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Influence of Magnesium Addition on the Mechanical and Corrosion Responses of 7249 Aluminum Alloy

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Abstract

The effects of 1.8-2.6% Magnesium addition on the mechanical and corrosion responses of 7249 aluminum alloy have been studied. Samples of the alloy in as-cast, T6 and RRA forms were made and subjected to tensile and hardness tests. Exfoliation, ferric-chloride and immersion corrosion analyzes were also carried out on the alloy forms. The results show that strength and hardness increased at the expense of ductility as the Mg content is increased to 2.6 %. RRA form exhibited the best tensile and hardness properties coupled with superior corrosion resistance. This characteristic behaviour of RRA form is predicated on the precipitation of coherent and stable equilibrium $MgZn_2$ phase.

Keywords: Magnesium, Aluminum 7249, corrosion, retrogression, re-aging, strength, microstructure.

INTRODUCTION

The 7xxx aluminium series are precipitation hardened alloys which consist of Zn, Mg and Cu as the major alloying elements. Its application is mostly in the automotive and aerospace industries. The peak strength is developed through the T6 temper while the T73

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temper produces corrosion resistance (Tsuchida, et al, 1980). In general, these temper specific properties are controlled by the precipitation sequence given as:

Solid solution → Guiner - Preston (GP) zones → ή → η → Equilibrium phase.

G-P zones are metastable, coherent solute clusters of Zn, Mg and Cu. The metastable ή, $MgZn_2$ or more correctly $Mg(ZnCuAl)_2$ appears as discrete platelets that are semi-coherent with the matrix and η is the incoherent equilibrium form of the same phase appearing as rods or plates (Islam and Wallace, 1983, Holt, et al, 1996 and Wallace, et al, 1998).

Retrogression is applied in the range 180-240°C after attaining T6 condition to cause rapid fall in hardness and yield strength as Guiner-Preston (G-P) zones dissolve and the solid solution is enriched in the strengthening elements (Es-Said, et al, 2003). The next stage is a transient period of hardness recovery as the remaining ή grows to a near optimum size distribution. This begins to fall again as this ή coarsens excessively and begins transforming to η. According to Pardo, et al, 2008, corrosion resistance increases steadily with hold time at the retrogression temperature. The recovery of strength during re-aging may be due to the re-formation of G-P zones or the formation of additional ή directly from the supersaturated solid solution or via the initial formation of G-P zones. The net result of the RRA process is a material with strength slightly below that of a single step aged T6 material together with resistance to environmentally assisted cracking, including SCC, equivalent to that of an over-aged T73 material. Retrogression and re-aging of Al7075 in the T6 temper significantly improves the materials resistance to exfoliation and stress corrosion cracking (Sankaran, et al, 2001).

Stress corrosion cracking (SCC) of primary structural components manufactured from Al 7075-T6 forgings, extrusions and plate products continues to plague aging aircraft. A

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two-step heat treatment, Retrogression and Re-aging (RRA), applied to 7xxx series aluminum alloys in the T6 temper has been shown to greatly enhance the SCC resistance of these materials with minimal trade off in strength (Iskandar, et al, 2002).

Studies on the effects of alloying element on mechanical properties of 7249 alloy have been attempted with emphasis on improving the alloy by altering the processing route. The magnesium allowed in 7249 Al alloy ranges between 2.0% and 2.4% (Iskandar, et al, 2002). It combines with Zinc to form $MgZn_2$ precipitate which strengthens the alloy. The current study seeks to improve the mechanical properties of Al 7249 by adjusting the composition of magnesium above 2.4% to examine its effects on the mechanical and corrosion responses of Al 7249 in the T77 form.

EXPERIMENTAL PROCEDURE

The aluminium 7249 alloy used for this study was made from Al 6063 ingot. Zinc and copper were added and the mix was melted in a crucible furnace. The chemical composition of the alloy produced is presented in Table1.

Table 1: Chemical composition of 7249 Aluminium alloy

Element	Al	Zn	Cu	Mg	Others

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% composition	87.42-88.22	8.1	1.84	1.8-2.6	0.04

The magnesium content was varied in the range 1.8-2.6% of the total charge make up from which cylindrical samples of Ø1.96 cm and thickness 14.6 cm were produced in sand moulds.

After casting, 15 samples were produced and divided into three groups of five samples identified as As-cast, T6 and T6 + Retrogressed and Re-aged.

Some of the As-cast samples were solution treated at 484^{0}C for one hour, quenched in water and naturally aged to give the T6 form. After T6 treatment of samples some were retrogressed at 200^{0}C for 40 minutes followed by re-aging at 120^{0}C for 24 hours. Tensile and hardness test pieces were made from the heat treated samples. The tensile testing was carried out in accordance with ASTM standard E8 at the rate of 10^{-3}s until fracture occurred. The data generated were used to compute the ultimate tensile strengths of the samples shown in Figures 1 and 2. The hardness values (Figure 3) of the samples were determined using Rockwell hardness tester with 100kg indenter on an Ø18.5 mm and 5 mm thick piece. Exfoliation corrosion tests were also conducted on samples in accordance with ASTM standard G34.

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Samples for microstructural examination were prepared on an Ø10 mm and 5mm thick test piece. The test pieces were ground successively on 80,240,360 emery papers and polished using diamond/ alumina paste. The polished pieces were etched for 8 seconds in a solution containing 20g NaOH pellet dissolved in 50 cm^3 of water. Photo micrographs were taken using an optical metallurgical microscope at a magnification of X200. The results are shown in Plates 1-4.

RESULTS AND DISCUSSION

The ultimate tensile strengths of the samples increased as the amount of Mg added increased in the alloy with RRA> T6 > as-cast within the range considered. The minimum strength at 1.8% Mg for As-cast,T6 and RRA are 138 MPa,161MPa and 203 MPa respectively while the maximum values at 2.6% Mg are 152MPa,175MPa and 234 MPa (Figure 1).

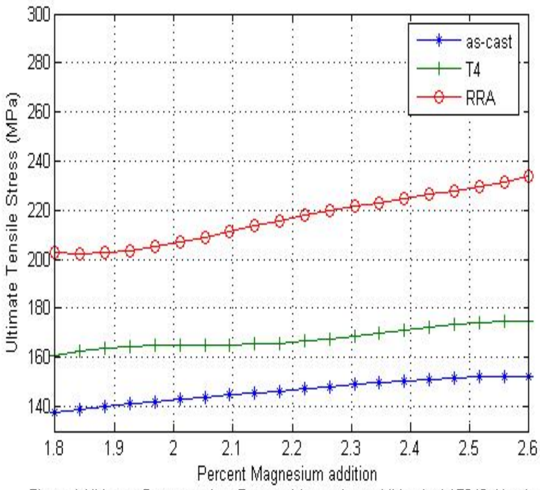

Figure 1 Ultimate Stress against Percent Magnesium addition in AA7249 Aluminum

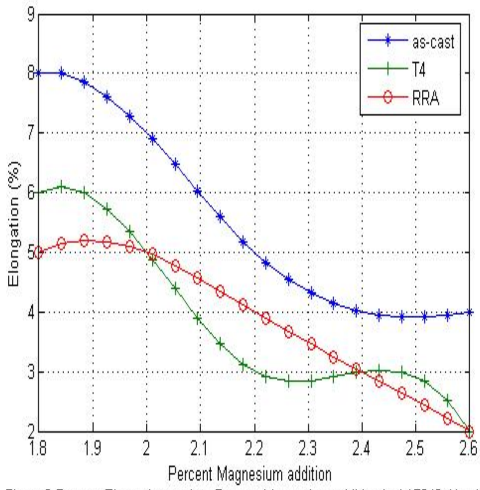

Figure 2 Percent Elongation against Percent Magnesium addition in AA7249 Aluminum

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The elongation responses of the samples showed a decline trend with increased Mg addition as elongation peaked at 1.8% Mg and the corresponding values for As-cast, T6 and RRA are 8,6 and 5 respectively. Minimum elongation occurred at 2.6% Mg having 4, 2 and 2% elongation respectively for As-cast, T6 and RRA (Figure 2). The hardness of test samples increase in nearly a linear pattern as magnesium content increases for the three groups. The T6 and RRA samples exhibited improved hardness over the As-cast samples in tandem with Mg content. However, RRA samples demonstrated superior hardness values throughout the range. Thus, the minimum hardness values at 1.8% Mg for As-cast, T6 and RRA samples are 32, 35 and 48 HRN respectively (Figure 3). These trends indicate that strength and hardness properties can be improved in the alloy if $MgZn_2$ precipitates are induced in the matrix (Siddiqui, et al, 2000).

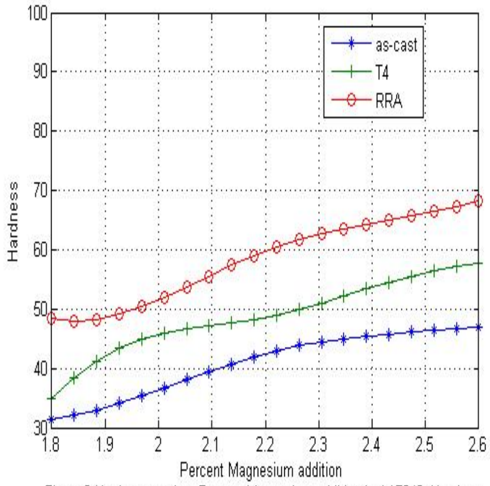

Figure 3 Hardness against Percent Magnesium addition in AA7249 Aluminum

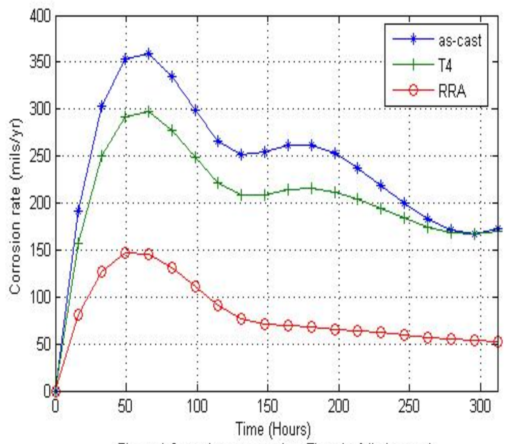

Figure 4 Corrosion rate against Time (exfoliation test)

In Figure 4, corrosion rate of the alloy forms initially increased to a peak value of 350, 290 and 150MPy for As-cast, T6 and RRA test samples after about 50 hrs and thereafter

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decreased. The RRA form demonstrated superior resistance during exfoliation test and also show good resistance to corrosion in ferric-chloride solution. The peak value of 50 MPy for RRA was attained at 50hrs and decreased slowly to about 25MPy after 300hrs (Figure 5). The immersion test does not have significant effect on the test forms of the alloy. This however, does not diminish the RRA capacity to resist corrosion as shown in Figure 6. Its maximum value of 0.3 MPy was attained after about 300 hrs of exposure.

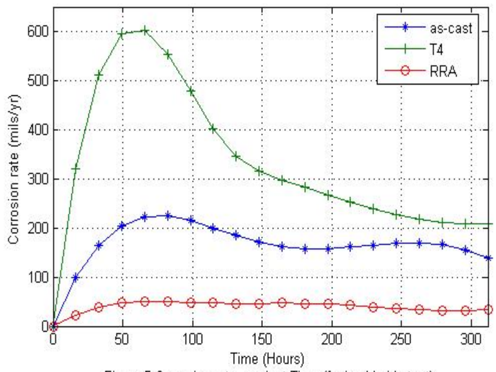

Figure 5 Corrosion rate against Time (ferric chloride test)

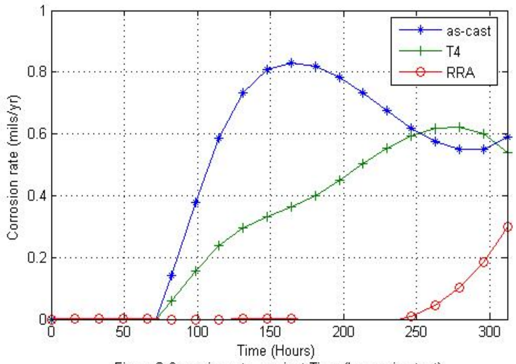

Figure 6 Corrosion rate against Time (Immersion test)

Better corrosion resistance of RRA is linked to the precipitation of the $MgZn_2$ phase possessing high positive electrode potential which is retained during corrosion tests and the erosion of low electrode potential intermetallic phases present in the alloy. The amount of $MgZn_2$ precipitates at the grain boundaries decreases in the alloy forms in the order: As-cast > T6 > retrogressed and Re-aged (Plate 1). At 2.6% Mg addition most of the added Mg is in solution (Plate 2). The T6 form contains substantial precipitation of $MgZn_2$ at the grain boundaries which increased strongly with retrogression and re-aging treatments (Dumont, et al, 2003).

The samples in Plate 1 corroded in decreasing pattern as the amount of $MgZn_2$ precipitated decreases (Plate 3). At 2.6% Mg addition, the corrosion resistance increased as the alloy is

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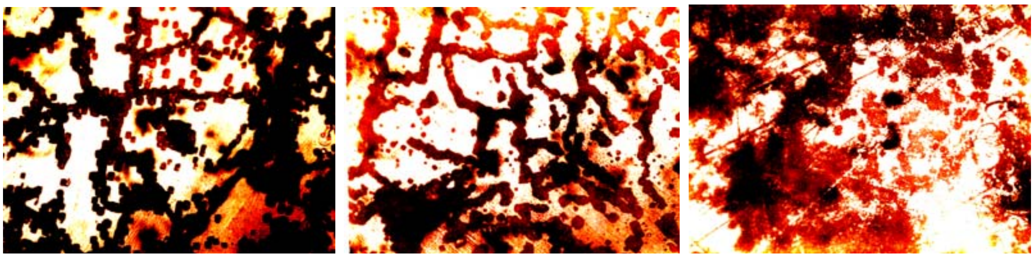
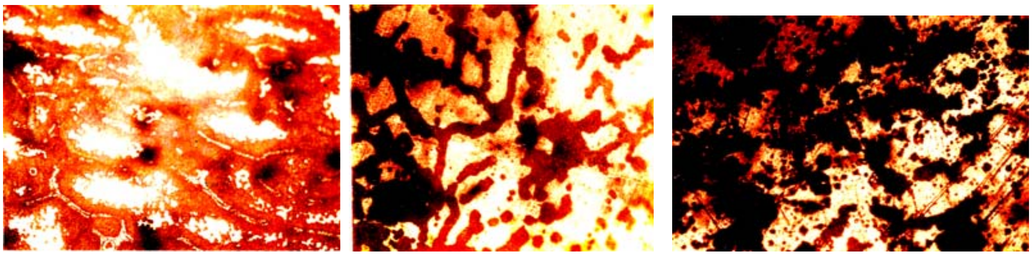
retrogressed and re-aged. The resistance is due to the preservation of strength-promoting $MgZn_2$ phase at the expense of other intermetallics (Plate 4).



(a) (b) (c)

Plate1 Microstructure forms of Al 7249 with 1.8% wt Mg content (a) as-cast (b) T6 (c) RRA.



(a) (b) (c)

Plate 2 Microstructure forms of Al 7249 with 2.6% wt Mg content (a) as-cast (b) T6 (c) RRA.

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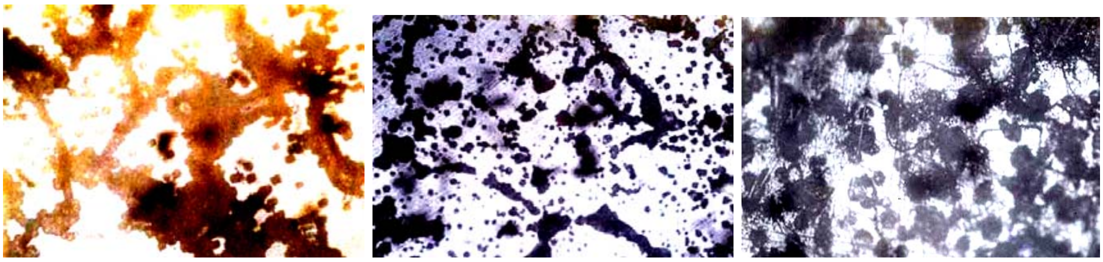

(a) (b) (c)

Plate3 Microstructure forms of Al 7249 with 1.8% wt Mg content (a) as-cast (b) T6 (c) RRA.

(a) (b) (c)

Plate 4 Microstructure forms of Al 7249 with 2.6 wt% Mg content (a) As-cast (b) T6 (c) RRA.

Conclusion

The exfoliation result obtained for RRA form of the alloy in this study is similar to that obtained by Es-said et al [5]. This study has shown that strength increment and exfoliation resistance of this alloy can be improved upon with magnesium addition above the 2.4% earlier specified. The strength obtained for the RRA sample at 2.6% Mg addition is superior (235MPa) to the naturally aged at both zero and 168 natural aging hours (207MPa) recorded in the work of Iskandar et al, 2002.

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