

Improvement of Heat Treatment Application of Aluminium Forged Parts

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Abstract

In industrial applications, hot forging of aluminum alloy AA 6082 is applied after heating of the billets at 480 °C degree by induction heater in a couple of minutes. The forged part is cooled down to room temperature and then conventional solution treatment and aging process are applied.

In this study, the aim was to analyze the change in mechanical features of samples quenched from forging temperature and followed by aging.

Experiments were performed on AA 6082 alloys at three different temperatures (480-510-540 C) along 15 minutes heating time period where some of which are upset forged then quenched and aged.

At the end of every experiment, samples mechanical characterization was made by hardness inspection and tensile tests. All of the samples were investigated under optical microscopy (OM) besides scanning electron microscopy (SEM-EDS).

Required hardness value of min 90 HB, measured after quenching and aging process, could only be achieved on the samples with the heating temperature of 540 °C.

1. Introduction

AA 6082 aluminum alloy are commonly used for machine, aviation and automotive industry because of its high corrosion resistance, good formability through forging and extrusion, good machinability and high strength subsequent to heat treatment [1]. T6 temper is the most commonly applied treatment to increase the strength of alloy AA 6082. During this heat treatment, solution treatment and forging are applied at different temperatures respectively for different alloys. Forging temperature for AA 6082 is defined as 450-500 °C [2]. Before forging, aluminum parts heated in induction heaters and then forged at this temperature.

Several studies are reviewed during the literature surveys about forging of AA 6082 [2-7]. Some of these studies have examined the effects of different aging heat treatment to the microstructure and mechanical properties. Some of other studies have examined the availability of replacing rolled or extruded parts with castings. These studies are focused on the usefulness of this material as cast or after homogenization heat treatment.

In this study, it is aimed to quench directly after forging of the AA 6082 alloy parts at the high temperature and then aged for 8 hours at 180 °C. In fact, this method is similar to the T5 tempering applied for aluminum alloys. From this point of view, it is observed that there is very little information in the literature about the production of aluminum alloy AA 6082 by T5 treatment. The existing studies examined the properties of these alloys with small number of variables, so they consist very limited information. In this context, a study at a predefined heating time of 15 minutes, is examined by Zvinys and friends. In addition, most important point, proper forging temperatures to obtain the right solution temperature is investigated [3]. There was not given any information about the conditions of forging and heat treatment presented in TALAT aluminum heat treatment programs [2].

In the literature, there are not many details about the microstructure and mechanical properties of the AA 6082 aluminum alloy with or without deformation after short-term heating by induction.

2. Experimental

During the studies, AA 6082 alloy bars rolled to diameter of 36 mm and length of 85 mm are supplied from company ASAŞ. Quality certificates stating its hardness as of 47-52 HB also declares nominal requested range and measured value of chemical composition of this alloy as shown in Table 1. Figure 1a shows schematically conventional T6 heat treatment applied to aluminum alloys. Temperature-time graph used in this study is shown in Figure 1b. In this study, the

parts are forged after 15 minutes induction heating, then quenching in a water bath and aged 8 hours at 180 ° C. In figure 2, the work flowchart followed for the experimental work is given. Figure 2 shows, two different groups of samples investigated in this study, flow chart with or without 10% deformation after the solution treatment of the AA 6082 aluminum alloy.

Table1. Chemical composition of alloy AA 6082.

Element	Nominal (wt%)	Alloy Tested (wt %)
Si	0,70 - 1,30	1,00
Mg	0,60 - 1,20	0,66
Mn	0,40 - 1,00	0,42
Fe	0,50 (max)	0,23
Cr	0,25 (max)	0,10
Zn	0,20 (max)	0,01
Cu	0,10 (max)	0,01
Ti	0,10 (max)	0,02
Others	0,05 - 0,15	0,06
Al	Balance	

Processing route in this study is compared with conventional thermal processing path as shown in Figure 1.

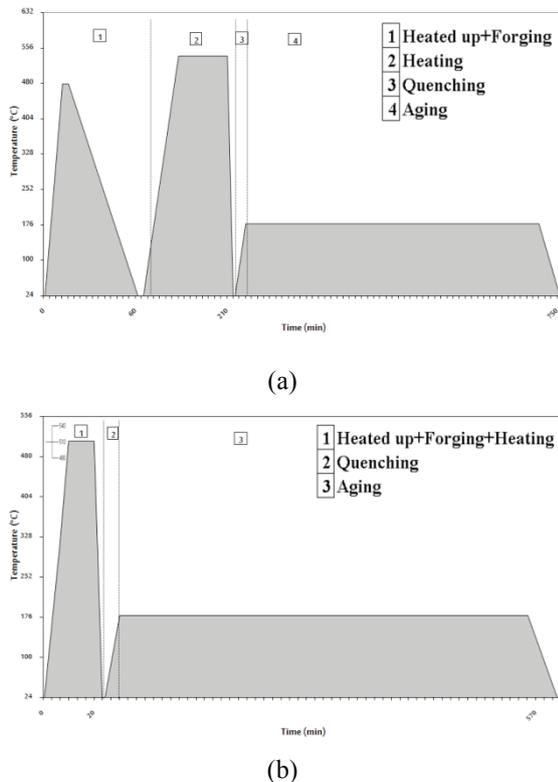


Figure 1. Thermal process applied to aluminum alloys; (a) conventional T6 and (b) experimental heat treatment cycle performed in this study.

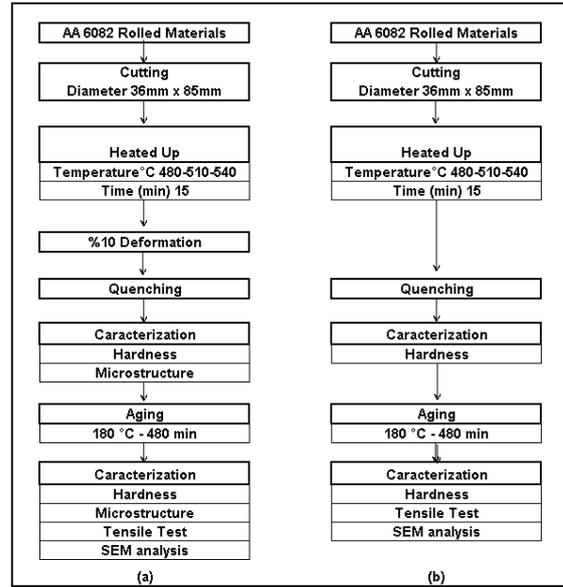


Figure 2. Experimental process flow chart; (a) with 10% deformation (b) without deformation.

The first group of samples of AA 6082 alloy prepared by cutting a cylindrical bar, heated to 480, 510, 540 ° C for 15 minutes by the induction heating, then deformed at a ratio of 10% on a forging machine prior to quenching into water baht. Second group materials are heated to desired temperature and directly quenched to water bath without any deformation. All of the samples are aged at 180 ° C along 8 hours.

All the sample groups are characterized before aging and after aging. Brinell hardness tests are done by using Emcotest hardness tester and tensile tests are done on Zwick tensile testing instrument. Microstructure analyses are done by using optical microscopy (OM), scanning electron microscopy (SEM) and energy dispersive X-ray spectral analysis (EDS).

3. Results and Discussion

Mechanical test results are given in detail in Table 2. According to these results, hardness of the samples was found among 50-88 HB before aging, and 50-106 HB after aging. After aging tensile strength and elongation values were respectively within the range of 160-345 N/mm² and 18-25%. The reason for such a wide range of variation in elongation and strength values may be considered as non-homogeneous distribution of precipitation phases within the microstructure due to low induction heating temperature as solution treatment process and short heating time of 15 minutes resulting with the insufficient quantity of coherent and semi coherent structure of precipitation phase formation within alloy microstructure [8]. In this case, hardness and tensile strength of AA 6082

alloy decreases after aging. According to the standards of AA 6082 aluminum alloy (from industrial point of view) the hardness value must be over 90 HB in order that any part made of this alloy can be used as a machine component. Looking at the results given in Table 2; samples with solution treatment temperature of 540 °C for 15 minutes and then subjected to aging at 180 °C for 8 hours have the hardness values above this limit.

Table 2. Mechanical test results.

AL 6082			Tensile test results after aging			Hardness results before aging HB	Hardness results after aging HB
Temperature °C	Time (dk)	Deformation %	Yield strength (N/mm ²)	Tensile strength (N/mm ²)	% elongation Min.		
			Min 260 N/mm ²	Min 310 N/mm ²	%6		
480	15	0	-	160,4	25,32	50	50
		10	-	162,3	23,62	55	62
510	15	0	205,6	240,5	21,9	76	78
		10	215,02	249	21,82	80	82
540	15	0	288,34	338,51	18,12	84	102
		10	290,33	344,72	18,47	88	106

Quenched and aged samples are tested by brinell hardness. Figure 3 shows hardness variation depending on the heating temperature and time, aging status and deformation condition. Hardness values were taken into account as the average of at least 5 measurements on a sample.

Tensile strength tests results also showed similar tendency to the hardness values as shown in Figure 4. It can be concluded that 10% deformation does not have any influence on the strength value.

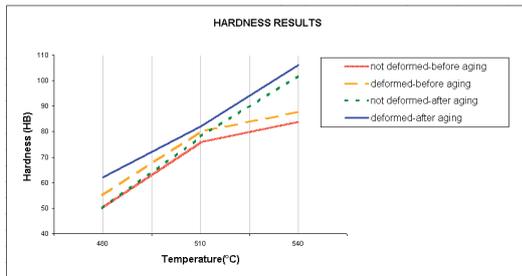


Figure 3. Samples hardness results as deformed or not deformed as well as aged or not aged.

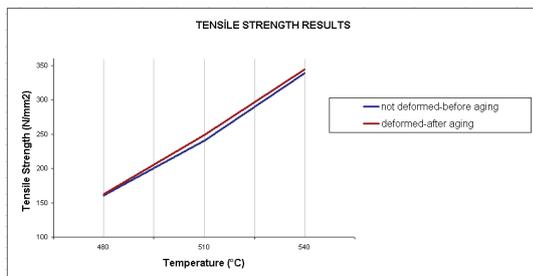


Figure 4. Sample tensile strength results as deformed or not deformed as well as aged or not aged.

Figure 5 shows microstructural changes before and after aging of samples subjected to different solution heat treatment temperatures for 15 minutes. Precipitation phases of aged samples are observed to be finer and distributed more homogeneously within the structure compared to non-aged samples. In addition, it is observed that precipitation phase of the samples after aging distributes from coarser to finer structure with the increasing solution treatment temperature. In another word, coarse precipitates at low solution treatment temperatures are dissolved and spread over the matrix with finer precipitation as the process temperature increase.

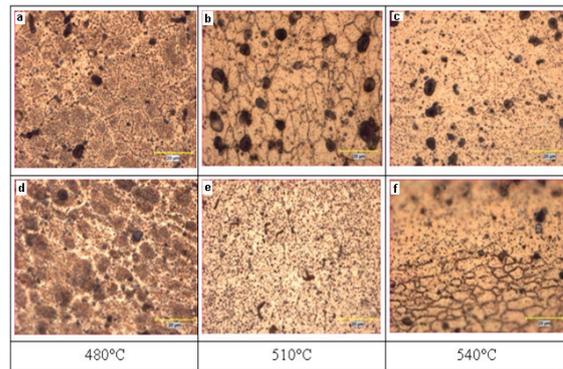


Figure 5. Optical microstructures of samples heated with induction at different temperatures for 15 min, deformed and quenched; before aging at (a) 480 °C, (b) 510 °C, (c) 540 °C, and after aging at 180 °C 8 hours; (d) 480 °C, (e) 510 °C, (f) 540 °C.

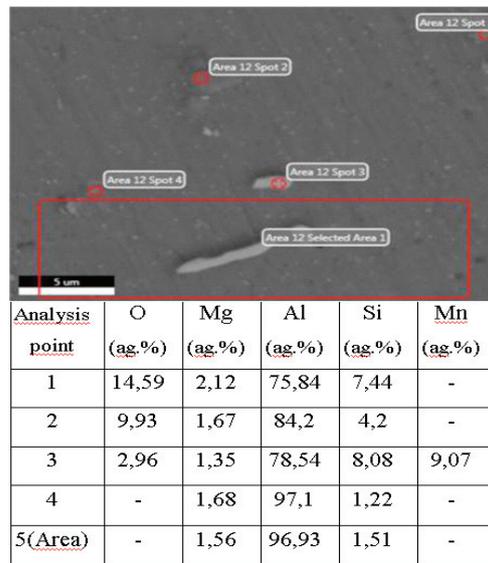


Figure 6. SEM pictures and EDS analysis of parts heated at 540°C 15 minutes, quenched and aged at 180°C 8 hours.

SEM-EDS results of the samples heated at 540°C for 15 minutes and aged along 8 hours at 180°C

after the water bath quenching are given in Figure 6.

Figure 6 shows the microstructure of very rough precipitate which does not have any particular geometry. It is also observed the presence of very thin and light gray colored spherical precipitates. SEM-EDS analysis results of this precipitate phase shows that Mg, Al ve Si elements are concentrated more on the analysis points with number 1, 2 and the same elements with the addition of Mn on point 3. Areas numbered as 4 and 5 are the matrix structure. Considering the elements consisted by precipitate phase and earlier studies on alloy AA 6082, these intermetallic compounds are thought to be two or three components such as hard Mg_2Si , $Al_{10}SiMn_3$ and $Al_{15}Si_2Mn_3$ [8].

4. Conclusion

The results obtained in this study are:

1. Variation of microstructure, tensile strength and hardness values of deformed and the non-deformed samples are lower than expected.
2. Hardness and tensile strength values of the samples increase with increasing holding temperature. Sample heated at 540 °C for 15 minutes and aged at 180 ° C for 8 hours, gave satisfactory hardness results above 90 HB considered as a limit value for commercial applications.
3. Finest and most homogeneous precipitation structure after aging of the samples is observed to be the oneshold at highest heating temperature among the experiments performed at 480, 510, 540 °C along 15 minutes.
4. Al, Si, Mg and Mn elements were observed within the chemical composition of the precipitate in the matrix phase.

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