

Effect of Cd Additive on the Hardness and Tensile Properties of Al-Mg-Si Alloy

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Abstract
The aim of this paper is to study the effect of adding Cd element to aluminum alloy series (6000) on the mechanical properties (hardness & ultimate tensile strength) which have been studied .A permanent mold casting method was used for preparing the specimens of alloys by adding Cd at (0.1,0.3,0.5)% wt . to (Al-Mg-Si) alloy. Heat treatment homogenous alloy ingots were carried out at (550ºC) for (24 hours) .These heat treatments for all specimens were conducted after cutting the ingots to the required dimensions ,solution heat treatment at (500ºC) for (1 hour) and then quenching in the water at room temperature. Then natural aging was carried out at room temperature for (90 days) ,whilst with in this period the hardness of alloys were measured at subsequent equal interval . The artificial aging for the prepared alloys was carried out, at (160and 180) ºC for an interval ranging between (5 mins. & 35 hours) .The Vickers hardness and ultimate tensile strength were measured .The hardness and ultimate tensile strength of Cd alloys have relative improvements by natural aging.
Keywords: Cd element, (Al-Mg-Si) alloy, homogenous, artificial& natural aging.

INTERODUCTION

Aluminum alloys have a number of characteristics, the most important are light-weight and high strength"[1]".Series (6000) is heat treatable Aluminum alloy, it is very important when used in automotive body parts , automotive skin panel , railway carriages, pipes due to the present of Mg ,Si elements as the impurities during the alloy production , which lead to high machine ability ,weld ability, Form ability, increasing strength by phase precipitation (Mg_2Si) during aging hardening"[2-4]". Vesnamaksimovic "[5]".studied the effect of small additions of Si and Ge on hardness of commercial Al-Cu alloy .He found that for the same level of micro alloying in alloy Al-Cu-Si-Ge, a maximum hardness was achieved (3) times faster than in alloy Al-Cu, the accelerated precipitation kinetics is a consequence of the presence of fine Si and Ge particles, serving as heterogeneous precipitation sites for θ" strengthening particles .Brook "[6]" studied the effect of equivalent amounts of Si and Ge on hardness of Al-Cu alloys after aging at (165) °C ,he showed that the higher peak hardness of Al-Cu-Ge alloy appears at shorter aging time compared to that of Al-Cu-Si alloy. Closset "[7]" studied the effect of equivalent amounts of Se on hardness of Al-Si-Mg alloys after aging at (155) °C ,he noticed an increasing in the hardness .Kim "[8]" studied the fracture behavior of Al-Si alloy by varying aging condition under resonant vibrations, he showed that strength of alloy can be improved by aging. Surappa "[9]" studied the effect of the particles of Al2O3 on relative expansion & tension resistance of pure Al & Al-Si alloys , he noticed decrease in relative expansion and rises tension resistance with increasing of the particles of Al2O3. Yang "[10]" studied the effect of the Bauxite particles on Al-Cu alloy ,he showed an increasing in the strength and hardness. Guden "[11]" studied the effect of the SiC particles on Al-Cu alloy ,he showed an increasing in the stress , strain and hardness. Kwon "[12]" studied the effect of Cu & Ni particles on Al-Si alloy ,he showed an increasing in ultimate tensile strength & hardness. Gibson "[13]" studied the effect of Si & graphite particles on Al-Si alloy ,he showed that graphite increasing solidification & friction factor of alloy. Etter "[14]" studied the effect of Al & graphite particles on Al-Si alloy ,he noticed that additive graphite and Al particles composite increasing strength and fracture toughness of alloy . Silcock "[15]" studied the effect of aging temperature on hardness of different ratios of Cu particles on high pure Al , he showed that the precipitation phases will changed with aging temperature . Vietz "[16]" studied the effect of aging temperature on hardness of different ratios of Ag particles on Al-Zn-Mg alloy, he showed that the effect of Ag particles will change with the Zn and Mg content .Makin"[17]" studied the effect of aging temperature on Al-Zr-Li alloy .He found that Zr element highly effected the hardness of Al-Li alloy. Polmear"[18]" studied the effect of Ag element on Al-Zn-Mg-Cu & Al-Cu alloys .He found that Ag element is increasing the hardness of alloys. Chaturvedi "[19]" studied the effect of Si on Al-Cu-Mg alloy .He found that Si is increasing the strength and hardness of the alloy .Price"[20]" studied the mechanical properties of (Al+2%Ag) &((Al+15%Zn) alloys. He found that the present of GP zone lead to high yield strength. Brook "[21]" studied the effect of small amounts of Cd ,In, Sn ,Mg ,Si and Gr on the Al-Cu alloys. He found that the Cd ,In, Sn elements due to high precipitation and high stability ,Mg ,Gr elements increasing the velocity of consisting the phase θ′& increasing hardness.

Lizhen et al. "[22]" Al–0.66Mg–0.85Si–0.2Cu alloys by Zn addition was investigated by electron back scattering diffraction (EBSD), high resolution electron microscopy (HREM), tensile and Erichsen tests, the alloys displayed excellent mechanical properties. .Gilmore "[23]" studied the effect of small amounts of ,In ,Mg, and Si on the Al-Cu-Li alloys on mechanical properties. He found that the ,In, element due to modifies θ" morphology and Mg element due to increasing the precipitation of the phase θ". Laughlin "[24]" studied the effect of ,Cu and Mn element on the Al-Mg-Si alloys on mechanical properties. He found that the increasing Cu due to increasing peak hardness. Miao "[25]" studied the effect of natural aging of the Al-Mg-Si alloys on the mechanical properties. He found that increasing the hardening precipitation before natural aging. Deschamps "[26]" studied the effect of strain hardening on the mechanical properties of Al-Mg-Si-Cu alloys. He found an increase in yield strength. Hirth "[3]" studied the effect of Si content in the Al-Mg-Si-Cu alloys on mechanical properties &aging behavior. He found increasing strength and formability. Ohmori "[27]" studied the effect of increasing Si content on the Al-Mg-Si alloys on aging behavior. Kawai "[28]" improved the Al-Mg-Si alloys as a shock absorber on aging behavior. He found an increasing yield strength. Ravi "[29]" studied the effect of Fe element on the mechanical properties of Al-Si-Mg alloys. He found an increase in Fe element leads to increasing mechanical properties. Ganmer "[30]" improved the mechanical properties of the Al-Si-Mg alloys by adding Eu ,Sr elements . Chakrabarti "[31]" studied the effect of Cu element on the mechanical properties of Al-Mg-Si alloys. He found that increasing Cu element leads to increasing strength.

Age Hardening

After heat treatment and quenching, hardening is achieved at room temperature (natural ageing). In some alloys sufficient precipitation occurs in a few days at room temperature to yield stable products with properties that are adequate for many applications. These alloys sometimes are precipitation heat treated to provide increased strength and hardness in wrought and cast alloys. Other alloys with slow precipitation reactions at room temperature are always precipitation heat treated before being used "[32]".The artificial ageing or precipitation heat treatments are low temperature long time processes .Temperatures range from(100-200)°C at times from (5-48)hours"[18]".

Experimental Work

This work included an evaluation of the alloys .The Al-Mg-Si alloys used in the present study were chemically analysed by using atomic emission spectra photometer at" Nasser State Company for Mechanical Industries/Iraq". The chemical compositions of this alloy were listed in the table (1) .

Heat treatment

Alloys under investigation were homogenized and subjected to solution heat treatment before natural ageing as showed in table (2).

Preparation of the Specimens

All alloys were cut to circular form specimens of 4mm thickness with 2cm diameter in order to test the ultimate tensile strength and hardness. These specimens were ground by emery paper of grades (100, 150, 500, 1000). Then the specimens were washed in de ionized water and dried in air. After that the specimens were polished with nap cloth containing alumina particles size of (5μm) by using polishing machine, washed in alcohol and dried.

Vickers Hardness test

The hardness test of investigated specimens had been carried out by using MIC 10 Agfa NDT GmbH tester using a suitable probe for measuring hardness .It is a digital instrument that depends on an ultrasonic ray having high accuracy.

Ultimate Tensile Test

The maximum tensile strength for the alloys used in this paper were estimated depending on the MIC 10 Agfa NDT GmbH tester by using a suitable probe for measuring the ultimate tensile strength, without any shape preparation of specimens like dumbbell shape but just a circular form specimens .

Results and Discussion

The effect of natural ageing on hardness

Fig. (1) Shows the relationship between the hardness and the ageing time for the present alloys. The behaviour of these alloys at room temperature was noticed to be similar nearly and increases to peak hardness as a function of

Cd element .Therefore peak hardness for alloy(b3), represented the maximum value (125) kg/mm^2 , the other was the (118) kg/mm^2 for alloy(b2) and the minimum hardness(101) kg/mm^2 for alloy (b1), this means that the average hardness for alloys(b1,b2,b3) is the highest value than alloy(a) due to the reaction of Cd alloying element with vacancies which is consists of GP zones(Guinier-Preston zone), the role of Cd to redistribute the vacancies and increase the precipitation particles density, refining coherent precipitation particles as well as precipitation Cd in the lattice of an alloy matrix and resist the dislocations movement causing increasing hardness"[5,21]".

The effect of artificial ageing at (160 ºC) on the hardness
Fig. (2) shows the relationship between the hardness and the ageing time at (160 ºC) for used the specimens ,notice the positive effects due to the presence of Cd element, first on hardness specimen (b1,b2,b3) when compared with specimen (a), second on aging time and reduce the time needed to show a peak hardness, because the effect of Cd on precipitation processes by heat treatment which depends on two operations, first redistribution of vacancies and diffusion of precipitation particles in a lattice of matrix .Second nucleation & growth phases and controlling the precipitation volume, particles distribution which lead to increasing nucleation & growth phases θ′ and θ" during artificial ageing[5,21].

The effect of artificial ageing at (180 ºC) on the hardness
Fig. (3) shows the relationship between the hardness and the ageing time at (180) ºC for all specimens, notice that the peak hardness of all specimens are the same average values at aging temperature (160) ºC but that peaks appear at small time (45)minutes as a resultant of increasing aging temperature (180) ºC which is the effect of aging time & precipitation phases.

The effect of artificial ageing at (160ºC) on the Ultimate Tensile strength
Fig. (4) shows the relationship between the ultimate tensile strength and the ageing time at (160) ºC for all specimen, notice that the average values of peaks be equal for all specimens ,so increasing Cd element have little effect on ultimate tensile strength ,due to the precipitation of Cd element in the lattice of matrix ,resists the movement of dislocations and increases precipitation density of phases .

The effect of artificial ageing (180)ºC on the Ultimate Tensile strength
Fig. (5) shows the relationship between the ultimate tensile strength and the ageing time at (180) ºC for all specimen, noticing that the average values of ultimate tensile strength at (180) ºC are larger than the average values of ultimate tensile strength at (160) ºC for all specimens due to the high aging temperature and presence Cd element which makes to refine the grain size of particles and homogenize the distribution of precipitation phases.

Conclusions
1- It has been noticed that the increasing Cd element leads to increasing hardness at natural aging.
2- Increasing Cd element caused to reduce the time for hardness peak appear at (160 ºC)
3- The average values of hardness & ultimate tensile strength of present alloys to be equal at both aging temperatures.
4- Artificial aging at (180) ºC reduces the time for appearing hardness peaks and is better than artificial aging at (160) ºC .

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Table (1) the Chemical composition of Al-Mg-Si alloys

	ELEMENTS %									
type	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Cr**	**Ti**	**Cd**
a	rest	0.77	0.23	0.030	0.44	0.58	0.010	0.01	0.006	-----
b1	rest	0.77	0.22	0.028	0.42	0.56	0.009	0.008	0.004	0.10
b2	rest	0.75	0.23	0.027	0.43	0.54	0.010	0.007	0.005	0.30
b3	rest	0.74	0.21	0.030	0.41	0.55	0.008	0.010	0.006	0.50

Table (2) conditions of Heat Treatment of Alloys

Al-Mg-Si alloys	**Condition**
a,b1,b2,b3	Homogenous at 550ºC for 24 hrs.+ Quenching + Heat treatment at 500ºC for 1hr. + Quenching + natural aging at room temperature for 90 days.
a,b1,b2,b3	Homogenous at 550ºC for 24 hrs.+ Quenching + Heat treatment at 500ºC for 1hr. + Quenching + artificial aging at(160, 180) ºC for interval ranged between (5 min. & 35 hours) .

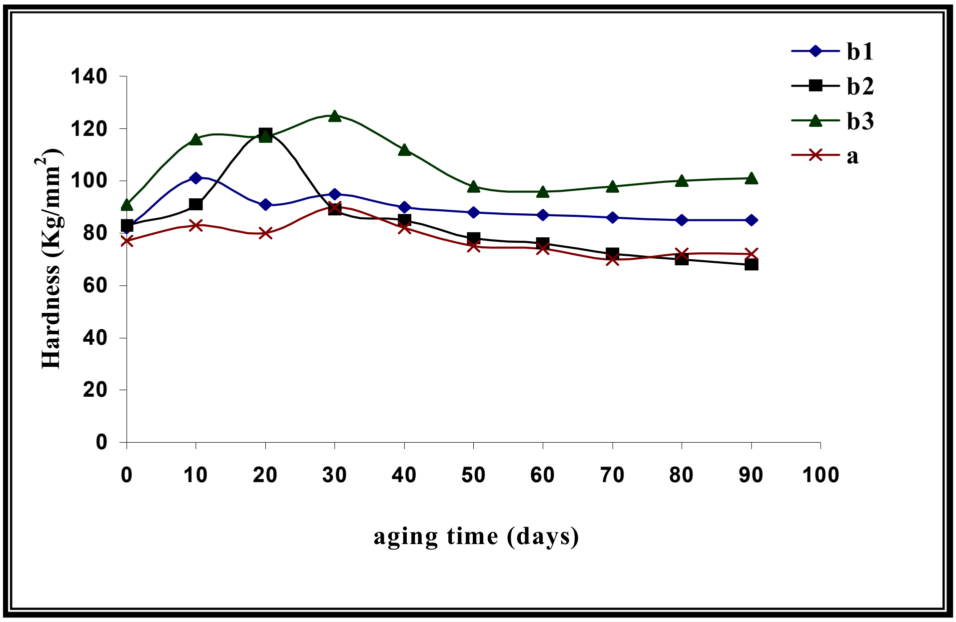

Fig. (1) Relation between hardness & aging time at natural aging For specimens (b_3, b_2, b_1, a)

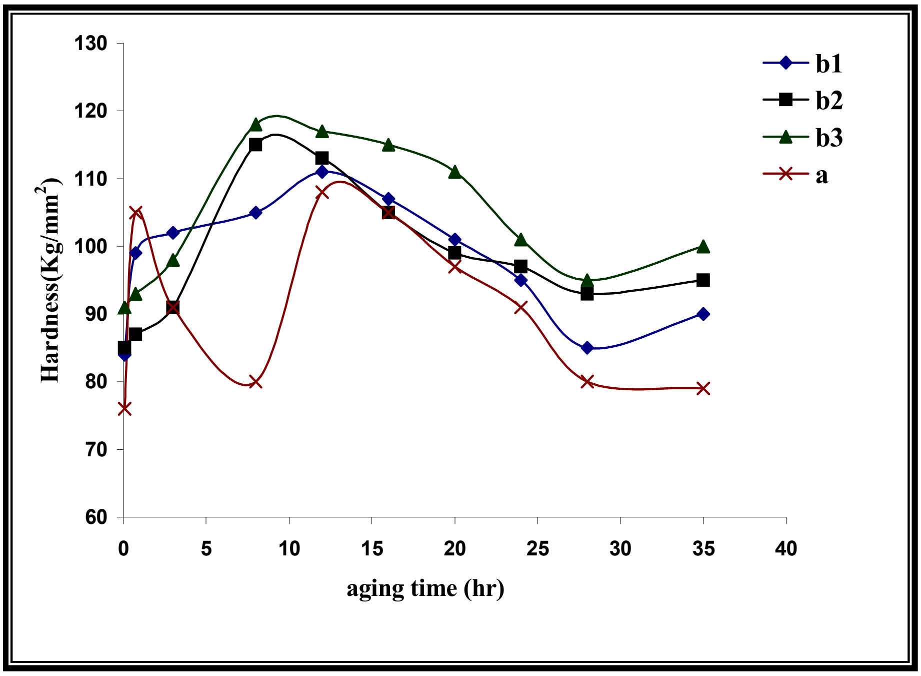

Fig. (2) Relation between hardness & aging time at temperature (160) ºC For specimens (b_3, b_2, b_1, a)

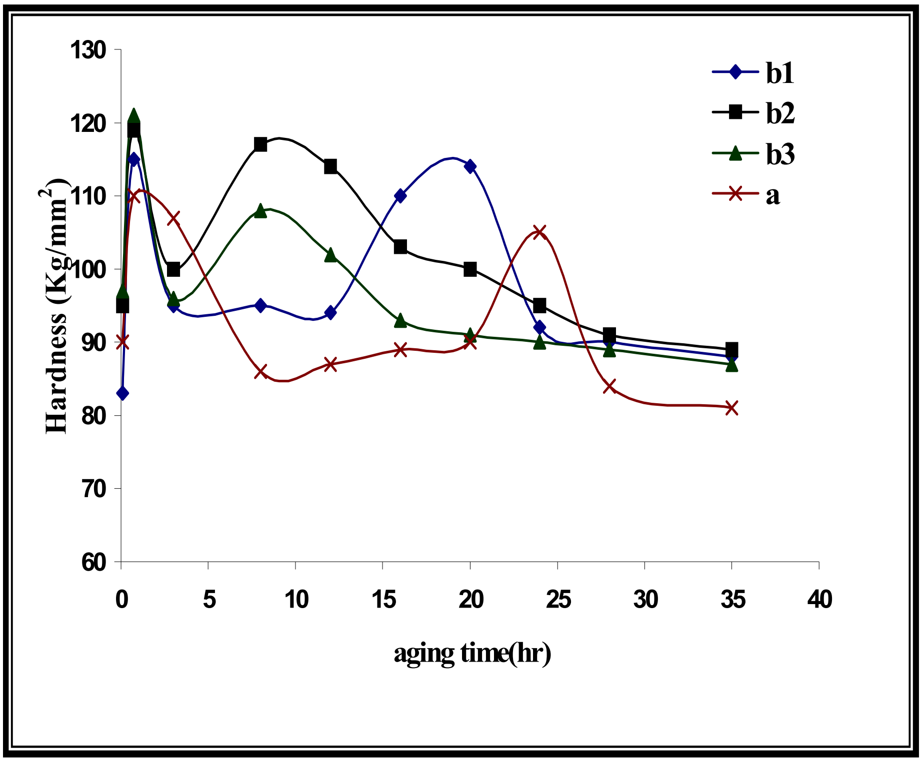

Fig. (3) Relation between hardness & aging time at temperature (180) ºC For specimens (b_3, b_2, b_1, a)

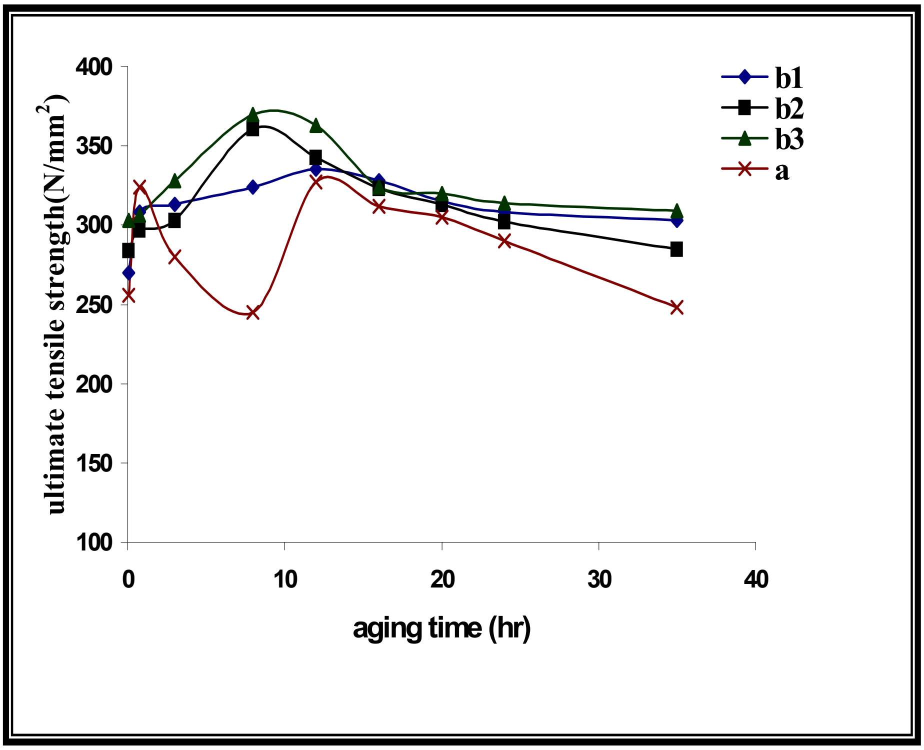

Fig. (4) Relation between ultimate tensile strength & aging time at temperature (160) ºC For specimens (b_3, b_2, b_1, a)

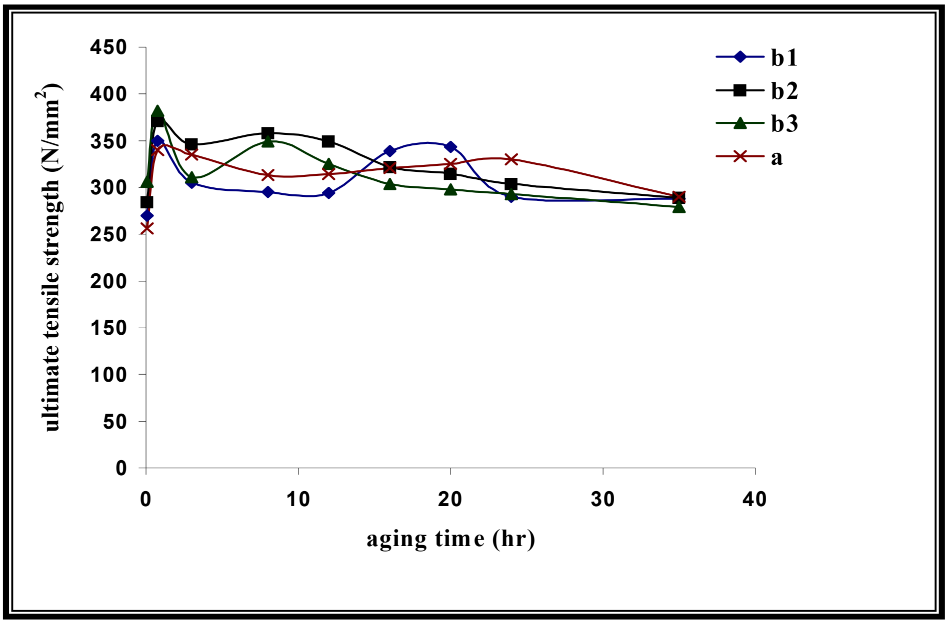

Fig. (5) Relation between ultimate tensile strength & aging time at .temperature (180) ºC For specimens(b_3, b_2,b1,a)