International Research Training Group IRTG 2657
Computational Mechanics Techniques in High Dimensions

Efficient Computational Analysis of Composite Joints Through Machine Learning Assisted Abstract Modelling Techniques

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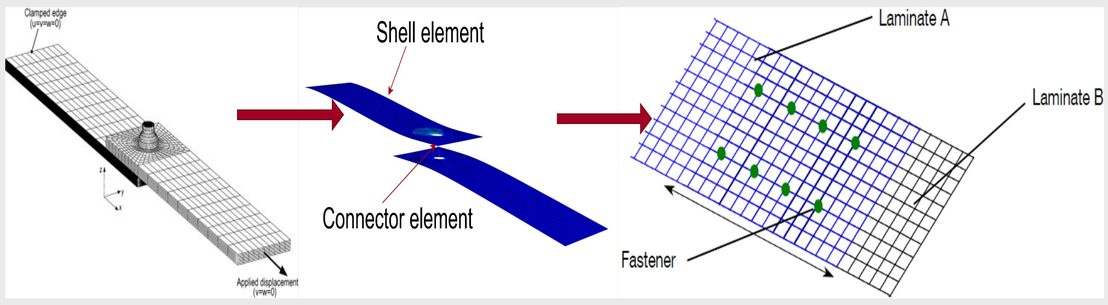
Second Cohort – Starting date: 01.09.2024

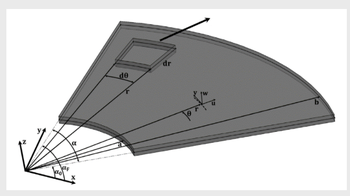
Background

- High fidelity simulation of composite joints is computationally expensive owing to nonlinearities.
- As a result, simulation of large structures containing fields of bolts is not possible.
- Abstract models make it possible to quickly simulate the far field response of composite joints but they cannot capture all the nonlinearities.



Results

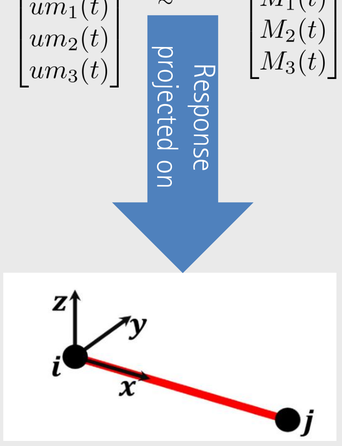
- **Method to extend the Beam spider:**



Subject to loading conditions

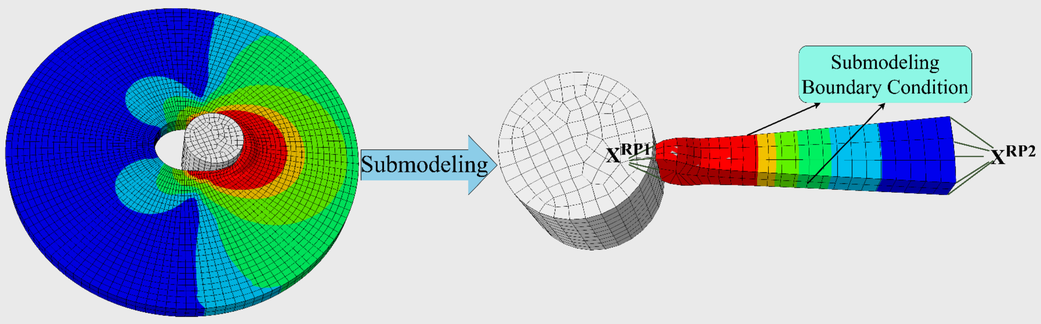
$$\underset{\sim}{u}(t) = \begin{bmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \\ um_1(t) \\ um_2(t) \\ um_3(t) \end{bmatrix} \quad \underset{\sim}{F}(t) = \begin{bmatrix} F_1(t) \\ F_2(t) \\ F_3(t) \\ M_1(t) \\ M_2(t) \\ M_3(t) \end{bmatrix}$$

Response projected on



- Discretize the annular disc into wedges and apply loading conditions.
- Capture the nonlinear behavior of the wedge.
- Train a neural network with this data
- Couple the neural network with a 2-node user element
- Create beam spider with these elements.

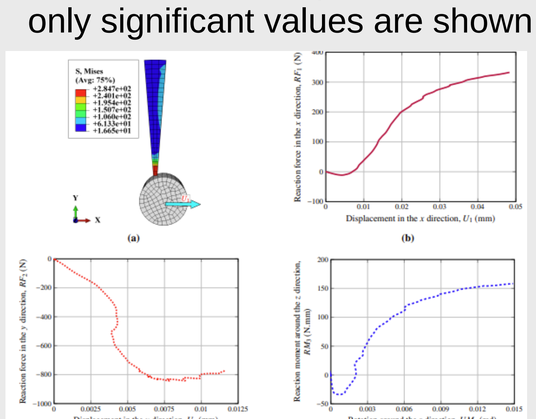
- **Method to extract data from the wedges:**



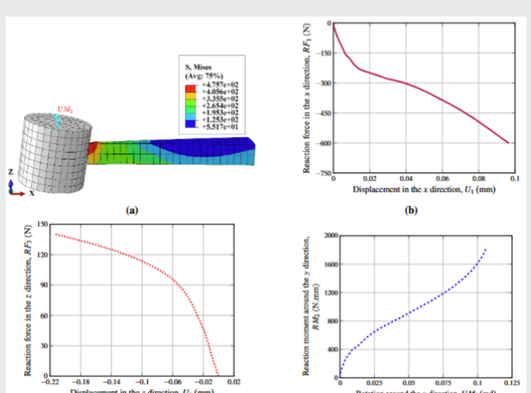
- Formulate the BVP for the annular disc with encastered outer edge, isotropic elasto-plastic material, and displacement loading on the rigid bolt.
- Create and solve a wedge submodel BVP and Extract displacement and reaction force at reference points 1 and 2, connected to the outer and inner curved surfaces via kinematic coupling.

- **Example wedge response :**

Reaction force-displacement curves for a wedges. Curve's with only significant values are shown



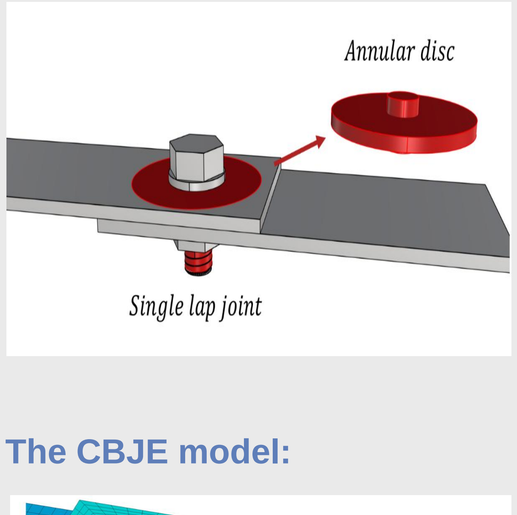
Bolt subjected to displacement loading condition along x-axis.



Bolt subjected to in plane rotation along y-axis.

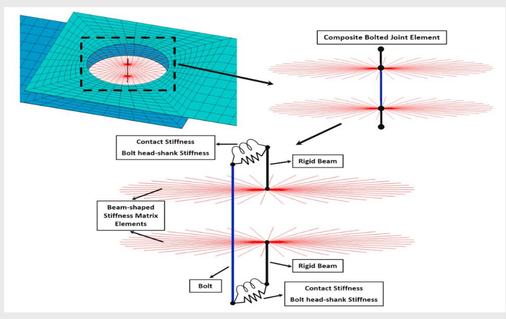
Methodology

- **Basic Idea:**



- All the non-linearities are present only in the Annular disc region.
- Capturing this behavior accurately in an abstract model will ensure accurate and fast simulation.

- **The CBJE model:**



- The Composite bolted joint element was developed by Belardi et. Al. 2019.
- The CBJE model will be extended by –

- **Extending CBJE model:**

1. Incorporating ML-assisted beam spider that can simulate large strains and material non-linearity.
2. Recalibrating rheological elements for large strains.
3. Recalibrating the beam for finite rotations in bolt.

Outlook

Isotropic beam spider for large strain and plasticity

Anisotropic beam spider

X.CBJE model

Application of X.CBJE model to large structure

IRTG Environment and Activities

- Student supervision :- 1 Master thesis
- Student assistants :- 2 Hiwis
- Experimental Campaign :- Modified Arcan fixture
- Public relations for institute (ISD)
- Planned stay ENS Paris-Saclay: October 2026-March2027

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