The Influence Of Preaging On Some Mechanical Properties Of Heat Treatable Automobile Body Sheet Aluminum Alloy (6063)

Dr. Shawnim Rashied Jalal
Received on: 1/3/2005
Accepted on: 7/7/2005

Abstract

In this study the influence of preaging on the mechanical properties of heat treatable body sheet Al alloy (6063) was used in new automobile designs. It was evaluated with a view to establishing its role on the strengthening characteristics.

The results showed a considerable improvement in yield, tensile strength and hardness with an increasing level of strain (increasing the density of dislocation tangles). This was achieved with out using preaging which is apply in usual operation of auto body parts, so this investigation show that the body sheet must be used in an under aged condition

تأثير التعتيق المسبق على قسم من الخواص الميكانيكية لصفائح سبائك الالمنيوم نوع(٦٠٦٣) المعاملة حراريا والمستخدمة في هياكل السيارات

الخلاصة

يتناول البحث تأثير عمليات التعتيق الصناعي على الخواص الميكانيكية لصفائح سبائك الالمنيوم نوع ٦٠٦٣ والمستخدمة في تصميم صناعة هياكل السيارات الجديدة.

ولقد تبين من هذا البحث ان هناك تحسنا واضحا في الخواص الميكانيكية مثل مقاومة الشد ، اجهاد الخضوع والصلادة مع زيادة نسبة الانفعال (زيادة التشابك الحاصل في الانخلاعات المتكونة اثناء التشكيل).

تم الحصول على هذا التحسن في الخواص دون استخدام عملية التعتيق المسبق قبل عملية التشكيل وهي الطريقة العامة المتبعة في صناعة هياكل السيارات من هذه السبيكة .

يستنتج من البحث ان هذه الصفائح يجب ان تستخدم قبل الوصول الى حالة اعلى متانة اي في مرحلة (under aged condition).

*University of Salahaddin- College of Eng.– Mechanical Dept.- Erbil

https://doi.org/10.30684/etj.24.5.9
University of Technology-Iraq, Baghdad, Iraq/2412-0758

INTRODUCTION

Heat treatable (age hardenable) 6063 Al alloy (Al-Mg- Si) alloy are an important group of Al alloys and are widely used as medium strength structural alloys. In the continuing drive for automobile weight reduction. .The benefits of 6000 series alloys include formability, weldability, corrosion resistance and low cost [1,2,3,4,5]. This alloy can be strengthened through precipitation of several metastable phases. The understanding and control of precipitation during aging is therefore critical for achieving optimal properties. Although nevertheless it is generally agreed that the precipitation process in Al-Mg-Si can be roughly divided into the following steps[3,4,5,6,7,8,9].

$$\boldsymbol{\alpha\ (SSSS) \rightarrow GPZ1 \rightarrow GPZ2 \quad \beta'' \rightarrow \beta' \rightarrow \beta\ (Mg_2Si)}$$

Where α (SSSS) is the super saturated solid solution, GP zones are generally considered spherical clusters with unknown structure [1,3]. The β'' are fine needle-shaped zones and it is the main strengthening phase in this alloy. β' are rod-shaped precipitates ,the β phase are usually Mg_2Si platelets on [100] of Al .

Although the precipitation process in Al-Mg-Si alloys has been extensively studied the understanding of the hardening process is still incompletes since any change in composition, processing and aging practices etc. could affect the precipitation [1].

The usual operation for manufacturing autobody parts include ingot casting ,hot and cold rolling ,quenching of a sheet ,holding at room temperature (natural aging),stretching small degree of deformation 5-10% painting and drying (artificial aging) [5].

The influence of preaging [which may happen at room temperature or high temperature] before deformation on mechanical properties of 6063 Al alloy were the subject of this study.

EXPERIMENTAL PROCEDURE

Chemical composition of the 6063 Al alloy used in this study are listed in table-1 .

Table -1
The chemical composition of
(6063) Al alloys

Element Type	Si	Cu	Mg	Zn	Mn	Fe	Cr	Zr	Al
6063 Al alloy	0.56	0.005	0.424	—	0.009	0.212	—	—	Bal.

Specimen of dimension (60*27*7) mm cutting from 6063 Al sheet alloy. This alloys were first annealing at 500 °C for 1hr then solution treated at 540 °C for 30min. at the single phase (α), water quenched ,some of as quenched samples preaging at 170 °C for 10hrs.and given 5,15,20% strain by using rolling machine with minimum number of passes consistent followed by post aging at 170 °C for 10 hrs.

The other samples after quenching given 5,15,20% strain without preaging followed by post aging at 170 °C for 10 hrs.

Tensile test specimens were mechanical from above samples according to the ASTM A 370 standard tensile tests were performed by using a(MT 3037) universal testing machine ,Treco-stockholm, Sweden at a strain rate of 0.06 S^{-1}

The value of absorbed energy for fracture (area under the stress strain curve) were obtained by using new program (Mathcad) which was suitable for this alloy than impact test.

Hardness reading were on metallugraphically prepared surfaces for all condition by using automatic bench hardness tester [Ernest hardness testers model TWIN].

The examination of microstructure is one of the principle means of evaluating alloys and products of determine the effect of various heat treatment process and deformation, these examination were carried out by optical microscope.

RESULTS AND DISCUSSION

The results of the present investigation can be classified in to tow condition as shown in table2-3

Table-2 show the mechanical properties of samples with preaging

Alloy condition	Yield stress MPa	Tensile stress MPa	Ductility %	Hardness HB	Fracture Energy Joule/ cm^2
Quenched	182	214	24	45	17
Quenched+presagingat170°Cfor 10hrs+5%def+aging at 170 °C for 10hrs	251	272	23	72	18
Quenched+presagingat170°Cfor 10hrs+15%def+aging at 170 °C for 10hrs	253	283	23	79	15
Quenched+presagingat170°Cfor 10hrs+20%def+aging at 170 °C for 10hrs	235	257	20	75	14

Table-3 show the mechanical properties of samples without preaging

Alloy condition	Yield stress MPa	Tensile stress MPa	Ductility %	Hardness HB	Fracture Energy Joule/ cm^2
Quenched	182	214	24	45	17
Quenched+5%def+aging at 170 °C for 10hrs	256	280	22	73	15
Quenched+15%def+aging at 170 °C for 10hrs	262	291	20	85	15
Quenched+20%def+aging at 170 °C for 10hrs	268	298	19	87	12

Fig-1 The relation between deformation and yield stress

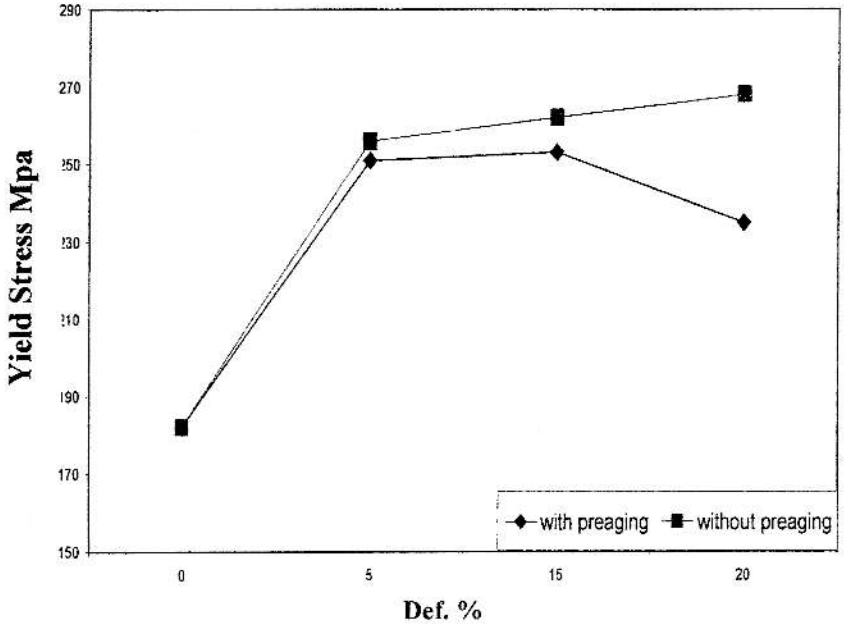


Fig-2 The relation between deformation and tensile stress

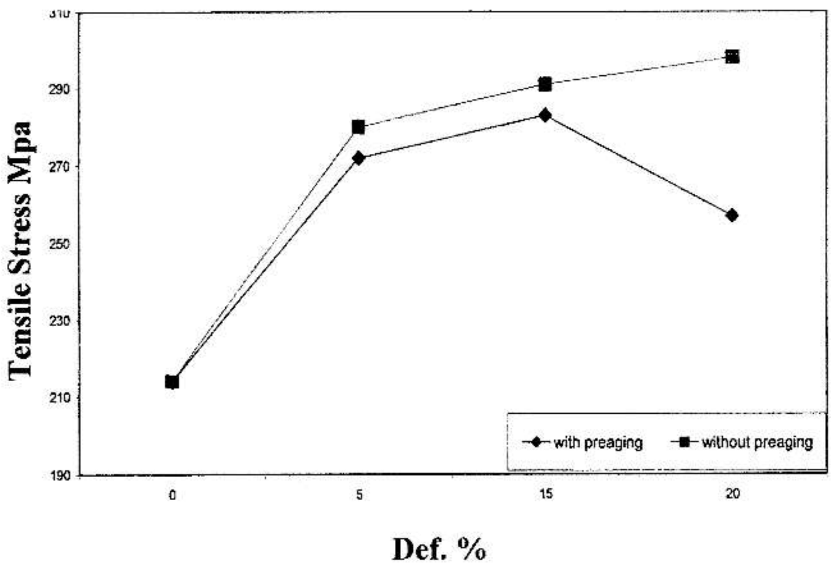


Fig-3 The relation between deformation and HB

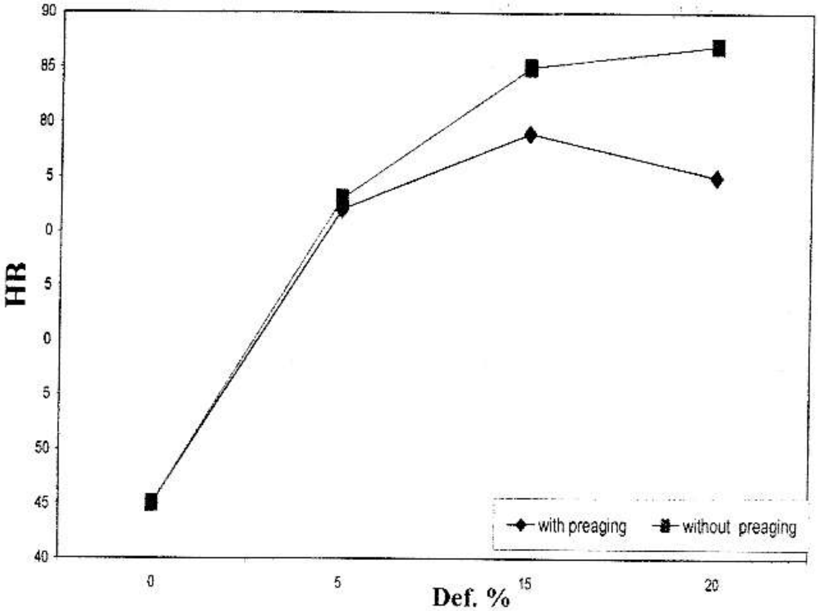


Fig-4 The relation between deformation and ductility %

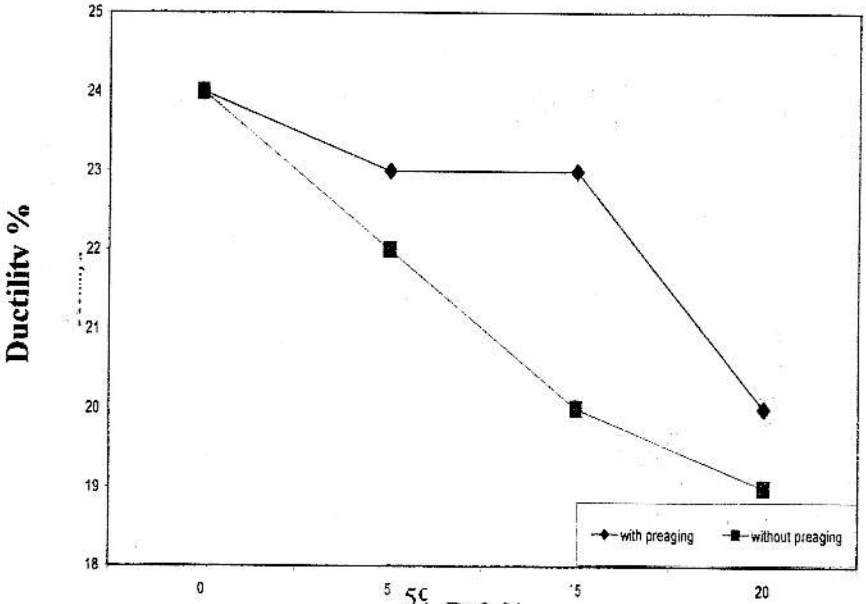
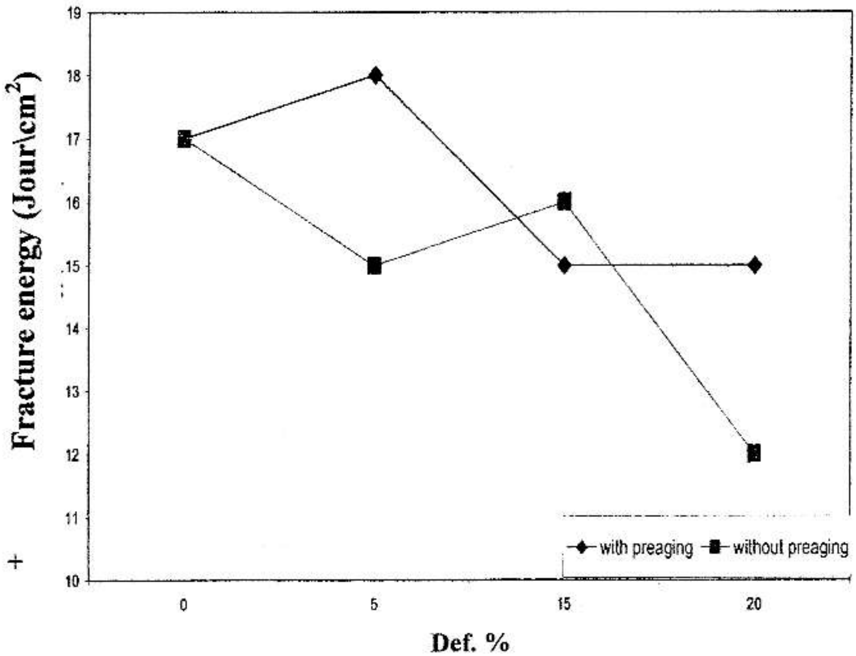


Fig-5 The relation between deformation and Fracture energy



figs 1,2,3 show the effect of preaging on the yield, tensile strength and hardness. During preaging (first condition) solutes diffuse toward dislocation, due to mutual elastic interactions. High diffusivity in the dislocation core drives these solutes to the precipitates lying on the dislocations.
This results into rapid growth of these precipitates to very large sizes and in average increased rate of coarsening of the precipitates β
(Mg 2Si) over aged condition and in a decrease of mechanical properties. The larger the deformation the larger this decrease .
Previous studies [8,10] also find that increasing deformation percent reducing mechanical properties of preaging alloys.
Deformation after aging results in the partial loss of coherency of the fine β$''$ particles and

facilities the β'' to β transition which has much less strengthening ability. This cause the observed decrease in (yield ,tensile strength) from 251Mpa , 272Mpa at 5% deformation to 235Mpa , 257Mpa at 20% deformation respectively.

Deformation at 20% have not been found to produce drastic changes in aging response and equilibrium phase precipitation Mg2Si may take place.If the letter occurs, the amount of solute available for subsequent precipitation during aging will be greatly reduced. So the long aging time (20 hour)in this condition sufficient to produce equilibrium phase precipitation. The corresponding decrease in ductility fig-4 considerably smaller for both conditions and the essential decrease in ductility from 24% to 20% in first condition is due to the hindering of dislocation mobility as a result of their pining by β' precipitate which change in to β (Mg2Si), so in second condition (before peak age) the decrease in ductility was more than first condition this ascribed to a greater volume fraction of β' formation.

The effect of pre aging may be positive or negative. Further more the understanding of the under lines mechanisms is far from complete(3)

In our investigation the effect of pre aging is negative due to lowering in mechanical properties compared with second condition (without pre aging).

In this context M. Murayama and K. Hono [7] show that pre aging at low temperature 70 ^{o}C gives positive effect on the post artificial aging, because aging at this temperature a low spherical GP zones are formed, the chemical nature of which is similar to co clusters which are reverted at this temperature resulting in reduced precipitation kinetics.

The samples which not subjected to preaging deformation is performed in quenched condition , precipitation can occur during the deformation it self (dynamic precipitation) at a much faster rate than in conventional condition [11].

This precipitate formed during deformation are GP zones which is change to β'' in the aging process after deformation causing improvement in yield ,tensile strength fig-1,2

The increase in the strength of the material with an increasing level of deformation% is explained as arising from addition to dislocation and dislocation-precipitation interactions.

The hardness increased continuously with increasing deformation rate fig.3 in this condition because the dislocation distribution can be attributed to the presence of fine precipitate particles which inter act with the dislocation and therefore prevent recovery .

The samples which not subjected to pre aging (second condition) quenching it from solid solution, a region of solute segregation and clustering called Gp zones was formed, these produced local strains and increased the strength of the material, with artificial aging strength was further increased by re-ordering of larger clumps of Cu or Si in the Gp zone (β'') the coherent precipitates formed here produced increased strain in the matrix thus increasing the strength of the material due to the increased amount dislocation tangles with reducing ductility).

In this context Quainoo [12] show that a considerable improvement in yield and tensile strength with an increasing level of deformation.

Fig 5 indicate the closeness of response of fracture energy for all degree of deformation % . The variation is so slight but it was better in first condition due to the β precipitate which gives rise to a structure with reduced strength but more ductile . fracture energy were performed by using anew program [Mathcad] which gives the value of the fracture energy [the area under the tensile stress-strain curve] to absorb energy under simple tensile loading .

This program better than impact test which is not suitable for highly ductile alloy since they do not exhibit rapid crack propagation under elastic condition (13).

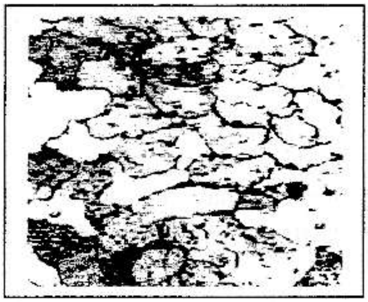


Fig- 6
Microstructure of specimen deformed 5% with presaging [300X]

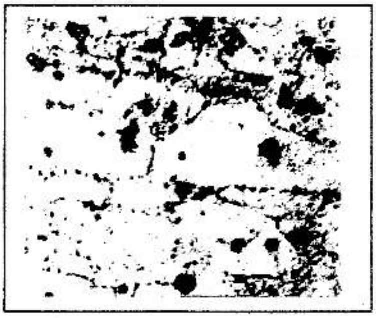


Fig – 7
Microstructure of specimen deformed 20% with presaging [300X]

Fig – 8
Microstructure of specimen deformed 5% without presaging [300X]

Fig – 9 Microstructure of specimen deformed 20% without presaging [300X]

Fig (6,7) indicate the effect of pre aging on precipitation at 5,20% followed by post aging respectively coarsening of the precipitates β (Mg2Si) due to over aging.

Fig 8,9 shows the microstructure of specimen which did not subjected to pre aging 5,20% deformation followed by post aging. fine precipitates β'' , β' compared with figs(6,7) improved mechanical properties of this alloy.

Conclusions

1- the results showed a considerable improvement in yield and tensile strength, hardness with an increasing level of strain with out using pre aging. This study indicates that pre aging is not importuned in usual operations for manufacturing auto body parts.
2- The behavior of this alloy is complex but in general, consistent with the change in the nature of the obstacles to dislocation motion going from a supersaturated solid solution deformation to a fine distribution of β' (without pre aging), and a coarser distribution of precipitates β\`\`\`\` (with pre aging) during over aging.
3- It is expected that the importance of prior strain on the subsequent nucleation rate will depend upon the amount of strain.
4- This investigation show that the body sheet Al alloys must be used in an under aged condition [before peak age condition] .
5- The deformation of super saturated solid solution is

complex and requires further investigation.

References

1- W. f. Miao and D. E. Laughlin, (***Precipitation hardening in Al alloy 6022***), scripta materialia, 40 (***1999***), pp. 873 – 878.

2- L . P.Troeger, Edge A. starker, (***New process produces superplastic aerospace / Automotive Al alloy***), Advanced engineering materials, 2 (***2000***), PP.802-806.

3- W. F. Mlao, D. E. Laughlin, (***Effect of Cu content and pre aging on precipitation characteristics in Al alloy 6022***), metallurgical and materials transactions, 31A(***2000***), pp. 361 – 371 .

4- M. Murayame, K. Hono, M. Saga, (***Atom probe studies on the early stages of precipitation in Al – Mg – Si alloys***), materials science and Engineering, A250 (***1998***), pp. 127-132

5- D . G. Eskin, Marina L. Khharakteroja, (***The effect of silicon and copper on the precipitation hardening of sheet of 6xxx–series alloy***), material in technologije 35 (***2001***), pp.5-8.

6- D. J Chakrabarti Yingguo Peng, David E. Laughlin, (***Precipitation in Al-Mg – Si alloys with Cu additions and the role of the θ and related phases***), scripta mat., Vol. 40 (***2000***), pp. 873 –878.

7- M. Murayame, K. Hono, M. Saga, M. K. Kuch, (***pre – precipitation stages of Al – 0.7 Mg – 0.33 Si alloy***), preprint of the 44th international field Emission society, materials science and engineering, A. in press.

H. J. Rack, (***The influence of prior strain upon precipitation in a high – purity 6061 Al alloy***), materials science and Engineering, 29(***1977***), pp. 179-188.

9- S. Esmaeili, L. M. Cheng, A. Deschamps, D. J. Lioyd, W. J. Poole, (***The deformation behavior of AA6111 as a function of temperature and precipitation state***), materials science and engineering, A319 – 321, (***2001***), pp. 461 – 465

10- Larche, F. C., (***dislocations in solids***) Vol. 4 north Holland, Amsterdam, (***1979***), pp. 135 – 139.

11- A. Deschamps, Y. Brechet, P.Guyot, (***Interaction between plasticity and precipitation***), published in: proceedings of the 7th seminar of the international federation of heat treatment and surface Engineering, Hungary, 1999, pp.1-10.

12- G. K. Quainoo, S. Yanacopolos, A. K. Gupta, (***Strengthening characterristics of AA 6111 Aluminum***), Canadian metallurgical Quarterly. Vol.40 (***2001***), pp. 211-220

13- Ron Cobden, (***TALAT Lecture1501,Aluminum: physical properties, characteristics and alloys***), EAA – European Aluminum Association, (***1994***), pp. 1- 27.