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PROPERTIES ENHANCEMENT OF Al-Zn-Mg ALLOY BY RETROGRESSION AND RE-AGING HEAT TREATMENT

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Abstract

The higher strength 7xxx aluminum alloys exhibited low resistance to stress corrosion cracking (SCC) when aged to the peak hardness (T6 temper). The overaged alloys (T7 temper) developed to enhance the SCC with loss in the strength of the alloy. Recently, retrogression and re-aging (RRA) heat treatments are used for improving the SCC behavior for alloys in T6 tempers such as 7075, 7475 and 8090. In this study, an application of retrogression and re-aging heat treatment processes are carried out to enhance toughness properties of the 7079-T651 aluminum alloy, while maintaining the higher strength of T651-temper. The results of charpy impact energy and electrical conductivity tests show a significantly increases in absorbed energy and electrical conductivity values, when the alloys are exposed to various retrogression temperatures (190, 200, 210^{o}C) and times (20, 40, 60 minutes), and then re-aged at 160^{o}C for 18 hours.

Keywords: Aerospace materials, 7079-T651 aluminum wrought alloy, Retrogression and Reaging Heat Treatment Process, Impact, Electrical Conductivity, and Hardness.

1. Introduction

Requirements for lighter and stronger products are the driving force for continuous improvement of aluminium alloys, due to their composition, performance, production and technology [1-3]. The conventional 7000 series Al-Zn-Mg aluminum alloys such as

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7075-T6 and 7079-T6 are widely used as structural materials for aerospace applications [4]. Their strength is derived from the precipitation of η' phase (semi-coherent $MgZn_2$) in the grain interiors and of η phase (non-coherent $MgZn_2$) along the grain boundaries as reported in the literatures [4-7]. It was reported [8-10] that the thick sectioned products of the 7079 alloys at the peak-aged condition (T6) are highly resistant to SCC when stressed in the longitudinal and long-transverse directions relative to the grain structure, however, are susceptible to SCC in the short - transverse direction. The technique [12, 13] of retrogression and reaging (RRA) heat treatment as a process applied to alloy 7075-T6 to improve the SCC resistance of the alloy equivalent to the overaged condition (T7 temper, 38% IACS), while maintaining high strength of T6 condition(5-10% loss in strength). Zhihui Li et al [13] studied the effect of RRA treatment (170-190°C) on the strength and electrical conductivity of 7B04 aluminum alloy (Chinese brand). Their results showed that the electrical conductivity was improved with a 3% reduction in strength below T6 temper when the alloy retrogressed at 180°C for 60 minutes. Gazda et al [14] studied phase transformations during RRA in some AlZnMgCu alloys using differential thermal analysis (DTA) and electrical resistivity measurements. They found that the coarsening of grain boundary precipitates during retrogression step and re-precipitation of the matrix strengthening during re-aging step were attributed for improving the alloy resistance to SCC (as indicated by electrical resistivity) and maintaining good mechanical properties of T6 temper. The microstructural characterization of 7075 aluminum alloy in the RRA temper were investigated by Viana et al [15], using TEM and DSC techniques. They showed that the retrogression treatment resulted in dissolution of the less stable precipitates (GP zones and η') inside the grains, while the grain boundary precipitates grow and more spaced. The re-aging enhanced the re-precipitation of η' precipitates. The present investigation was undertaken to determine the effects of retrogression and re-aging (RRA) heat treatment on hardness, electrical conductivity, and impact energy of the 7079-T651 aluminum alloy.

2. Experimental Procedure

A commercial 7079-T651 aluminum alloy used in this investigation was in the form of plate 22 mm thick. Table 1 gives the chemical composition of the alloy. The as received plate properties were ~181HB hardness, ~32% IACS electrical conductivity, and ~10 Joule impact energy.

Table 1. Chemical Composition of the Commercial Aluminum Alloy

Elements	Si	Fe	Cu	Mn	Cr	Mg	Zn	Al
wt%	0.3	0.4	0.51	0.19	0.13	3.24	4.21	balance

The retrogression and reaging heat treatment process (RRA) was applied to the alloys in the T651 temper. All specimens (two sets) in the T651 temper were subjected to the retrogression at 190, 200, and 210°C for various times of 20, 40, and 60 minutes. The reaging treatment was carried out at 160°C for 18 hours. All heat treatments specimens were monitored by the measurement of hardness using Brinell hardness testing machine (M2N), electrical conductivity (average of at least 5 readings for both hardness and conductivity) using eddy current testing (Hocking NDT Phassec 2200), and absorbed energy (average of two readings) using charpy impact testing AMSLER machine type (PSW300M).

3. Results and Discussion

The change in hardness and electrical conductivity for the aluminum alloys is attributed to the various precipitation stages formed during the artificial aging treatment. In general, the first transformation stage is the formation of Guinier-Preston (GP) zones, which initiate at solute clusters coherent with the matrix. As aging progresses, the GP zones grow in size and transform to semi-coherent precipitates and then to non-coherent (equilibrium) precipitates. For the Al-Zn-Mg [4, 5-7] alloys, the precipitation sequence from supersaturated solid solution (sss) may be represented as: sss → GP zones (coherent $MgZn_2$) → η' (semi-coherent $MgZn_2$) → η (non-coherent $MgZn_2$)

3.1 Hardness measurements

Figures (1,2) give the variation of hardness with retrogression time curves for 7079-T651 (Al-Zn-Mg) alloys that are exposed to retrogression heat treatment for various retrogressed times (20, 40 and 60 minutes) at 190, 200 and 210°C and then reaged at 160°C for 18 hours respectively. The initial hardness (peak hardness) for the as received specimen in the T651 temper indicates hardness value of ~181 HB, which is attributed to the contribution of precipitation hardening (formation of η'-semi-coherent $MgZn_2$ phase), and strain hardening (cold work). It is evident that the hardness of the alloys in R-T651 decreases as retrogression time increases and/ or retrogression temperature increases (i.e, 4%, 6% and 16% decrease in hardness after 20 minutes retrogressed at 190, 200 and

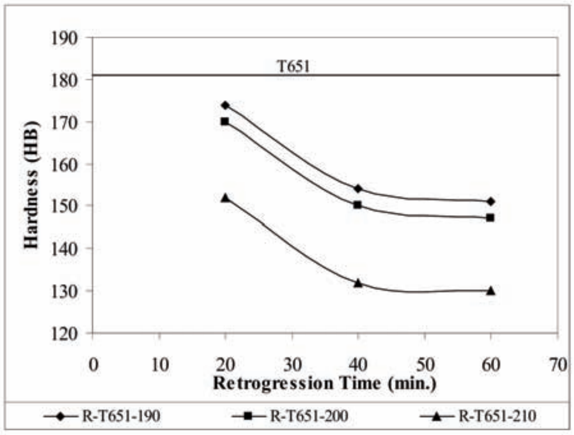

Fig. 1. Hardness vs. retrogression time for 7079 – T651 (Al-Zn-Mg) alloys, R-T651: retrogressed at 190°C, 200°C, and 210°C, water quenched.

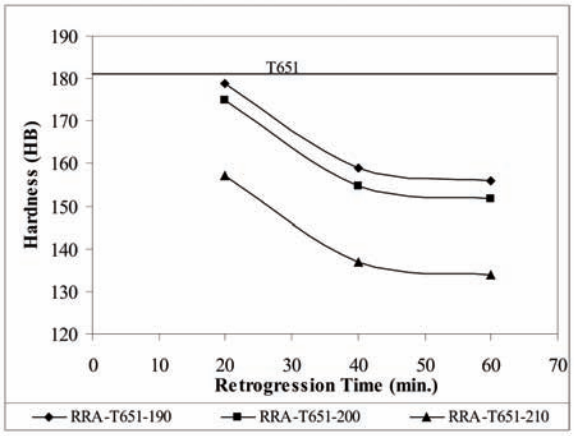

Fig. 2. Hardness vs. retrogression time for 7079 – T651 (Al-Zn-Mg) alloys, RRA-T651: retrogressed at 190°C, 200°C, and 210°C, water quenched, and then reaged at 160°C for 18 hrs.

Figure 1. Schematic of laboratory scale sintering pot

210°C respectively), which may be attributed to dissolution of the less stable phases (GP and η') and a decrease in dislocation density. The RRA-T651 alloys show that the re-aging processes restore some of the hardness back to the alloys, indicating the re-precipitation of meta-stable phases.

3.2 Electrical conductivity measurements

The effect of retrogression (R-T651) and retrogression-reaging (RRA-T651) treatments on electrical conductivity as function of retrogression times are shown in Figures (3 and 4) for the alloys that retrogressed at 190, 200 and 210°C, and retrogressed and reaged at 160°C for 18 hours respectively. The results indicate that the electrical conductivity rises with increasing time or temperature of retrogression. The increased electrical conductivity of the alloys is inferred a decrease of susceptibility of SCC, which may be attributed to coarsening precipitates

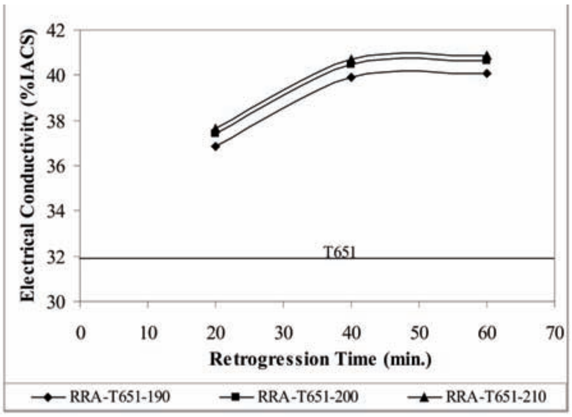

Fig. 4. Electrical conductivity vs. retrogression time for 7079 – T651 (Al-Zn-Mg) alloys, RRA-T651: retrogressed at 190°C, 200°C, and 210°C, water quenched, and then reaged at 160°C for 18 hrs.

in both R-T651 and RRA-T651 alloys. It was reported [12] that the accepted limit for electrical conductivity for 7057-T6 aluminum alloy is ~38%IACS.

3.3 Impact energy measurements

The impact test was performed for the alloys in RRA-T651 temper to determine the

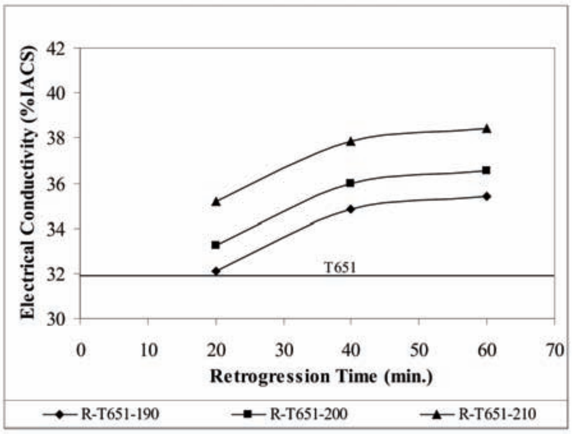

Fig. 3. Electrical conductivity vs. retrogression time for 7079 – T651 (Al-Zn-Mg) alloys, R-T651: retrogressed at 190°C, 200°C, and 210°C, water quenched.

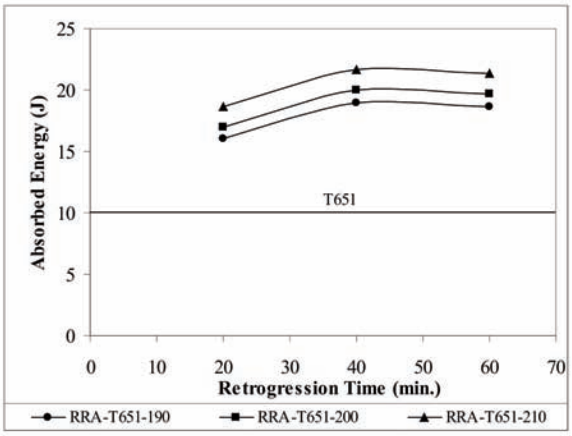

Fig. 5. Absorbed energy vs. retrogression times for the 7079 – T651 (Al-Zn-Mg) alloys: RRA-T651: retrogressed at 190°C, 200°C, and 210°C, water quenched, and then reaged at 160°C for 18 hrs.

influence of the retrogression and reaging heat treatment parameters on the absorbed energy when compared with the alloys in T651 temper. The results showing in Figure 5 indicate that the absorbed energy is 1.6 to 2 times higher for RRA-T651 (16-20 J) than T651 temper (10J), which is consistent with the electrical conductivity results.

The increase in electrical conductivity and impact energy with retrogression times (cf. Figures 4 and 5) may be attributed to growing of equilibrium phases at grain boundaries, which improve the alloys stress corrosion cracking resistance during the retrogression treatment and maintaining high strength during the re-aging, which are in agreement with other studies [13-15].

4. Conclusions

The obtained results show that the application of retrogression and re-aging heat treatment to the 7079-T651 aluminum alloy improves the microstructure of the alloys as inferred from the results of hardness, electrical conductivity, and impact. The study shows that the absorbed energy for RRA-T651 (16J) alloys is 1.6 times higher than T651 temper (10J), when the alloy is retrogressed at 200^{o}C for 20 minutes and reaged at 160^{o}C while maintaining a higher strength of T651 temper.

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