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Corrosion behaviour of Al-Li-Cu-Mg-Zr alloy in 3.5% NaCl solution

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The effect of heat treatment on the general corrosion behaviour of Al-Li-Cu- Mg-Zr alloy in 3.5% NaCl solution was investigated by weight loss data, A.C. impedance and small amplitude cyclic voltammetry studies. X-ray diffraction studies were made to identify the phases in this alloy. The underaged temper was more resistant to general corrosion than the overaged temper. The increase in corrosion rates on the overaged temper is due to microstructural changes resulting from ageing.

Key words: Al-Li alloy, corrosion, impedance, SACV

INTRODUCTION

The low density and high stiffness aluminium-lithium alloys (Lighter Light Alloys) offer a potential weight savings of around 10% over the conventional aluminium alloys. Therefore, Al-Li alloys are of considerable commercial interest to aerospace industry. Extensive efforts towards the commercialisation of Al-Li alloys have been made in the eighties and only limited data is available on the corrosion behaviour of Al-Li alloys. Overageing of Al-Li alloys increased the susceptibility to corrosion [1]. 8090 Al-Li alloy exhibited greatest resistance to all forms of attack in the underaged condition [2]. The corrosion rate of 2090 Al-Li alloy is higher than 7075 alloy [3]. The present investigation was undertaken on indigenously developed Al-Li-Cu-Mg-Zr alloy to determine the effect of heat treatment on the general corrosion behaviour in 3.5% NaCl solution.

EXPERIMENTAL

The material used in this study was an alloy of composition Al-2.7, Li-3.1, Cu- 0.78, Mg-0.22, Zr (all values in weight %). The experimental procedures for heat treatment, specimen preparation and test solution are given in the earlier paper [4]. Corrosion studies were carried out on underaged and overaged tempers. The immersion corrosion tests were performed for 3 days and the corroded samples were cleaned in concentrated nitric acid as prescribed by ASTM G1-81.

A.C. impedance measurements were carried out at the corrosion potential in the frequency range of 5 mHz to 10 kHz using the Solartron Frequency Response Analyser, Model 1174 coupled with a potentiostat. Small amplitude cyclic voltammetry (SACV) studies were performed by cycling the potential to 20 mV on either side of the corrosion potential using Wenking LB 75 potentiostat in conjunction with Wenking VSG 72 voltage scan generator and a Rikadenki X-Y recorder. X-ray diffraction studies were made on underaged and overaged tempers to identify the phases.

RESULTS AND DISCUSSION

The weight loss data for underaged temper (0.42 mm/y) and overaged temper (0.53 mm/y) indicate that overaged temper shows an increase in weight loss as compared with underaged temper. Figure 1 shows the impedance diagrams at the corrosion potential for underaged and overaged tempers. The charge transfer resistance (R_t) values for underaged and overaged tempers are 1930 $\Omega \cdot cm^2$ and 700 $\Omega \cdot cm^2$ respectively. R_t decreases with ageing time, indicating increase in corrosion rates with ageing.

The results SACV studies are shown in Figs. 2 and 3. The polarisation resistances estimated from the potential-current curves are 3200 $\Omega \cdot cm^2$ for underaged and 952 $\Omega \cdot cm^2$ for overaged condition. The polarisation resistance is inversely proportional to the corrosion rate. The corrosion rate for overaged is thus higher as compared with

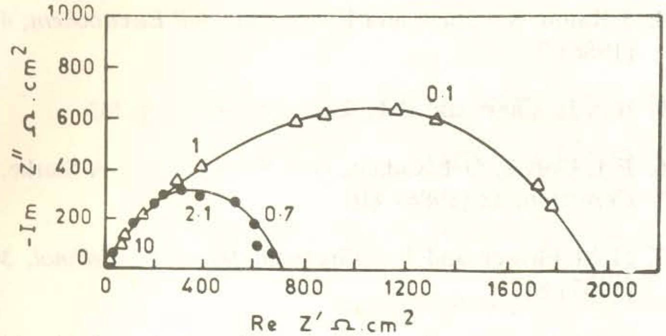

Fig. 1: Impedance diagrams at the corrosion potential in aerated 3.5% NaCl at 303K. Underaged alloy (·) and overaged alloy (△). (frequency marks in Hz)

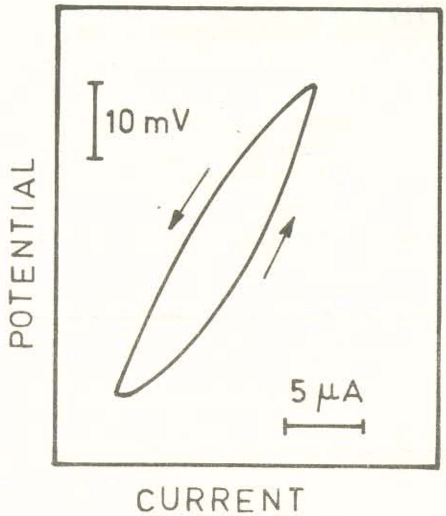

Fig. 2: Potential-current curve in the vicinity of the corrosion potential for the underaged alloy in aerated 3.5% NaCl at 303K. Scan rate 0.5 mV/sec

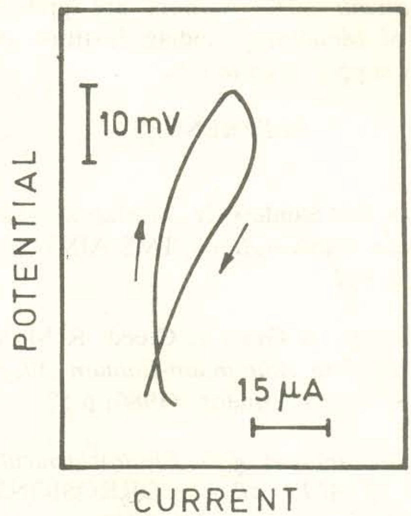

Fig. 3: Potential-current curve in the vicinity of the corrosion potential for the overaged alloy in aerated 3.5% NaCl at 303K. Scan rate 0.5 mV/sec

underaged condition. The reverse cycling was observed for overaged (Fig. 3) which reveals that the pitting tendency is more on overaged condition. This result correlates well with the result of pitting corrosion studies on this alloy [4].

The results of weight loss data, impedance measurements and SACV studies for underaged and overaged conditions indicate that corrosion rates increase with ageing time. X-ray diffraction measurements showed that δ' (Al_3Li) and Al_3Zr phases were present on underaged condition, while δ', weak δ (AlLi), weak T_1 (Al_2CuLi) and Al_3Zr phases were detected for overaged condition. δ and T_1 phases nucleate heterogeneously. The presence of δ in the overaged condition is significant since this phase incorporates more lithium than δ', and is anodic with respect to the matrix [1]. So, the increase in corrosion rate on overaged condition of this alloy is due to the presence of δ anodic phase. Corrosion rates increase with ageing in Al-Li alloys [1,5,6]. The increase in corrosion rates with overageing on Al-Li, Al-Li-Mn and Al-Li-Zr alloys is due to the formation of δ phase [1].

The gradual transformation of the θ' precipitates to T_1 precipitates occurs on overageing [7, 8]. This transformation results in the development of strain at the grain boundaries of the overaged temper. T_1, the heterogeneous phase is less corrosion resistant than copper-rich θ' phase and therefore, the presence of T_1 on overaged condition of this alloy is also responsible for the increase in corrosion rate. Another change occurring with ageing in Al-Li alloys is the coarsening of δ' precipitates [9]. The coarsening of δ' precipitates follows Ostwald ripening kinetics. Recent research work [5] showed that the increase in corrosion rates with ageing on Al-Mg-Li alloy is attributed to the increasing size distribution of δ' precipitates. The increase in corrosion rate with the ageing of the alloy investigated in this study may also be due to the coarsening of δ' precipitates.

CONCLUSION

(1) Weight loss data show an increase in corrosion rate on overageing. (2) The charge transfer resistances estimated from the impedance measurements decreased on overageing, indicating increased corrosion rates on the overaged condition. (3) The polarisation resistance calculated from the small amplitude cyclic voltammetry study showed that the corrosion rate of the overaged alloy was higher than the underaged alloy. (4) The increase in corrosion rates on overaged condition is due to the presence of δ (AlLi) and T_1 phases, and the coarsening of the δ' precipitates during ageing.

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