The challenges of finite element crack growth models for adhesive joints to make reliable and useful risk assessment in aircraft structures

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Contents

• Research of structural repairs in Finland
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Tampere University
• Established in 1965
• ~1,600 employees
• ~19,000 deg students
• Research combines natural sciences, technology and business
Research of aeronautical structural repairs in Finland

- Much of the previous research was carried out in Helsinki University of Technology (Aalto)
- Activities nowadays moved to Tampere University

→ Research group of Plastics and Elastomer Technology

Dr. Kanerva     Dr. Sarlin
Academic scope

- Research of the group in this area focuses on adhesive joints in composites and metal-composite structures.

- Adhesive joints are used in military aircraft and there is an interest to apply adhesive joints (also to future commercial aircraft).

- Adhesive joints can be very lightweight and durable.

- Adhesive joints are challenging structural details due to the inability to confirm the quality of the prepared joint.
For aircraft structures, the pure stress analysis via failure criteria and proper strength allowables (via standard test procedures) is an acceptable procedure.

The assessment of a risk typically based on finite element methods based on either critical energy release rate or stress concepts of crack and its growth.

However, a more accurate and tailorable solution could be, e.g. the Virtual crack closure technique (VCCT).

Also cohesive zone modelling (CZM) could offer some advantages to fit the effects of environmental effects or crack onset, for example. However, the parameters of the more advanced crack growth methods are difficult to validate experimentally.

Finite element models and parameters
Case examples
Recent activities: FEM

• Combined methods, for crack nucleation (onset) and damage evolution (propagation), e.g. CZM-VCCT

• CZM zone applied to model crack nucleation and VCCT handles the (self-similar) crack propagation or delamination for composites

Recent activities: Cracks and experiments

- Sensitivity studies of the effects of multiple failure sites (e.g. cracks, debonds, pre-delaminations) → interaction

- DIC (digital image correlation) for crack propagation and crack-tip strain field recording for ENF, DCB, fatigue fracture tests
Examples of challenges

- Shear strain measurement for lap-shear testing (e.g. TALS) or mode II fracture toughness (ENF)
- Standard: specified sensor with a mechanism
- Academic means: DIC and resolved strain components

**Challenge:**

No ‘final’ validation of DIC-derived shear strains
- subset - glue line thickness dependency
- virtual strain gauge definition not straightforward
- single laboratory not enough for validation
Examples of challenges

• CZM-involving crack models

• Standard: VCCT or onset-related $G_c$ (or stress analysis)

• Academic means: traction-separation laws with >3 parameters

• **Challenge:**
  No standard tests for CZM parameters not to mention authorization for combined methods

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1. J. Jokinen, M. Kanerva, 
   Appl Compos Mat 26 (2019), 709-721.
Current alignment of interchange of solutions

Academia
- Critical strains
- Critical stresses
- Fracture toughnesses

Authority
- Environmental factors
- Fatigue data, SN-curves

Industry
- Fatigue behavior
- Use of specialized software, etc.
- A/B values, MoS, SF, RF based reliability

Publishable novelty

DIC, FEA
- FEA, material (plasticity) models
- VCCT, CZM, combined methods
- Special case studies

Gap
Examples of challenges:  solutions

- Research centers (university branches)
- Public/self-standng research institutes
- (International) collaboration, round-robin activities
- Societies, user communities for shared information
- Virtual testing
- Other?

- Basically, public common will towards fundamental, basic research …
- Basically, improved funding of university research
- (Maintenance outsourced)
Thank you for your attention!

Tampere University

Finnish Defence Forces

Patria Aviation

VTT

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