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Influence of Intermittent Aging in AA7075 Aluminum Alloy

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Abstract: Heat treatable AA 7075 Aluminum alloys have been used especially in the aerospace industry for several years for their high specific strength. The demands in lighter aerospace or road vehicles like electric cars are today's major concerns. In this study, it is observed for how far the strength can be increased for this reason the influence of intermittent aging in AA7075 Aluminum alloy investigated. Rolled mill product of stock AA7074 Aluminum alloy samples were heat-treated for T6 conditions following a homogenization at 500 ^{o}C for 96 hours, and solution treatment at 500 ^{o}C for 4 hours and quenching in water. Aged at 120 ^{o}C for 24 hours and quenched. After the T6 heat treatment, an additional aging heat treatment so-called T6I4 was done at 100 ^{o}C for 2, 4, and 6 hours. The T6I4 heat-treated AA7075 alloys' microhardness values were incrementally increased by the intermittent aging heat treatment. The maximum increase rate was achieved with secondary aging at 100 ^{o}C for 6 hours, 51 % more according to the T6 condition.

Keywords: 7075 Aluminum Alloy, Aging, Microhardness, Optical Microscopy

Introduction

The 7xxx series of aluminum alloys are commonly used in the aerospace industry in structural applications due to their low density, high strength, ductility, toughness, and fatigue resistance (Leacock, Howe, Brown, Lademo, & Deering, 2013; Li et al., 2008; Panigrahi & Jayaganthan, 2011). AA7075 aluminum alloys, one of the commercial forged aluminum alloys containing zinc, copper, and magnesium-based alloys having very high mechanical properties such as 505 MPa yield strength and 11% elongation. Since AA7075 aluminum has many excellent properties such as low density, good corrosion resistance, machinability, and electrical conductivity besides its high mechanical properties, it is preferred in places where high strength is required such as aircraft bodies and wings (places where strength is required), machine parts, automotive industry and military fields (Li et al., 2008; Panigrahi & Jayaganthan, 2011; Pankade, Khedekar, & Gogte, 2018).

Aging is the most important heat treatment used for hardening in non-ferrous metals, primarily aluminum, and in high-strength stainless steel. Aluminum used in various industries such as aviation is strengthened by the aging process. The purpose of the aging hardening process, also known as the precipitation hardening process, is to precipitate the second phase, which has a hard structure, finely dispersed in the matrix phase (Pankade et al., 2018; Zou, Yan, & Chen, 2017).

For today’s manufacturers of automotive and aerospace vehicles, the substitution of aluminum alloys with high density alloys in engineering applications are major design concerns due to high fuel price (Başer, 2013). Light alloys such as aluminum and magnesium alloys are the main candidates materials for reducing the weight of vehicles, especially the battery operated cars (Hofer, Wilhelm, & Schenler, 2012) main structural parts need to have high specific strength. Among these age-hardenable aluminum alloys are major materials to reduce the

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vehicles' weight (Century, Kear, Board, & Systems, 1993). However, the final cost of structural element is another point to be take care of because of huge mass production rates (Roth, Clark, & Kelkar, 2001).

The 2XXX and 7XXX series age-hardenable alloys are sharing the biggest pie for its relatively high mechanical strength respect to its cost (Abd El-Rehim & Mahmoud, 2013). The studies about lowering the weight of vehicles goes back to '80s (Century, Systems, Board, Sciences, & Council, 1993; Vehicles & Board, 1982). There are some studies for reducing the weight of military or logistics vehicles by substitution of iron based alloys with aluminum based alloys were realized (Trucks, Board, & Sciences, 2003). There are numerous studies about secondary aging procedure for aluminum alloys. One of the studies was about AlSi10Mg alloy`s wear resistance (GÜL, 2014), the overview of aging heat treatment of AlSi10Mg alloy was held by Vatansever et.al (Fahri VATANSEVER, 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 B., 2020; Buha, Lumley, & Crosky, 2006; Hai, Ziqiao, & Zhixiu, 2005; Koch & Kolijn, 1979; R. Lumley, Polmear, & Morton, 2003, 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.

The intermittent aging is a method that improves mechanical strength, corrosion resistance. The intermittent application pattern is given in Figure 1. The temper designation explanations is shown in Table 1(R. P. Lumley, I. & Morton, Allan., 2004).

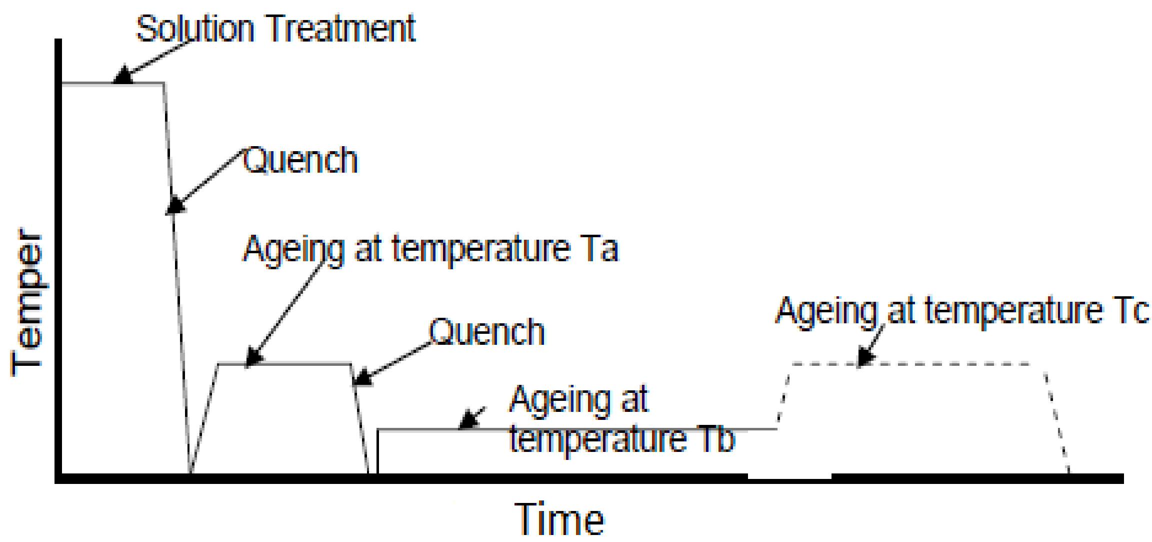


Figure 1. Stages for intermittent aging

Table 1. Intermittent aging designation explanations

Temper	Process
T6I6	Solution treat, quench, underage at (Ta), quench, age at 25-65^{o}C (Tb), re-age
T6I76	Solution treat, quench, underage at Ta, quench, age at 25-65^{o}C (Tb), re-age at artificial ageing temperature (Tc), where Tc>Ta.
T8I6	Solution treat, quench, cold work, underage at Ta, quench, age at 25-65^{o}C (Tb), re-age at artificial ageing temperature (Tc), where Tc≤Ta.
T9I6	Solution treat, quench, underage at Ta, cold work, age at 25-65^{o}C (Tb), re-age at artificial ageing temperature (Tc), where Tc≤Ta
T6I4	Solution treat, quench, underage at (Ta), quench, age at 25°C-65°C (Tb)
T6I7	Solution treat, quench, underage at (Ta), cool slowly (furnace cool or natural cool).
T77I4	Solution treat, quench, age at (Ta1), age at temperature (Ta2), where Ta2>Ta1, quench, age at 25-65°C (Tb)
T8I4	Solution treat, quench, cold work, underage at (Ta), quench, age at 25-65°C (Tb).
T9I4	Solution treat, quench, underage at (Ta), cold work, age at 25-65°C (Tb).

Materials and Method

Stock AA7075 aluminum alloy samples were supplied locally for this study. Following a T6 heat treatment, an intermittent aging heat treatment was done for different times. The microhardness tests were done for each experiment. The microstructures were obtained from an optical microscope for observing the microstructural changes

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. Aging heat treatment was done at 120 °C for 24 hours and quenched in water. Secondary aging heat treatment was realized at 100 °C for 2, 4, and 6 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 intermittent aging heat treatment improves the hardness. The hardness increases with aging time. The maximum value of hardness was obtained in samples aged 120 °C for 24 hours and intermittently aged at 100 °C for 6 hours giving 197 H_v. This hardness value is 92% higher than the samples aged only at 120 °C for 24 hours. The change in hardness was given in Figure 2.

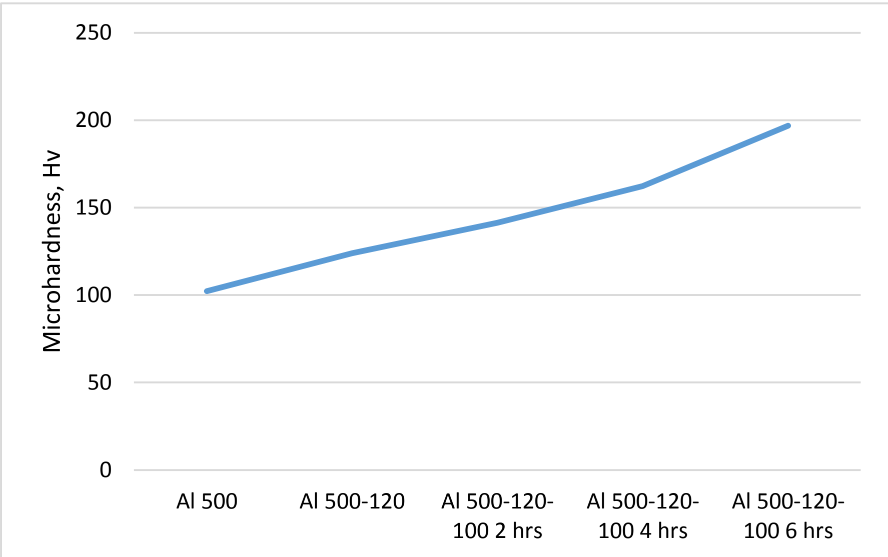
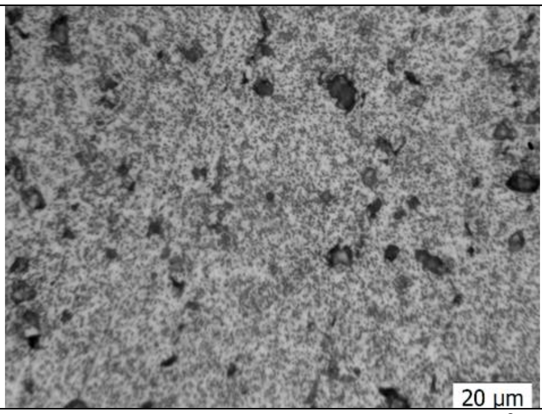


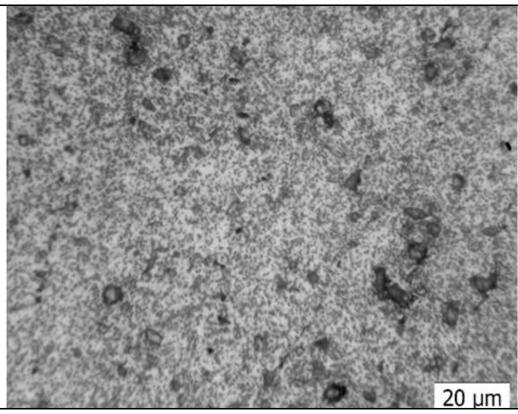
Figure 2. Microhardness change versus aging heat treatment

The microstructures of aged and intermittently aged samples were given in Figure 3. The microstructures revealed that the grains were coarsening by increasing time in intermittently aged samples. The factors causing the hardness increase are the second phase particles that have precipitated. 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 sediments grow further and reach a critical height, it is seen from the trend of the graph in Fig.1 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.

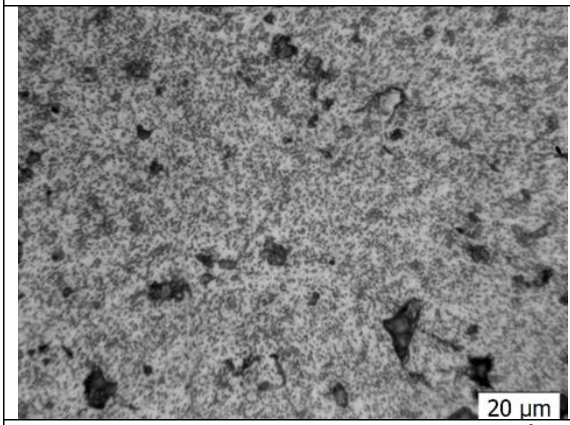
These results revealed that the production of materials with higher strengths would be possible because in this study almost the hardness value was obtained as twice the stock alloy. This means especially, in the production of vehicles it is possible to lower the aluminum weights at least half of the present applications.



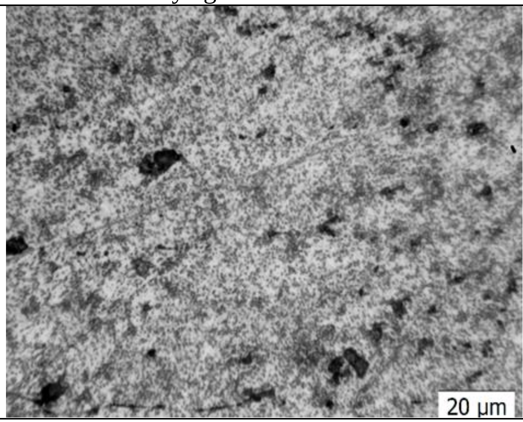
AA 7075 aluminum alloy Solutionized at 500 ^oC for 4 hours, and aged at 120 ^oC for 24 hours



AA 7075 aluminum alloy Solutionized at 500 ^oC for 4 hours, aged at 120 ^oC for 24 hours, and additionally aged at 100 ^oC for 2 hours



AA 7075 aluminum alloy Solutionized at 500 ^oC for 4 hours, aged at 120 ^oC for 24 hours, and additionally aged at 100 ^oC for 4 hours



AA 7075 aluminum alloy Solutionized at 500 ^oC for 4 hours, aged at 120 ^oC for 24 hours, and additionally aged at 100 ^oC for 6 hours

Figure 3. Microstructures of AA7075 aluminum alloy aged at 120 ^oC for 24 hours, and intermittently aged at 100 ^oC for 2, 4, and 6 hours.

Conclusion

The secondary aging heat treatment would be an emerging method 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 10% which is higher than ordinary aged ones.

In this study the T6I4 treatment at 100 ^oC for 6 hours also resulted in a peak hardness of 197 H_v this value is higher than T6 condition. This phenomenon may be related with 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 M., 2015).

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