Damage Tolerance and Damage Growth in Composite Aerostructures

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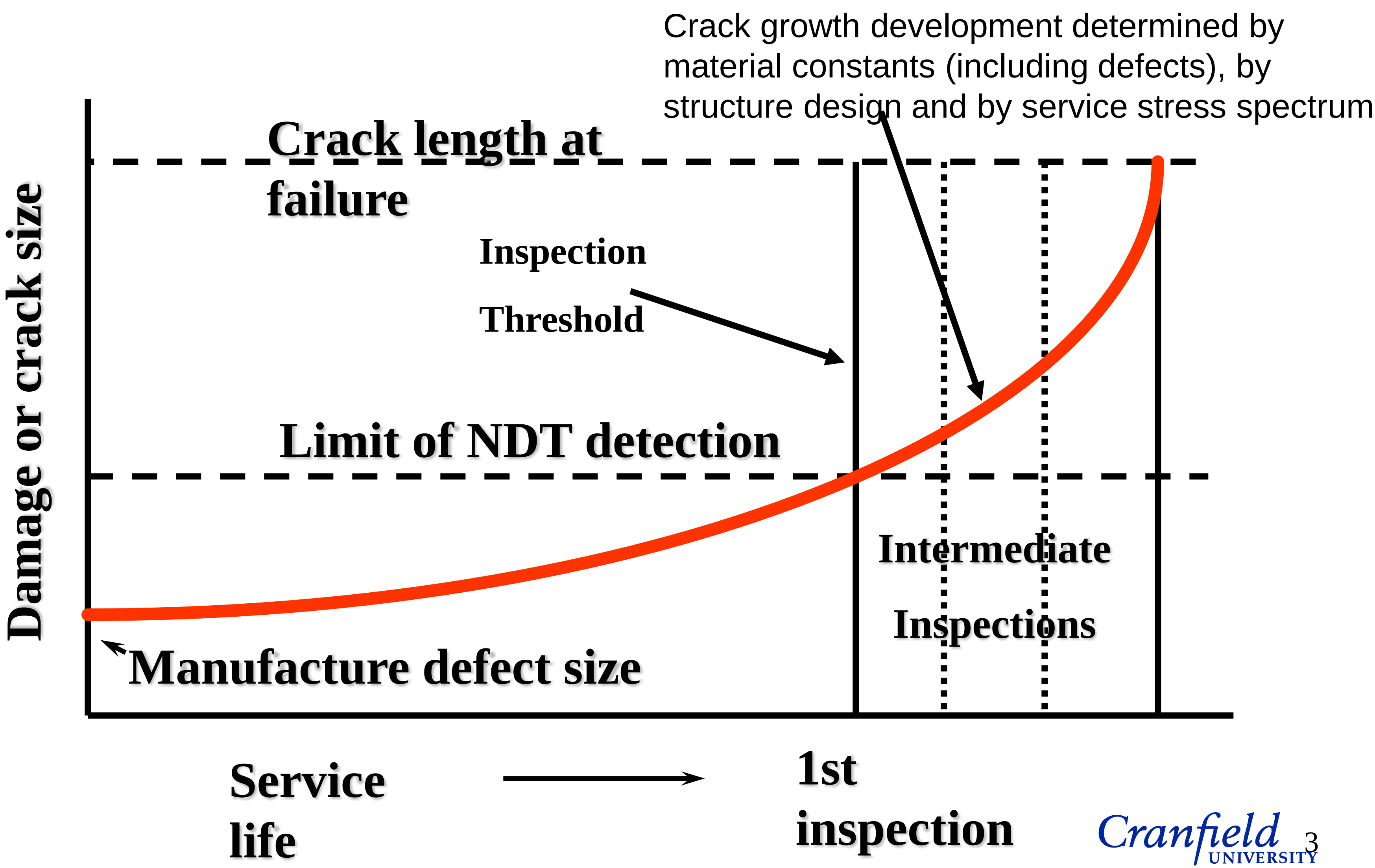
Workshop on NDT/SHM requirements for Aerospace composites
National Composites Centre, 9/10 February 2016

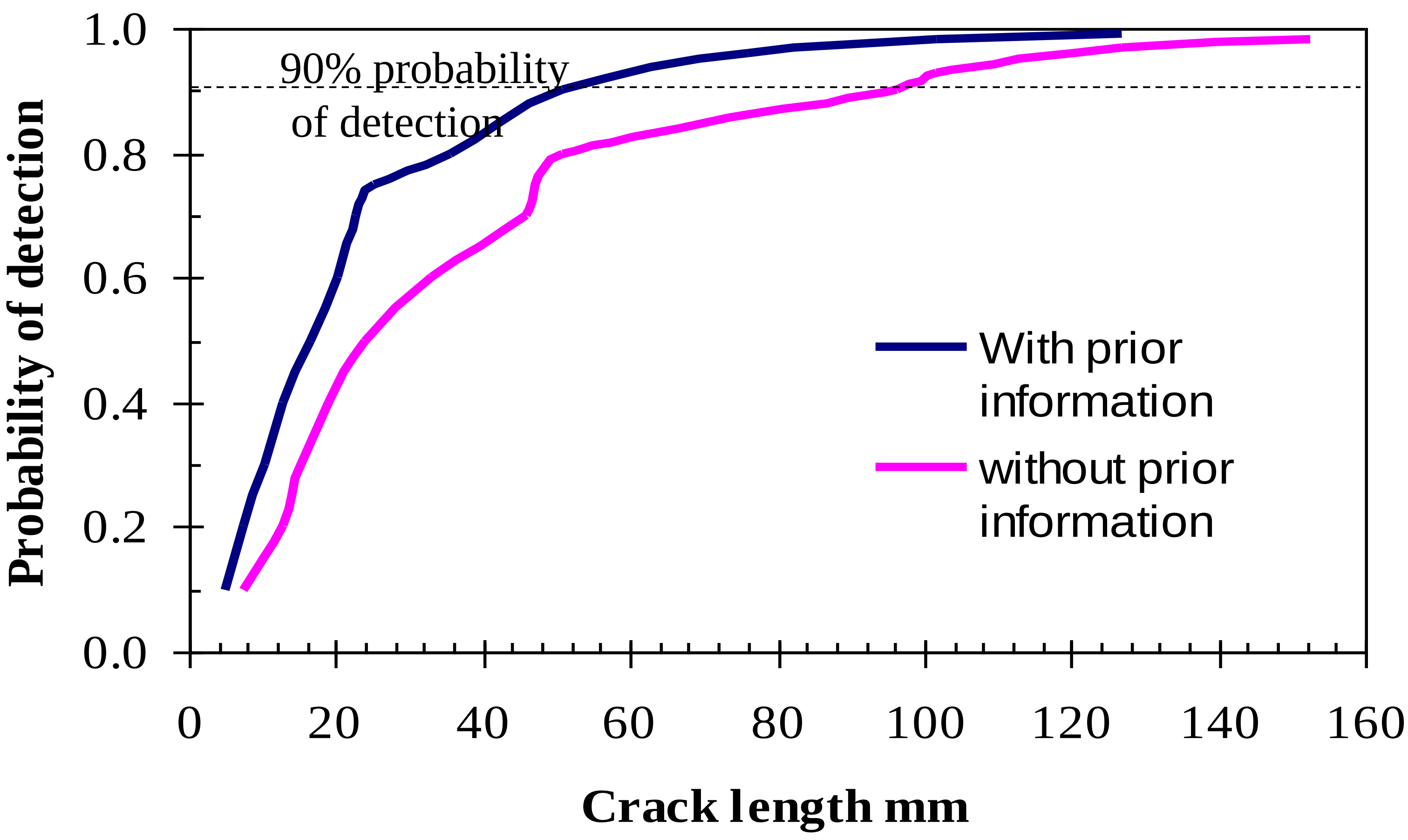
Plan of Presentation

- Damage processes in metal aircraft
- The role of NDT and inspection in Damage tolerance
- Damage processes in Polymer composites
- Damage Tolerant aircraft in polymer composites

Damage growth aluminium aircraft structures



Visual inspection for cracks JAL Boeing 757 aircraft



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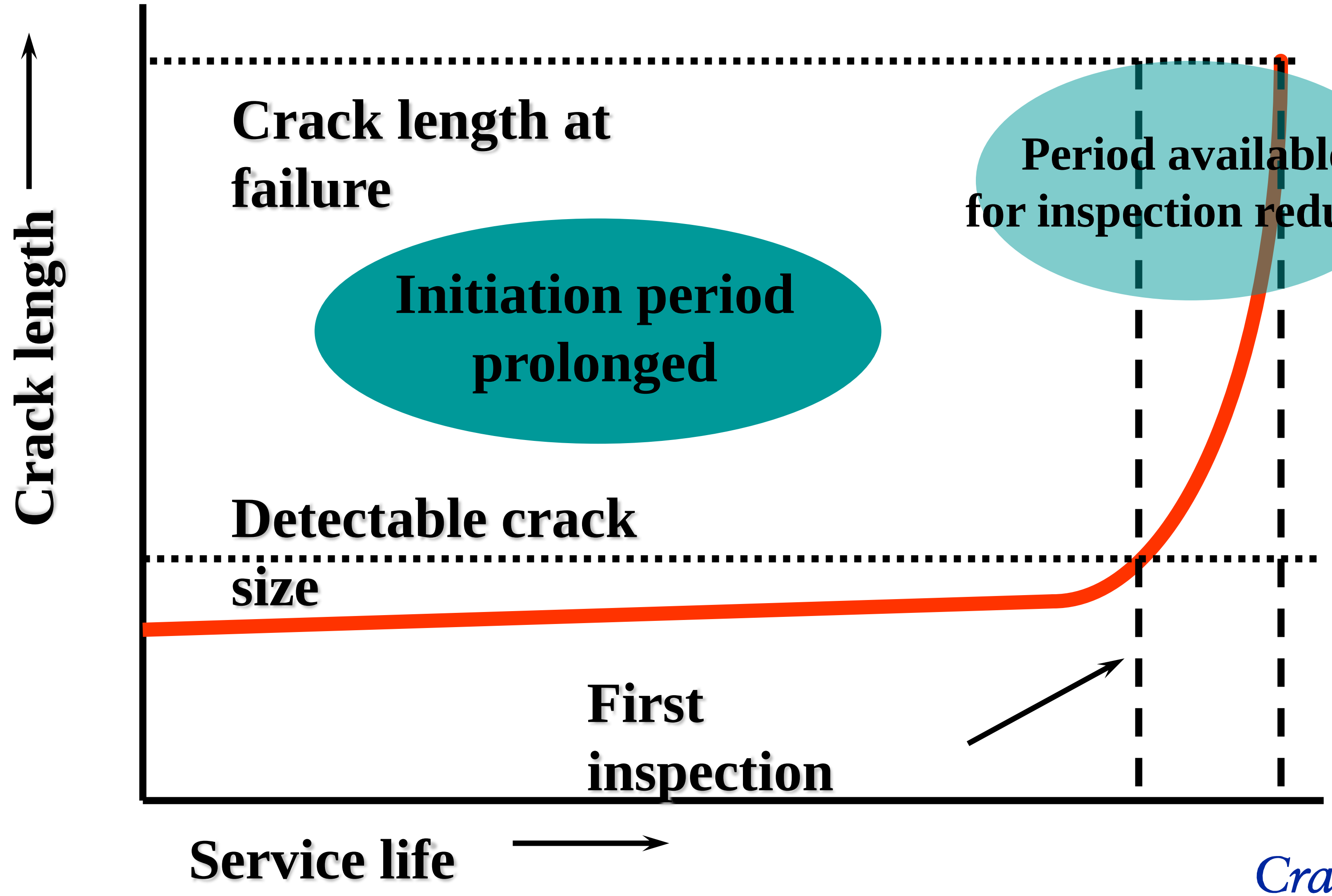
High Strength Metallic Materials; Difficulties with traditional approaches to damage tolerance



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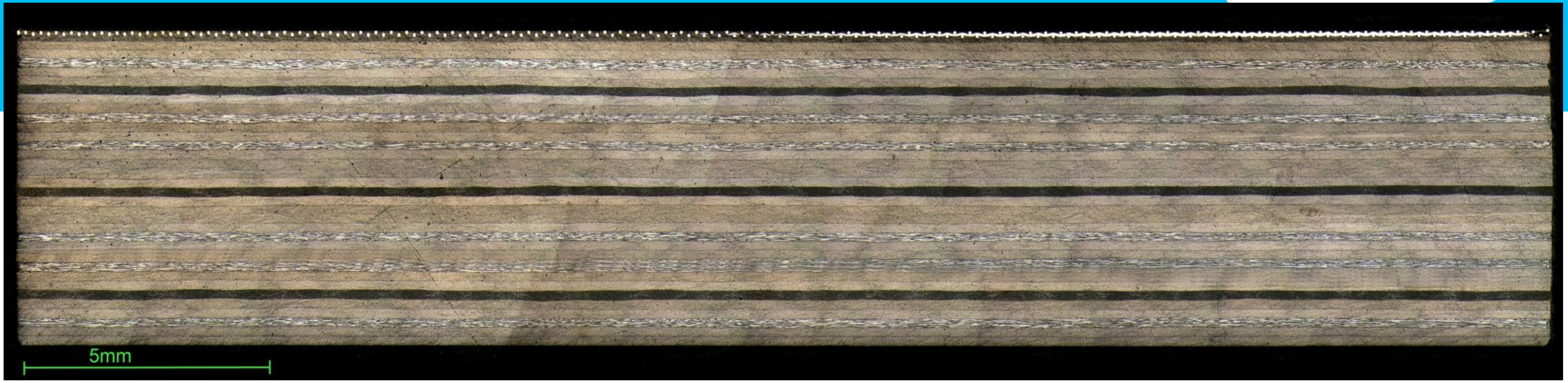
Impact damage in polymer composites

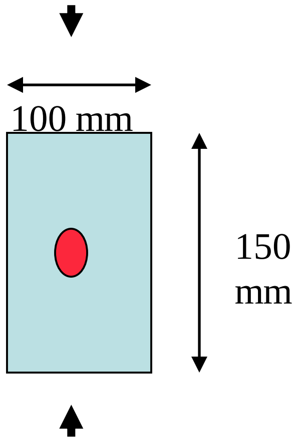


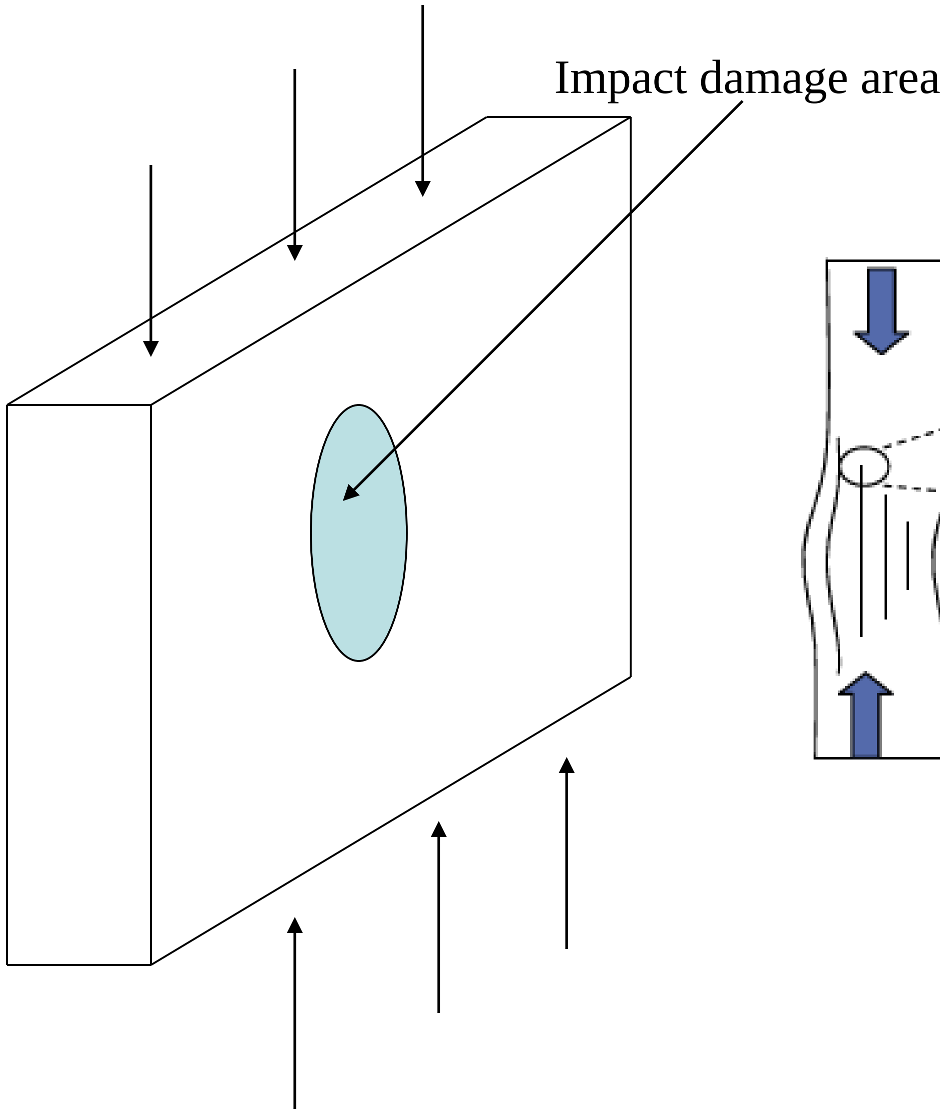
Surface dent

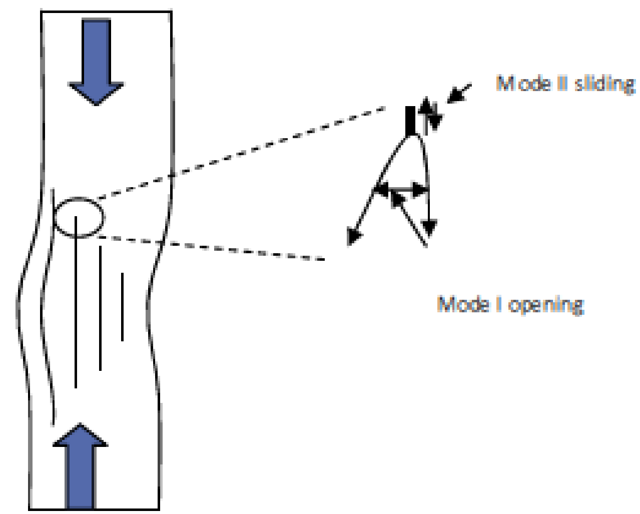
Residual Compression strength after impact

Composite material performance ranking test

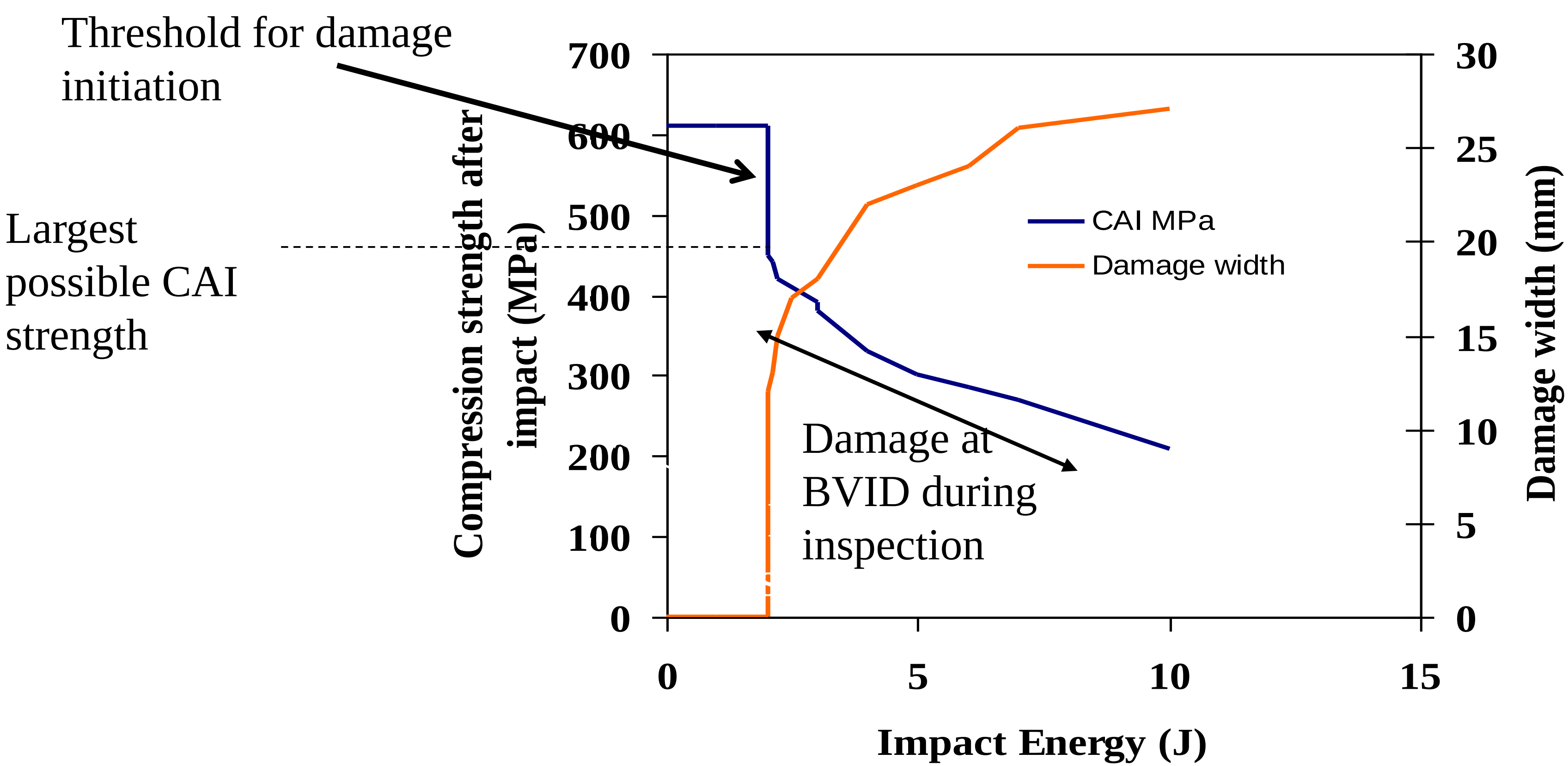
Boeing test







Threshold impact damage & compression strength - Small samples in Laboratory



From Mitrovic et al. Comp Sci Tech;1999, 59, pp 2059-2078

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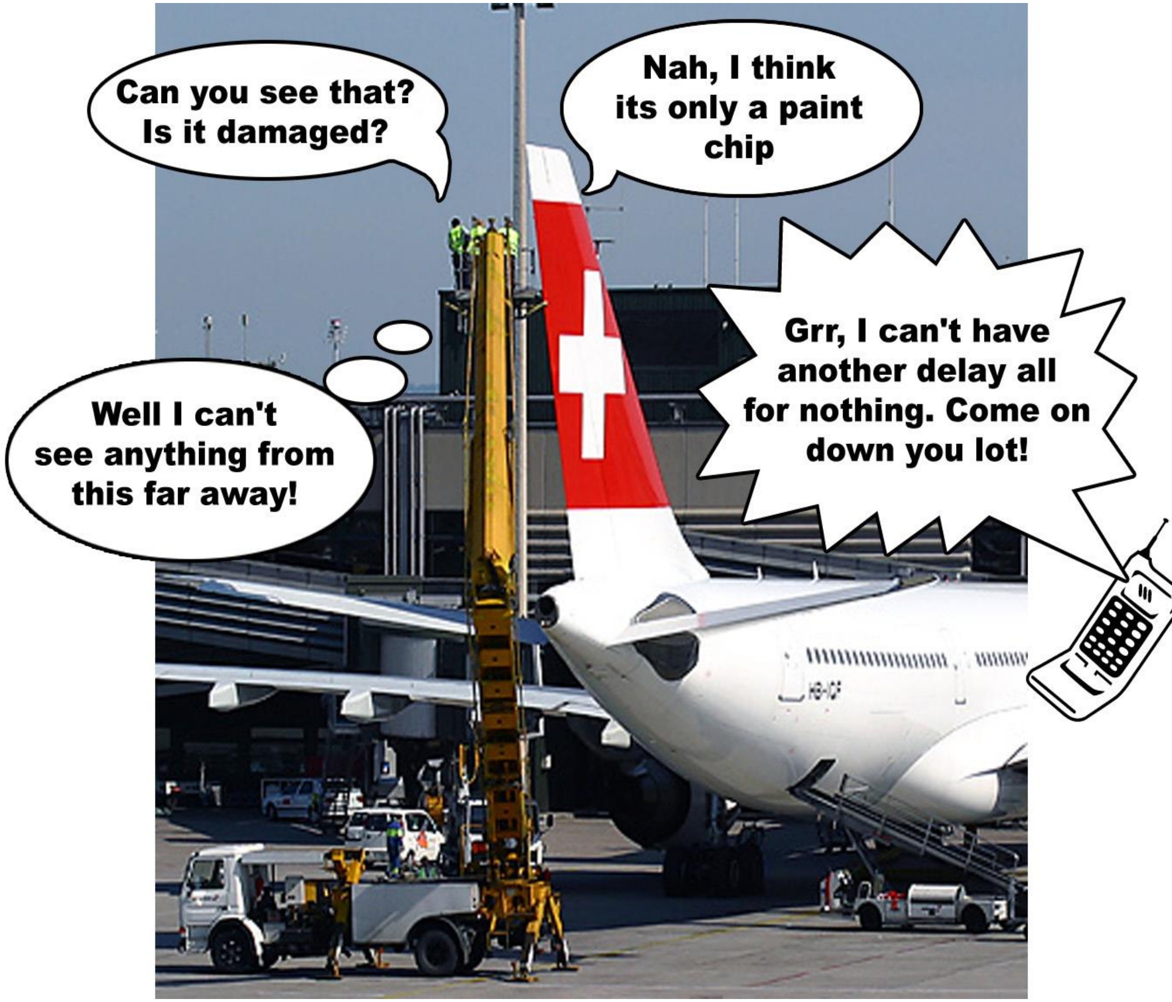
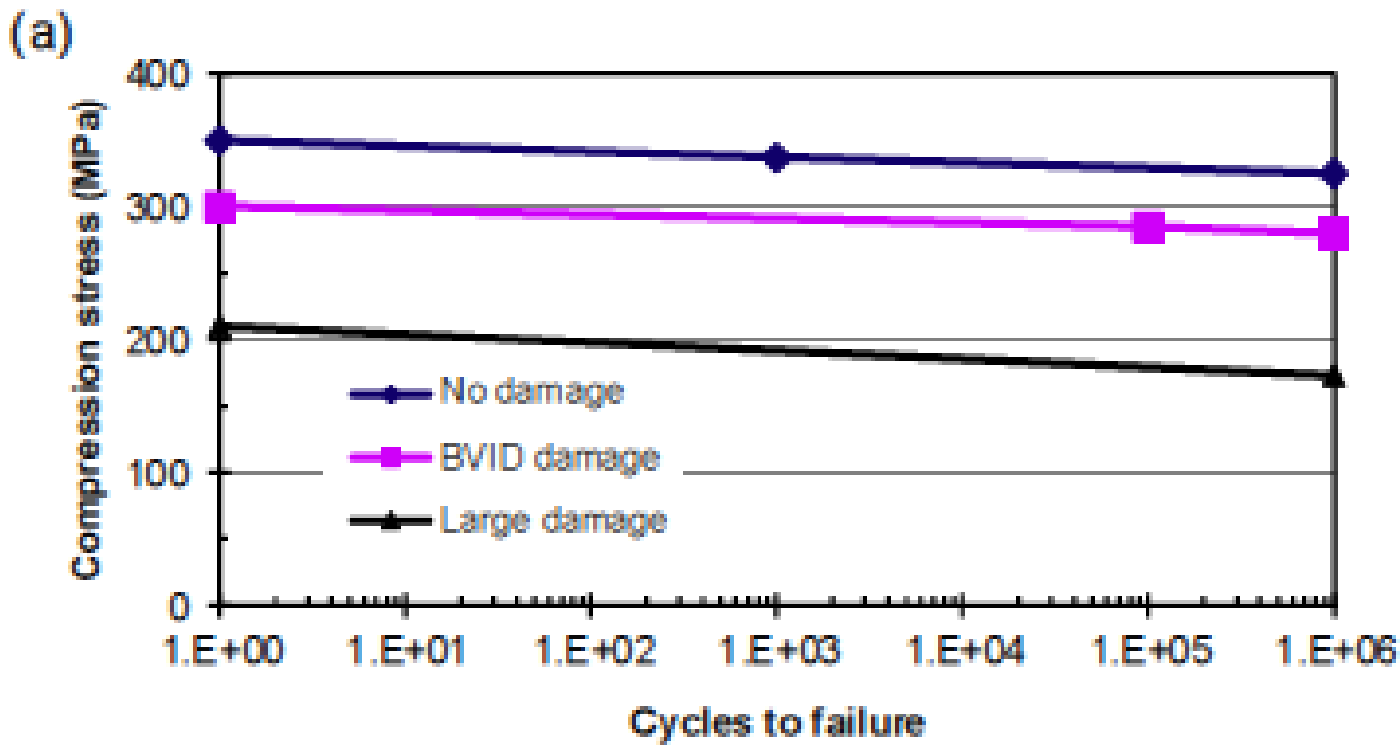
Inspection for impact damage

- Difficult to see damage in the first place
- No one knows if what they can see is actually damage
- Not the most comfortable place to be, even on a sunny day
- Can’t spend all day up there!



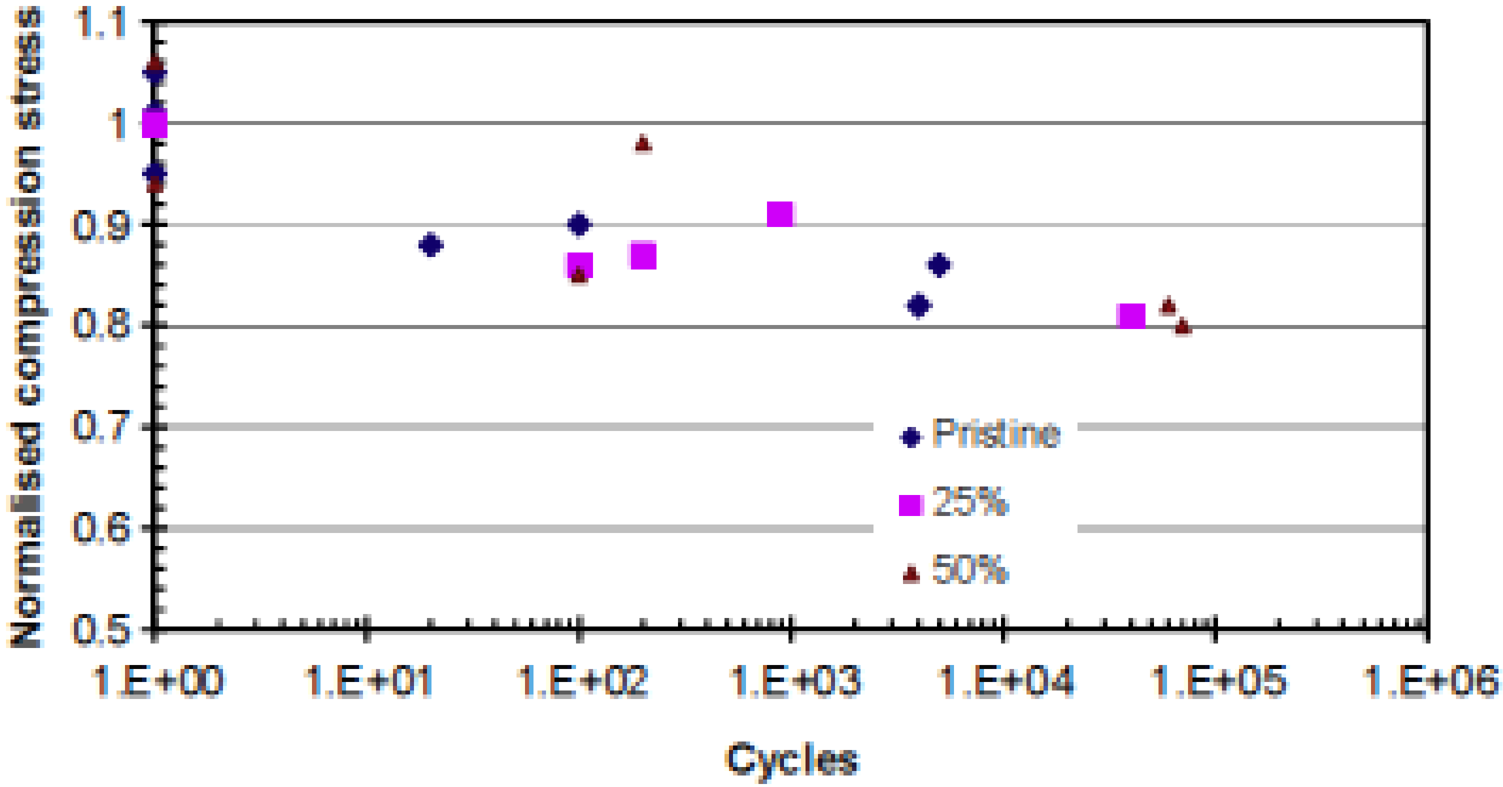
Photograph courtesy of Tobias Rose, Airliners.net

In-plane compression fatigue of pristine and impact damaged cfrp QI laminate



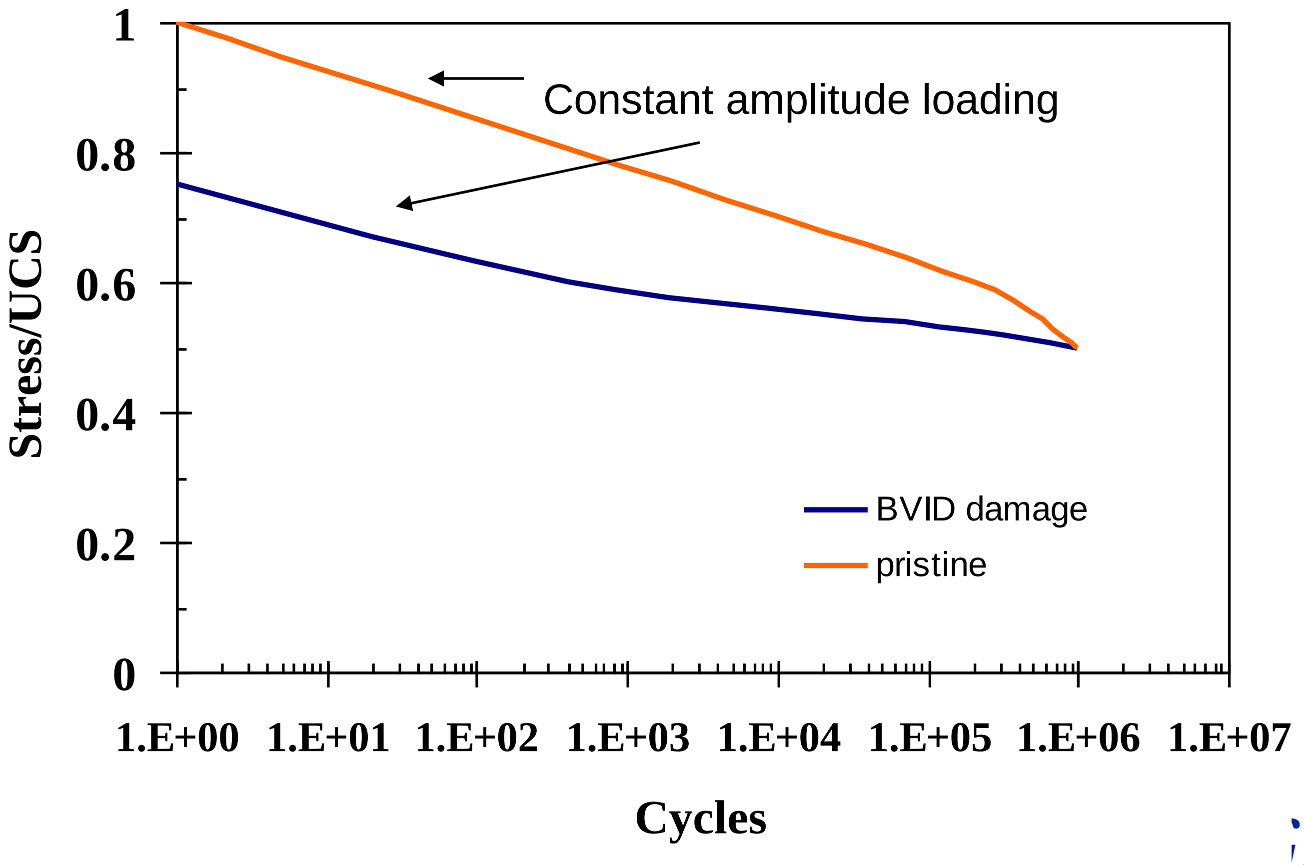
Adapted From Isa et al. Comp Struct.2011, 93, 2269-2276

Compression fatigue of pristine and damaged cfrp, normalised wrt CAI static strength



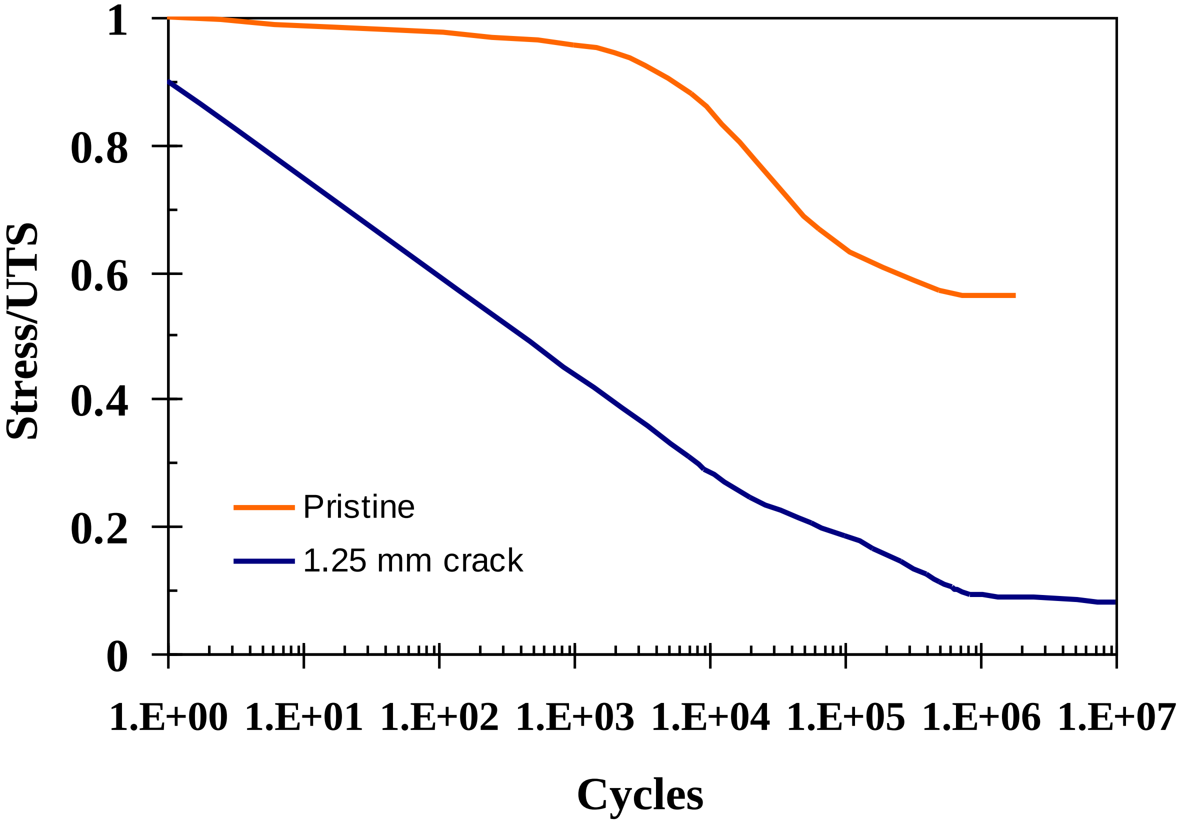
Adapted from Uda et al. Comp Scie Tech. 2009, 69, 2309-2314.

Compression fatigue pristine and impact damaged QI cfrp normalised wrt pristine compression strength



From Mitrovic et al. Comp Sci Tech;1999, 59, pp 2059-2078

2024 T3 aluminium in tension -fatigue lives with manufacturing damage



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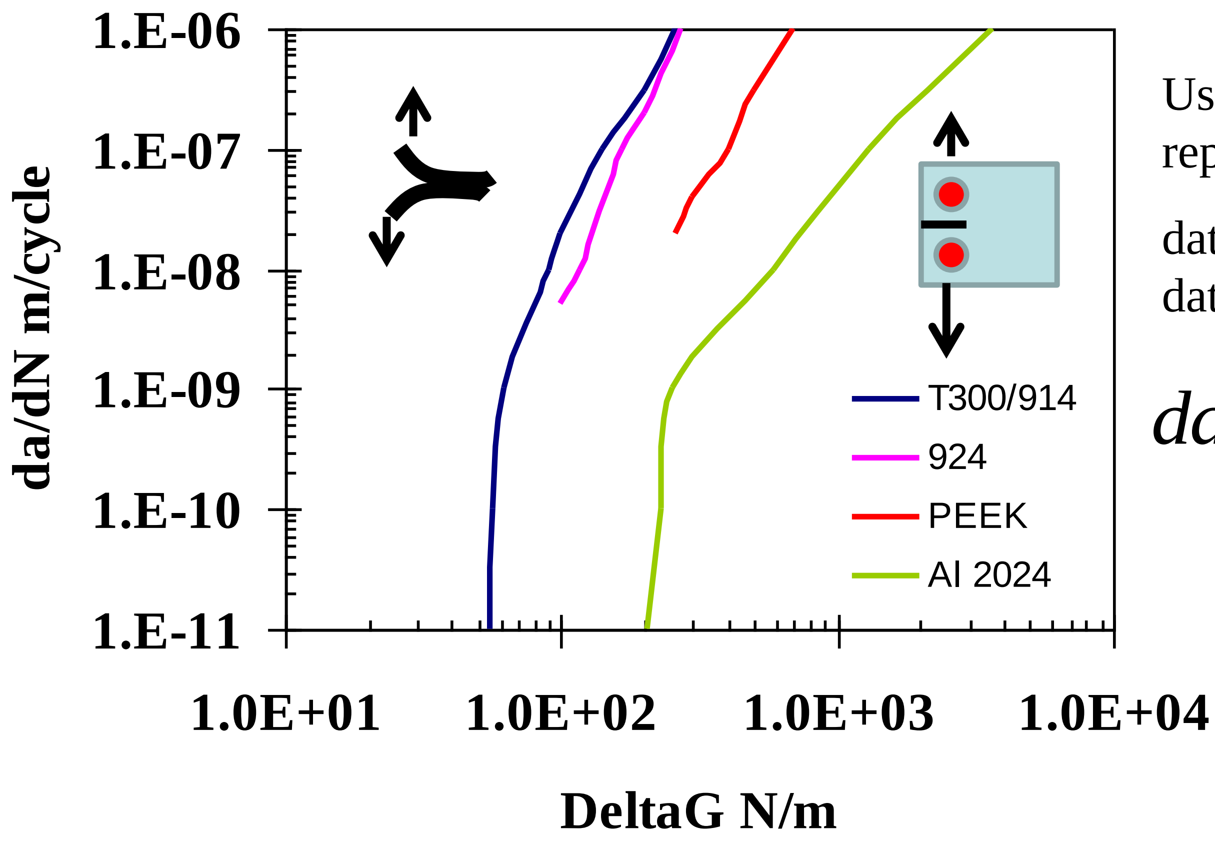
Delamination crack growth; UD cfrp Mode I, DCB samples; 2024 aluminium compact tension



Using $\Delta G = \Delta K^2 / E$ to represent aluminium

data from metals database

$$da / dN = C(\Delta G)^m$$

Cfrp data from Hojo et al Eng Frac Mech 1994, 49, 35-47

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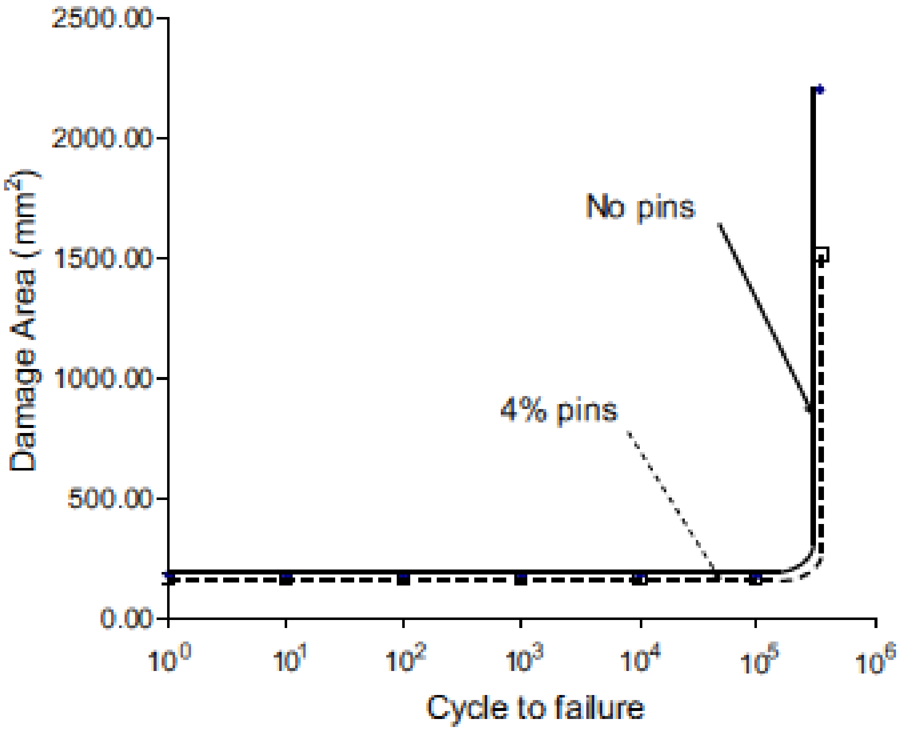
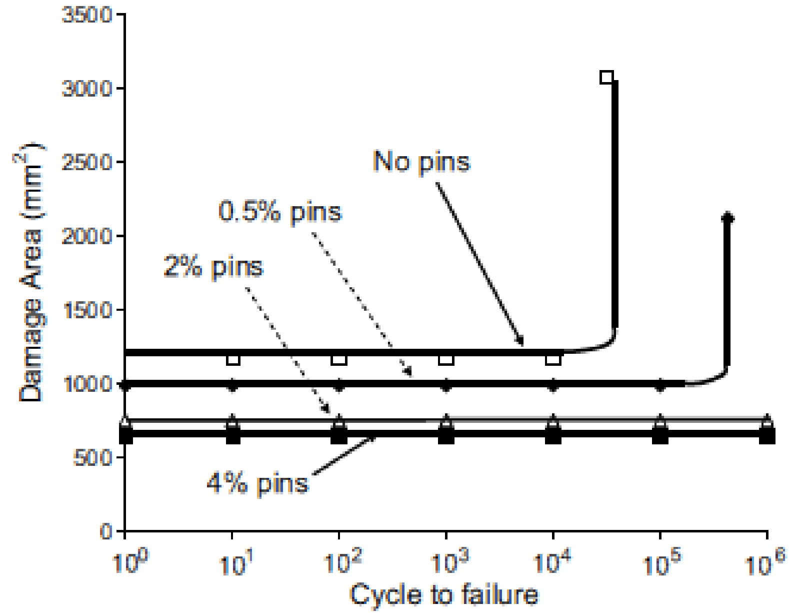
Fatigue delamination growth from impact damage; max compression stress 85% static CAI



Small impact small initial damage



Large impact & large initial damage

From Isa et al (2011); Comp. struct. 93 pp 2269-2276.

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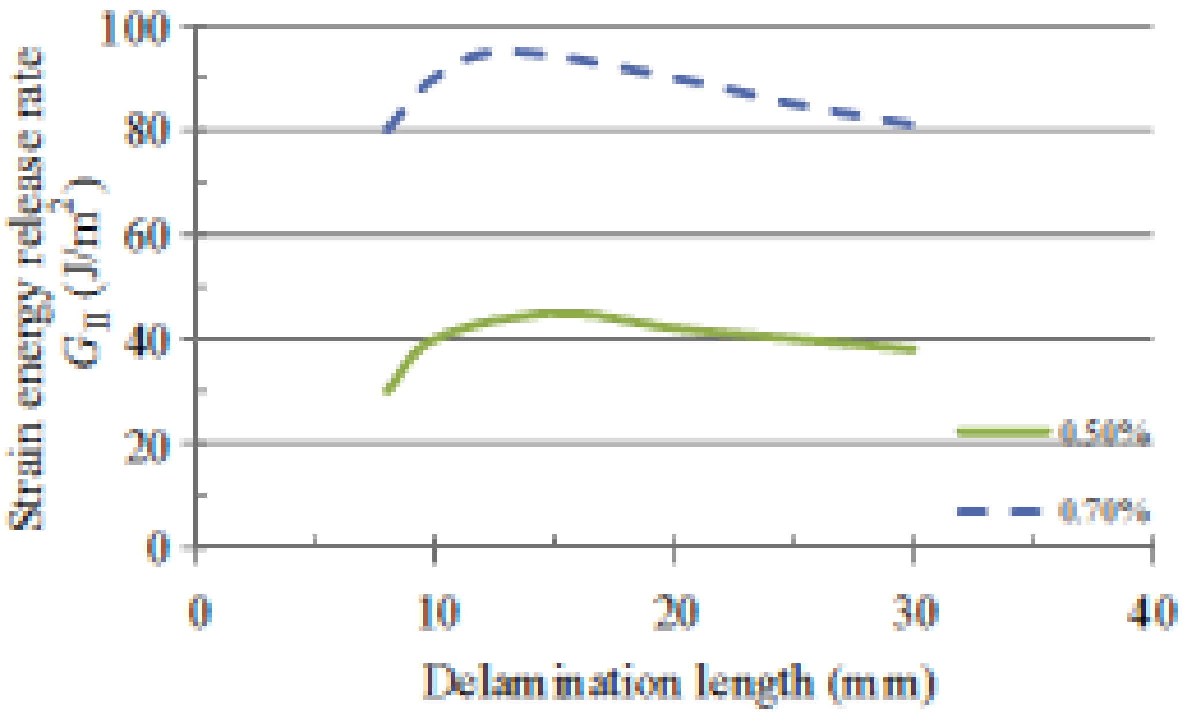
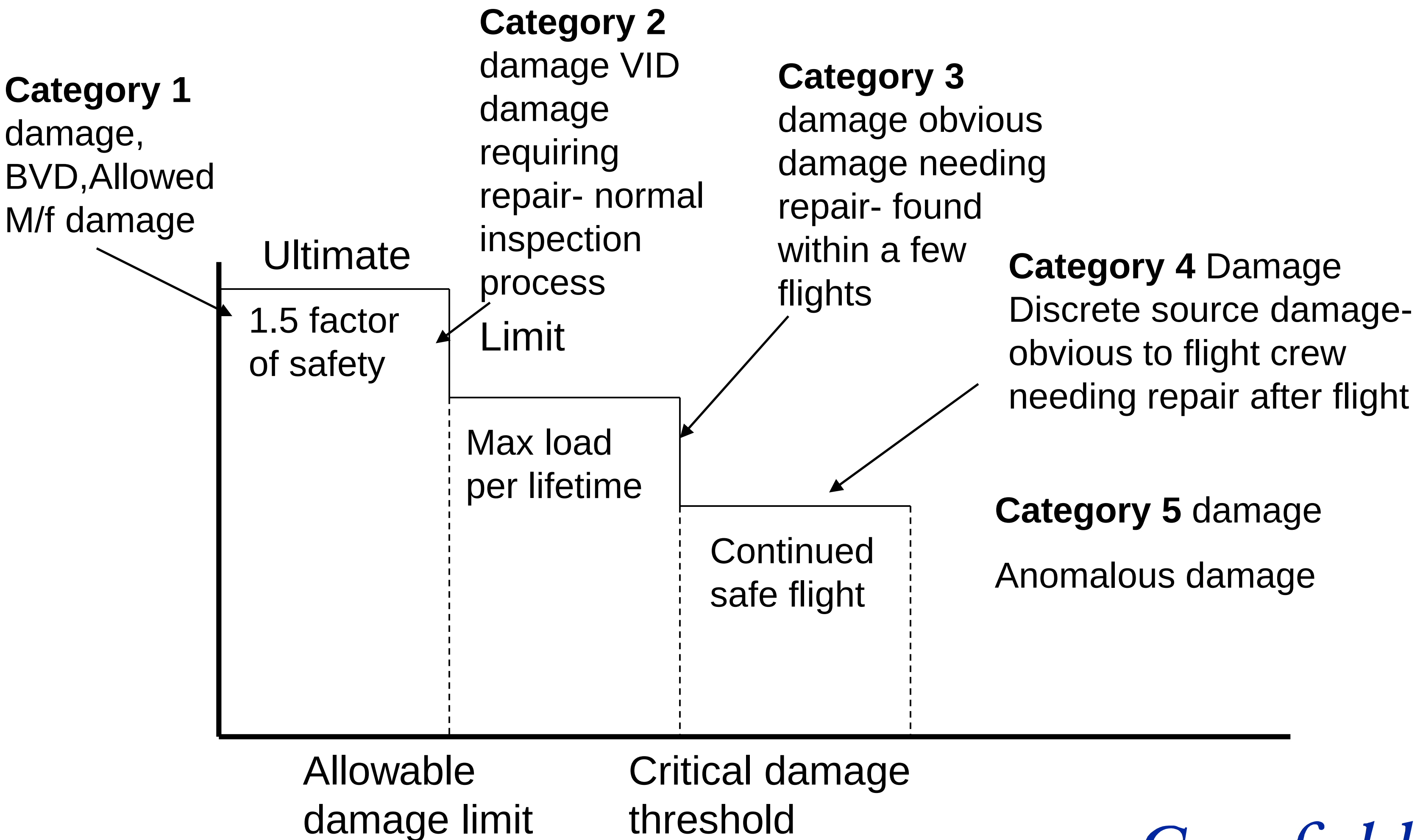
Calculated G values at tip of idealised delamination in compression strain



From Mitrovic et al. Comp Sci Tech;1999, 59, pp 2059-2078

Design load levels and damage severity- EASA AMC 20-29 Quantification?



Conclusions

- Current approaches to satisfy regulatory airworthiness requirements for design against fatigue were developed in a way suited to fatigue crack development in metals- particularly aluminium.

- Concept of slow crack growth with a high probability of detection is central to continuing airworthiness in metallic structures.

- Current generation of polymer composite laminates not behaving in a way suited to this approach
- High thresholds; rapid crack growth

NDT and damage growth
Questions

- How are inspection intervals set for zero damage growth?
- Can inspection detect when a defect is beginning to grow?
- Is there an alternative to visual inspection for damage?
- What service environment factors determine when a defect begins to grow? Can this be predicted?
- Could structural health monitoring play a role?

QUESTIONS?