Nonlinear and Impact Analyses of Composite Structures via Unified Formulation

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POLITECNICO DI TORINO

MUL2

Overview

AIM: Development of high-fidelity component-wise models based on advanced structural theories to improve the prediction capabilities of finite elements in impact analyses of composites

- ❑ Implementation of a global-local framework for computationally efficient analyses, and coupling of the MUL^2 code with commercial software
- ❑ Inclusion of nonlinear and multiscale capabilities, and implementation of damage modelling
- ❑ Development of explicit methods for nonlinear dynamics
- ❑ Implementation of contact algorithms in CUF
- ❑ Numerical assessments considering strain rate effects

Methodology – Carrera Unified Formulation

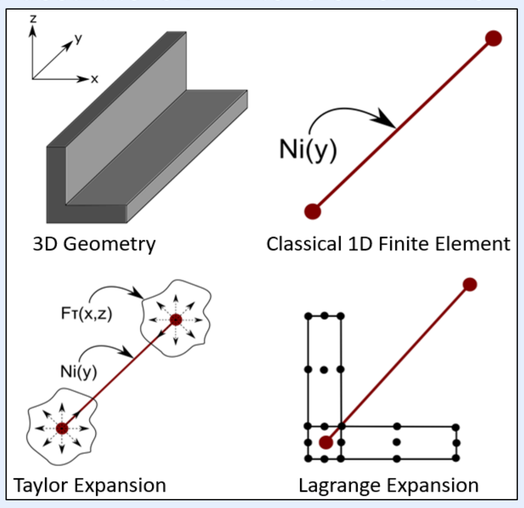
- ❑ A hierarchical formulation to generate refined structural theories through variable kinematic description

$$\boldsymbol{u}(x,y,z) = \boldsymbol{N}_i(y)\, F_\tau(x,z)\, \boldsymbol{u}_{\tau i}$$

- ❑ CUF 1D models are able to generate accurate 3D finite element like solution at reduced computational cost

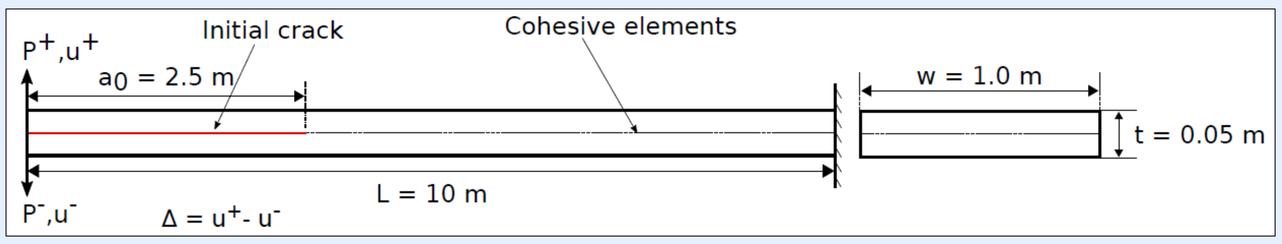
Capabilities of CUF:

- ❑ Component-Wise Analysis
- ❑ Implicit Non-Linear Framework
- ❑ Parallel Multiscale Framework
- ❑ Explicit Nonlinear Dynamics
- ❑ Contact Mechanics
- ❑ Explicit damage modelling



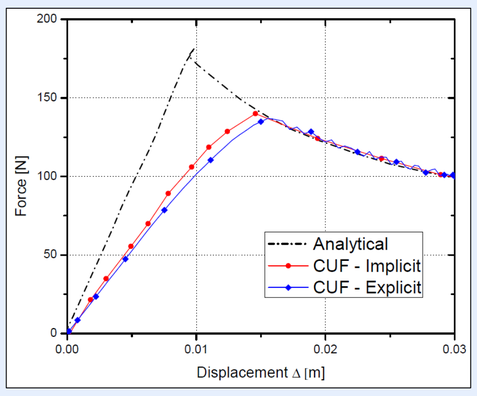
Refined 1D CUF models

Interface modelling - Delamination



Double cantilever beam test

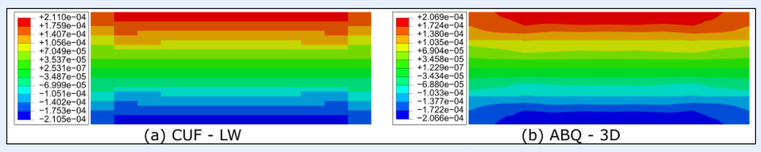
- ❑ Cohesive behaviour defined through mixed-mode traction-separation law
- ❑ Use of 2D-CUF models with 1D thickness expansion functions



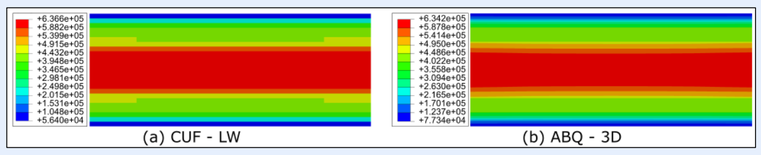
Force-displacement curve

Static and dynamic contact/impact analysis in CUF

- ❑ Static contact via a node-to-node discretisation
- ❑ Contact enforcement through the penalty approach
- ❑ **Newton-Raphson** method used for implicit analysis



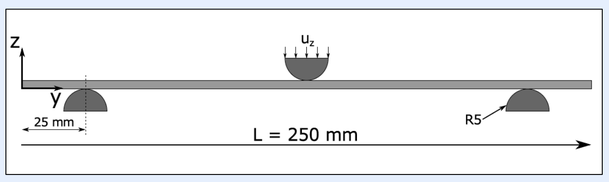
Transverse strain ε_{zz}



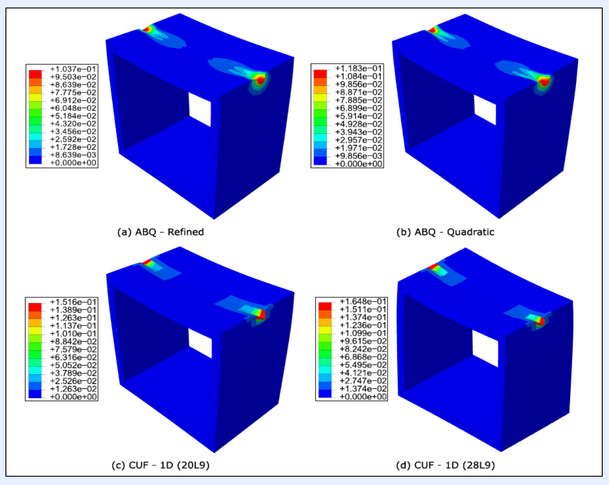
Transverse stress σ_{yz}

Bending test on a $[0/90]_{2s}$ composite beam

11x reduction in DOF
4x reduction in total wall time

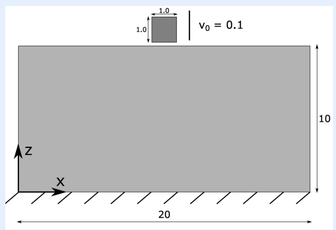


3-point bending test in CUF

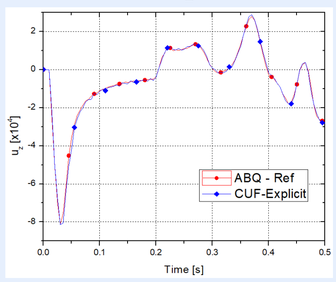


Elastoplastic contact analysis of a square tube

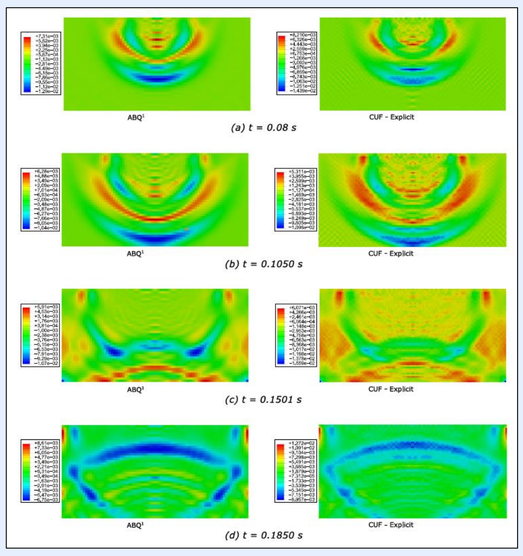
- ❑ Dynamic contact via a node-to-surface discretisation
- ❑ Contact enforcement using Lagrange multipliers
- ❑ **Explicit time integration** for transient analysis



2-D impact



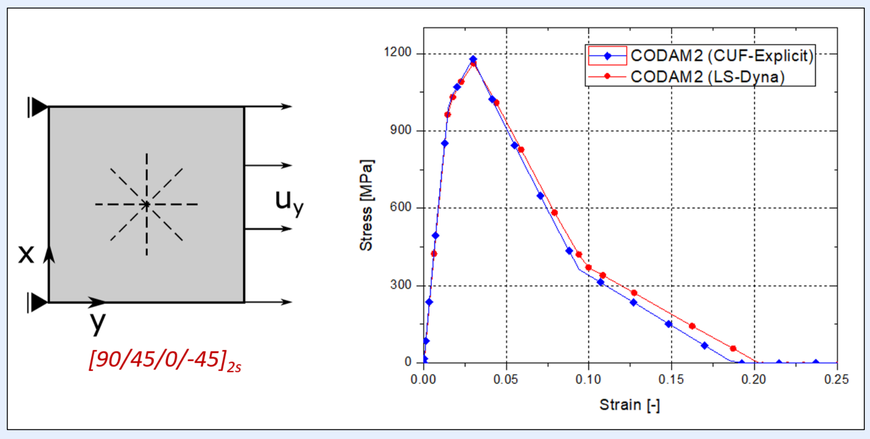
Vertical displacement u_z



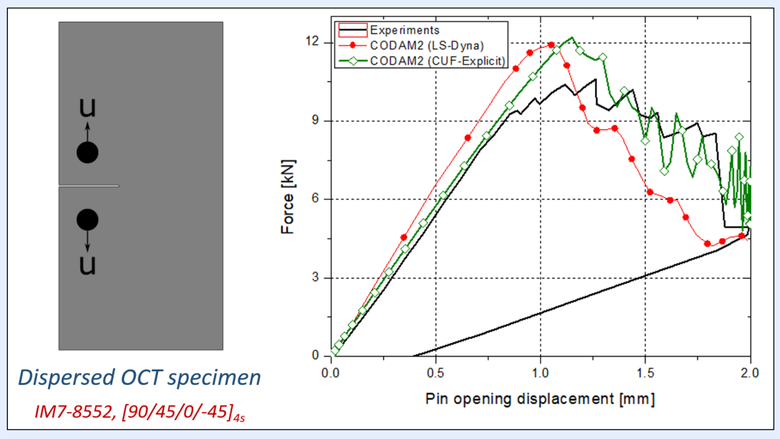
Stress wave propagation through target block

Explicit damage modelling with CODAM2 intralaminar damage model

- ❑ Implementation of the CODAM2 intralaminar damage model in CUF-Explicit
- ❑ Ply-level continuum damage model
- ❑ Stress-based failure initiation criteria with crack-band approach to scale fracture energy



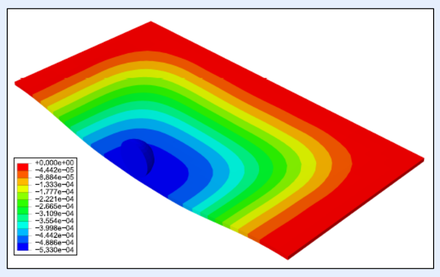
Single element laminate under tension



Compact Tension test of a dispersed-ply laminate

Current and Future Perspectives

- ❑ Implementation of surface-based contact models for a better description of contact interactions
- ❑ Further development of damage model to include compression
- ❑ Extension of CUF to impact analysis of composite structures



Sphere-plate impact

Publications

[1] M. Petrolo, **M.H. Nagaraj**, I. Kaleel, and E. Carrera, A global-local approach for the elastoplastic analysis of compact and thin-walled structures via refined models, Computers & Structures 206 (2018) 54-65
[2] A.G. de Miguel, I. Kaleel, **M.H. Nagaraj**, A. Pagani, M. Petrolo, and E. Carrera, Accurate evaluation of failure indices of composite layered structures via various FE models, Composites Science and Technology 167 (2018) 174-189
[3] E. Carrera, G. A. Fiordilino, **M. H. Nagaraj**, A. Pagani, & M. Montemurro, A global/local approach based on CUF for the accurate and efficient analysis of metallic and composite structures, Engineering Structures 188 (2019) 188-201

Acknowledgment

This research work has been carried out within the project **ICONIC** (Improving the crashworthiness of composite transportation structures), funded by the European Union Horizon 2020 Research and Innovation program under the Marie Sklodowska-Curie grant agreement No.721256.

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