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Effect of T6 and Re-Aging Heat Treatment on Mechanical Properties of 7055 Aluminum Alloy

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***Abstract*—**Heat treatable aluminum alloys such as 7075 and 7055, because of high strength and low density, are used widely in aircraft industry. For best mechanical properties, T6 heat treatment has recommended for this regards, but this temper treatment is sensitive to corrosion induced and Stress Corrosion Cracking (SCC) damage. For improving this property, the over-aging treatment (T7) applies to this alloy, but it decreases the mechanical properties up to 30 percent. Hence, to increase the mechanical properties, without any remarkable decrease in SCC resistant, Retrogression and Re-Aging (RRA) heat treatment is used. This treatment performs in a relatively short time. In this paper, the RRA heat treatment was applied to 7055 aluminum alloy and then effect of RRA time on the mechanical properties of 7055 has been investigated. The results show that the 40-minute time is suitable time for retrogression of 7055 aluminum alloy and ultimate strength increases up to 625MPa.

***Keywords*—**7055 Aluminum alloy, Mechanical properties, SCC resistance, Heat Treatment.

I. Introduction

ALUMINUM-Zinc-Magnesium alloys such as 7055 and 7075 are finding increased use in many application both in aerospace and non-aerospace, particularly for light weight vehicles. Alloys based on the Al–Zn–Mg system are widely used in the aircraft industry because of their high response to age hardening. The complete ageing sequence in a wide range of ternary compositions is [1]:

Supersaturated solid solution → GP (Zn, Mg) zones → η' (hexagonal) → η ($MgZn_2$, hexagonal)

From strength issue, many aircraft parts and structures fabricated from 7xxx series aluminum alloys, use T6 temper. However, this temper is prone to corrosion induced damage, including SCC and exfoliation. The issue has become increasingly important in view of the economical maintenance of old age in many commercial and military fleets. A two-step heat treatment, known as Retrogression and Re-Aging (RRA), has been shown to give high corrosion resistance in 7xxx aluminum alloys equivalent to the T73 temper, together with the T6 strength levels. Therefore, the process is very promising as an effective means to control corrosion damage in aircraft components made using T6 treatment [2].

The concept of retrogression and re-aging (RRA) was first developed by Cina and his colleagues in 1974 [3], [4] which consists of two steps: 1) retrogression of the 7xxx-T6 material at an intermediate temperature between the aging temperature and the solutioning temperature, and 2) re-aging of the retrogressed alloy at 120◦C for 24 hours.

During the reversion step (performed usually on T6 tempers) an initial reduction in hardness occurs following continuous decrease according to time and temperature of the reversion step. The initial decrease is commonly interpreted as a dissolution of the initially present GP zones or η' precipitates [5]-[9]. However, the mechanisms depend on the initial temper of the material and the parameters of reversion (notably time and temperature), so that a complete picture is still missing.

The re-ageing step is interpreted in many different ways. Several mechanisms have been invoked in the literature, including the growth of partially dissolved η' precipitates, the re-nucleation of precipitates, or the transformation to the stable η phase [7].

The aim of this paper is to investigating the effect of reversion time on the tensile strength and microstructure of the 7055 alloy.

II. Experimental Procedure

The present study was carried out on an alloy prepared from casting and with alloying elements (wt. %) 7.7 Zn, 2 Mg and 2.1 Cu (with minor additions of Zr and Ag to control grain size and precipitates). The alloy prepared by casting of high purity aluminum (99.99%), industrially pure zinc (99.9%), industrially pure magnesium (99.9%), and industrially pure copper (99.9%), high purity silver (99.99%) and A1-5%Zr master alloy. Graphite crucible-type electrical resistance furnace was used to melt the alloys at 780°C. Afterwards, melt was cast in a water-cooling copper mold. The as-cast Samples with 150*50*10 mm dimensions were homogenized at 470◦C for 24 h, then hot rolled with about 40% reduction. Hot rolling performed at a lab rolling mill with 40 rpm rolling speed at 430◦C.

Material received as a 7 mm thick plate, subjected to a 6 hours solution treatment at 471◦C, followed by a water quench, and 24 h of heat treatment at 120◦C (T6 temper). The samples immediately were subjected to 200◦C reversion temperature at several times (30, 40 and 50 minute) and quenched in cold water. Finally, the T6 temper repeated. The scheme of the heat treatment procedure is shown in Fig. 1.

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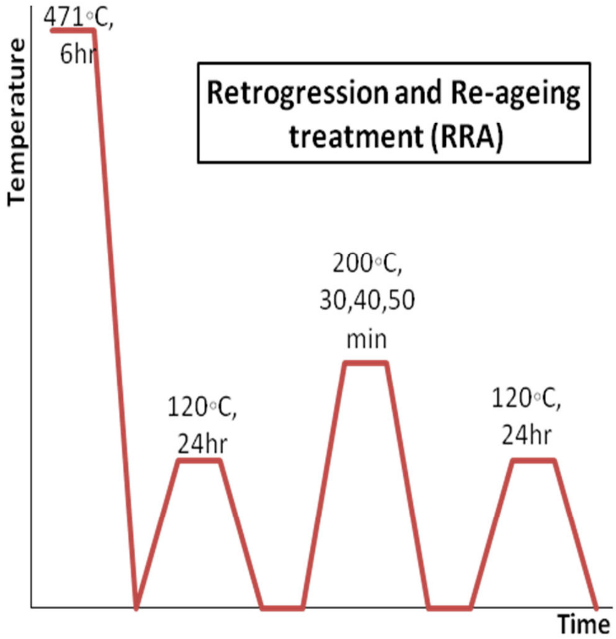

Fig. 1 Scheme of the heat treatments used

All mechanical property measurements were made at ambient temperature on the specimens machined from RRA treatment according to ASTM B557-06 small size standard. Tensile properties were determined on the specimens with dimensions of 4mm diameter and 20mm gauge length using a SANTAM 25 ton mechanical testing machine.

Metallographic specimens were cut and prepared from heat-treated samples. Optical microscope OLYMPUS BX60 was used for microstructure observations and Keller's etchant was used for etching.

III. Results And Discussions

The tensile properties for 7055 aluminum alloy treated by different reversion times are listed in Fig. 2.

The results show that strength in 40 minute times meets the maximum amount and then decreases gradually.

It is observed that in 40 minute reversion time, strength increases during the re-ageing step. This is due to the nucleation of new particles inside the grains (Fig. 3 (b)). The fact that strength decreases in reversion time less than 40 minute is probably due to an insufficient time which resulted in prevention of new particles nucleation inside the grains.

The ultimate strength after 50 minutes reversion time is 596 MPa that is smaller than 606 MPa for 30 minute reversion time.

In samples with 30 and 40 minutes reversion time, mean grain size is equally the same and approximately is 52 micron.

As the time increases, the grain size increases to 200 micron which resulted to decreasing of mechanical properties. It seems that 40 minutes is suitable time for obtaining the best mechanical properties. Moreover, when the reversion time increases to more than 40 minutes, precipitation coarsening occurs and could not pin the dislocation and the strength of the alloy will decrease.

Typical morphologies of samples with different reversion time at 200°C are shown in Figs. 3-5 with different magnifications.

At the first stage, reversion proceeds in several steps. When the temperature of the sample (aged temper) is raised, at the first, a decrease in volume fraction is observed. This dissolution can be resulted from the combination growth of large (stable) precipitates and the dissolution of smaller (unstable) ones. If the reversion treatment is continued after the end of this dissolution stage, a coarsening stage occurs rapidly, where precipitates are observed to grow to large sizes and volume fraction decreases [10]. The mean size of the precipitates at the first time (30 minutes) is 7 micron and at the final stages (40 minutes) reaches to 13 micron. The best compromise is to finish the reversion stage when mechanical properties (tensile and yield strength) reaches to their maximum value and drops continuously.

In terms of chemistry of the precipitates and matrix, strong changes appear during this reversion stage. The diffusivity of Zn is much higher than that of Cu, which leaves the precipitates at the first, resulted in a strong increase in the matrix Zn content and a corresponding increase in the Cu precipitate content [11]. It is interesting to note that this evolution is in opposition in the ageing treatment resulted in a peak-aged temper, where Zn firstly incorporates the precipitates, resulted in a high Zn content and a high Cu matrix content of the precipitates [12].

It is now possible to analyze the objective of the reversion treatment. The requirement is to increase the solute content to a level where re-nucleation of particles will be possible during the re-ageing stage, while keeping the size of remaining precipitates to a reasonable value. Thus, it is important to control precisely the duration of the reversion step in order to avoid precipitate coarsening, which occurs very rapidly once the stage of dissolution is finished.

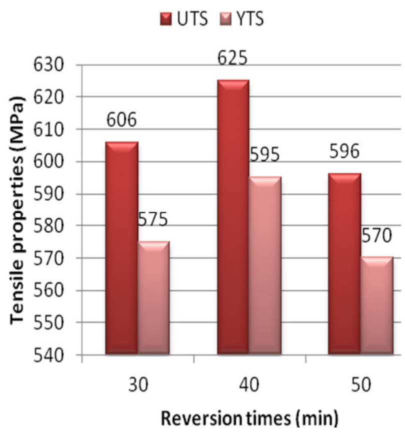

Fig. 2 Tensile properties for 7055 alloy treated by RRA different reversion times

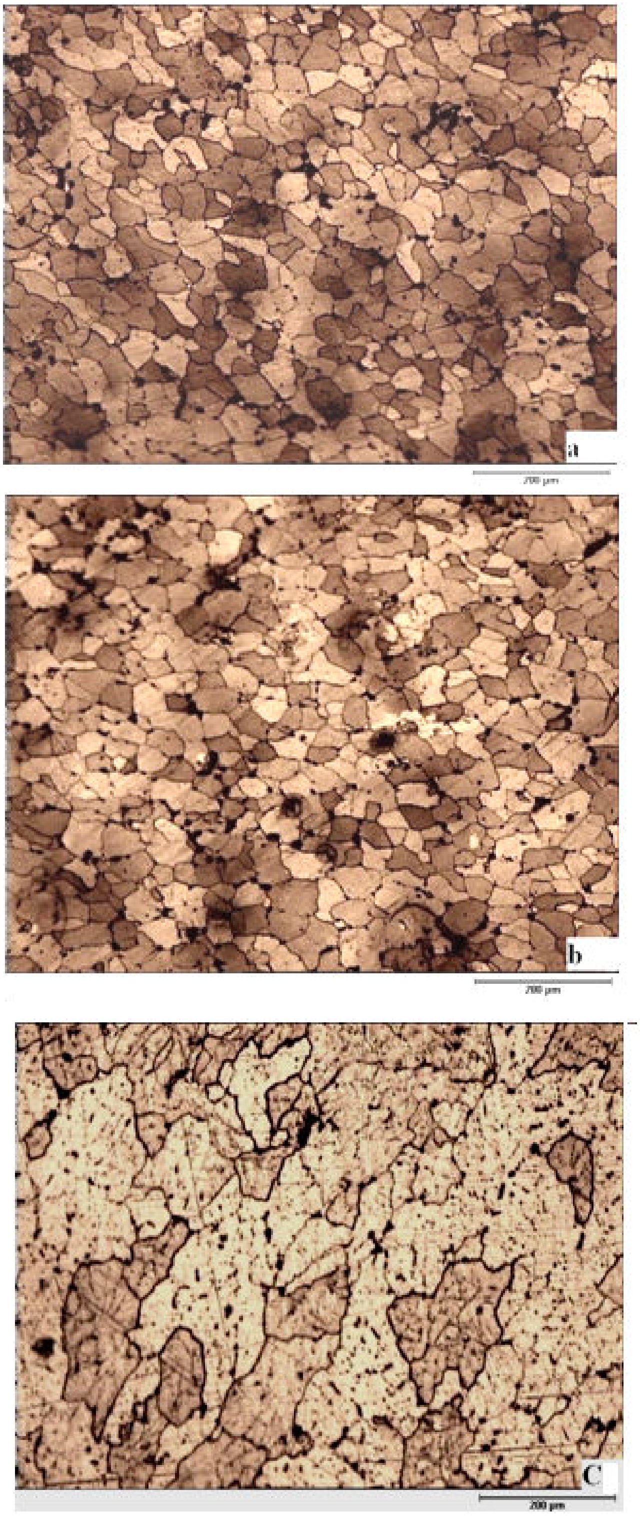

Fig. 3 Evolution of microstructure of 7055 Aluminum alloy with different reversion time: (a) 30 min; (b) 40 min; (c) 50 min. Magnification: ×200

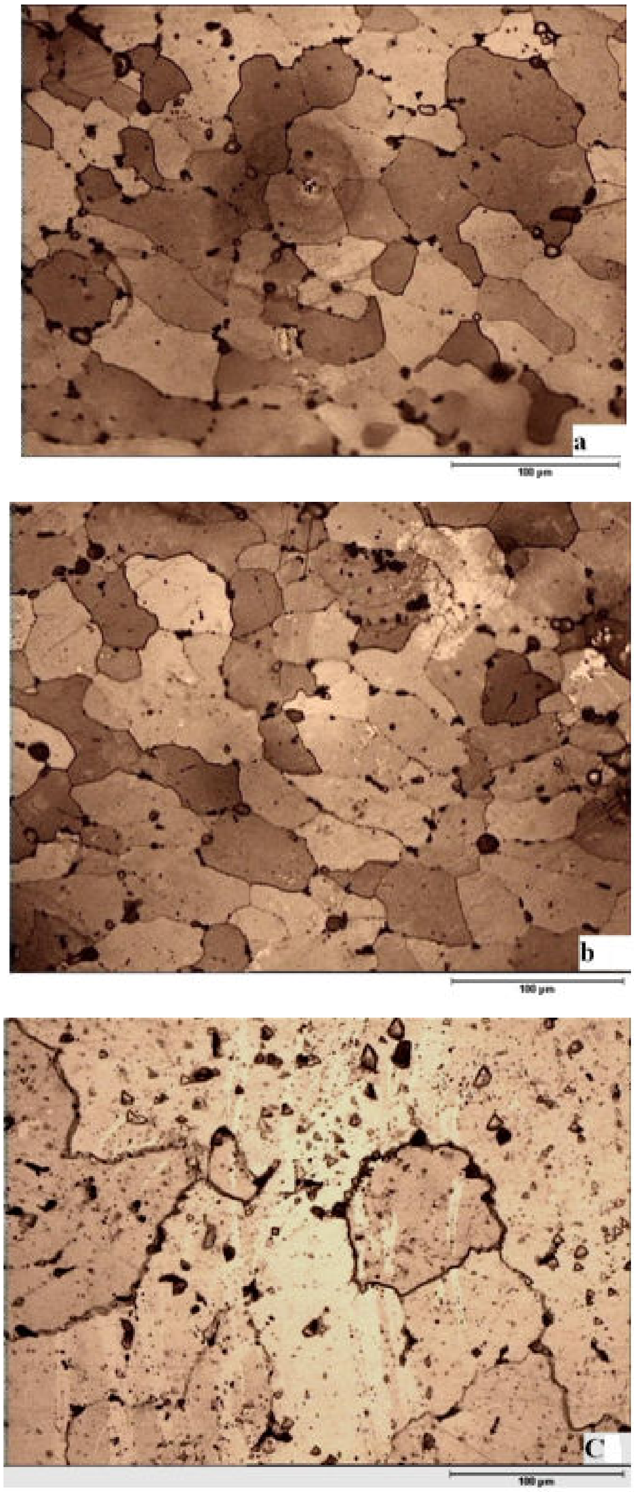

Fig. 4 Evolution of microstructure of 7055 Aluminum alloy with different reversion time: (a) 30 min; (b) 40 min; (c) 50 min. Magnification: ×500

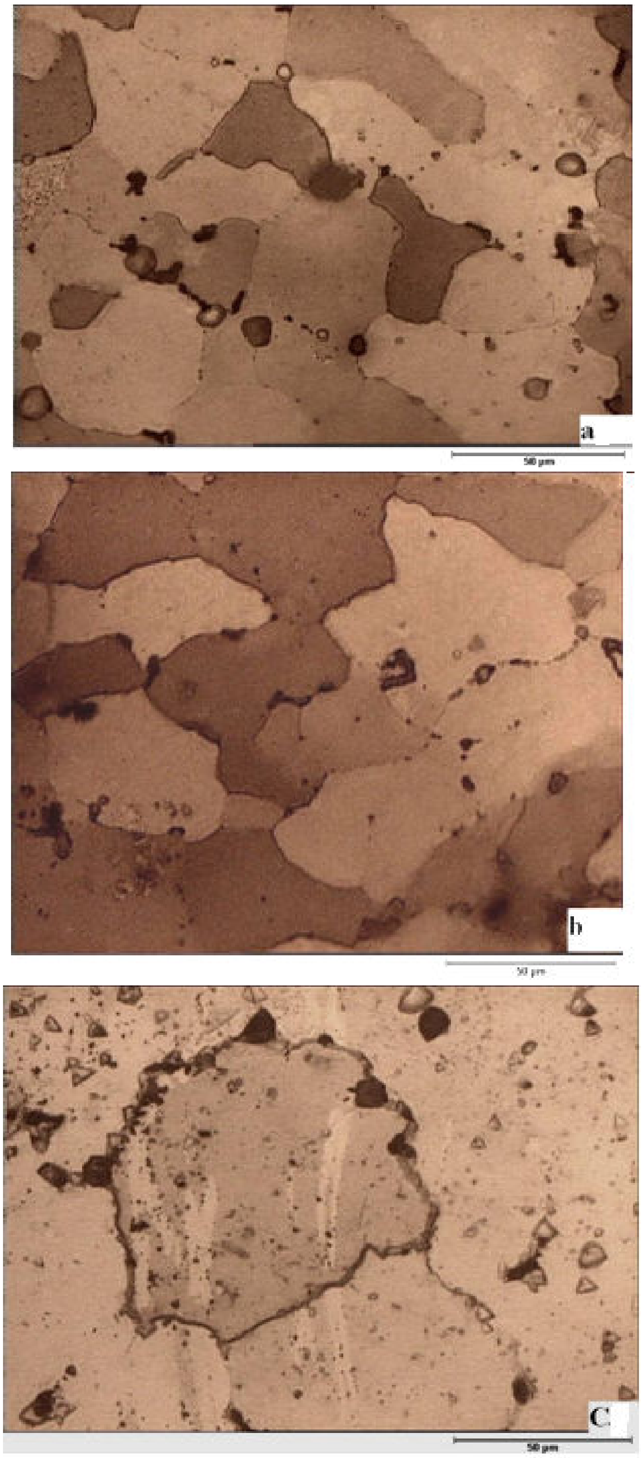

Fig. 5 Evolution of microstructure of 7055 Aluminum alloy with different reversion time: (a) 30 min; (b) 40 min; (c) 50 min. Magnification: ×1000

IV. Conclusion

With increasing the reversion time, both the grain size and precipitate size increase that will effect the mechanical properties.

The 40 minute reversion time is relatively suitable time in 7055 aluminum alloys for obtaining maximum strength and ultimate strength increases up to 625MPa.

By Retrogression and Re-Aging (RRA) heat treatment in comparison with T6 heat treatment maximum ultimate strength can be obtained.

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