Fatigue crack growth and failure in components made of AA2050 and AA7050

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Stress Methods, Structural Analysis

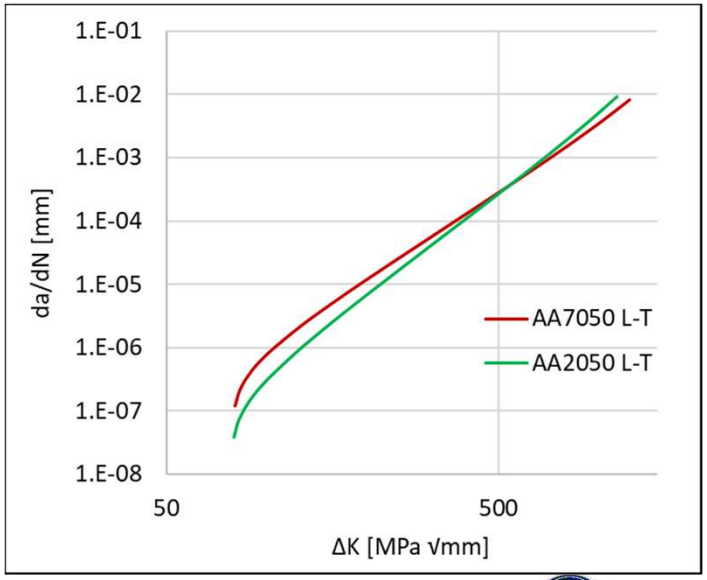
Saab Aeronautics

AA7050-T7451 and AA2050-T84

Background:

- Thick plate Al-Li alloy AA2050-T84 is introduced in Gripen E/F airframe as an alternative to AA7050-T74451.
- AA2050 has relatively higher stiffness and lower density.
- Design data from small standard specimens in CA loading.
- What are the crack growth and failure characteristics of AA2050 in components including stress gradients in spectrum loading?
- Fatigue and residual strength (RS) tests on several geometries:
  - Canard wing pivot
  - Attachment lugs
  - Notched plates
  - Frame flange

Design data	
L-T, L-S	AA2050/AA7050
R_m	1.3 %
E	5.9 %
ρ	-3.9 %
da/dN_{av}	-30%
KIC	-10%



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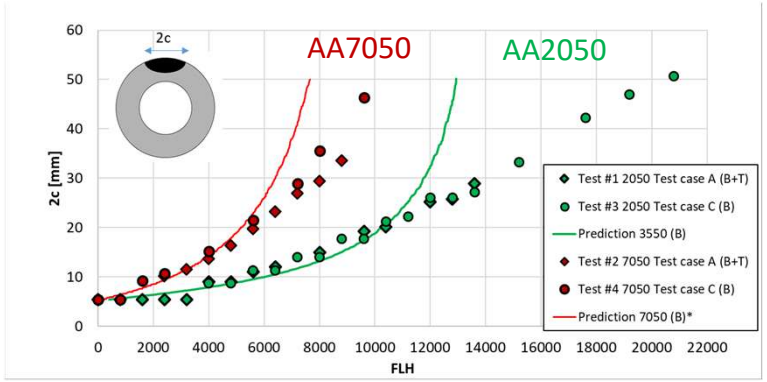
Canard wing pivot

Test summary:

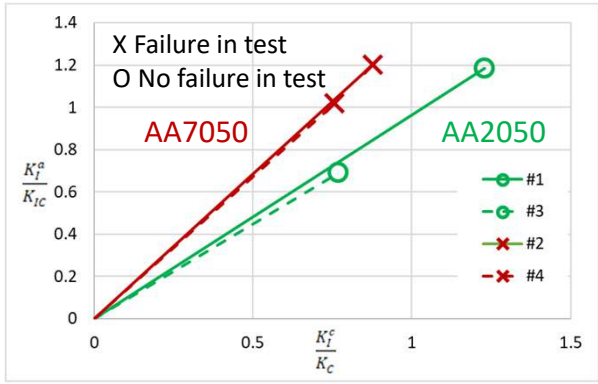
- Simplified geometry
- 4 specimens with artificial defects L-S
- Biaxial spectrum loading (bend/twist)
- RS test

Results:

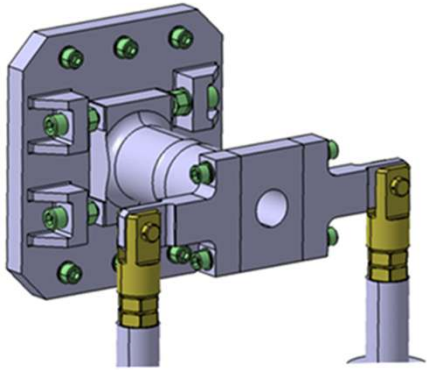
- Lower crack growth rate in AA2050
- High apparent RS in AA2050, no failure
- Crack turning towards L observed in AA2050

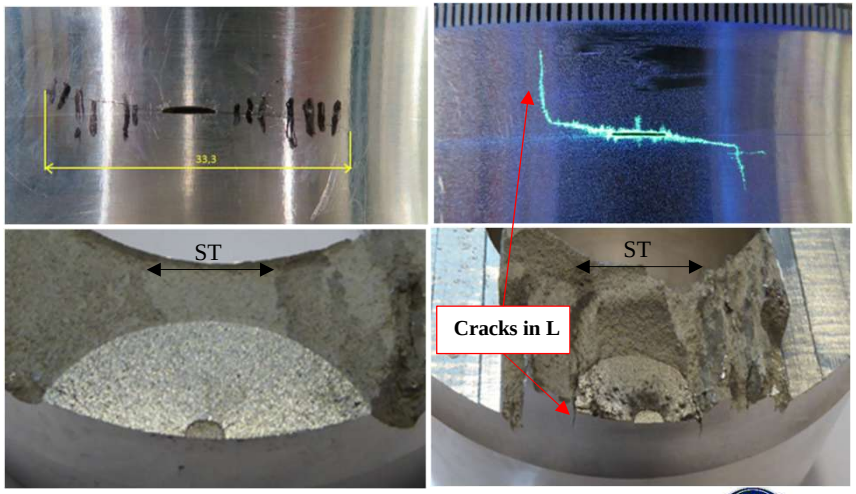


Fatigue crack growth



Residual strength





AA7050 AA2050

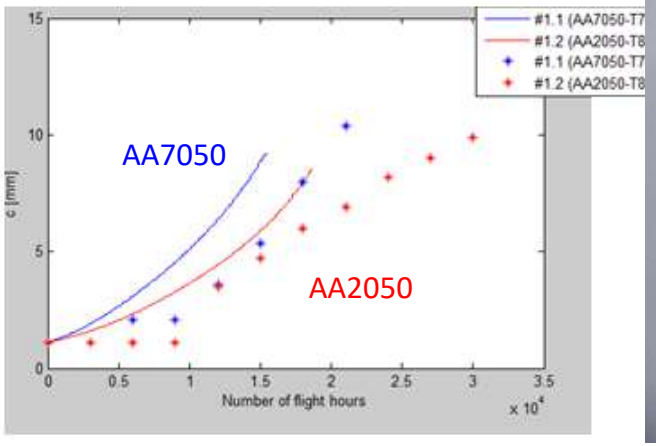
Attachment lugs

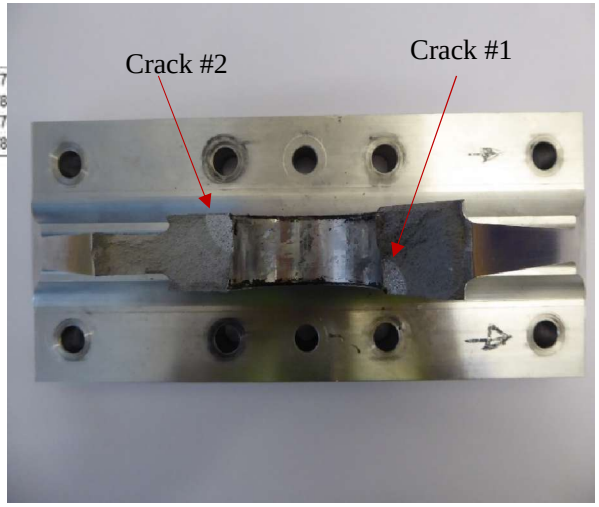
Test summary:

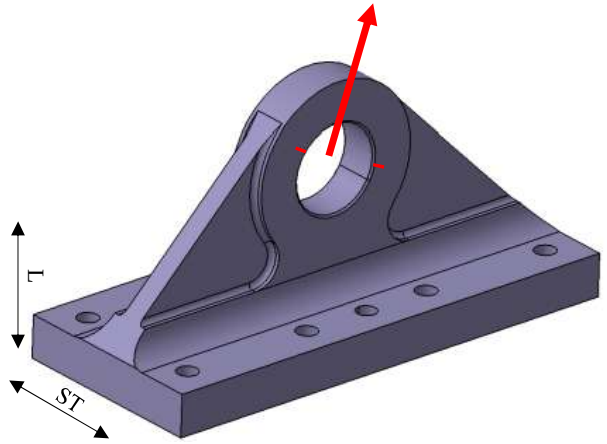
- Tapered lug geometry
- 2 specimens with 2 artificial defects L-S
- Spectrum loading, inclined load
- RS test

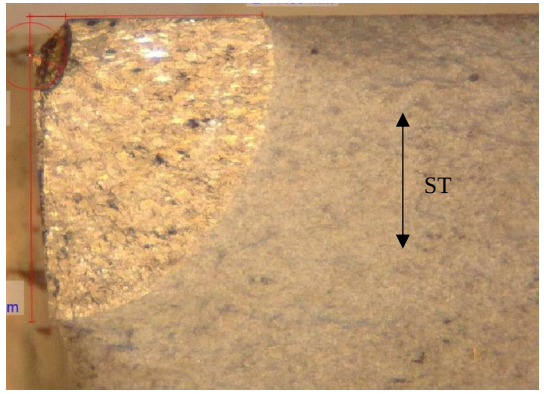
Results:

- Lower crack growth rate in AA2050
- High apparent RS in AA2050, no failure
- Crack turning towards L observed in AA2050

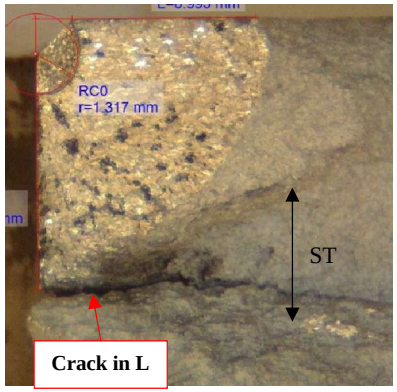








AA7050



AA2050

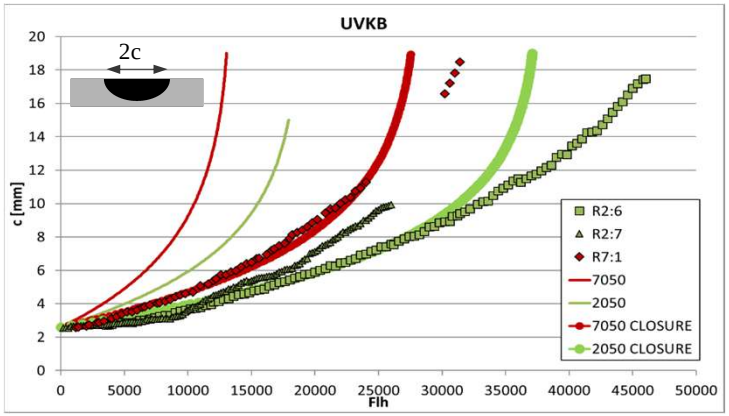
Notched plates

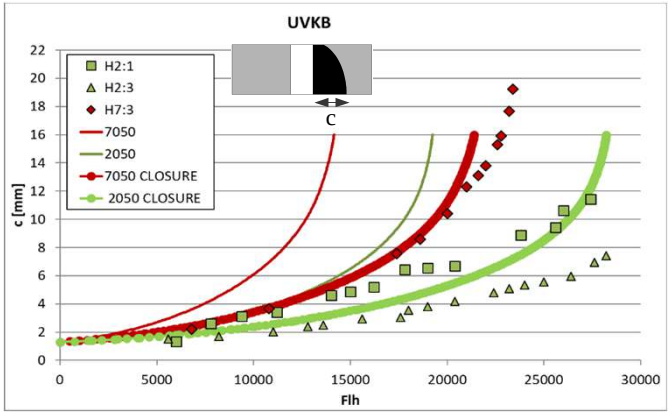
Test summary:

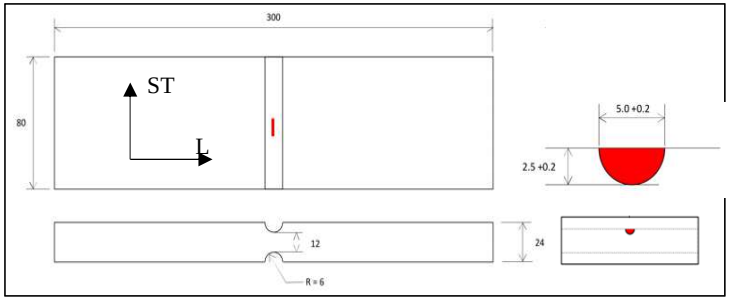
- Plate w double radii, surface crack, L-S, 7 spec.
- Plate w hole, corner crack, L-S, 7 spec.
- Tensile/compressive spectrum loading
- RS tests to failure

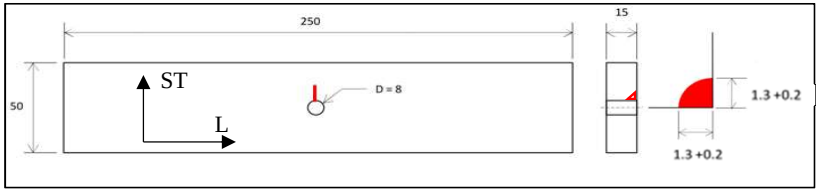
Results:

- Lower crack growth rate in AA2050
- High apparent RS in AA2050
- Crack turning towards L observed in AA2050

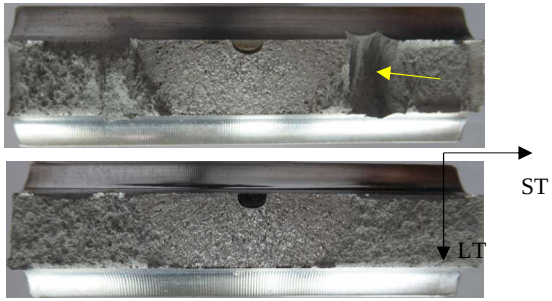






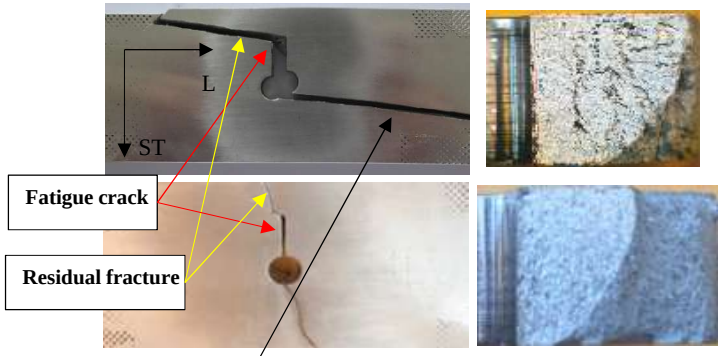


AA2050



AA7050

AA2050



AA7050

WHAT IS THIS???

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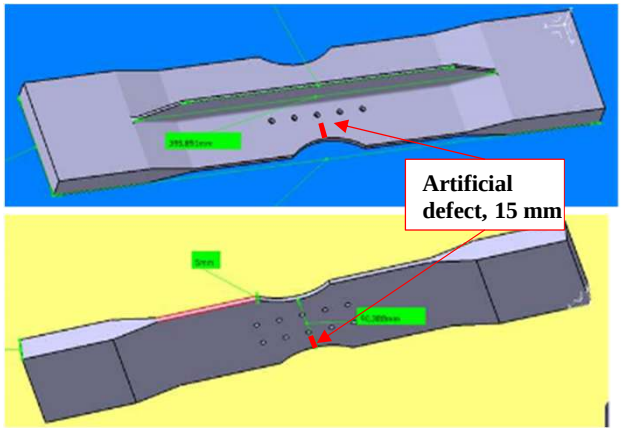
Frame flange

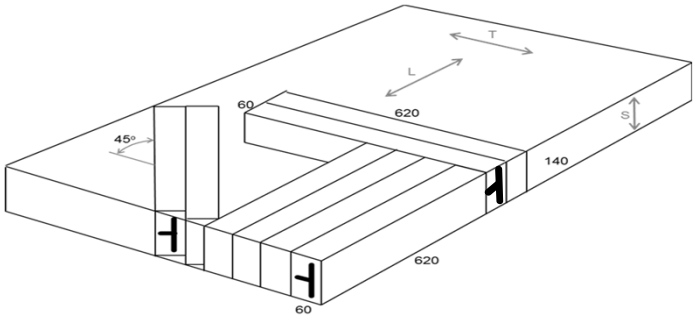
Test summary:

- Simplified geometry of frame flange with radius, w or w/o holes and an edge defect
- 8 specimens with L-S, T-S and $(L\text{-}LT)_{45°}$ - S
- Only RS tests to failure

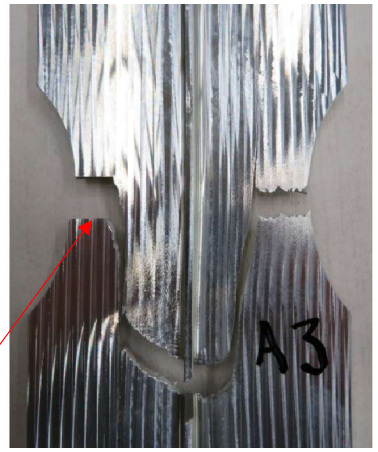
Results:

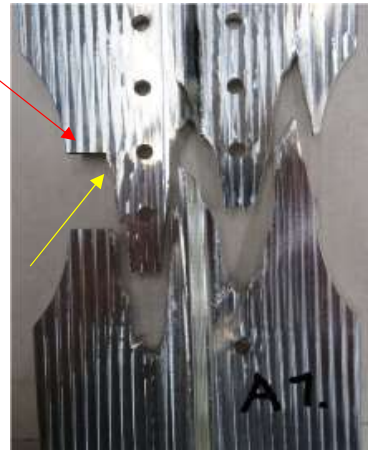
- High apparent RS in AA2050
- Crack turning towards L observed in AA2050





AA2050





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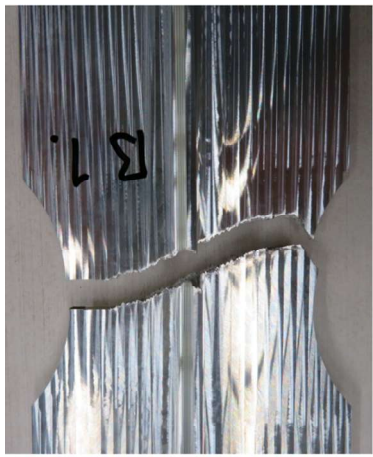

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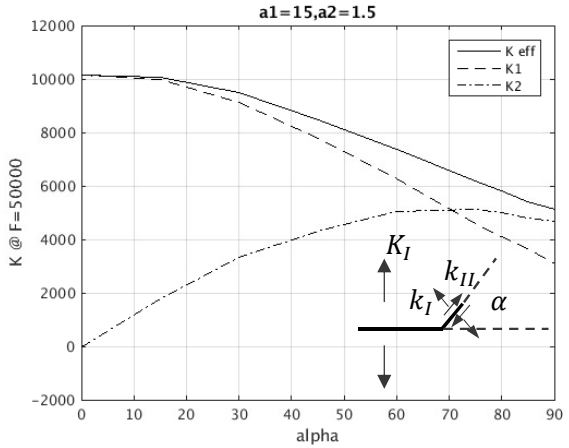
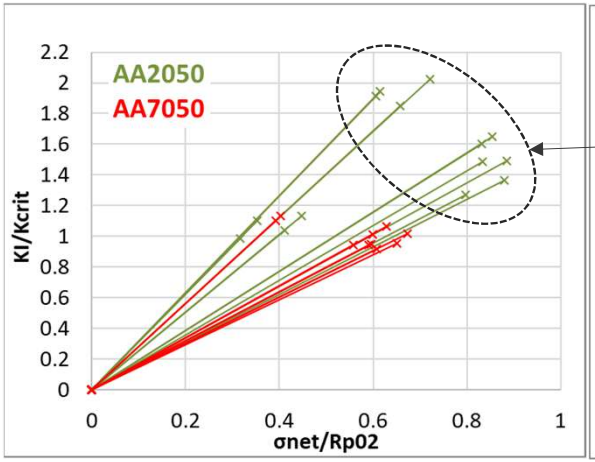
Residual strength, notched plates and frame flange

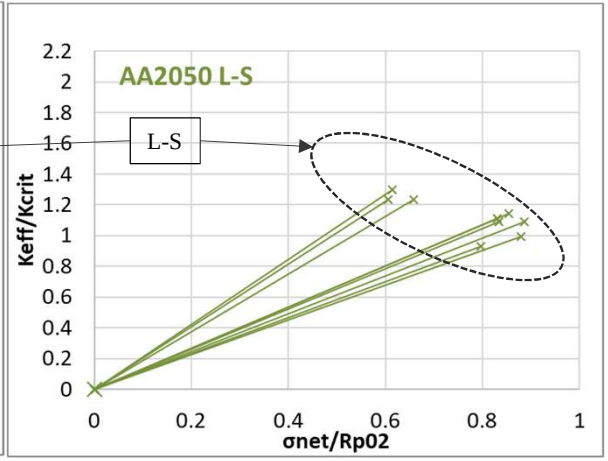
- RS assessed using two assumptions:
  1. Plane fracture, no crack turning
  2. Branched fracture, crack turning at ~80°



1. Plane fracture



2. Branched fracture



1. Plane fracture

$$K_I = \sigma_0\sqrt{\pi a}\cdot f\left(\frac{a}{W}\right)$$

$$K_{crit,L-S} = K_{IC} + \frac{6 - i(t,K_I)}{4}(K_C - K_{IC})$$

where $f\left(\frac{a}{W}\right)$ is determined by handbook solution or FEM and σ_0 is the applied stress at failure.

2. Branched fracture

$$k_{eff} = \sqrt{k_I^2 + k_{II}^2} = 0.474 \cdot K_I$$

$$k_I = cos^3\left(\frac{\alpha}{2}\right)K_I$$

$$k_{II} = sin\left(\frac{\alpha}{2}\right)cos^2\left(\frac{\alpha}{2}\right)K_I$$

$K_{crit,S-L}$

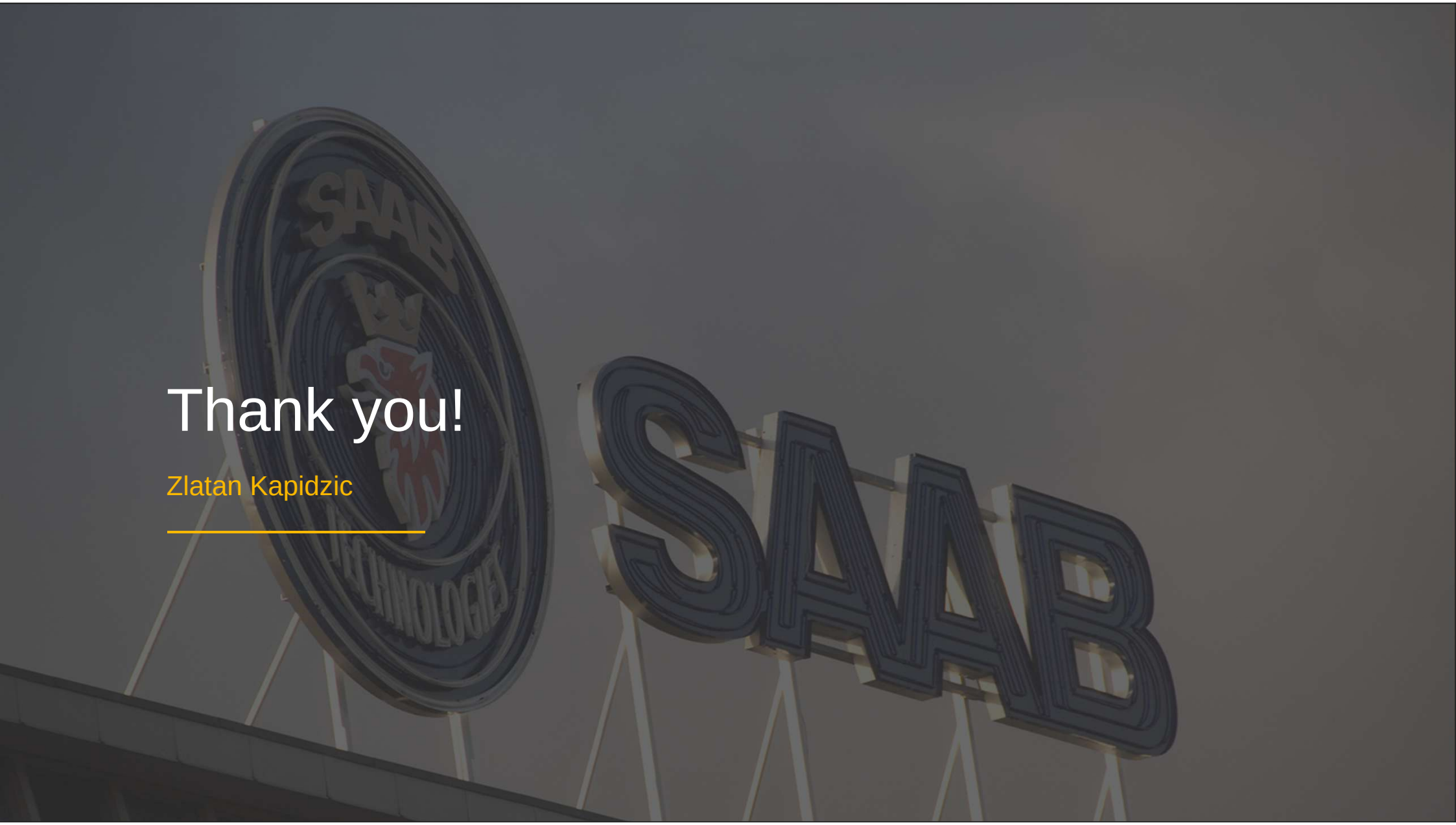
Conclusions regarding AA2050

Results of the present study:

- Macroscopically planar FCG at small and medium ΔK, fairly well predicted.
- Generally lower FCG rate than in AA7050.
- Severe crack turning towards L-direction, observed in all AA2050 RS tests in L-S .
- Apparent high RS in AA2050 tests (under predicted by planar fracture assumption), explained by crack turning.
- Fracture along L-direction in previously un-cracked sections.

Comments:

- What are the fracture characteristics and strength of AA2050 in absence of fatigue cracks? (Rikard Rentmeester)
- How is crack turning affecting RS in biaxial loading?
- What is the significance of fracture toughness design data (based on C-T specimens)?



Thank you!

Zlatan Kapidzic