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Correlation of intergranular corrosion behaviour with microstructure in Al-Cu-Li alloy

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ABSTRACT

The IGC behaviour, OCP and microstructure of AA1460 (Al-3.12Cu-2.14Li-0.12Sc-0.12Zr, in wt.%), following HT1 (heat treatment without predeformation) and HT2 (heat treatment with predeformation) tempers were investigated. Both δ′ (Al_3Li) and T_1 (Al_2CuLi) phases were precipitated within grains during heat treatment, while T_1 phase also precipitated in the vicinity of grain boundaries. The evolution of inter- and intra-granular microstructures in AA1460 influenced the local and global electrochemical characteristics, which in turn influenced the temper dependent corrosion morphologies of AA1460. A correlation between OCP and corrosion mode was proposed, which may be used to compare the IGC sensitivity of AA1460 with different tempers.

1. Introduction

Lithium (Li) containing aluminium (Al) alloys alloys possess low density, high specific strength, and low fatigue-crack growth rates. The combination of these properties make them suitable for aerospace applications [1,2]. Modern Li containing Al-alloys nominally contain copper (Cu), and such Al-Cu-Li alloys are age-hardenable. Therefore, it is important to understand and manipulate the heat treatment of Al-Cu-Li alloys to optimise both the mechanical properties and corrosion performance.

Studying the effect of ageing on the corrosion of Al-alloys has attracted significant research attention [3–9]. Several heat treatment processes such as the overaged tempers T73, T74, T76, and retrogression and re-ageing (RRA) have been developed to improve the corrosion resistance of some Al alloys [10–13]. Yang et al. [14] compared the corrosion behaviour of Al–Zn–Mg–Cu alloys after various ageing treatments and reported an improvement in corrosion resistance by ageing treatments resulting in discontinuously distributed precipitates at grain boundaries. Wang et al. [15] observed a narrow precipitate free zone (PFZ), coarsened and discontinuous grain boundary precipitates (GBPs), and decreased SCC susceptibility in Al-Zn-Mg alloys after two-stage ageing. Correlations between heat treatment and sensitization in 5xxx series Al-alloy were studied by Zhang et al. [16–18], who proposed an empirical model for the evolution of grain boundary precipitates to rationalize sensitization dependent intergranular corrosion (IGC). Intergranular corrosion behaviour of Al alloys has generally been reported to be dictated by the composition, distribution, nearest neighbor distance, and size of GBPs [19–24].

Ageing treatments have a significant influence on the corrosion behaviour of Al-Cu-Li alloys [25–28]. For an Al-Cu-Li alloy (AA2096) with T8-ageing at 160 °C, Connolly et al. [29,30] reported existence of two stress corrosion cracking (SCC) susceptibility “windows” in the severely under-aged and over-aged conditions. However, the peak-aged condition did not display SCC sensitivity. Li et al. [31] and Liu et al. [32] also revealed that the corrosion mode of Al-3.7Cu-1.2Li and Al-2.7Cu-1.7Li alloys in IGC solution evolved with ageing time in the following order: General IGC, localised IGC, pitting corrosion with IGC, and that this evolution process was dependent on the ageing temperature. It was reported that with T8 ageing treatment at 155°C, the AA2050 (an Al-Cu-Li alloy) became progressively susceptible to intragranular corrosion in 0.7 M NaCl solution [33] (as opposed to IGC). This was posited to be a result of the formation and growth of both intergranular and intragranular T_1 precipitates, which decreased the copper content in solid solution – apparently balancing the electrochemical behaviour of the grains and grain boundaries, Nevertheless, it was reported that peak-aged AA2050 was immune to IGC, whilst the over-aged condition had no significant influence on the IGC sensitivity [34]. Ott et al. attributed the IGC of AA2050 in the overaged condition

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Table 1
Aging treatments applied to aluminium alloy AA1460 sheet.

Aging treatments	Aging temperature	Aging time (h)
HT1	145°C	0.5, 5,10, 18, 24, 34, 44, 68, 105
	160°C	0.5, 5, 10, 14, 22, 29, 33, 39, 51, 96
	175°C	0.5, 5, 13, 17, 25, 29, 37, 42, 96, 112
HT2	130°C (1st step) followed by	4, 10, 20 (at 130°C)
	160°C (2nd step)	4, 8, 2, 20, 45, 76 (at 160°C after at 130°C for 20 h)

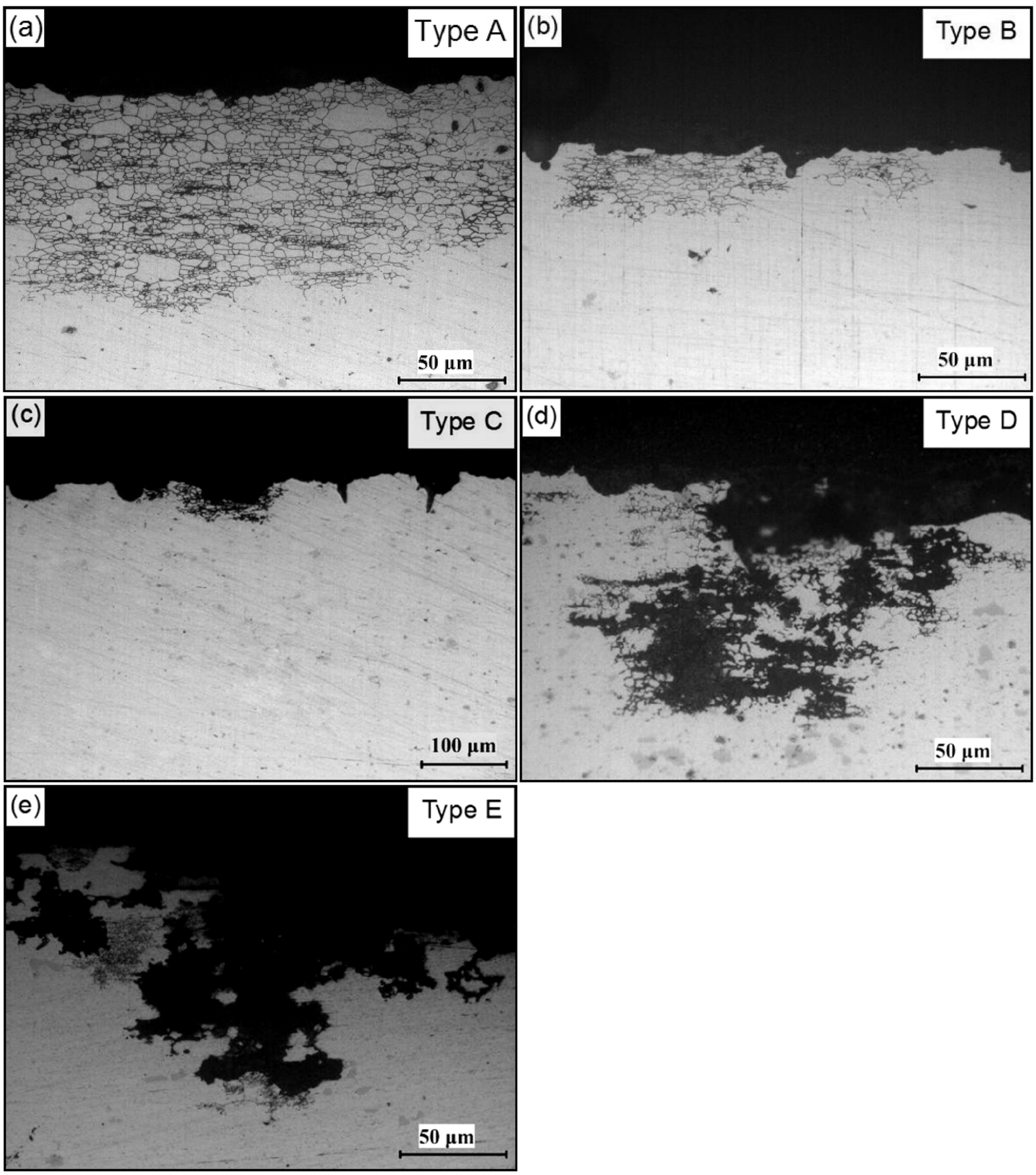

Fig. 1. Representative cross-sectional corrosion morphologies of aluminium alloy 1460 immersed for 6 h in.1 M NaCl + 0.1 M h_2O_2 solution representing: (a) general IGC - Type A (HT1-aged at 145 °C for 10 h), (b) local IGC - Type B (HT2-aged at 160 °C for 8 h following at 130°C for 20 h) and three different types of pitting corrosion corresponding to (c) Type C (HT1-aged at 175 °C for 0.5 h), (d) Type D (HT1-aged at 175 °C for 112 h) and (e) Type E (HT2-aged at 160°C for 76 h following at 130°C for 20 h).