The effect of (0.5-1)%Mn addition on the microstructure and hardness of Al6061-alloy

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Abstract

This study has been carried out to examine the microstructure and hardness of Al6061-T6 alloy with and without a (0.5 -1 mass%) Mn addition .The 6061 Al-alloy work pieces were solution heat treated at 520 °C for 1 h followed by quenching in water at room temperature. The work pieces were artificially age hardened at 200 °C for a period of 1and 2 h in a furnace and subsequently cooled in air. From the results, the microstructures of the as-cast alloys are characterized by the presence of Mg2Si,Si particles and AlFeSi particles. After added (0.5%Mn) and (1%Mn),Al6Mn particles have been appeared in the microstructure ..When (1%Mn) was added the size of Al6Mn particles were larger than the same particles when the addition was (0.5%Mn).The aging causes increasing in the size of Al6Mn particles, increasing the aging time to 2hr causes coalesced of the particles of Al6Mn. The particles of Al6Mn were acted as barrier of dislocation which cause increasing in hardness, the increasing of aging time causes coalesce of the particles which causes reducing in the hardness.

Keyword:Al6061,hardness,treatment,microstructures,Mg2Si,Al6Mn

1-Introduction

Industrial application of aluminum alloys has been expanded for advantages of their light weight, workability, and excellent corrosion resistance[1,2].Aluminum alloys are widely used in the automotive industry nowadays, since recent trends incline toward achieving higher performance without increasing weight. Thus, automotive components are increasingly being made of aluminum alloys in order to reduce overall weight [3,5,9]. Soo woo nam and duck hee lee, investigated that as the Manganese content increase over 0.5wt% in such aluminum alloys as the 6000 and 7000 series alloy, hardness, yield and ultimate tensile strength increase significantly without decreasing ductility. The added Mn forms manganese dispersion of Al6Mn, this dispersoid has an incoherent structure relationship with respect to the matrix, Fcc, in retarding the motion of dislocations that increase strength [11]. Abdulwahab et al. have investigated the micro structural and mechanical properties upon thermal aging of a sand cast antimony-modified A356-type Al-Si-Mg alloy. The prepared alloy was solution heat treated at 540^{o}C /1hr then subjected to thermal aging treatment at 180^{o}C for 1-5 hr. There mechanical properties; tensile properties, hardness and impact strength were used as criterion. From the results, the tensile properties and hardness increased with thermal ageing treatment. While the impact energy and elongation decreased upon ageing. The tensile properties of antimony-modified Al-Si-Mg alloy improved with ageing time and that the microstructures indicate spherodization of the silicon flakes to fine structures, which account for the improved properties [10].Improving the quality (better structure and mechanical properties) involves the application of two major processes:(1) addition of alloying elements during the melting stage and melt treatment (grain refining and modification) or (2) heat treatment[4,7].In this research both processes were used , (0.5 -1 mass%) Mn were added to specimens of 6061Al alloy. The prepared specimens were solution heat treated at 520 ^{o}C for 1 hr followed by quenching in water at room temperature. Following the solution heat treatment, the work pieces were artificially age hardened at 200 ^{o}C for a period of 1 and 2 h in a furnace and subsequently cooled in air. x-ray and microstructure inspection were used to find out changes in the structure, hardness inspection is applied to investigate the effect of this addition and heat treatment on hardness.

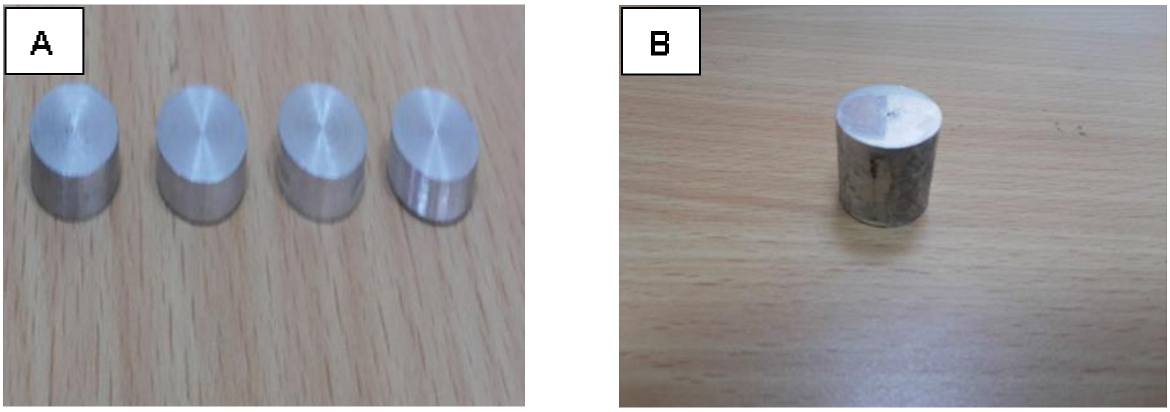
2-Experimental

The work ingots of Al6061 were cut into smaller pieces, cleaned, dried, and melted to prepare the required alloys (as received, with 0.5% Mn, and 1%Mn). The melting process was carried out in a SiC crucible of 2 kg capacity, using an electrical resistance furnace. The melting temperature was maintained at 750 ± 5 ^{o}C. The chemical composition of alloys was analyzed by the specialized institution of Engineering Industries-Baghdad .The chemical composition of alloys are summarized in **Table1**.The alloys were solution heat treated at temperature of 520^{o}C in an electric heat treatment furnace, soaked for 1 hr at this temperature and then rapidly quenched in warm water. The quenched specimens were then aged at 200^{o}C, for 1-2hr before cooling in air. The microstructure was examined for the polished samples surfaces by optical microscopy (OM) and X-ray

diffraction (XRD) technique. Vickers micro hardness tests were conducted on the samples with an applied load of 500 g□
□

Table: 1 Chemical compositions (mass%) of the alloys used in the present study

alloys	Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Pb	V	Cd	Zn
6061	Bal	0.681	0.302	0.321	0.067	0.89	0.202	0.004	0.006	0.010	0.001	0.006
6061+ 0.5Mn	Bal	0.683	0.422	0.321	0.430	0.752	0.20	0.005	0.007	0.011	0.001	0.006
6061+ 1Mn	Bal	0.543	0.397	0.275	0.988	0.616	0.20	0.005	0.007	0.011	0.001	0.006

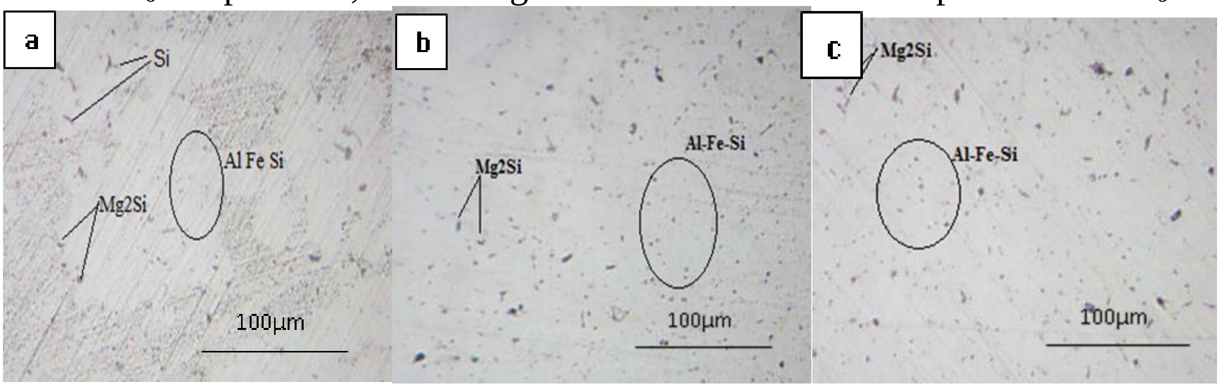


Figure(1) (a)Specimens of XRD test ,(b) Specimen of hardness and microstructure test

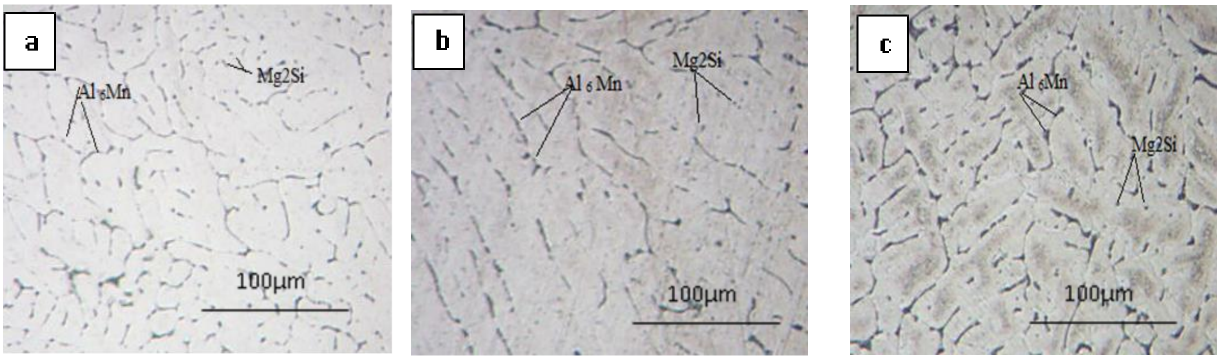
3-Results and Discussion:

1.3- Microstructure:

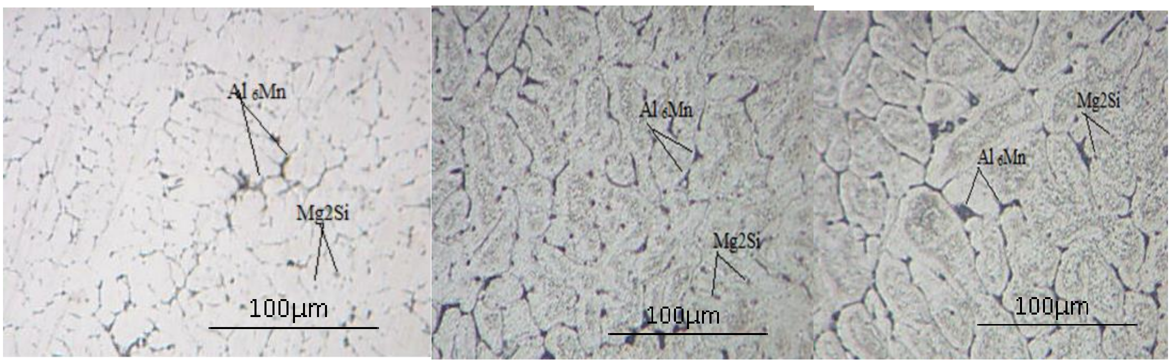
The microstructure of the as cast alloy is shown in **Figure2(a),**The Al6061 alloys contain Si particles , fine AlFeSi intermetallics and a small volume fraction of undisclosed Mg_2Si which is normal for Al6061.**Figure 2(b,c)** shows the microstructure of a heat treatment structure of specimens , it can be noted that ,with increasing heat treatment the Si particles are replaced by fine AlFeSi particles[12]. **Figure3** shows the microstructure of Al6061after added (0.5%Mn),this structure have particles of Al_6Mn and Mg_2Si.Appling heat treatment for 1 hr causes increasing in the size of Al_6Mn particles. increasing the aging time for 2 hr causes coalesce of Al_6Mn particles. **Figure4** shows the microstructure of Al6061after added (1%Mn),this microstructure show the particles of Al_6Mn and Mg_2Si .When 1 Mn was added the size of Al_6Mn particles were larger than the same particles when the addition was (0.5%Mn). A larger quantity of Mn was added into the alloy so the size of Al_6Mn particles increases as well[13]. The heat treatment causes increasing in the size of Al_6Mn particles, increasing the aging time to 2hr causes coalesced of the particles of Al_6Mn



Figure(2) (a) as cast without heat treatment ,(b) as cast with T6 heat treatment (200 ^oC for 1hr),(c) as cast with T6 heat treatment (200 ^oC for 2hr).



Figure(3) (a) Al6061+0.5%Mn with out heat treatment ,(b) Al6061+0.5%Mn with T6 heat treatment (200 oC for 1hr),(c) Al6061+0.5%Mn with T6 heat treatment (200 oC for 2hr).



2.3Micro hardness

Figure5 shows the variation of micro hardness values of Al 6061 alloy with 0.5%Mn addition and with 1%Mn addition as a function of aging when aged for 1 and 2 hours. The hardness of Al 6061 alloy was increased after applying the heat treatment and increasing the aging time and the micro structures indicate to convert of the silicon flakes to fine structures, which account for the improved properties[6]. It should be noted that the hardness of the Al6061alloy is always lower than that of the Al6061%Mn alloy at any aging time, Al6061 after heat treatment shows fine particles of AlFe Si phase and these particles are very discrete and that cause increasing in hardness, there is also a presence of very fine Mg2Siparticles within the Al matrix.Mg2Si phase is considered to be the main strengthening phase for the Al-Mg-Si-Cu alloy. When 0.5%Mn was added, fine particles of Al6Mn were produced, these particles may act as barrier of dislocation which cause increasing in hardness, the increasing of heat treatment causes coalesce of the particles which reduce the hardness[8] .When 1%Mn was added, the quantities of Al6Mn increase with an increase in Mn contents, thus their effects on inhibition of dislocation movements increase as well, so the hardness of alloy was increased. with increasing of the heat treatment the particles of Al6Mn were coalescing so the hardness would be reduced.

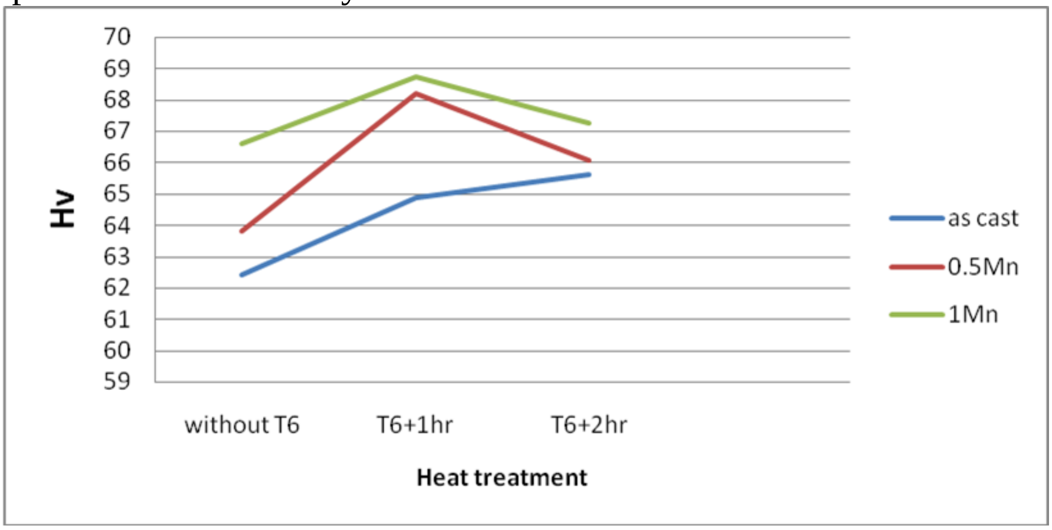
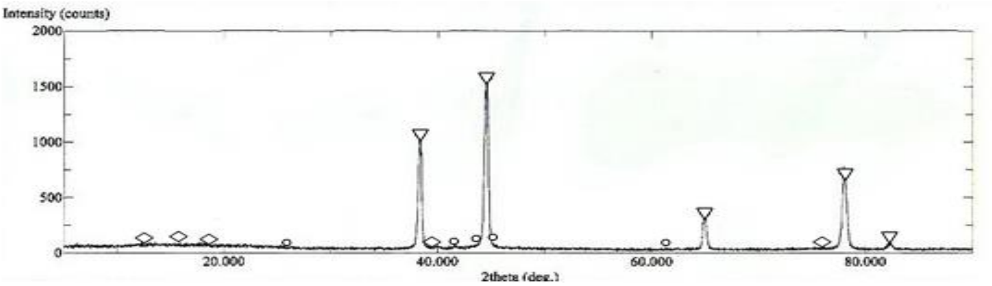
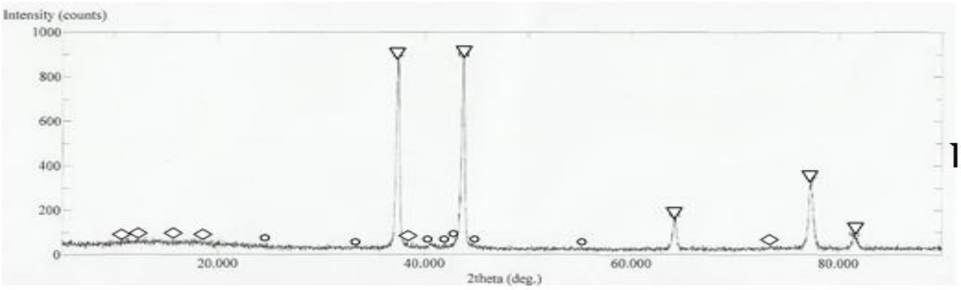


Figure (5) shows the variation of micro hardness values of Al 6061 alloy, with 0.5%Mn addition and with 1%Mn addition as a function of aging when aged for 1 and 2 hours

Figure 5. shown X Ray diffraction for samples of Al-6061 alloy and prepared alloys

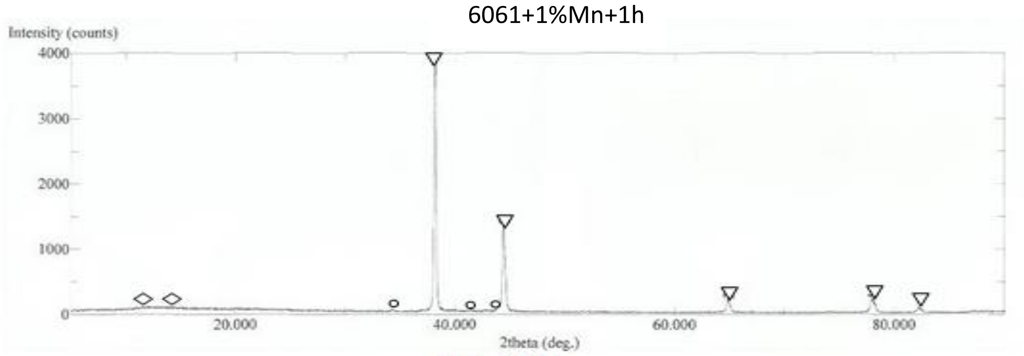


6061+0.5%Mn+1h

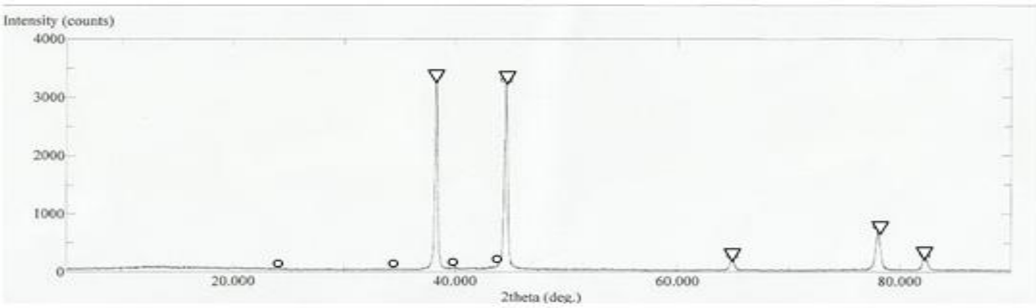


6061+1%Mn+1h

6061+1%Mn+1h



6061+1%Mn



6061+2h

(o Mg_2Si) – (◊Al_6Mn) – (∆Al) – (•Al Fe Si)

Figure(6) XRD Graphs

Conclusion-3

-**1**The microstructure of the as cast Al6061alloy is contained fine particles of AlFe Si intermetallics and a small volume fraction of undissolved Mg2Si.

-2The microstructure of Al6061after added (0.5Mn and 1Mn)is contained particles of Al6Mn.

-3Specimens are shown that the volume fraction and size of (AlFe Si and Al6Mn) particles increase by applying T6 heat treatment and increasing aging time.

-4Increasing the aging time cause coalesced of the particles of (AlFe Si and Al6Mn. (

-5It can be notice that, the hardness was increased with heat treatment, the increasing of aging time causes reducing of hardness and the reason of that is the merging of the particles of (AlFe Si and Al6Mn .(

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تأثير إضافة المنغنيز (1-0.5%) على البنية المجهرية والصلادة لسبيكة ألمنيوم مغنيسيوم سليكون (Al6061-alloy)

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الخلاصة

هذا البحث يتناول دراسة البنية المجهرية و الصلادة مع و بدون إضافة(1-0.5٪) منغنيز لسبيكة Al6061-T6. تم إجراء المعاملة الحرارية المحلولية للعينات عند درجة حرارة 520 م^o لمدة ساعة ثم الإخماد بالماء بدرجة حرارة الغرفة ثم تعتيق العينات لمدة (1 و 2) ساعة عند درجة حرارة 200 م^o في الفرن ثم التبريد في الهواء. تبين النتائج ان البنية المجهرية للسبيكة بدون إضافة تحتوي على أطوارMg_2Si و$AlFeSi$ بالإضافة إلى دقائق السليكون. بعد إضافة(Mn٪1-0.5) تظهر البنية المجهرية وجود دقائق Al_6Mn ،ويكون حجم هذه الدقائق اكبر عندما تكون الإضافة1% Mn. عند أجراء التعتيق لمدة ساعة نلاحظ زيادة في حجم هذه الدقائق، عند زيادة زمن التعتيق لمدة ساعتين نلاحظ تجمع لهذه الدقائق . دقائق Al_6Mn تعمل كعائق لحركة الانخلاعات مما يسبب زيادة في الصلادة. زيادة زمن التعتيق يسبب في تجمع هذه الدقائق مما يسبب انخفاض الصلادة .