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Effects of overaging on microstructure and tensile properties of the 2055 Al-Cu-Li-Ag alloy

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ABSTRACT

The lightweight, unconventional 2055 Al-Cu-Li-Ag alloy exhibits an excellent specific strength in the T83 state, but no literature reports the effects of overaging on this alloy. In the present work, the suitability of the alloy for lightweight components operating at high temperature is evaluated. Thermal exposure in the range 215–305 °C was investigated, highlighting its consequences on both microstructure and mechanical properties. In the most severe overaging state (24 h at 305 °C), the typical T_1 precipitates (Al_2CuLi) are dissolved, leading to the formation and coarsening of ϑ' and Ω phases. In all overaging conditions, the alloy performance was superior or at least comparable to that of another third generation Al-Li alloy, AA2099, which is characterised by a slightly lower density and encouraging mechanical properties for high temperature applications. Compared to AA2099, the AA2055 alloy provides a higher specific strength (the basic requirement for mass savings) both in the T83 and in the most severe overaging state (24 h at 305 °C). This work highlights that AA2055 is a promising candidate for lightweight components operating up to 305 °C, and it lays the basis for high temperature tests of the alloy.

1. Introduction

Recently patented by Alcoa in 2012 [1], the AA2055 belongs to the 2xxx series of Al alloys, containing Cu as the major alloying element. It is an unconventional 2xxx alloy, since it contains a considerable amount of Li, Zn, Mg and Ag, which definitely makes it one of the most promising candidates of the third generation of Al-Li alloys. As widely reported in [2–4], the third generation of Al-Li alloys combines excellent mechanical properties, high stiffness, good corrosion resistance and fracture toughness with very low density, which successfully translates into a significantly high specific strength if compared to conventional 2xxx or 7xxx Al alloys. Li addition makes a key contribution in both density reduction (each 1 wt% of Li addition accounts for $-0.079\ g/cm^3$ density reduction, according to Peel et al. [5]) and elastic modulus increase (1 wt% Li addition is expected to provide 6% increase in Young's elastic modulus [4]).

Generally speaking, the major strengthening effect in Al-Cu-Li alloys is provided by the T_1 (Al2CuLi) phases, which precipitate along the {111} plane of the Al matrix [6–9] and tend to nucleate at grain or subgrain boundaries. Aiming to discourage the incidence of precipitate free zones at the grain interior, cold stretching prior to aging is regularly adopted during the heat treatment of Al-Cu-Li alloys, since a dense network of dislocations provides for heterogeneous nucleation sites for T_1 [10–15]. Further, the more severe the pre-stretching (up to 15% according to Rodgers et al. [13]), the more the T_1 precipitation kinetics are accelerated, which leads to a higher volume fraction of precipitates, a finer T_1 size, and a lower coarsening rate during overaging.

Among the other strengthening precipitates, δ' (Al_3Li), ϑ' (Al_2Cu) and S′ (Al_2CuMg) are commonly observed in the third generation of Al-Cu-Li alloys [4,16,17]. δ' precipitates were one of the main strengthening phases of the second generation of Al-Li alloys [4], generally containing more than 2 wt% Li and therefore exhibiting an attractive low density. Several drawbacks were however attributed to the high content of Li, such as poor thermal stability, leading to low fracture toughness after thermal exposure, even at temperatures in the range 70–85 °C [4,18].

Due to the presence of Li in both phases, δ' and T_1 are in competition and evidence confirms that higher Cu/Li ratio enhances T_1 precipitation [19,20]. The trend in the third generation of Al-Cu-Li alloys is to maximize the volume fraction of T_1 at the expense of δ', due to the fact that the former is less sensitive to degradation after thermal exposure [4,12,19,21,22].

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Table 1
Chemical composition limits [wt%] of AA2055, provided by Alcoa (the alloy supplier).

Cu	Li	Zn	Ag	Mn	Mg	Ti	Zr	Fe	Others, each	Others, tot	Al
3.2–4.2	1.0–1.3	0.3–0.7	0.2–0.7	0.1–0.5	0.2–0.6	0.1	0.05–0.15	0.1	0.05	0.15	Bal.

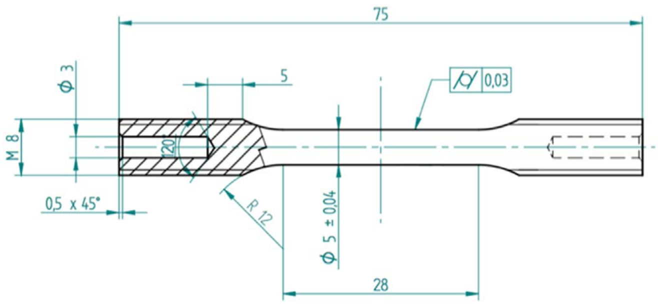

Fig. 1. Geometry and dimensions [mm] of tensile specimens.

Since Al-Cu-Li alloys were specifically developed to satisfy the requirements of structural aerospace components, both lightweight and thermal stability at temperatures in the range 70–150 °C were considered fundamental (due to aerodynamic heating). As a result, the effects of thermal exposure on Al-Cu-Li alloys have been commonly investigated below 200 °C, aiming to study the decay of properties during the lifecycle of aerospace components. In particular, Davydov et al. [18] investigated the effects of exposure at 85 °C and 95 °C up to 1000 h and 300 h respectively, on both Al-Li-Mg-Sc-Zr and Al-Li-Cu-Sc-Zr alloys; similarly, Deschamps et al. [22] analysed the effects of long term aging at 85 °C on Al-Cu-Li-Mg alloys, highlighting the superior thermal stability of T_1 precipitates compared to δ'. Long thermal exposure (over 7000 h) at temperature as high as 107 °C and 163 °C was investigated by Mou et al. [23], while Kumar et al. [12] evaluated the effects of soaking at 160 °C; both the studies revealed the presence of S′ and T_1 in Al-Cu-Li-Ag alloys, yet substantially coarsened after prolonged overaging. Finally, Ortiz et al. [24] examined the effect of thermal exposure up to 177 °C, highlighting a monotonous decrease in hardness and yield strength.

However, fuel efficiency and low weight are critical for aerospace as well as for automotive components, which makes it worth investigating the possibility to expand the employment of Al-Cu-Li alloys in the latter field. Even if high specific strength and stiffness are considerably attractive, automotive components are much more demanding than aerospace components in terms of high temperature resistance, which needs to be investigated up to 300 °C. Jabra et al. [25] reported the consequences of overaging of Al-Cu-Li alloys at temperatures as high as 290 °C, revealing a consistent decay of tensile properties. However, to the authors' best knowledge, there is a lack of research focused on the

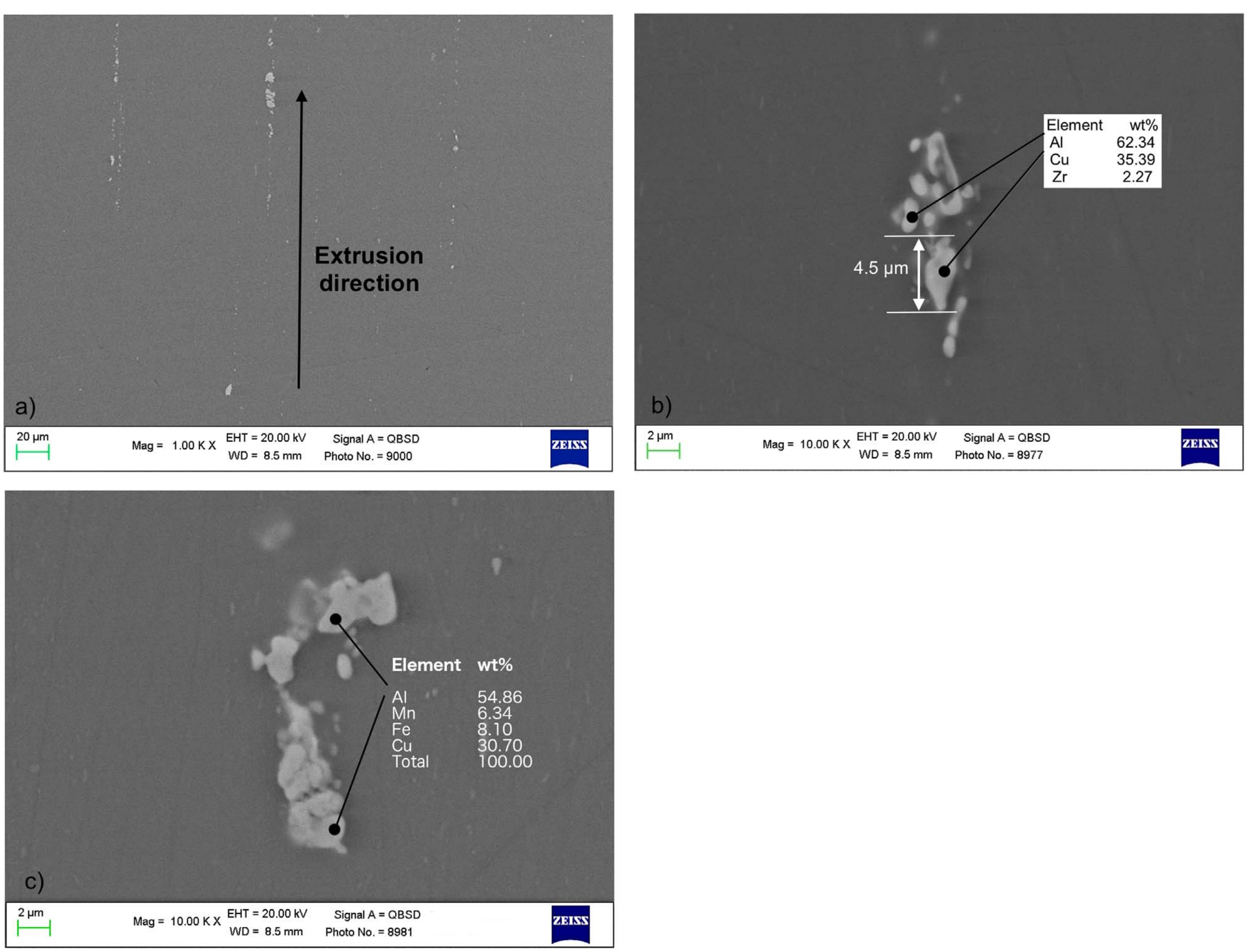

Fig. 2. SEM investigations of T83 metallographic sample: (a) low magnification, (b), (c) higher magnification highlighting the secondary phases.

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