Virtual Parameter Determination for Damage Tolerance Analyses of Composite Structures

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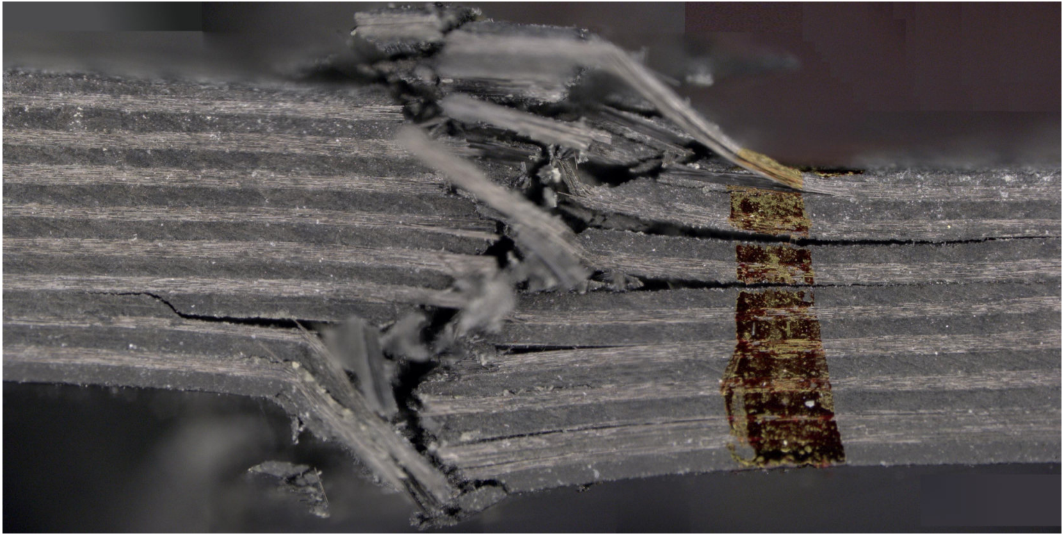
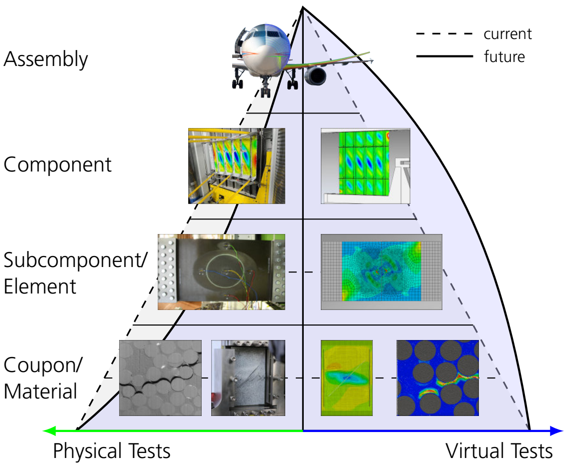
DLR



Challenges

- Task: Safe structures
  - Sizing complex structures
  - According regulations
- Goals:
  - Time-cost-risk reduction
  - Test determination & assessment
- By simulative prediction
- Requirement: Capture relevant phenomena
- Approach: Building Block



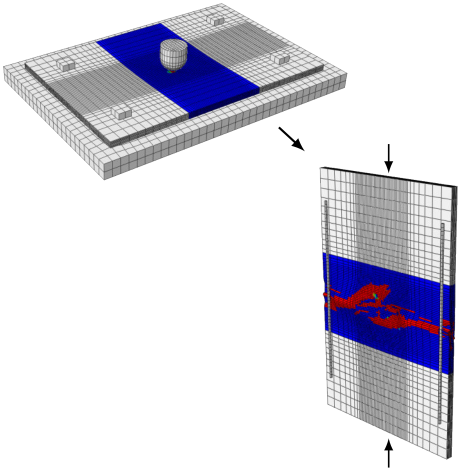
From phenomenon via modelling to simulation

- Sequence:
  - Test program
  - Understand phenomon
  - Enable modeling
- Fitness for new
  - Material
  - Production technology
  - Topology
  - ...
- Modeling still valid?

> . . . the quality of a model is largely a function of its fitness for purpose.
>
> *A. Saltelli*

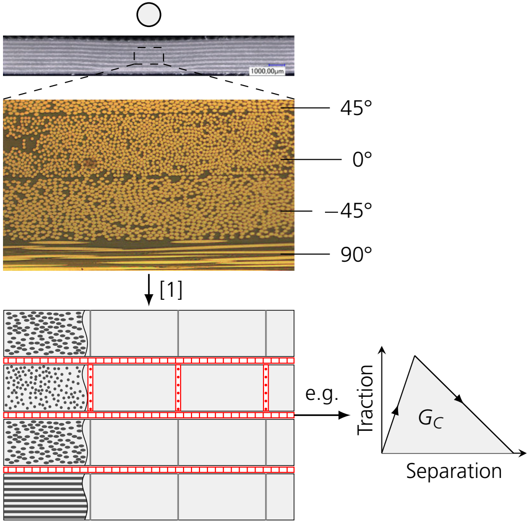
From phenomenon via modelling to simulation

- Example: FEM
  Residual strength determination
- Configuration:
  - Monolithic CFRP
  - Compression after impact
- Phases:
  - Impact
  - Compression damaged specimen
  - Comparison of strengths
- Aspects:
  - Stiffness
  - Damage
  - Stability



From phenomenon via modelling to simulation

- Closer look
- Damage phenomena
  - Fibre damage
  - Inter-fibre damage
  - Delamination
- Modeling
  - Discretization
  - Damage models:
    - interlaminar
    - intralaminar
  - E.g. cohesive zone models
- Valid for different configuration?
- Why needed?

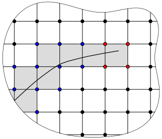


Damage - part of the problem or part of the solution?

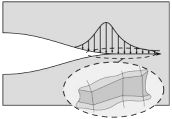
- FEM, deformation **u**:
  - Can be very accurate & numerically efficiently
  - For undamaged domains
  - Assumptions?
  - ↯: Not fulfilled @ discontinuities, e.g. cracks
- Extensions:
  - XFEM, CZM, contact laws,. . .
  - Teach FEM reproduction phenomena
  - Treat symptoms

Continuum mechanics (CM) & FEM

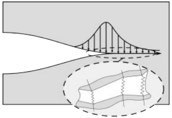
- Assumptions [2]:
  - Continuous medium ↯
  - **u** 2x continuously differentiable ↯
  - Conservation equations satisfied
  - ...
- Momentum conservation: $\mathrm{div}(\boldsymbol{\sigma}) + \mathbf{b} = \rho\ddot{\mathbf{u}}$



XFEM



CZM



Contact

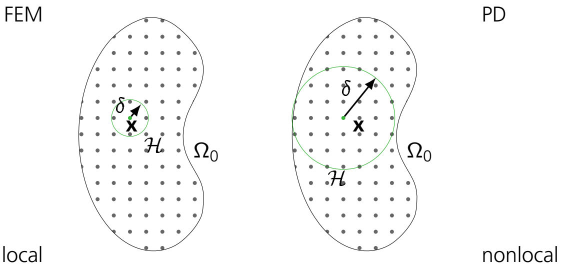
Damage - part of the problem or part of the solution?

- More universal method?
- Peridynamics
  - Integral formulation
  - Nonlocal
  - Cracks part of integration domain
  - CM special case of PD
  - Meshfree discretization
  - Peridigm [3]
  - Own extensions

Peridynamics (PD)

- Assumption: Conservation equations satisfied
- Momentum conservation:

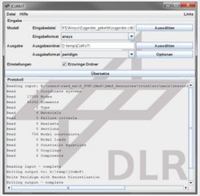
$$\int_{\delta} \left(\underline{\mathbf{T}}(\mathbf{x}, t)\langle \mathbf{q} - \mathbf{x}\rangle - \underline{\mathbf{T}}(\mathbf{q}, t)\langle \mathbf{x} - \mathbf{q}\rangle\right) \mathrm{d}V_{\mathbf{q}} + \mathbf{b} = \rho \ddot{\mathbf{u}}$$

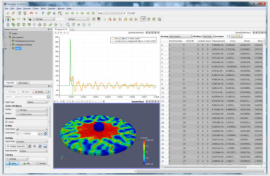


Simulation of phenomena with less modeling

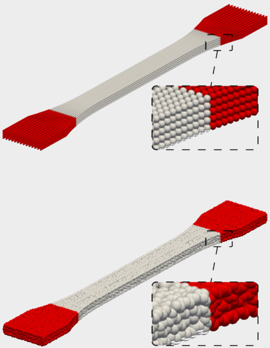
Critical evaluation of peridynamics

Pre- & Postprocessing

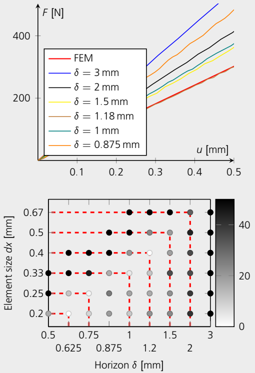




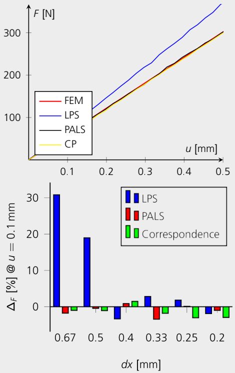
Discretization



Convergence [4]



Formulations [5]

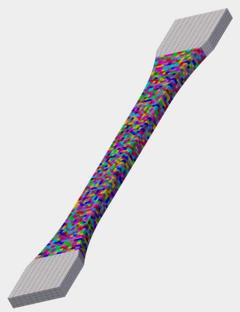


Simulation of phenomena with less modeling

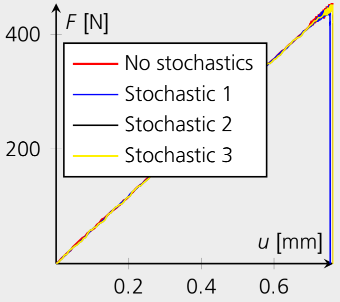
Bottom-up

- Stiffness, Damage & Robustness

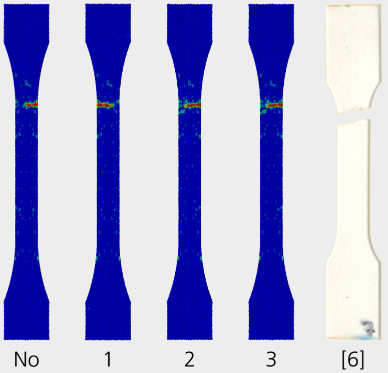
Base FE model



Force-Displacement



Failure patterns

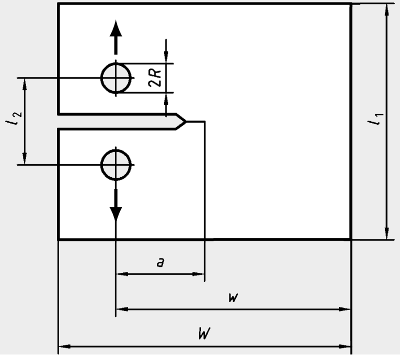


Simulation of phenomena with less modeling

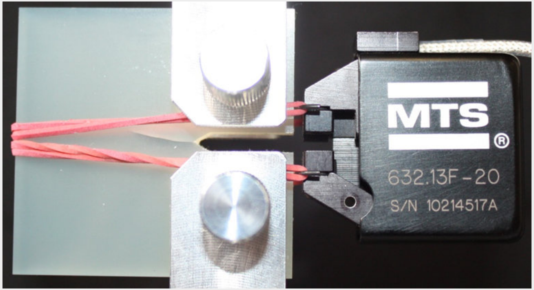
Bottom-up

- Determination G_C: CT specimen

ISO 13586:2000(E) [7]



Experiment

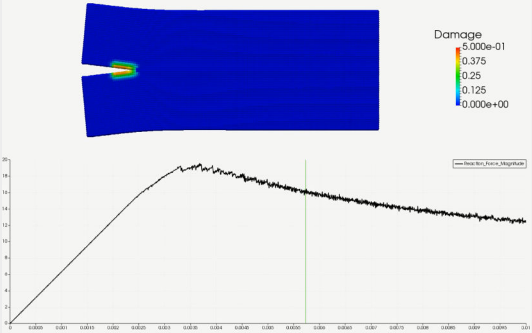


Simulation of phenomena with less modeling

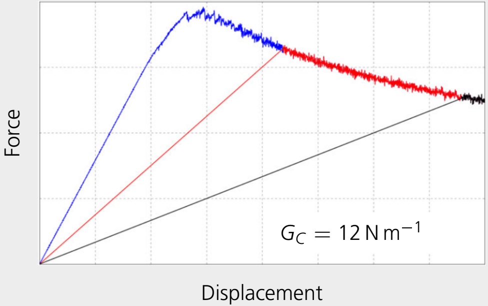
Bottom-up

- Determination G_C: CT specimen

Crack tip



Results

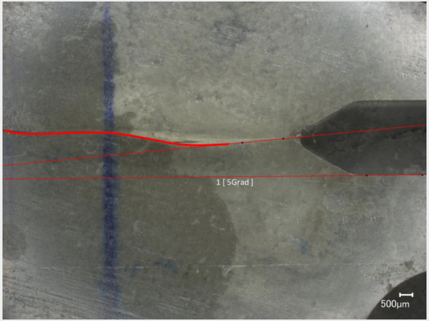


Simulation of phenomena with less modeling

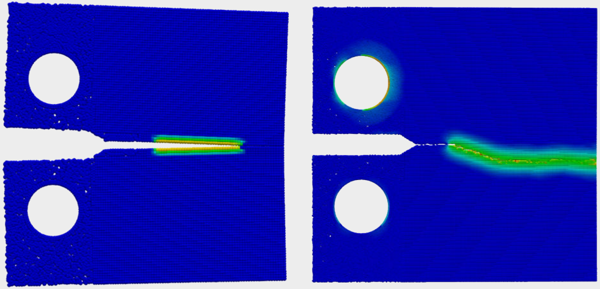
Bottom-up

- Determination G_C: CT specimen

Imperfections



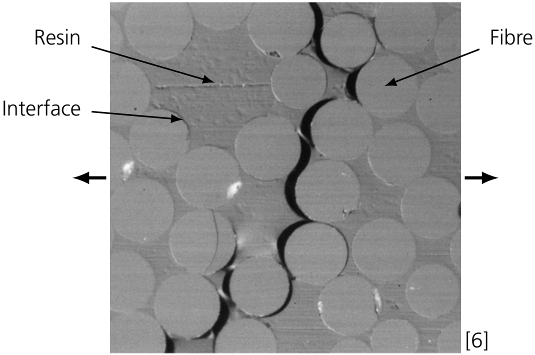
Results



Simulation of phenomena with less modeling

Complex problem

- Comparison modeling approaches damage for comparable significance
- [8]

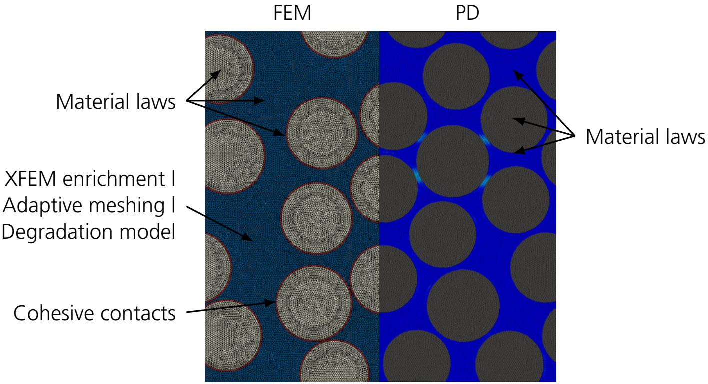


[6]

Simulation of phenomena with less modeling

Complex problem

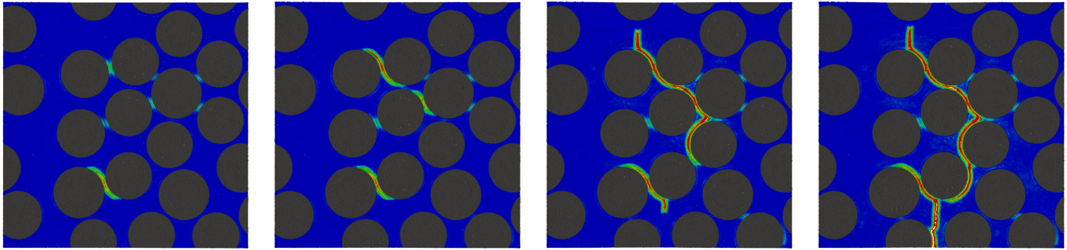
- Comparison modeling approaches damage for comparable significance
- [8]



Simulation of phenomena with less modeling

Complex problem

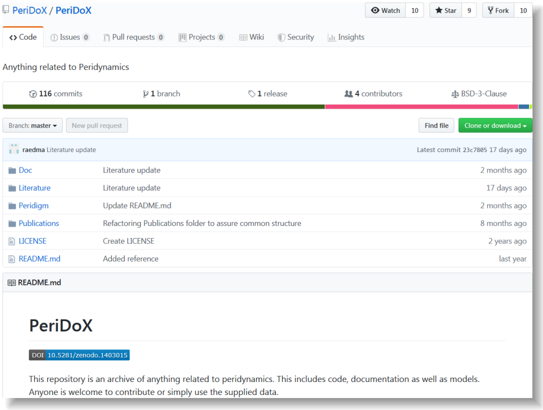
- Comparison modeling approaches damage for comparable significance
- [8], Peridynamic solution



- Reproduction physical phenomena, without additional modeling
- Damage can be part of the solution!

Conclusion & Outlook

- Conclusion
  - More physics, less modeling
  - Enhanced verification of simulation-based modeling with FEM
  - Potential simulative predictions extended range applications
- Outlook & research topics
  - Further quantitative validation
  - FE-PD coupling
- Cross-verification amongst partners, e.g. @ LSU, USA, Feb. 2020



https://github.com/PeriDoX/PeriDoX

Thank you for your attention.

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