Materials Science and Engineering A 485 (2008) 468–475

MATERIALS SCIENCE & ENGINEERING A

www.elsevier.com/locate/msea

Improvements in mechanical and stress corrosion cracking properties in Al-alloy 7075 via retrogression and reaging

Y. Reda, R. Abdel-Karim *, I. Elmahallawi

Department of Metallurgy, Faculty of Engineering, Cairo University, Giza, Egypt

Received 4 September 2006; received in revised form 4 August 2007; accepted 7 August 2007

Abstract

Aluminum alloy 7075 has been widely studied, due to its excellent mechanical properties developed by age hardening and their extensive uses in the aircraft structure. Tensile test specimens were tested in various preaging conditions (100, 120, 140 °C) and various retrogression temperatures T_7 (160, 180, 200 °C) in order to evaluate the effect of heating cycles on the mechanical as well as corrosion properties. The optimum condition was preaging at T_6 120 °C and retrogressing at T_7 200 °C, which gave the highest hardness and tensile properties.

The corrosion behavior of three-point-loaded specimens after 7 days of immersion in 3.5% NaCl solution, using modified electrochemical cell, was studied. The most resisting condition for SCC was preaging at $T_6 = 100$ °C and retrogression at $T_7 = 160$ °C for 250 min. Specimens retrogressed at 200 °C for 8 min showed low resistance to stress corrosion cracking.

Keywords: Aluminum alloy 7075; Retrogression; Reaging; SCC

1. Introduction

Aluminum alloy 7075 is widely used for aircraft structural materials because it is a high strength and a low density [1]. Because of the Navys unique service requirements, this alloy is subjected to aggressive conditions where it often encounter salt water spray and/or salt fog environments. Since commercial purity aluminum alloys contain numerous constituent particles that have electrochemical potentials different from that of the matrix and corrosion pits can readily develop at these particles. Once corrosion pits are formed they act as stress concentration sites leading to stress corrosion cracking [2].

In commercial aluminum alloys, pitting corrosion has been found to occur at intermetallic constituent particles. According to Gao et al. [3], two types of particles were identified. Type A particles were anodic with respect to the matrix and tend to dissolve themselves, while type C particles were cathodic to the matrix and tended to promote dissolution of the adjacent matrix. Types A particles were those with Al, Mg, and Zn and type C particles were those with Fe, Cu, Mn.

The conventional method of solving the low corrosion resistance problem has been to overage the material (T73). Consequently a strength loss of 10–15% was inevitable. Retrogression and reaging was advised in order to overcome this problem. This method consists of retrogression the T_6 structure at a high temperature within the two-phase field, then reaging at the original T_6 condition [1]. Cina and Ranish [4] utilized temperatures $T_6 = 120$ °C for preaging treatment, and temperature $T_7 = 200$ °C for the retrogression process, then reaging the alloy at low temperature similar to the T_6 aging temperature and time. Retrogression and reaging results in an optimum combination of corrosion resistance and mechanical properties.

The objectives of this study were to quantify the effect of RRA treatments with preaging temperature ≤140 °C and low retrogression temperature ≤200 °C on the strength and SCC resistance of alloy 7075, by applying a modified electrochemical potentiodynamic testing using three-point-loaded tensile specimens. The effects of heat treatment cycles as well as the applied stress were studied.

2. Experimental techniques

The material used in this investigation was Aluminum alloy (7075-T_0), delivered in the form of a 0.5 mm thick plate of the chemical analysis illustrated in Table 1.

* Corresponding author. Tel.: +2 02 0106690945.
E-mail address: randa38@hotmail.com (R. Abdel-Karim).

0921-5093/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.msea.2007.08.025

Table 1
Chemical analysis of Al-alloy 7075 (wt.%)

Zn	Mg	Cu	Mn	Si	Fe	Cr	Ti	Total other	Al
5.7	2.4	1.6	0.3	0.4	0.5	0.2	0.2	0.15	Rem

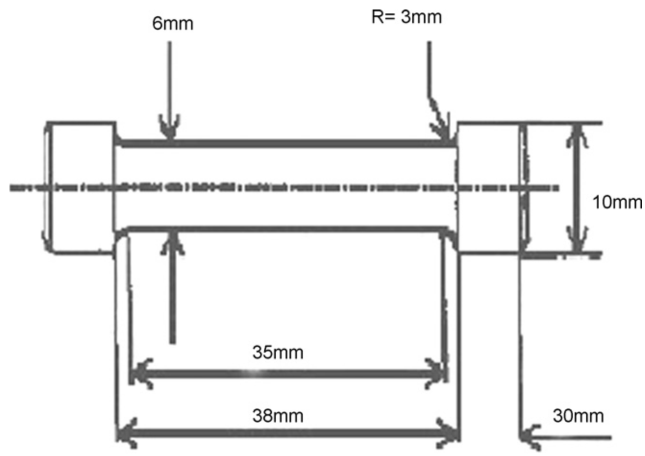

Fig. 1. Tensile specimen.

All specimens were machined according to requirements of ASTM B557 [5], for both tensile and corrosion testing (Fig. 1). Tensile specimens taken from as received condition, were solution treated by heating to 470 °C for 30 min; water quenching, then were artificially preaged at 100, 120 °C as well as 140 °C for 24 h, and retrogressed at different temperatures namely; 160, 180 and 200 °C. All specimens were finally reaged at 120 °C for 24 h. The heat treatment duration was chosen according to previous data [6] provided: retrogression at 160 °C for 250 min, 180 °C for 34 min and 200 °C for 8 min, which gave the best values of mechanical properties. The Brinell Hardness (HB5) was measured by using Wilson hardness testing machine, having a hardened spherical ball of diameter 1/16 mm. A load of 15 was used as per requirements for non-ferrous metal. The reported results are an average of six readings.

The tensile specimens for corrosion testing were three-point-loaded using a special teflon frame (Fig. 2). A motor driven rotating wheel (Fig. 3) was forcing a fiber pin leading to a specimen's displacement $\Delta L = 4$ mm. The stress applied was equivalent to $\sigma = 178$ MPa, which was calculated according to

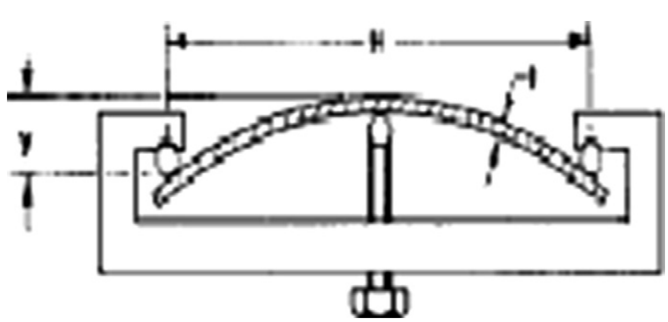

Fig. 2. Three-point-loaded specimen for SCC testing.

Fig. 3. Modified electrochemical cell showing the rotating wheel forcing the fiber pen.

the following equation:

$$\sigma_{\text{uts}} = \frac{6EtY}{h^2} \quad (1)$$

where E is the modulus of elasticity (66 GPa), t thickness of specimen (0.5 mm) Y displacement (4 mm) and h is the distance between fixed point (35 mm).

The corrosion cell was composed of test specimen, auxiliary graphite electrode and a saturated calomel reference electrode. The loading frame and test specimen were immersed in 3.5% NaCl solution for 7 days before applying electrochemical testing. All the measurements took place using a scan range from −200 to1000 mV with a scan rate 0.5 mV/s, using a power supply Meinsberg MS6 galvanostat/potentiostat, under stress and non-stress conditions. Evaluation of corrosion rate in mm/year was obtained using Tafel Extrapolation technique.

3. Results

3.1. Microstructure characterization

The effect of preaging and retrogression cycles on precipitation morphology of aluminum alloy 7075 is illustrated in Fig. 4a–l using SEM. Generally, the structure of this alloy consists of a mixture of α phase (S.S of Zn in Al) and intermetallic second phase.These areas appear by using HNO_3 etchant solution as white and dark area, respectively. At $T_6 = 100$ °C, Fig. 4a shows constituent particles aligned in the direction of working, with large areas of α phase. Theses constituents primarily evolve from the presence of Fe, Mn and Si particles. They are irregularly shaped and can be formed during alloy solidification whilst not being appreciably dissolved during subsequent thermomechanical processing. Rolling and extrusion tends to break up and align constituent particles into bands within the alloy. Often constituents are found in colonies made up of several intermetallic crystals. Typical examples include Al_3Fe and Al_7Cu_2Fe [7]. Such particles do not represent a significant aspect in the development of mechanical properties in high strength Al alloys.