

# Effects of Composition & Microstructure on SCC in Aerospace Al-Zn-Mg-Cu Alloys

Steven Knight

(supervisors: B. Muddle & S. Lynch)

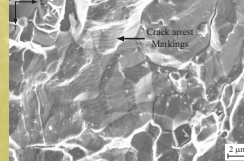
## Background



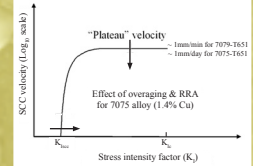
SCC service failure of 7079-T651 component from a F-111 aircraft



Optical micrograph showing a section through an intergranular crack in 7079-T651 (Keller's etched)



SEM of intergranular SCC fracture in 7079-T651 tested in 75% relative humidity air at 25°C



Effect of overaging and RRA on SCC kinetics. Doubts re. effects on low-Cu alloys (7079 & 7022)

Stress Corrosion Cracking (SCC) is a major problem in aging aircraft, especially for peak-aged 7075 & 7079 alloys: SCC occurs in moist-air & aqueous environments at stress intensity factors greater than a threshold value ( $K_{I,SCC}$ )

## Key Questions

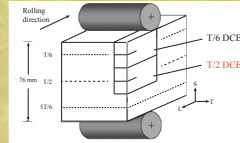
- Can remedial measures, such as overaging or retrogression and re-aging (RRA) heat-treatments, or environmental control, be taken to minimise SCC problems in low-Cu 7079 aircraft components?
- What microstructural or micro-chemical factors determine the SCC resistance of 7XXX aluminium alloys – i.e. what is the relative importance of grain-boundary precipitates (size, distribution & chemistry), PFZ width & composition, matrix precipitation (slip mode), and grain-boundary structure & misorientation (crystallographic texture)? *(A long-standing issue!)*

## Alloys studied

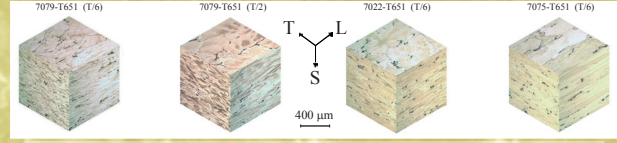
(wt%)	Zn	Mg	Cu	Cr	Mn	Zn/Mg
7079	4.3	3.2	0.6	0.16	0.19	1.3
7075	5.4	2.3	1.4	0.2	0.02	2.3
7022	4.8	3.1	0.9	0.15	0.26	1.5

Fe, Si & other impurities are similar in each alloy

Composition of T/6 & T/2 through-thickness positions are not significantly different (SCC kinetics affected by position for 7079, but not for 7075 & 7022)



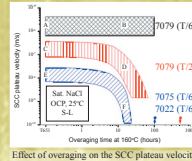
S-L Double Cantilever Beam (DCB) specimens in the T/2 and T/6 thickness positions through the thickness of plate



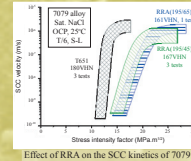
Optical micrographs showing pancake-type grain structure in each of the alloys studied (Keller's etched -10sec). Constituent particles were elongated in the rolling direction for each alloy. Dendrite-like etching patterns were most pronounced in 7079-T651 (T/2)

## Key Results

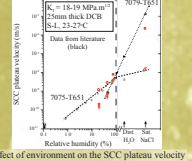
- Up to three orders of magnitude difference in plateau velocities for:
  - different alloys in the same heat-treatment condition
  - 7079-T651 alloy in different through-thickness positions of rolled plate
- Overaging markedly decreases SCC plateau velocities for 7022 & 7079 (T/2) (as well as for 7075) – but has no effect for 7079 (T/6)
- Overaging and RRA increase the threshold stress intensity factor for SCC ( $K_{I,SCC}$ )
- Relative SCC resistance of different alloys is very sensitive to environment



Effect of overaging on the SCC plateau velocity



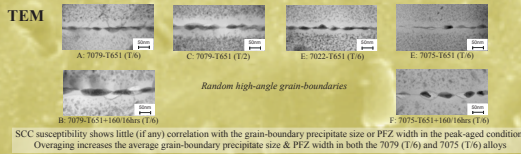
Effect of RRA on the SCC kinetics of 7079



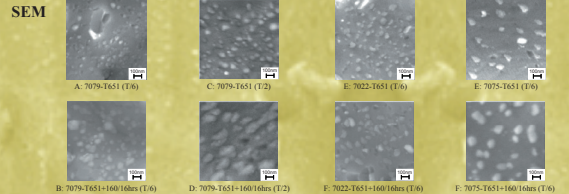
Effect of environment on the SCC plateau velocity

## Comparison of Alloys & Heat-treatments (denoted by letters in above figure), by Thin-foil TEM, SEM (of grain-boundary precipitates), X-ray Diffraction (texture), & AFM of slip mode

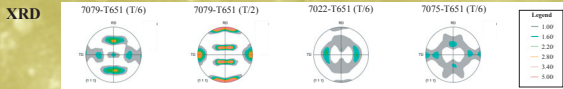
Brittle Intergranular Fracture Surfaces produced at -196°C



SCC susceptibility shows little (if any) correlation with the grain-boundary precipitate size or PFZ width in the peak-aged condition. Overaging increases the average grain-boundary precipitate size & PFZ width in both the 7079 (T/6) and 7075 (T/6) alloys

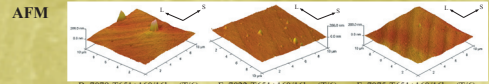


SCC susceptibility shows little (if any) correlation with the grain-boundary precipitate size in either the peak-aged or overaged conditions. Overaging increases the average grain-boundary precipitate size, spacing & area fraction in each of the alloys studied



X-ray diffraction texture analysis showing {111} pole figures for the alloys studied. Texture was strongest in the T/2 position of the 7079 alloy

Re-solution-treatment & aging to the peak-strength (T6) condition increased the SCC plateau velocity of 7079 in the T/2 position to that of the T/6 position, indicating texture is not rate controlling



Topographical AFM of deformed (~8%) overaged specimens showing that the slip mode is wavy & not significantly different between each of the alloys studied

## Conclusions

- Microstructural features, such as matrix & grain-boundary precipitates, PFZ width, grain-boundary misorientation, or slip mode do not appear to directly control SCC susceptibility
- Micro-composition, especially Cu content, of grain-boundary precipitates, or PFZ (or grain-boundary segregation) may be the determining factor(s) affecting SCC kinetics of 7XXX alloys via crack-tip electrochemical processes
- Remedial heat-treatments, including overaging & RRA, can be effective at reducing the SCC susceptibility, even in low-Cu alloys, such as 7079 & 7022, contrary to 'conventional wisdom'
- Environmental controls, such as reducing the moisture content in air, significantly increase the resistance to SCC, especially for the 7079 alloy.