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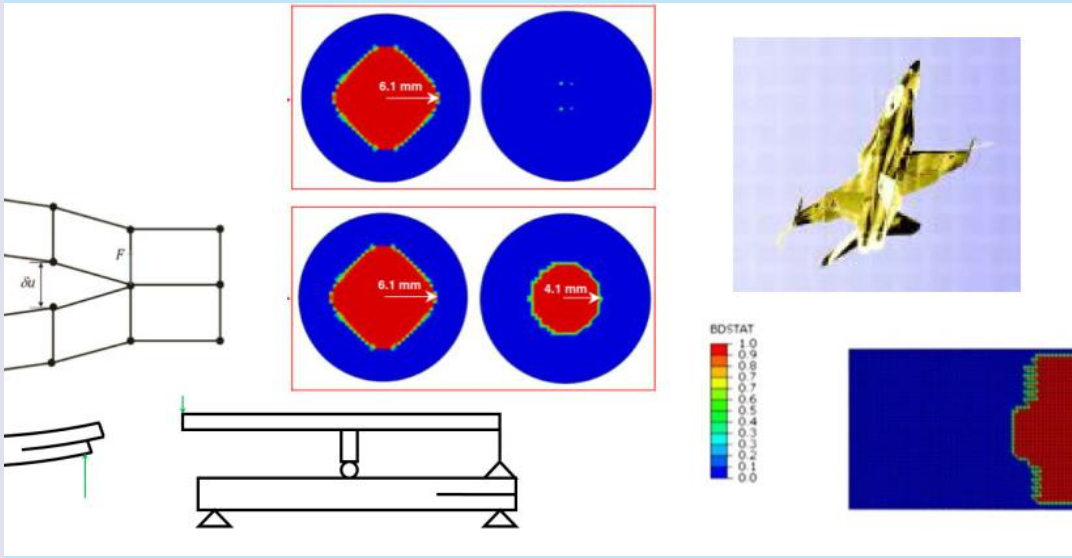
The challenges of finite element crack growth models for adhesive joints to make reliable and useful risk assessment in aircraft structures



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Tampere University

Tampereen yliopisto
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Contents

- Research of structural repairs in Finland
- Academic scope
- Industrial needs & academic solutions

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

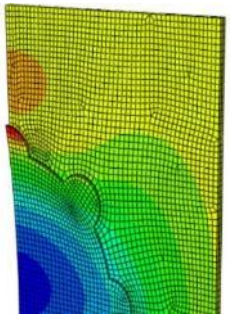
→ Research group of **Plastics and Elastomer Technology**

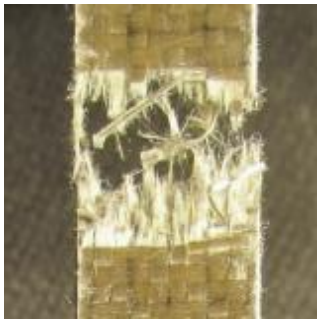
Dr. Kanerva

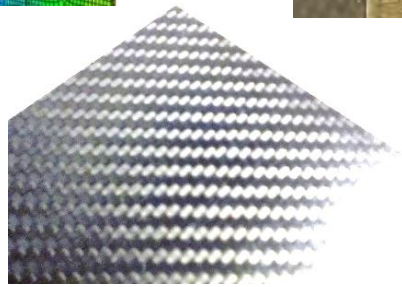
Dr. Sarlin

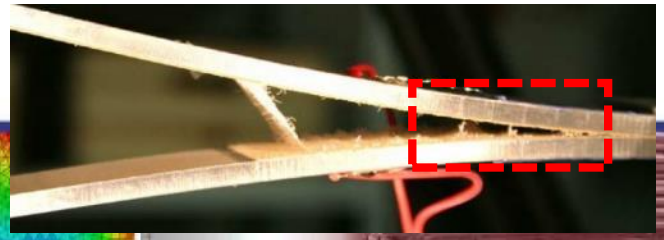
Academic scope

- 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

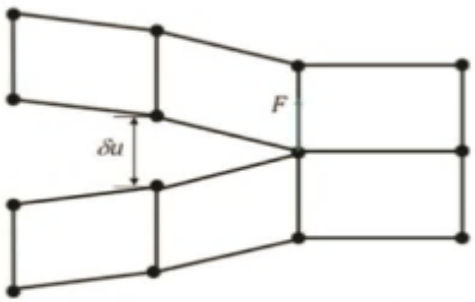




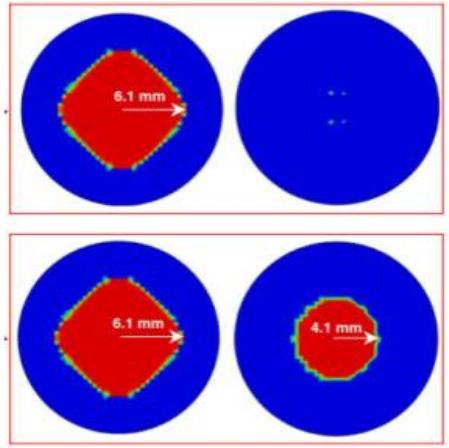




Finite element models and parameters

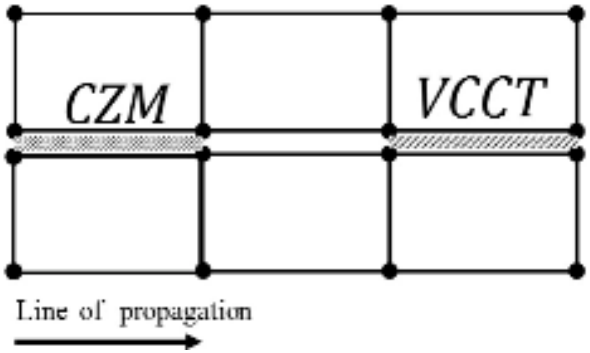


- For aircraft structures, the pure stress analysis via failure criteria and **proper strength allowables (via standard test procedures)** is an acceptable procedure
- The assessment of a risk typically based on finite element methods based on either **critical energy release rate or stress concepts 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**



Case examples

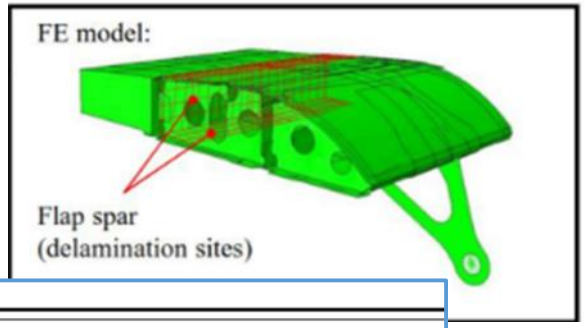
CZM-VCCT:

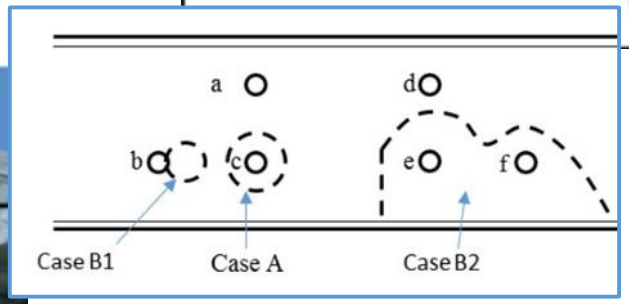


Recent activities: FEM

- 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



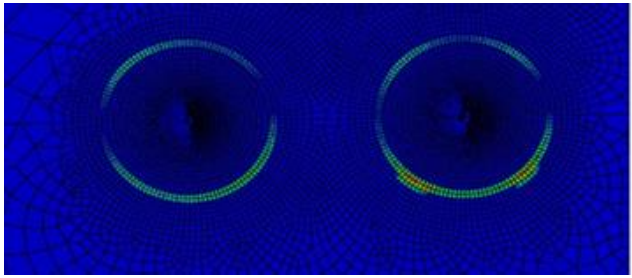


1. J. Jokinen, M. Wallin, O. Saarela, Int J Adhes Adhes 62 (2015), 85-91.

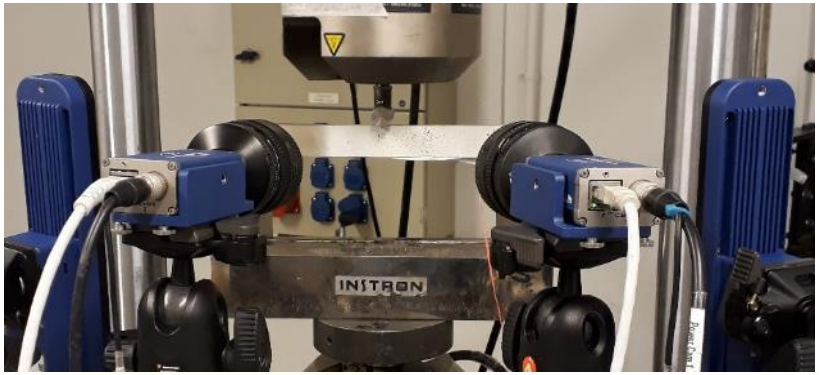
2. J. Jokinen, M. Kanerva, M. Wallin, O. Saarela, Int J Adhes Adhes , 88 (2019), 50-58.

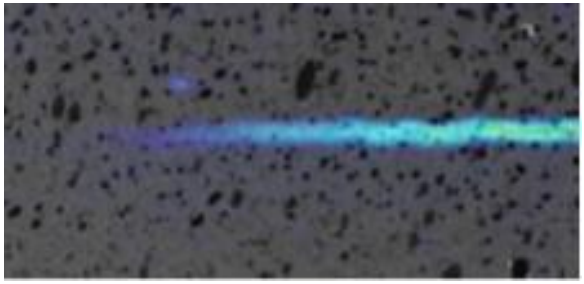
Recent activities: Cracks and experiments

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

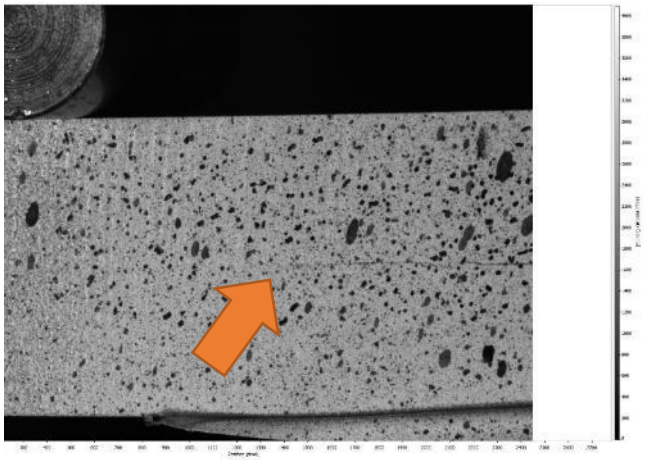


- DIC (digital image correlation) for crack propagation and crack-tip strain field recording for ENF, DCB, fatigue fracture tests





Examples of challenges



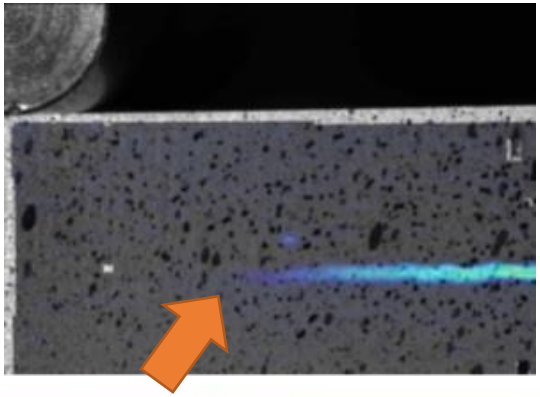
- Shear strain measurement for lap-shear testing (e.g. TALS) or mode II fracture toughness (ENF)

- Standard: specified sensor with a mechanism
- Academic means: DIC and resolved strain components

- ***Challenge:***

  No ‘final’ validation of DIC-derived shear strains

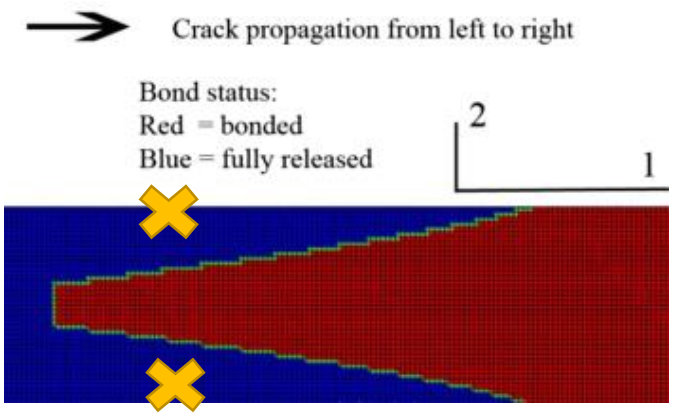
  - subset - glue line thickness dependency
  - virtual strain gauge definition not straightforward
  - single laboratory not enough for validation



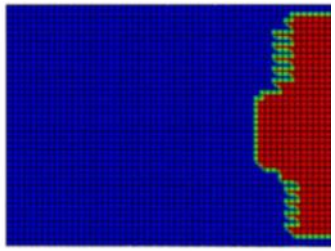
Examples of challenges

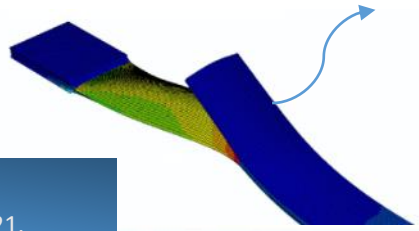
- CZM-involving crack models
- Standard: VCCT or onset-related G_c (or stress analysis)
- Academic means: traction-separation laws with >3 parameters
- ***Challenge:***
  No standard tests for CZM parameters not to mention authorization for combined methods

VCCT:



CZM-VCCT:





CLS-specimen

1. J. Jokinen, M. Kanerva, Appl Compos Mat 26 (2019), 709-721.

Current alignment of interchange of solutions

Publishable novelty

Academia

DIC, FEA

FEA, material (plasticity) models

VCCT, CZM,
combined methods

Special case studies

Fatigue *behavior*

Gap

Critical strains

Critical stresses

Fracture toughnesses

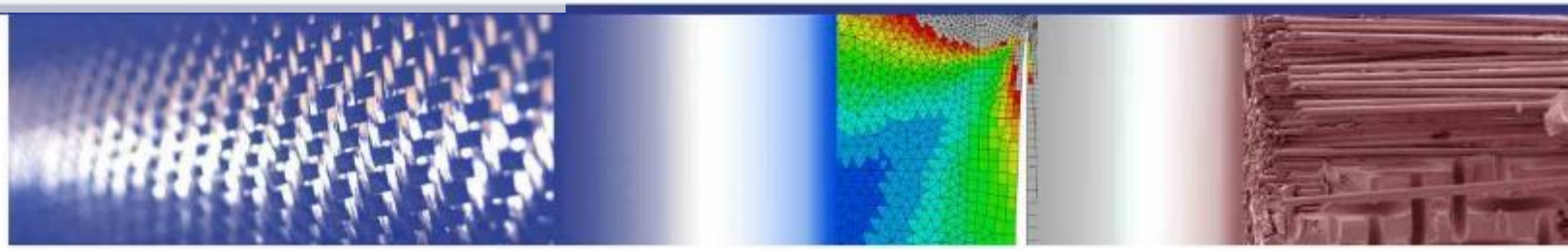
Environmental factors

Fatigue data, SN-curves

Authority

Industry

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



Examples of challenges: *solutions*

- Research centers (university branches)
- Public/self-standing 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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