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RMIT UNIVERSITY

Outcomes of research into small fatigue crack nucleation and growth in AA7085-T7452

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Outline

- Why study AA 7085-T7452?
- Why small fatigue crack nucleation and growth?
- AA 7085-T7452 small FCGRs
- Microstructure effects
- Equivalent Initial Discontinuity (EIDS) in AA 7085-T7452
- Causes of Type 1C anodized EIDS differences in AA 7XXX alloys
- Stress effect in AA 7085 Type 1C anodized EIDS
- Outcomes of research into AA7085 small fatigue crack nucleation and growth
- Summary
- References

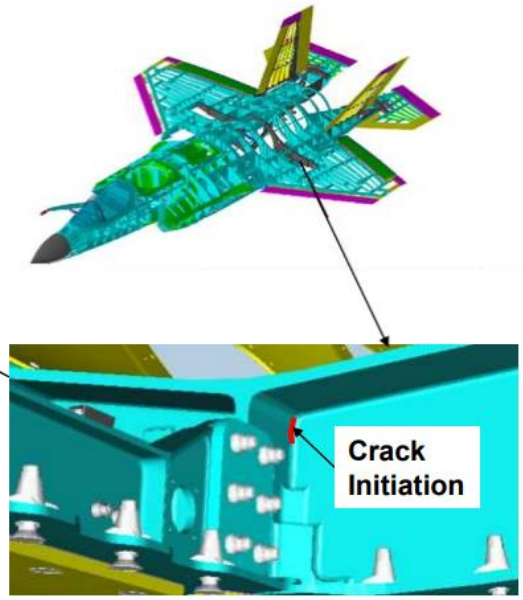
Why study AA7085-T7452?

- AA 7085 one of the more recent Al, Zn, Mg, Cu high strength alloys. Developed for thick section properties in aid of unitized airframe designs (A380, F-35) [1]
- Unexpected fatigue cracking in AA 7085 parts still occurs despite structural integrity advances [2]. F-35 durability test lessons learnt included the need for higher-fidelity stress analysis and accounting for the fatigue effects of etch/anodise treatments [3].

- **Bulkhead A, 7085-T7452 Forging**

Crack Location

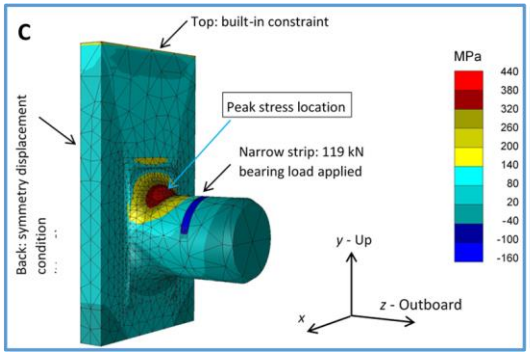
Final Crack Path

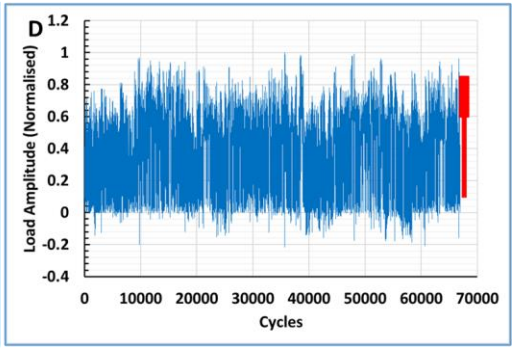


Crack Location

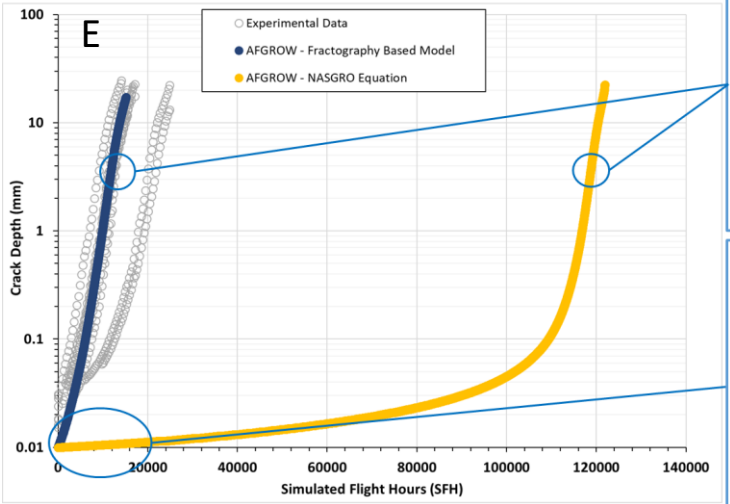
Why small fatigue crack nucleation and growth?

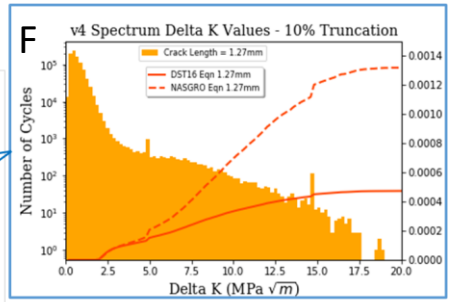
- Prediction of small fatigue crack nucleation and growth under spectrum loading important but poorly done without dedicated models/data sets [4], [5], [6]

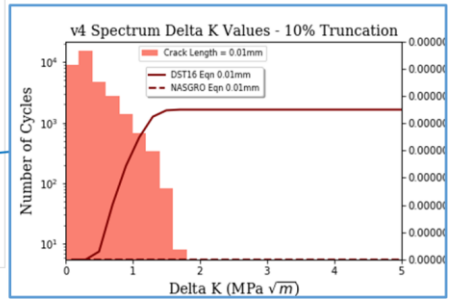




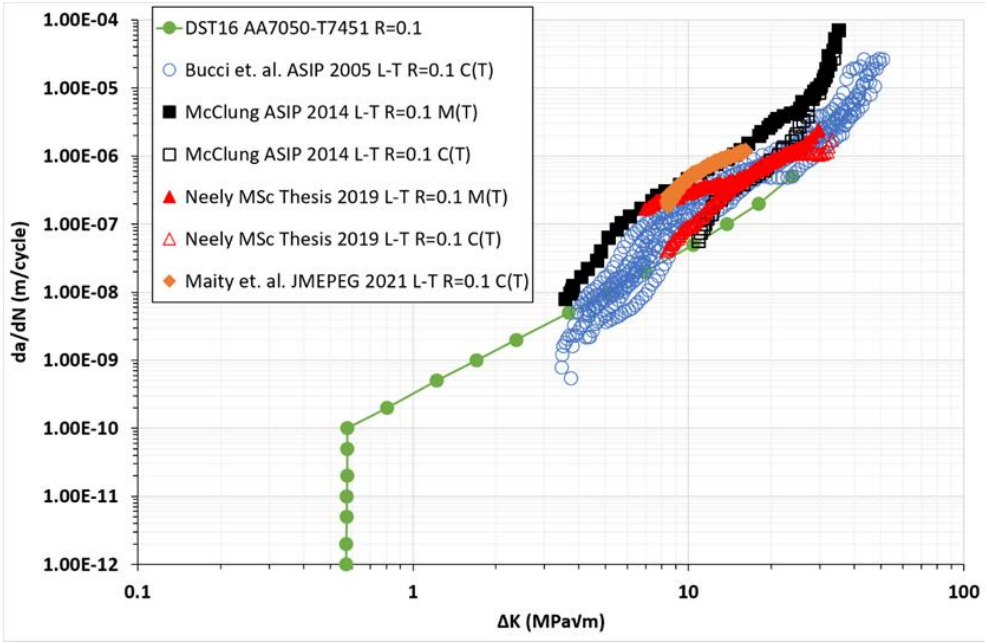
Small crack case study:
[A] A combat aircraft critical structural location,
[B] represented by a coupon,
[C] correlated stressing model,
[D] flight measured manoeuvre plus buffet spectrum,
[E] crack growth prediction vs experimental results using a small crack model vs NASGRO eqation
[F] evidence of the importance of small and near-threshold fatigue crack regime [6]



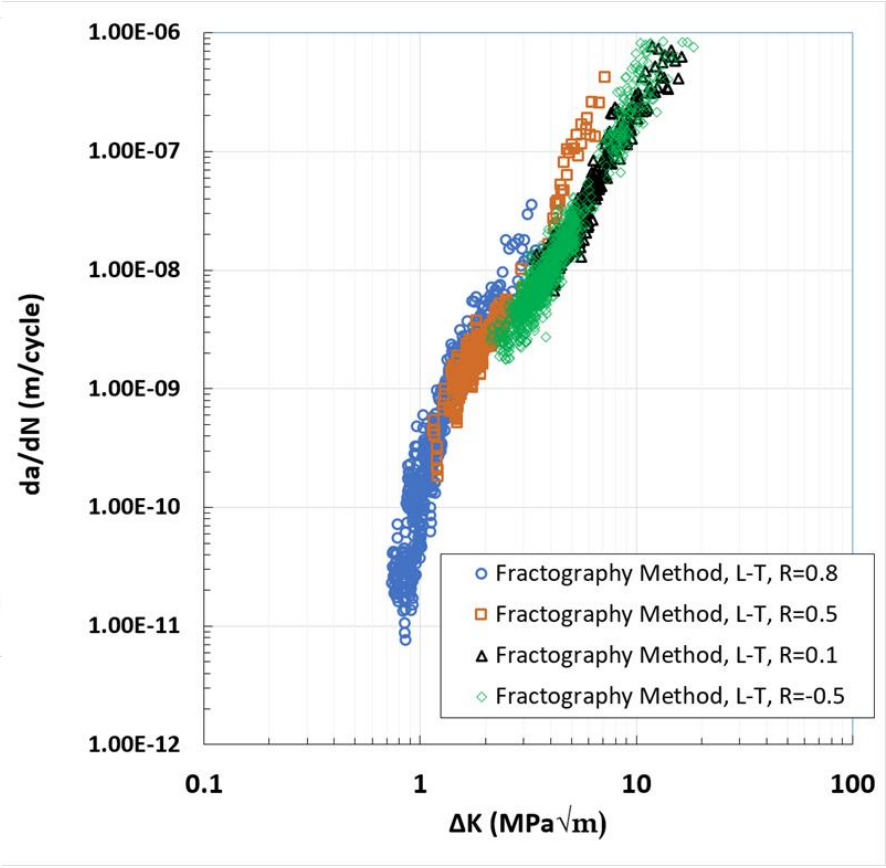




AA 7085-T7452 small FCGRs

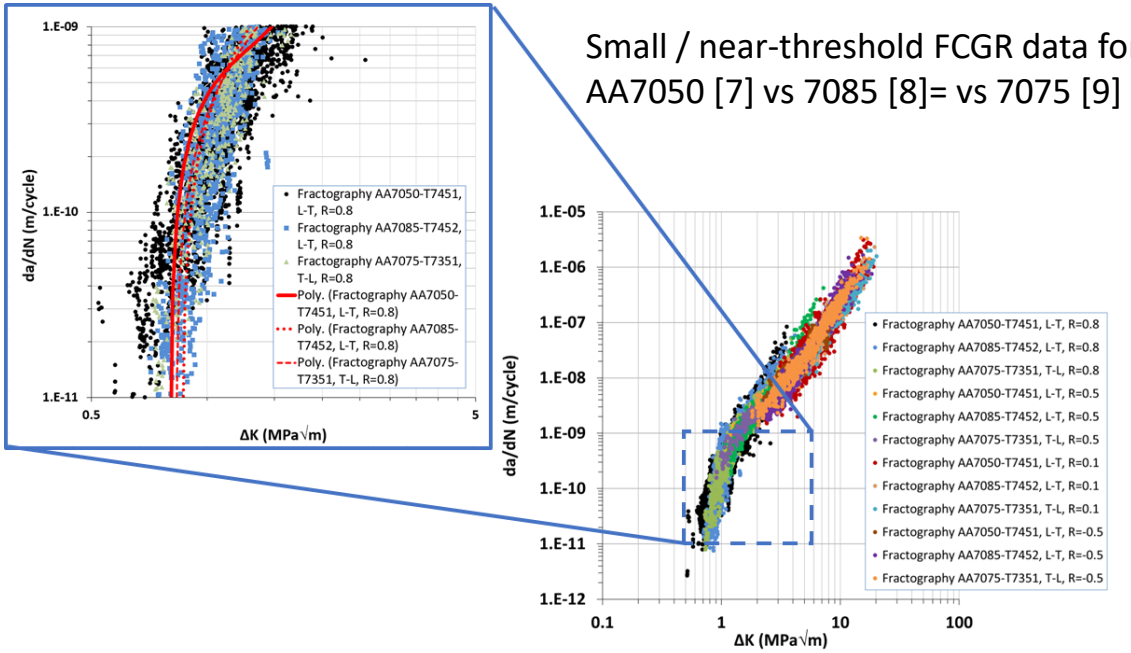


Open literature FCGR data for AA7085. Inadequate for characterising FCG in small and near-threshold region, DSTG characterisation of AA 7050 shown in green [7]

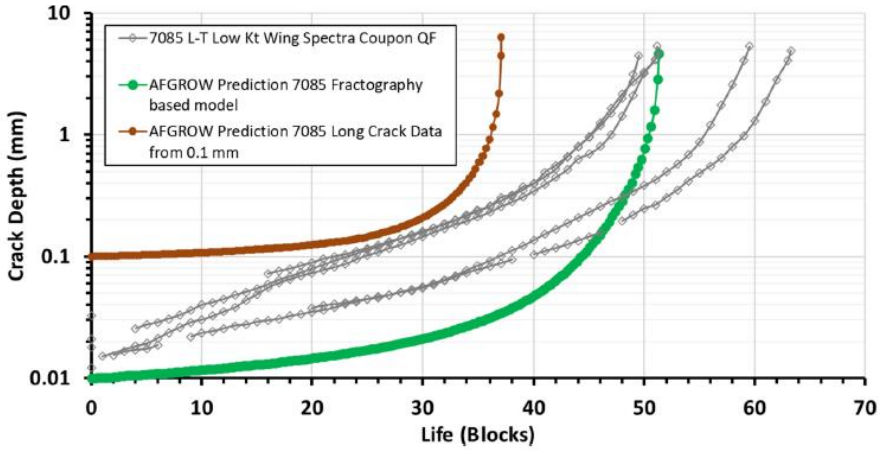


Small FCGR data developed for AA 7085-T7452 using the fractography method [8]

AA 7085-T7452 small FCGRs cont.



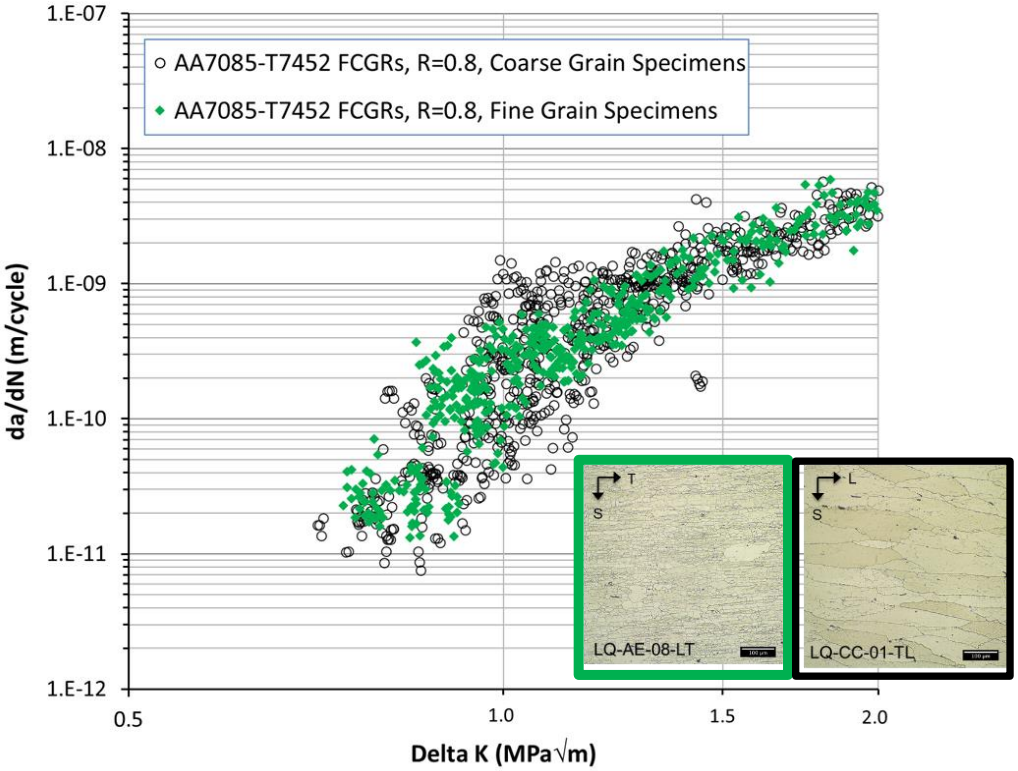
Small / near-threshold FCGR data for AA7050 [7] vs 7085 [8]= vs 7075 [9]



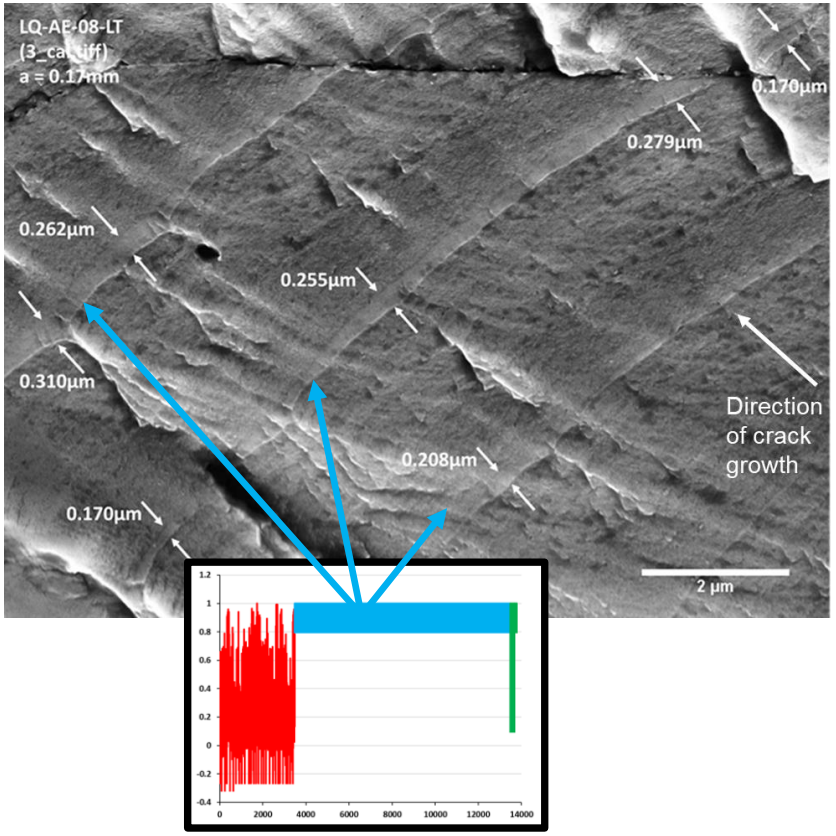
Predictions using new vs open literature 7085 data [8]

- **Finding:** Improved characterisation of small crack and near-threshold regime over any other published data.
- Faster FCGRs in AA 7050 than AA 7075 and AA 7085 in the small crack and near-threshold regime (ΔK = 0.5 MPa$\sqrt{m}$, $1x10^{-12}$ to 10^{-9} m/cycle).
- Data validity demonstrated via LEFM blind predictions of a complex manoeuvre plus buffet aircraft spectra.

Microstructure effects



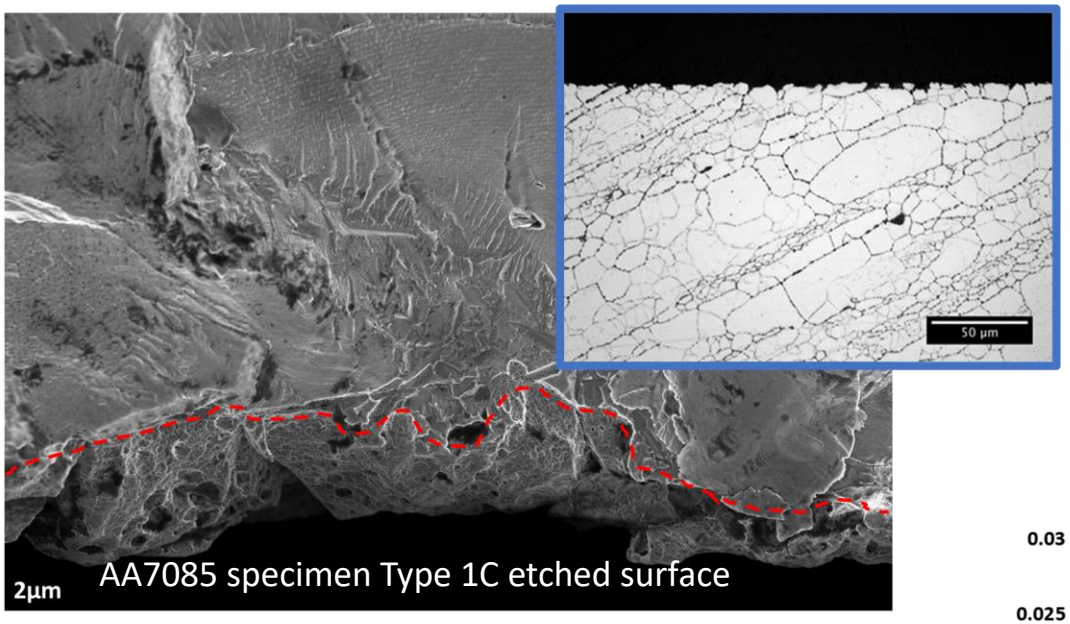
AA7085 FCGR data for crack depths below 0.2mm segregated by grain size [10]

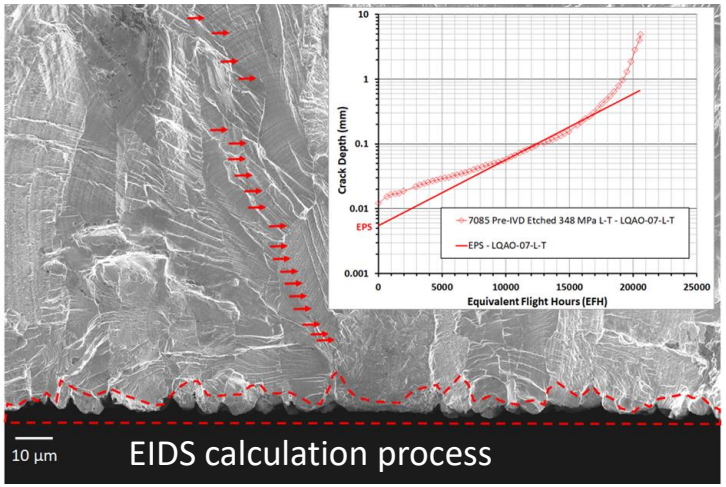


Fractography measured FCGRs at a crack depth of 0.17mm [10]

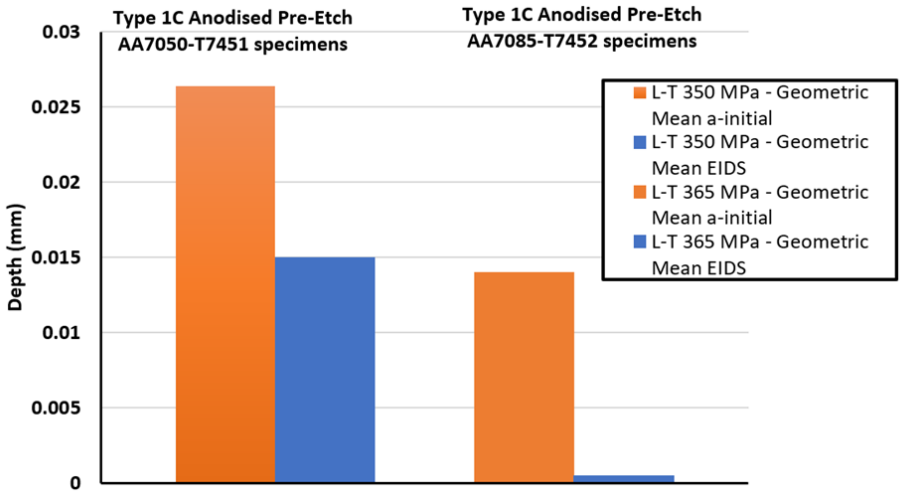
- **Finding:** AA7085 microstructure responsible for scatter in FCGR that continuum mechanics approaches, such as LEFM, would consider identical i.e. same depth & shape, but no effective difference in macro AA7085 small FCGR by grain size [10].

Equivalent initial discontinuity sizes (EIDS)



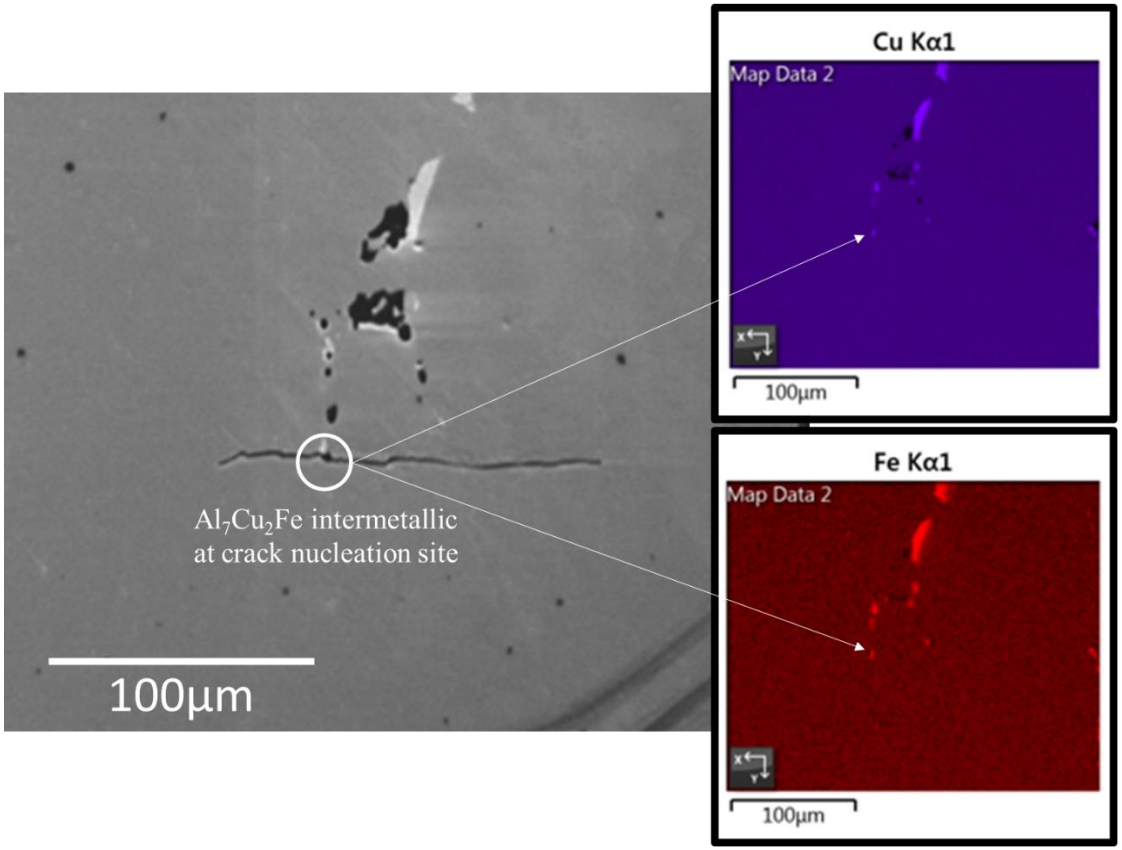


Finding: Using fractography techniques, EIDS for production etch pitting due to Type 1C anodising in AA 7085-T7452 was found to be less effective in nucleating fatigue cracks than AA7050-T7451 [10]-[12].



Geometric mean discontinuity and EIDS for Type 1C anodised AA7050/7085 [10]-[12]

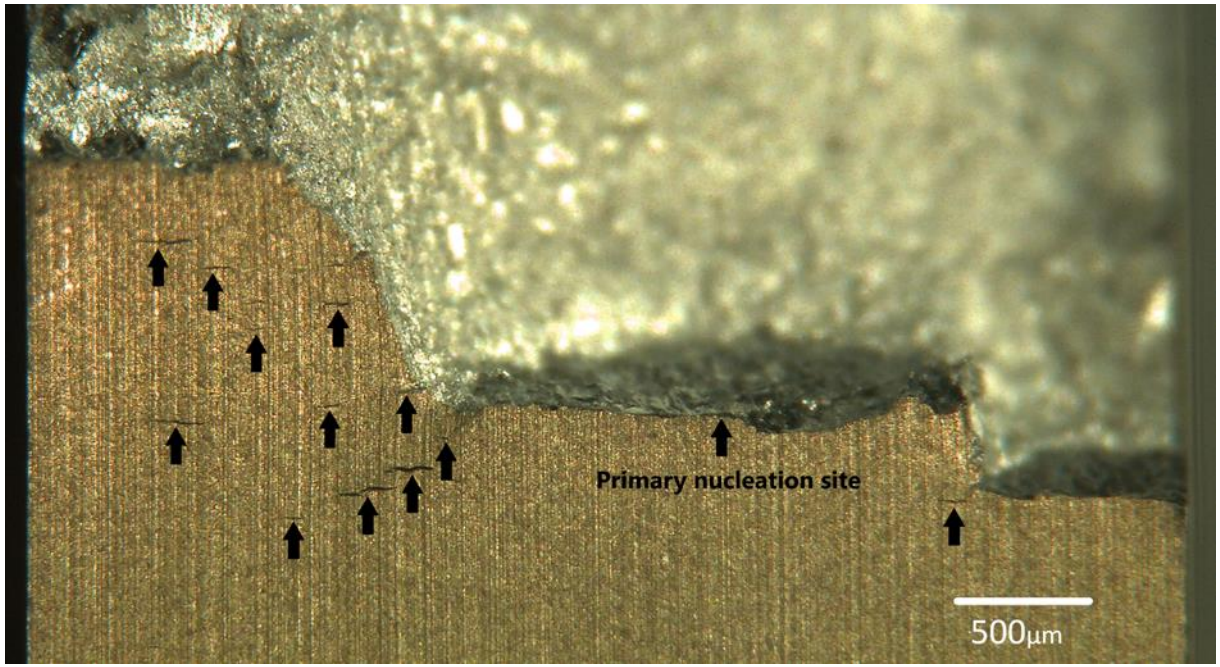
Causes of Type 1C EIDS differences in AA 7XXX



Scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDS) images of etched Al_7Cu_2Fe intermetallics at, and adjacent to, fatigue crack nucleation sites in a Type 1C anodised AA7050 specimen.

- **Finding:** The relative size (volume), number and concentration of surface breaking intermetallics, typically Al_7Cu_2Fe largely govern fatigue crack nucleation in these materials and surface finish.
- Due to reduced size, population, AA 7085-T7452 was less effective in nucleating fatigue cracks than AA7050-T7451.

Stress effect in AA 7085 Type 1C anodized EIDS



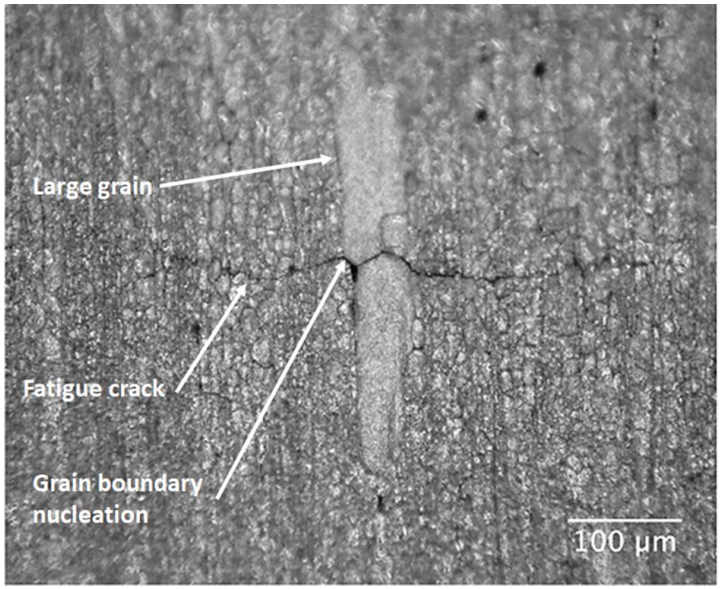
A 'high-Kt' 7085 type 1C anodises specimen with secondary crack nucleation sites in close proximity to the main fracture clearly identifiable.

Secondary cracks had 'stretched' open during failure and are identified with black arrows.

- **Finding:** More secondary fatigue cracks nucleated in higher stress specimens. Stress effect in EIDS distributions statistically significant [11].
- Higher local stresses 'activates' population of otherwise less effective fatigue crack nucleating discontinuities (etch pits).
- An etch pit's conduciveness to nucleate fatigue crack growth is established by its size, shape, orientation and favourable location within bulk microstructure.

Summary

- Developed and validated a small/near-threshold FCGR data set/model for AA 7085-T7452.
- Investigated the role of microstructure in contributing to near-threshold FCGR scatter in AA 7085-T7452.
- Compared small FCGRs for 3 x AA 7XXX materials.
- Developed EIDS values for AA 7050 and AA 7085 Type 1C anodized surface finish.
- Explained variability in EIDS results for Type 1C anodizing in these materials due surface breaking inclusion populations.
- Noted a stress effect in AA 7085 EIDS data.



All results published in open literature [4]-[12].

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