FRACTURE BEHAVIOUR OF AL-LI ALLOYS COMPARED TO CONVENTIONAL HIGH STRENGTH AL ALLOYS

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INTRODUCTION

Worldwide the aircraft industry is strongly interested in the development of the new Aluminium-Lithium alloys (1). These alloys not only reveal a substantial decrease in density along with an increase in stiffness but also an excellent fatigue crack propagation behaviour. Recently the first commercial applications of these new alloys have been announced, and it is anticipated that they will increasingly be used for the construction of the next generation commercial airplanes.

When compared to conventional Al plate material, Al-Li alloys often show lower ductility and fracture toughness values especially in the short transverse direction. The failure mode often is a low energy grain boundary fracture. The reasons for this fracture behaviour repeatedly have been discussed, but the main causes have not yet been clearly identified.

In the present study the fracture behaviour of the Al-Li alloy 8090 is compared to that of the conventional high strength Al alloy 7475.

EXPERIMENTAL PROCEDURE

The Al-Li alloy 8090 (Al-2.42wt.%Li-1.24Cu-0.60Mg-0.12Zr) and the control alloy 7475 were received in form of 25 mm and 80 mm thick plate, respectively. Both alloys were solution heat treated in a salt bath for 15 min/525 °C (8090) and 1 h/465 °C (7475) and artificially aged at 190 °C (8090) and 160 °C (7475). Tensile tests on cylindrical specimens were performed in the long (T) and short transverse (S) directions. Fracture toughness was determined by chevron-notched short bar specimens in TL and SL orientations. Fracture surfaces were investigated by SEM.

It should be mentioned that the 8090 plate stems from early laboratory scale material. Therefore, its mechanical properties can substantially differ from today's production material.

RESULTS AND DISCUSSION

The aging behaviour (yield stress and elongation) for the two alloys is given in Fig. 1. During the time period investigated, both alloys overage (Fig. 1a). Overall yield strength levels are lower for 8090; this is, however, consistent with the 8090 design philosophy, since this alloy is developed for the replacement of conventional medium strength and/or damage tolerant Al alloys. Whereas the yield strength of either alloy did not show a significant difference between the two testing directions (Fig. 1a), the elongation values for both alloys were always lower in short trans-

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verse direction (Fig. 1b). It is obvious that for short aging times both alloys show similar elongation values. With increasing aging, however, the short transverse ductility of 8090 is much lower compared to 7475.

Fracture toughness versus aging time is plotted in Figs. 2a and b for 8090 and 7475, respectively, in TL and SL orientations. For both alloys, the short transverse tests always reveal lower toughness. For 7475 the curves show a minimum (Fig. 2b) with the lowest values measured for the slightly overaged condition. This behaviour is typical for conventional high strengh Al alloys (2). For short aging times, 8090 generally reveals higher toughness than 7475. Extended aging leads to a drop in fracture toughness, however, with no increase beyond peak strength. This drop is particularly pronounced for the SL orientation (Fig. 2a).

The most obvious difference between the two alloys is the low short transverse ductility and toughness of 8090 after extended aging. Fractography on peak strength tensile specimens (S direction) revealed a macroscopically flat, intercrystalline fracture for 8090 parallel to the pancake-shaped grains (Fig. 3a), whereas for 7475 a transcrystalline ductile fracture was observed (Fig. 3b).

Various reasons for the low energy grain boundary fracture of Al-Li alloys have been discussed (3-7). These include the extensive coplanar slip due to the coherent and ordered nature of the age-hardening phase δ'; grain boundary particles along with a precipitate-free zone; segregation of impurity elements like Na, K or low melting compounds of those two elements at grain boundaries; or segregation of Li itself at grain boundaries.

The knowledge of the potential factors for low ductility and fracture toughness has been incorporated by the producers into the optimization of the Al-Li alloys. For example, there is a consensus among the producers that Na levels should be kept below 10 ppm. These and other measures led to the fact that today's Al-Li alloys reveal substantially improved short transverse properties.

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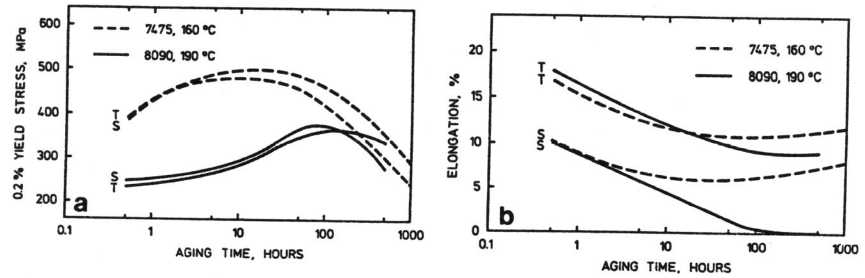

Fig. 1 Yield stress (a) and elongation (b) as a function of aging time in L and S direction for 8090 and 7475.

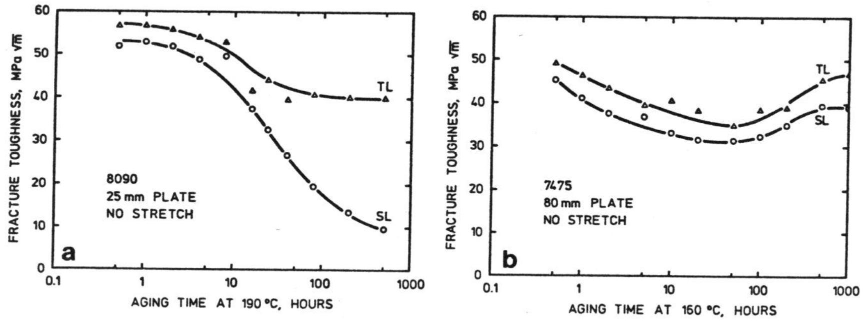

Fig. 2 Fracture toughness as a function of aging time in TL and SL orientation for 8090 (a) and 7475 (b).

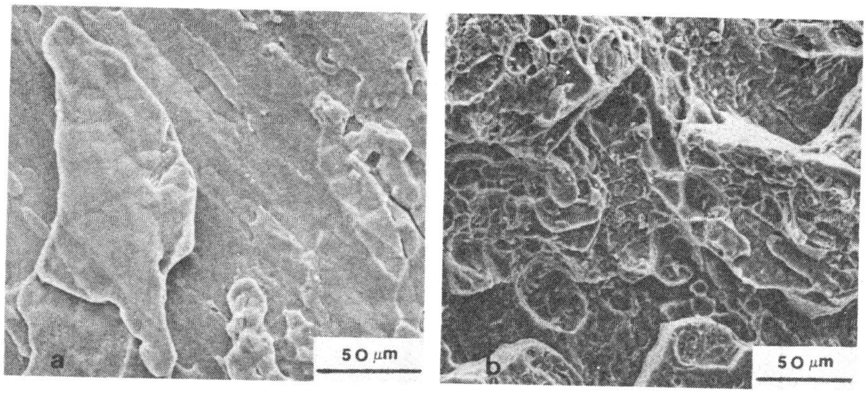

Fig. 3 SEM fractographs of peak aged 8090 (a) and 7475 (b) tensile specimens in S direction.