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Effect of aging time on microstructural and mechanical properties of 6061 aluminum alloy

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ABSTRACT

Aluminum alloy 6061 have moderate strength, good formability, and excellent corrosion resistance, it has a wide use in several engineering sectors. Age hardening is the main feature of this alloy. In this study, some mechanical characteristics of Aluminum 6061 samples aged to different times has been studied. The specimen's mechanical properties were improved in general; best mechanical properties were achieved after 2 hours of heat treatment at 200oC. Ultimate tensile stress, yield stress, ductility and microhardness variation with aging time are discussed regarding to the microstructural alteration caused by heat treatment. We found that the Mg2Si initiation and growth was a function for aging time, which was the main cause for improvement of the alloy mechanical features.

Keywords: 6061 Alloy, Heat Treatment, Aging Time , microstructure, Mechanical Properties

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1. Introduction

Aluminum is the most widely used nonferrous metal. Primary aluminum (in contrast to secondary aluminum, that obtained from scrap metal processing) accounts for approximately 75% of annual consumption[1]. Pure aluminum has poor mechanical properties, it is used for domestic products and for electrical conductors, but it must be alloyed for serious structural use[2-4]. Aluminum alloys have many benefits including light weight, lower melting points, good thermal conductivity, non-rusting nature, and ability to be used unpainted[4-6]. However, even the strongest alloys will corrode in some hostile environments, and may necessitate protection. Using gas-shielded processes, most alloys can be arc welded as easily as steel. Because of the high metal removal rates that are possible, milling can be a cost-effective aluminum fabrication technique [4]. Aluminum strength can be increased through alloying, and heat treatment, resulting in improved mechanical properties[7]. Alloys containing more than 1.4 percent Mg and Si. They gain strength when they aged. Because they are more question sensitive, about 0.25 wt% Cu is add to (6061) alloy to improve mechanical properties[1].

Heat treatment is one of the most significant method to enhance the mechanical features of Al-Si-Mg alloys. This treatment includes solution treatment and aging[8]. For getting supersaturated solid solution, the solution heat treatment is initially done at 500oC. Aging is accomplished by heating to 200oC for varying duration of time which results in several stages of precipitation (leading to stable β phase[9, 10].

Heat treatment's effect on the mechanical and microstructural properties of alloys has been extensively researched. The authors [11]studied and reported the effect of heat treatment modifies on the aluminum alloy mechanical properties. They discovered that heat treatment improves the mechanical features of 2024 and 6061 aluminum alloy. The best modification in the mechanical properties by heat treatment was for 2024 alloy. Heat treatment also used to modify the dynamic properties of simply sustained and aluminum alloy cantilever plate structure (6061, 2024). In [12], authors discussed aging impacts for different times on the 6061 mechanical alloy features. They discovered that the best mechanical characteristics were obtained after a 2-hour of aging period. More than two hours of artificial aging reduce the material's strength and hardness. Kumar et al investigated that the aging of solution treated samples has a positive action on mechanical characteristics. The nucleation rate of Mg2Si precipitates rose with increasing aging temperature. They also deduced that highest value of strength, elongation, toughness and hardness is obtained at 240oC because of Mg2Si precipitation with intermediate grain size and uniform distribution [13, 14].

The researchers Ozturk et al conducted aging treatment procedure for 6061 alloy and they found that after 200 minutes of aging at 200oC, the peak-aging conditions are reached. A slight difference in the Mg/Si atomic ratio could make a dissimilar time to peak ages. Then, the precipitates change the material's mechanical properties [15].

The current study compares four aging processes for Al-Mg-Si alloy (6061) and demonstrates the broad property range caused by changes in mechanical properties and microstructure. It concludes by assessing different test results.

2. Materials and experimental procedures

The metal utilized in this work is aluminum 6061 in the form of rods. Table 1. displays chemical components as obtained by X-Ray fluorescence:

Table 1. Alloy chemical compositions

element	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ni**
%wt	0.751	0.413	0.345	0.068	0.903	0.092	0.004
element	**Zn**	**Ti**	**Pb**	**B**	**Sn**	**V**	**Al**
%wt	0.015	0.023	0.007	0.002	0.001	0.008	97.3

The specimens of tensile test were in accordance with ASTM E8 standards, and the specimens were subjected to solution treatment involving heating the aluminum to 500oC for 120 minutes and then quenching in water. The second treatment was artificial aging at 200oC for different time: (30, 120, 240, 300) minute.

Tensile test machine used in this research is a computerized (WDW 200E, made in China) it's capacity 200KN, it's speed was 1 mm/min. For determine microhardness digital micro Vickers hardness tester was used (TH714, made in China), microhardness test was achieved after aging with an average of six hardness measurements for each aging treatment.

A metallurgical microscope was used to observe the microstructure in this work (model MTM-1A BEL Engineering, made in Italy). Table 2. Shows how the specimens were classified.

Table 2. Categorization of specimens

condition	**Specimen category**
Solution heat treated	A
Aging for 30 minute	B
Aging for 120 minute	C
Aging for 240 minute	D
Aging for 300 minute	E

3. Results and discussion

The purpose of doing microstructure test was to observe the changes resulting from the artificial aging process. "Precipitation sequence in 6061 alloy is as follows: super saturated solid solution (SSSS) ⟶ Si/Mg cluster ⟶ Guinier – Preston (GP) zones ⟶ β" ⟶ β' ⟶ β (Mg2Si) phase, where β gives the best mechanical resistance to the alloy[16, 17].

Figure 1. microstructure of Al 6061 after aging for: (A) 30 min (B) 120 min (C) 240 min. At 400 X

Figure 1. demonstrates that the initiation and growth of Mg2Si was a function for aging time. As the aging time was increased to 120 minutes, the number of precipitates increased, as shown in figure (1-B), and it increased even more after aging for 240 minutes, as shown in figure (1-C).

“If the alloy artificially aged without any aging time lag, the amount of cluster generated at the begin is much smaller. As a result, a high portion of solute atoms remain in solution. Some of these clusters will be able to absorb the excess solute during artificial aging, and grow to [1] an appropriate size to enhance mechanical properties, this is combined with a finer precipitate structure”. We can notice this from tensile test results (figure 2). which show significant gradual increase in ultimate tensile and yield stresses after aging process for various aging time. It can be seen that UTS was increased gradually from 201 MPa for the specimen A until 302 MPa for the sample C which represent the highest value and it decrease to 278 MPa for the sample E. yield stresses was increased in the same pattern it raised from 139 MPa for the sample B to 285MPa for the sample C which represent the best value in comparison with the other samples. With increasing aging time more than 120 min the value of the yield stress will decrease to the value 260 for sample E. In contrast, the percent elongation of the samples was decreased gradually from 37.5 % for the sample B to 11% for the sample E as shown in figure 3. In addition, microhardness results shown in figure 4. also shows that increasing age hardening temperature improved microhardness. The improvements in the tensile properties and microhardness can be explained by considering microstructure changes that occur during the age hardening process. This agreed with Shatha et al and F. Ozturk et al. [15, 12].

In addition to the presence of the Mg2Si phase, that improved mechanical features of size differences between the aluminum and solute atoms make aluminum matrix elastic stresses impede and obstruct the movement of dislocation, give rise to greater strength values. The strength increase when natural aging continues or turn out to be steady, whereas in artificial aging hardness and strength reach an ultimate value and then decrease with increasing aging time. The decrease in strength after a long period of aging time or at elevated aging temperatures is referred to as over aging. More grain boundary precipitates will be found in over aged alloys; it is mainly Si. Si limits ductility and causes intergranular embrittlement because of the Si proclivity to segregate to the boundaries of the grain, reducing fracture stresses and strain of the over aged samples. These results agreed with Totten and Mackenzi [1].

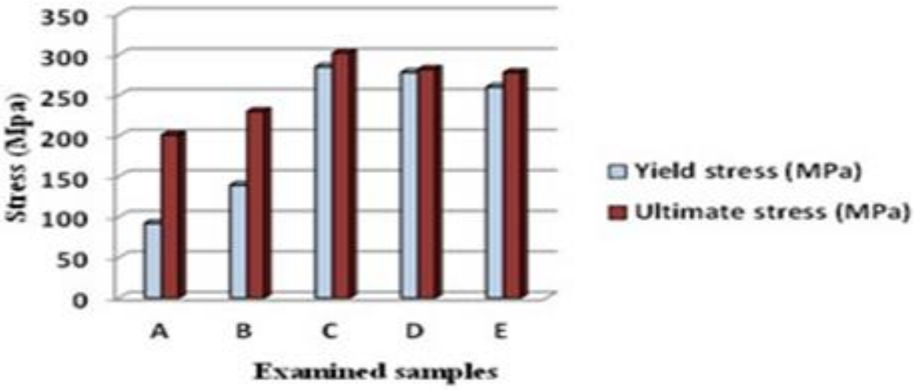

Figure 2. Yield stress and ultimate tensile stress for the examined specimens

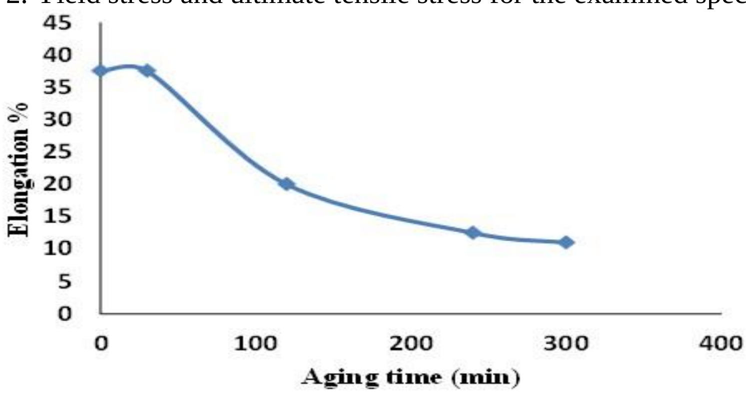

Figure 3. Percent Elongation for different aging time

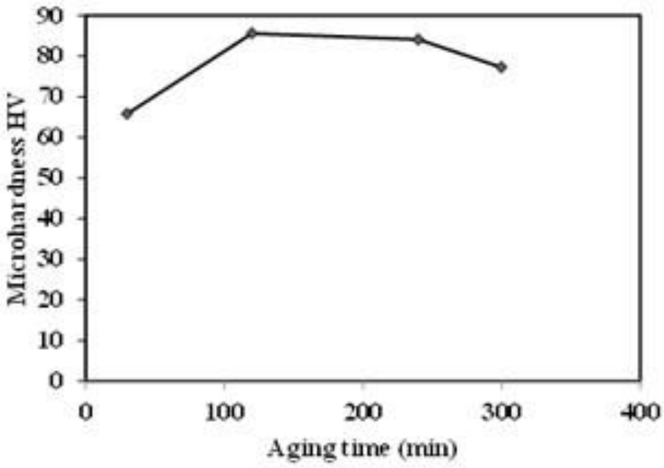

Figure 4. Hardness measurements for various aging time

4. Conclusion

Tensile test carried out for aluminum alloy 6061 for the evaluation of the influence of the aging time on the material strength. It is concluded that the mechanical properties improved gradually with increasing aging time until it reached 120 minutes, which represented the optimal aging time to obtain the best mechanical properties. It was also concluded that an increasing aging time increase the nucleation rate of Mg2Si precipitates. Aging for a period of more than two hours decreases the alloy mechanical features.

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