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Effect of Secondary Aging of AA7075 Aluminum Alloy to Hardness

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Abstract: In this study, one of the major aluminum alloys AA7075 was held to obtain the maximum benefit for structural parts. Nowadays for the energy efficiency of vehicles like electric cars or aerospace vehicles weight reducing efforts are needed. To obtain lighter structures specific strengths are gaining importance. In our study, AA 7075 aluminum alloy was processed with additional heat treatment rather than T6 condition to obtain high strength. According to our previous studies, statistical methods seemed very useful to predict probable strength very precisely, for this reason, Box-Behnken Surface Response Method was used. By applying statistical methods, the artificial aging temperature and time were optimized. According to optimized temperature and time, the secondary aging heat treatment was done. In this study three T6 conditions 150, 200, and 250 ^{o}C with four treatment times, 1,2,4 and 6 hours were chosen and applied. The secondary aging temperature and time were obtained from Box-Behnken optimization study results and found as 182 ^{o}C and 2 hours were applied to all samples. As a result, after secondary aging heat treatment maximum hardness of 151 Hv was obtained from samples that aged at 150 ^{o}C, and 250 °C for 1 hour, which is almost doubled because the T6 aged sample has a hardness value of 86 Hv. This is obvious that the strength almost doubled, therefore it is possible to use sections almost half of the T6 condition samples.

Keywords: 7075 Aluminum alloy, Aging, Microhardness, Optical microscopy

Introduction

The 7xxx series of aluminum alloys have been in service for several years in the aerospace industry for structural parts because of their superior properties i.e. low density, high strength, ductility, toughness, and fatigue resistance (Leacock et al., 2013; Li et al., 2008; Panigrahi et al., 2011). Nowadays, it has become more and more important for the electric car industry. AA7075 aluminum alloys have been preferred due to their high mechanical properties such as 505 MPa yield strength and 11% elongation. Besides its high mechanical properties, AA7075 aluminum has many excellent properties such as low density, good corrosion resistance, machinability, and electrical conductivity.

Aging is the most important heat treatment used for hardening in non-ferrous metals, mainly aluminum, as well as in high-strength stainless steel. Aluminum, which is used in various industries, such as aviation, is strengthened by the aging process. The aging process, also known as the precipitation hardening process, is the precipitation of the second phase by distributing it finely in the matrix phase, obtaining a hard structure. (Pankade et al., 2018; Zou et. al., 2017).

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For today's manufacturers of automotive and aerospace vehicles, the replacement of aluminum alloys with conventional alloys or steels in engineering applications is the major design concept for increasing fuel prices (Başer, 2013). Aluminum and magnesium alloys are the main candidate materials for reducing the weight of vehicles, especially battery-operated cars (Hofer et al., 2012) main structural parts need to have high specific strength. Among these; age-hardenable aluminum alloys are becoming primary materials to reduce the weights (Kear et al., 1993). Another point to be taken care of because of huge mass production rates is the production costs (Roth et al., 2001). The 2XXX and 7XXX series age-hardenable alloys are gaining importance for their relatively high mechanical strength concerning their cost (Abd El-Rehim et al., 2013). The studies about lowering the weight of vehicles go back to the '80s (Century et al., 1993; et al., 1982). Some studies have been carried out to reduce the weight of military or logistics vehicles by replacing iron-based alloys with aluminum-based alloys. (N.R.C., 2003). There are numerous studies on the secondary aging procedure for aluminum alloys. One of the studies concerned the wear resistance of the AlSi10Mg alloy (Gül, 2014), An overview of the aging heat treatment of AlSi10Mg alloy was made by Vatansever et.al (Vatansever et al., 2018). There are some studies about the effects of secondary aging and interrupted aging to aluminum alloys indicating that the secondary aging heat treatment have increasing the mechanical properties (Baksan et al., 2020; Buha et al., 2006; Hai et al., 2005; Koch et al., 1979; Lumley et al., 2003; Lumley et al., 2005). The goal of this study is to achieve superior properties from a cheaper aluminum alloy to substitute and compete with iron-based alloys as well as 2xxx, and 7xxx series aluminum alloys by secondary aging heat treatment following a T6 treatment.

Materials and Method

Stock AA7075 aluminum alloy samples were supplied locally for this study. The samples were solutionized at 500 °C for 4 hours and aged at 150, 200, and 250 °C for 1, 2, 4, and 6 hours, following this T6 heat treatment, a secondary aging heat treatment was done for as 182 °C and 2 hours. The secondary aging heat treatment conditions of 182 °C and 2 hours were obtained from our previous study results of Box-Behnken statistical studies (Baksan et al., 2018) (Figure 1). Microhardness tests were performed for each experiment. Microstructures were obtained from an optical microscope to observe microstructural changes.

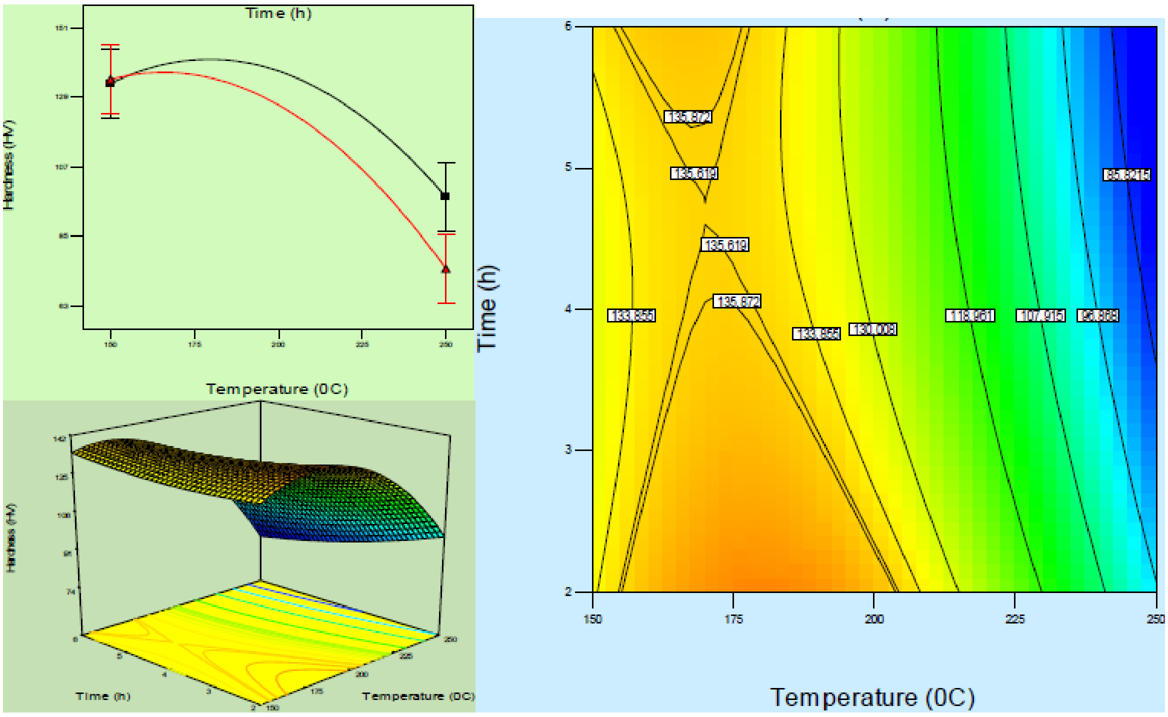


Figure 1. Box-Behnken optimization plots, (a) Aging time versus hardness (up-left), (b) 3D surface aging time-temperature and hardness plot (down-left), (c) isopleth of aging time and temperature plot (Baksan et al., 2018)

The samples were homogenized at 500 °C for 96 hours. The samples were solutionized at 500 °C for 4 hours and quenched in water at room temperature. The aging heat treatment was carried out at 150, 200, and 250 °C for 1, 2, 4, and 6 hours and quenched in water. Secondary aging heat treatment was carried out at 182 °C for 2 hours.

After completing the heat treatment procedure, the samples were polished and etched with Keller etchant.The microhardness testing was done by Futuretech make FV-800 instrument with 300 g load for 10 seconds.

Results and Discussion

The microhardness testing results showed that the secondary aging heat treatment improved the hardness. The hardness of secondarily aged samples decreases with the aging time. The maximum hardness value was obtained from samples that were aged at 150 °C, and 250 °C for 1 hour and secondarily aged at 182 °C for 2 hours, giving 151 H_v. This hardness value is 75% higher than the samples aged only at 150 °C for 6 hours which was obtained as 86 H_v. The change in hardnesses of secondarily aged samples was given in Figure 2.

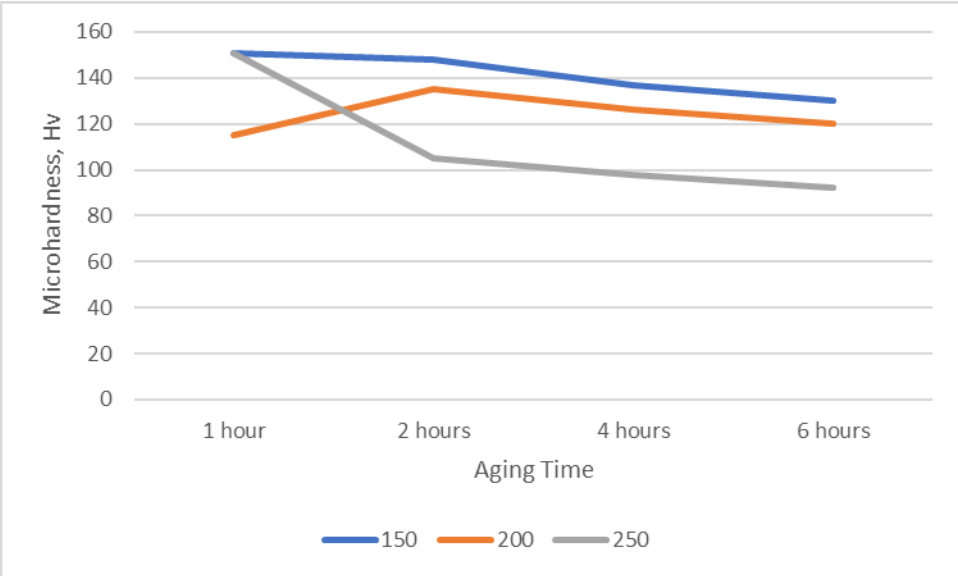
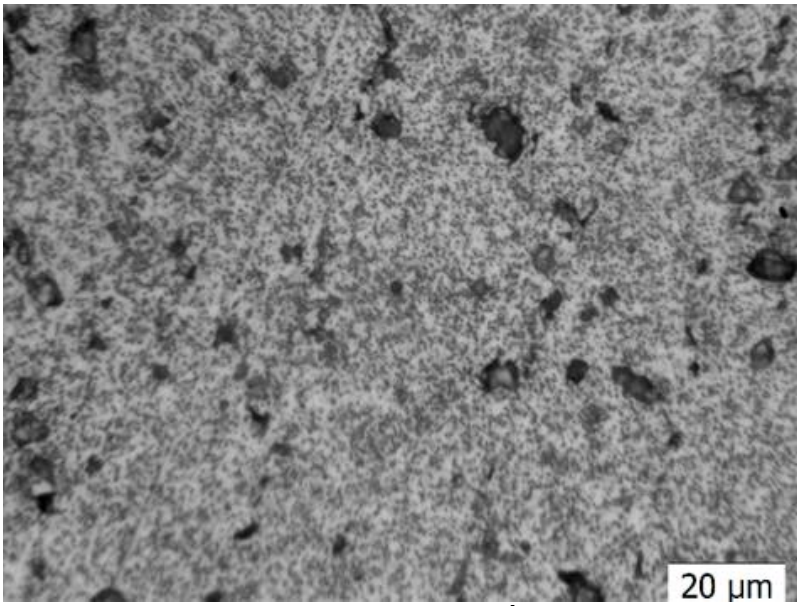
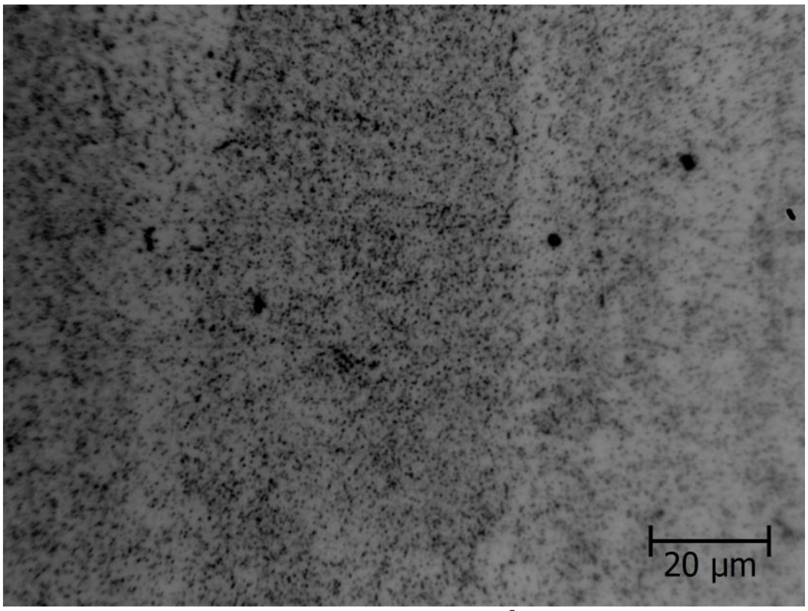


Figure 2. Microhardness change of samples secondarily aged at 182 °C for two hours at various T6 conditions



AA 7075 aluminum alloy Solutionized at 500 ^oC for 4 hours and aged at 150 ^oC for 1 hour



AA 7075 aluminum alloy Solutionized at 500 ^{o}C for 4 hours, aged at 150 ^{o}C for 1 hour, and additionally aged at 182 ^{o}C for 2 hours

Figure 3. Microstructures of AA7075 aluminum alloy aged at 150 ^{o}C for 1 hour, and secondarily aged at 182 ^{o}C for 2 hours.

The microstructures of aged and secondarily aged samples are given in Figure 3. The microstructures revealed that the grains were coarsening by increasing time in secondarily aged samples. During aging, with the effect of temperature, the precipitates dispersed through the matrix, as the aging continues, these clusters begin to form β precipitates compatible with the α matrix phase. These precipitates play a role in increasing hardness. As the aging continues, the precipitates grow further and reach a critical height, it is seen from the trend of the graph in Fig.2 but the time and hardness limit could not be detected because the experiments are limited to 6 hours. At higher magnifications, the fine precipitates were seen. As the aging time increases the fine precipitates dispersed very fine all over the matrix.

These results showed that it would be possible to produce materials with higher strengths since the hardness value of almost 75% higher than the stock alloy was obtained in this study. This means that it is possible to reduce aluminum weights in at least half of the current applications, especially in vehicle production.

Conclusion

The secondary aging heat treatment would be a weight reduction route for increasing the strength of age-hardenable alloys. This may also increase the service life of age-hardened parts. The increase in hardness in this study obtained more than at least 10% which is higher than ordinary aged ones. Our other studies revealed almost two-fold hardness values (Baksan et al., 2018)

In this study, the secondary aging heat treatment at 150 ^{o}C, and 250 ^{o}C for 1 hour also resulted in a peak hardness of 151 H_v this value is higher than T6 condition. This phenomenon may be related to reduced mobility of vacancies, and the growth of partially dissolved η' precipitates, the re-nucleation of precipitates, or the transformation to the stable η phase (Esmailian et al., 2015). It has been determined that two different aging temperatures give the same result, and it is obvious that it is preferable to use lower temperatures to save energy on the industrial production route. Therefore, 150 ^{o}C will be a more economical way to obtain high-strength materials.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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