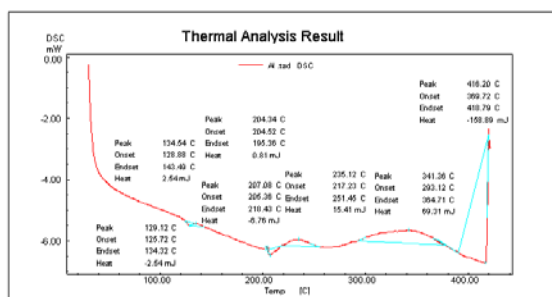
Fig.(12) DSC curves of the (B) alloy as-quenched in 0.35% PAG.

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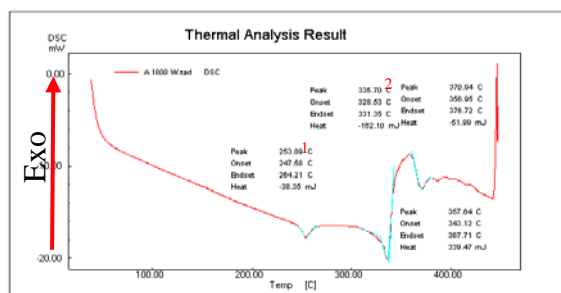
Fig.(13) DSC curve of the **A** alloy that quenched in water and aged.
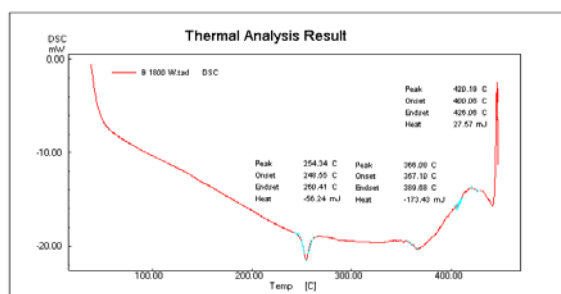
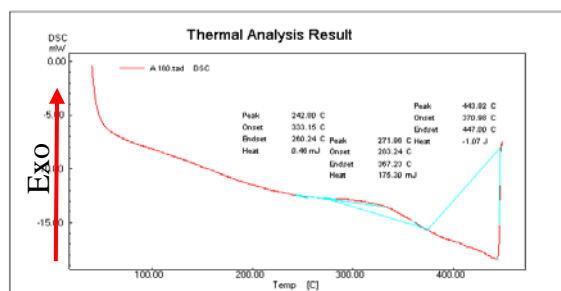**Fig.(14)** DSC curve of the (B) alloy that quenched in water and aged**.**
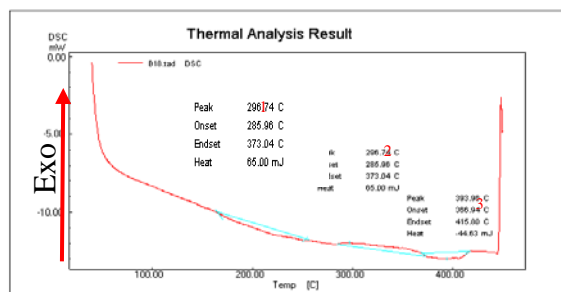

Fig.(15) DSC curve of the A alloy that quenched in 0.35% PAG and aged.

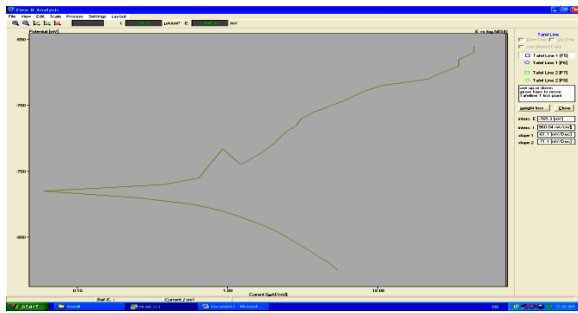**Fig.(16)** DSC curve of the **(B)** alloy that quenched in 0.35% PAG and aged.

Fig.(17) Tafel curve forA alloy that quenched in water.

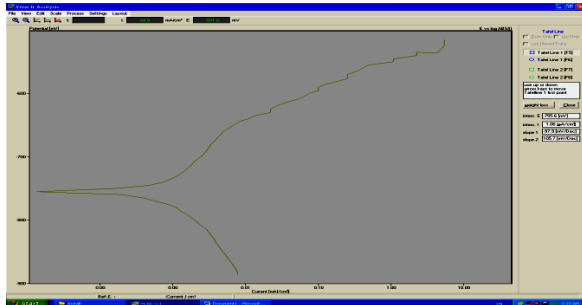**Fig.(18)**Tafel curve for A alloy (base alloy) that quenched in 35%PAG.

Fig.(19) Tafel curve for **B**alloy(containing Zr with Ag) that quenched in water.
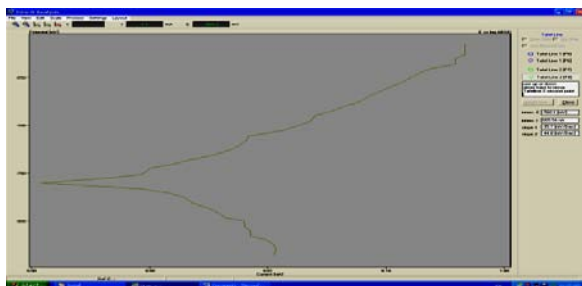

Fig.(20) Tafel curve for **B**alloy(containing Zr with Ag) that quenched in 35%PAG.
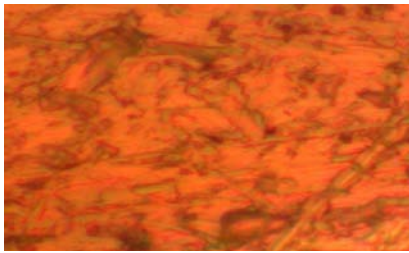
Fig. (21) Microstructure of A alloy after ageing treatment in 180°C to alloy that quenched in water. 800X
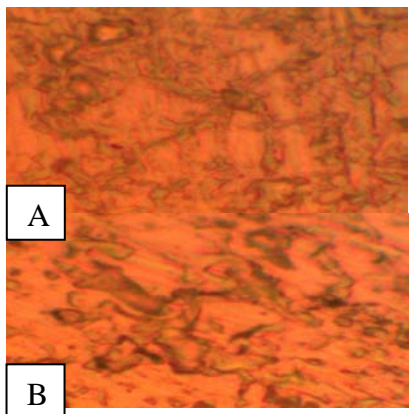

Fig. (22) Microstructure of B alloy after ageing treatment in 180°C A) to alloy that quenched in water B) to alloy that quenched in polymer. 800X
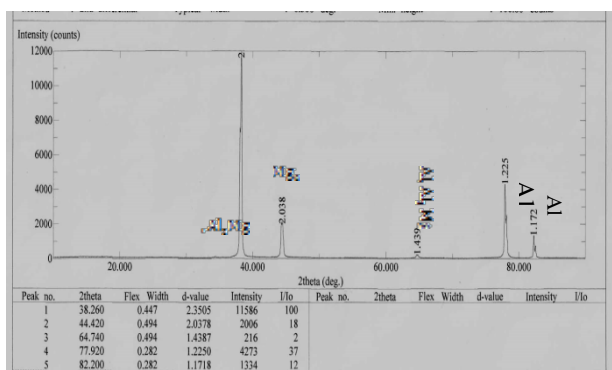

Peak no.	2theta	Flex Width	d-value	Intensity	I/Io	Peak no.	2theta	Flex Width	d-value	Intensity	I/Io
1	38.260	0.447	2.3505	11586	100						
2	44.420	0.494	2.0378	2006	18						
3	64.740	0.494	1.4387	216	2						
4	77.920	0.282	1.2250	4273	37						
5	82.200	0.282	1.1718	1334	12						

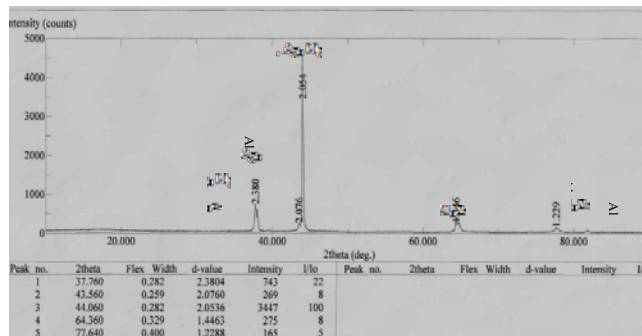**Fig.(23)** XRD pattern of **A** alloy at the as-aged state

Fig.(24) XRD pattern of **B** alloy at the as-aged state.

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