Investigation of Interlaminar Fracture Mechanics of FRP using Digital Image Correlation

Dr.-Ing. Matthias Merzkirch
Guest Researcher, Postdoc, Matthias.Merzkirch@nist.gov
Lecture/Workshop @ KIT, April 23rd - 26th, 2019
Concept & Aims of Lecture/Workshop

• **Interdisciplinary lecture/workshop:**
  – 4 days: Tuesday through Friday
  – Theoretical and experimental parts, tutorials
  – Handouts in English will be provided (‘fill in the gaps’)
  – Presentation in German (or English, if preferred)

• **Theoretical parts:**
  – Computational material science and manufacturing as motivation (‘Why testing?’)
  – Background/mechanics of fracture experiments
  – Different types of experiments for fracture testing on prototypical UD composites
  – Design of experiments (‘Everything is of interest but what/how much data is actually needed?’)
  – Experimental setup (MTS and DIC)
  – Data analysis and reduction
  – Sensitivity analysis (‘3 x same type of test vs. 1 test with 3 different views?’)

• **Experimental parts and tutorial – knowledge transfer:**
  – Prototypical material: CFRP – UD and/or fiber reinforced material of interest
  – Design of experiments:
    • Selected types of experiments
    • Experimental setup (MTS and DIC)
  – Data analysis and reduction
  – Sensitivity analysis
  – Discussion of results

• **Aims:**
  1. Interdisciplinary view on experimental testing
  2. Challenges in mechanical fracture testing
  3. Data interpretation (sensitivity analysis)
Motivation & Outline of Lecture/Workshop

1. **Models** need ‘data’ for crash simulation!
   - How do models look like? What data is needed?

2. What is the appropriate **Experiment**?
   - What test method(s) provide the data needed?

3. Enhanced **Manufacturing** of complex composites
   - Restrictions/necessary improvements for the experiment?

UD: **Interlaminar Fracture Testing:** Mode I and Mode II

→ Full description for cohesive zone modeling via traction separation laws
Agenda 1-2

**Tuesday, 23.04. (5.5 h)**
- Introduction:
  - Matthias Merzkirch & NIST
  - Audience
- Motivation:
  - Automotive & aerospace
  - Lightweight aspect
  - Computational material science: Cohesive Zone Models & Traction Separation Laws
- Digital Image Correlation - A short introduction:
  - Patterning
  - Principle of 2D and stereo DIC
  - Calibration
  - Examples
- Recommended literature
- Discussion, design and planning of experiments:
  - Interdisciplinary needs and expectations

**Wednesday, 24.04. (5.5 h)**
- Fracture testing of fibrous composites: overview
- Crack Tip Tracing with DIC
- Mode I testing (double cantilever beam flexure):
  - Principle
  - Photomechanics
- Fracture toughness $G_I$ acc. to:
  - ASTM
  - DIN
  - ISO
  - Non-standardized methods
- Sensitivity analysis
- Restrictions and challenges
- Through thickness properties:
  - Photomechanics & analytical solutions for traction separation law
- Tutorial
Agenda 3-4

**Thursday, 25.04. (5.5 h)**
- Mechanics of flexural testing (3pt bending)
  - Shear stress and shear deformation
- Mode II testing (3pt end-notched flexure):
  - Principle
  - Photomechanics
- Fracture toughness $G_{II}$ acc. to:
  - ASTM & DIN
  - Non-standardized methods
- Mode II testing (calibrated end-loaded split flexure):
  - Principle
  - Photomechanics
  - Fracture toughness $G_{II}$
- Comparison types of tests
- Restrictions and challenges
- Photomechanics - Traction separation law
- Tutorial

**Friday, 26.04. (4.5 h)**
- Discussion of results on fracture properties:
  - Mixed Mode behavior
  - Cohesive Zone Model & Traction Separation Laws
- Comparison of Young’s Moduli:
  - $E_T$ From tensile test
  - Flexural testing
    - 3 pt
    - 4 pt
    - Double cantilever
    - End loaded split test (single cantilever)
- Exam (1 h):
  - ECTS: 2
- Evaluation