University of BRISTOL

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Modeling of 3D woven fabrics for deformation and defect generation

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ACCIS

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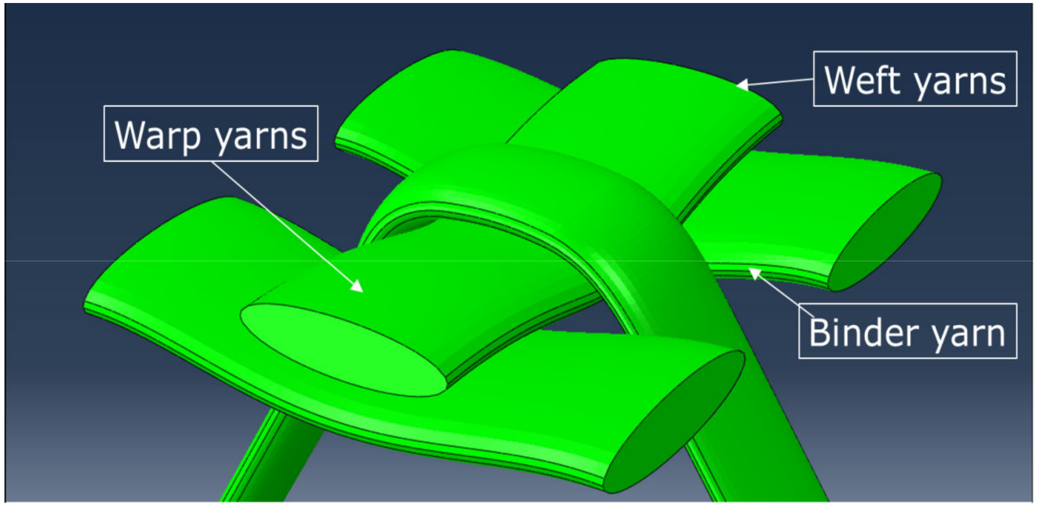
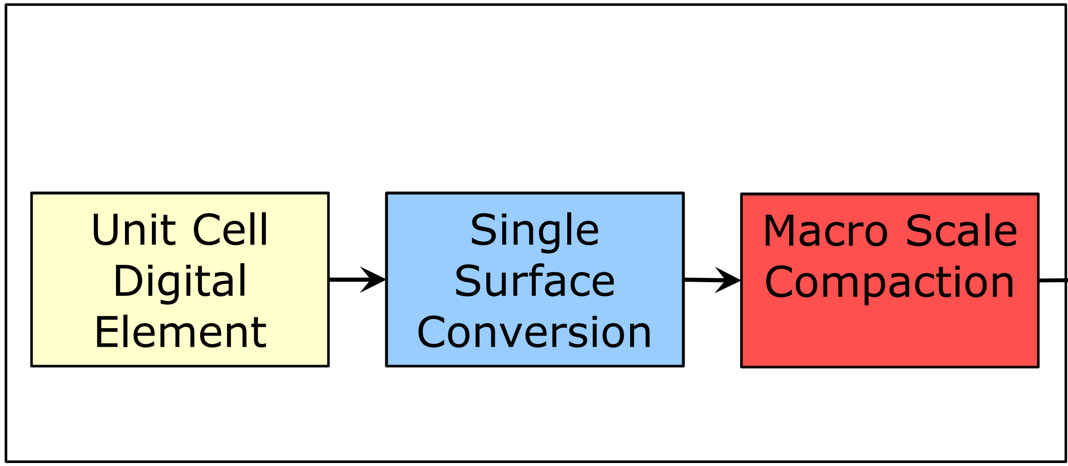
Multiscale modelling of 3D woven materials

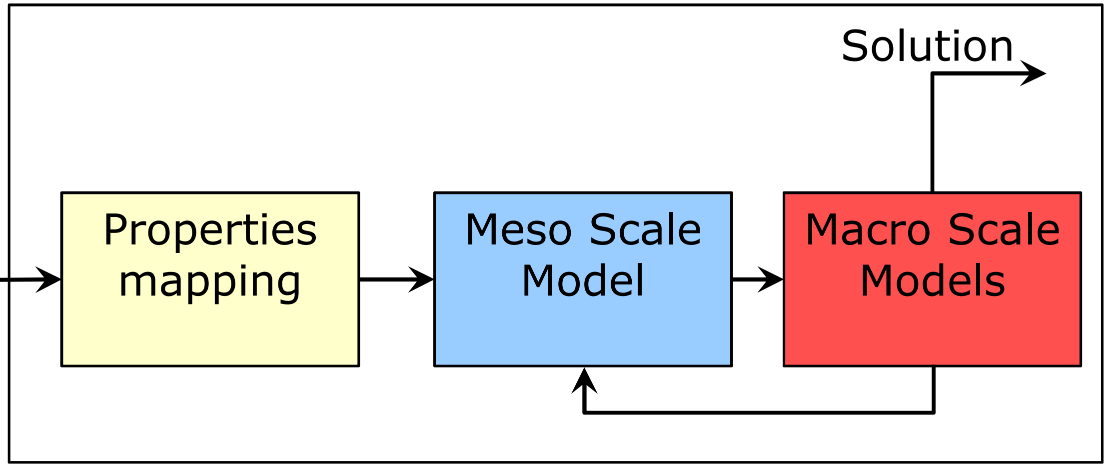
- An integrated modelling framework capable of *predicting 3D woven fabric deformation* during weaving and compaction.
- *Two modelling phases* are needed mechanical and kinematic. For both phases, a multiscale modelling approach is adopted for accuracy and computational efficiency.



Kinematic Modelling

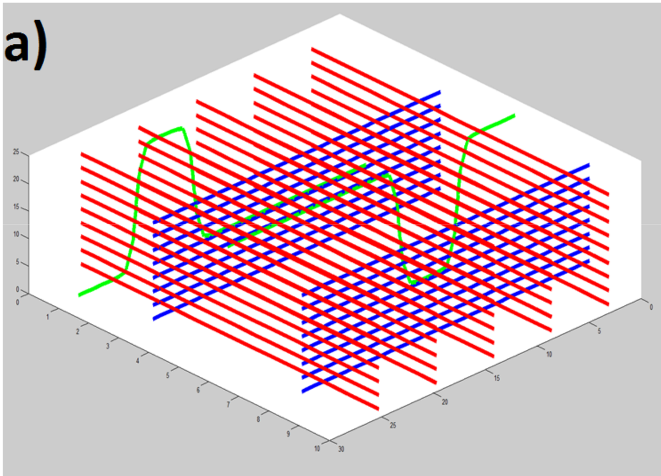


Mechanical Modelling

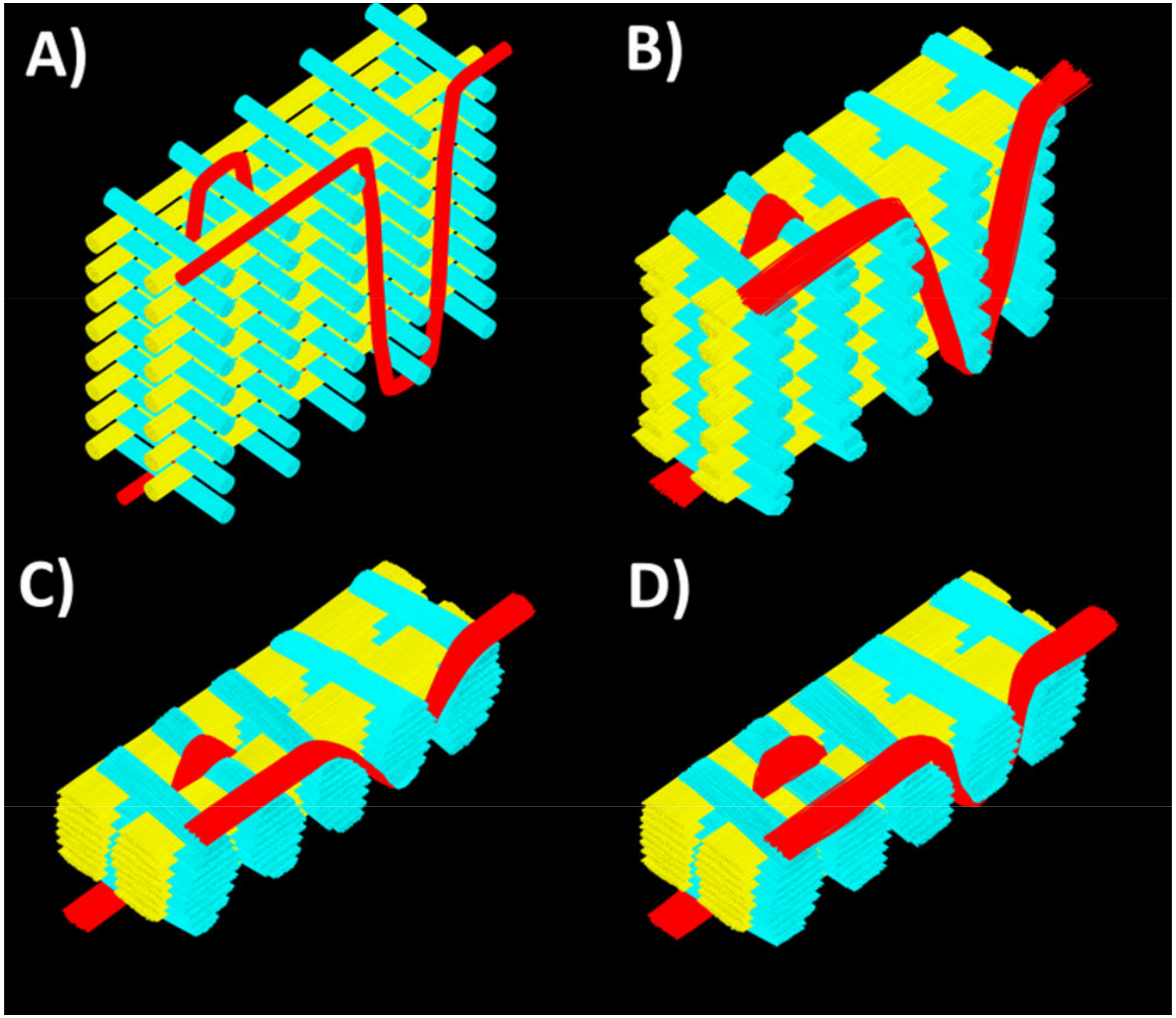


Unit cell as-woven geometry

- An initial *unit cell loose geometry* is built based on the fabric architecture and the number of fibres per yarn.
- Thermal load is applied to the bundles of beam elements to simulate the weaving process

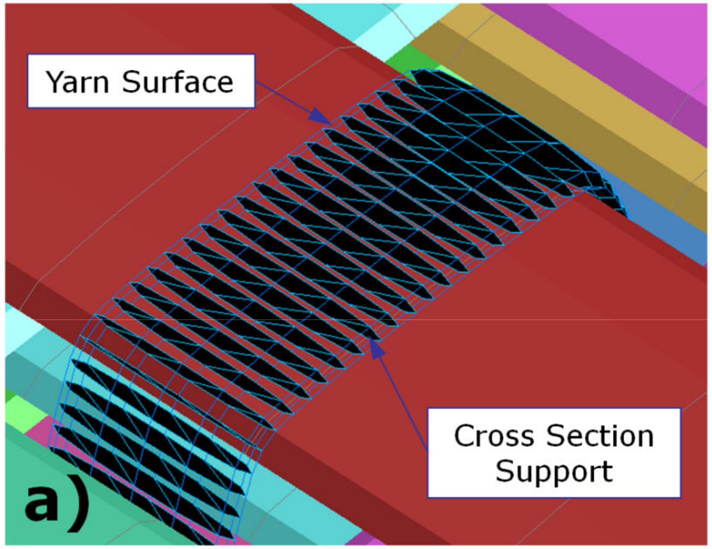


Initial yarn paths

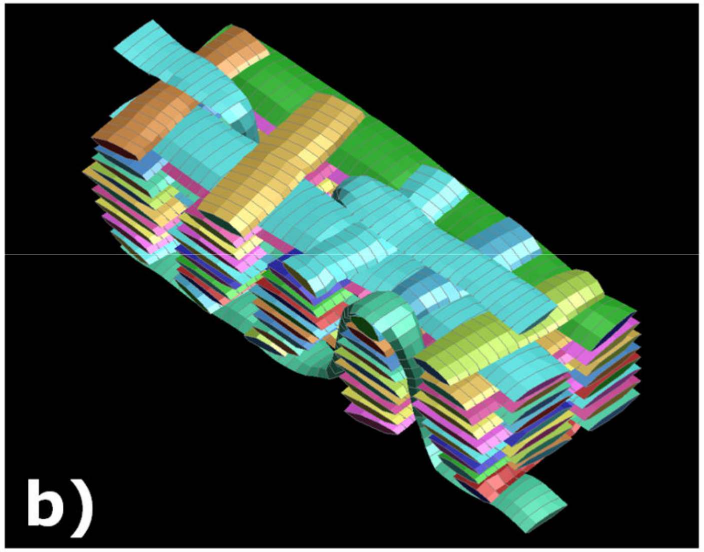


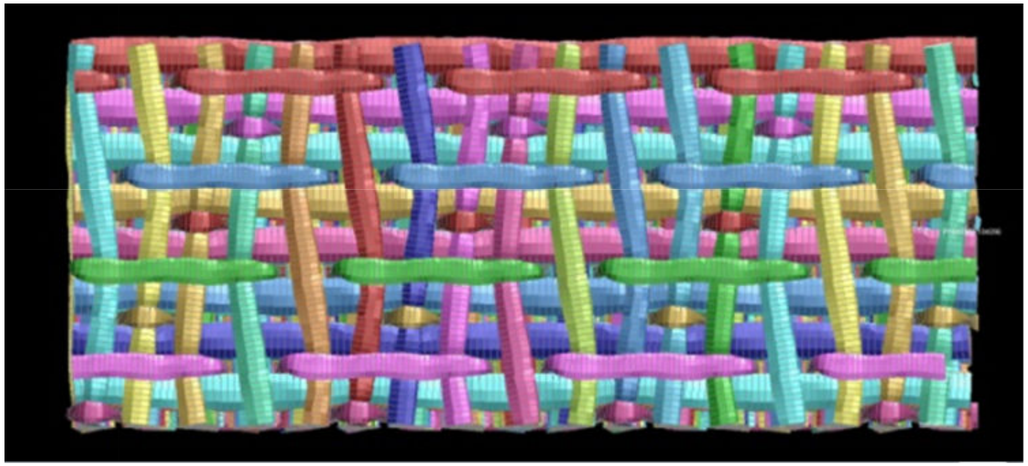
Weaving Simulation

Macro scale kinematic models



- For this length scale a yarn is represented by a single continues contact surface.
- To prevent the excessive cross section deformation viscolelastic cross-section supports are used.
- The viscoelastic support material properties are selected to have shear dominated deformation.
- The unit cell model is converted to a full scale model using tessellation.





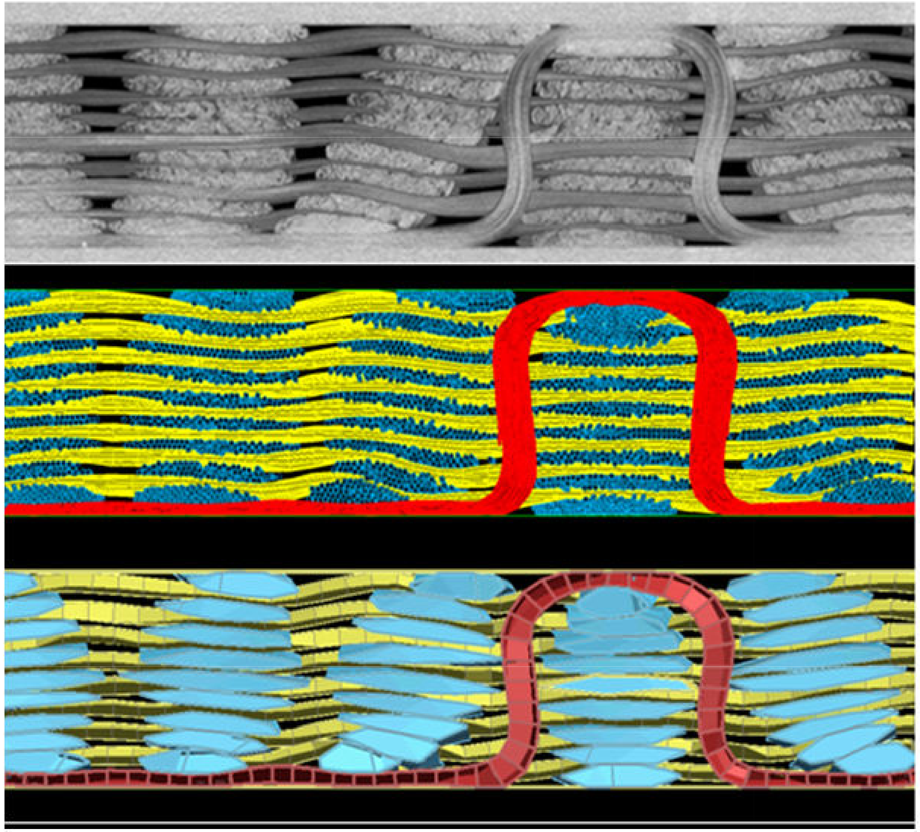
Unit Cell Example

Experiment CT Scan

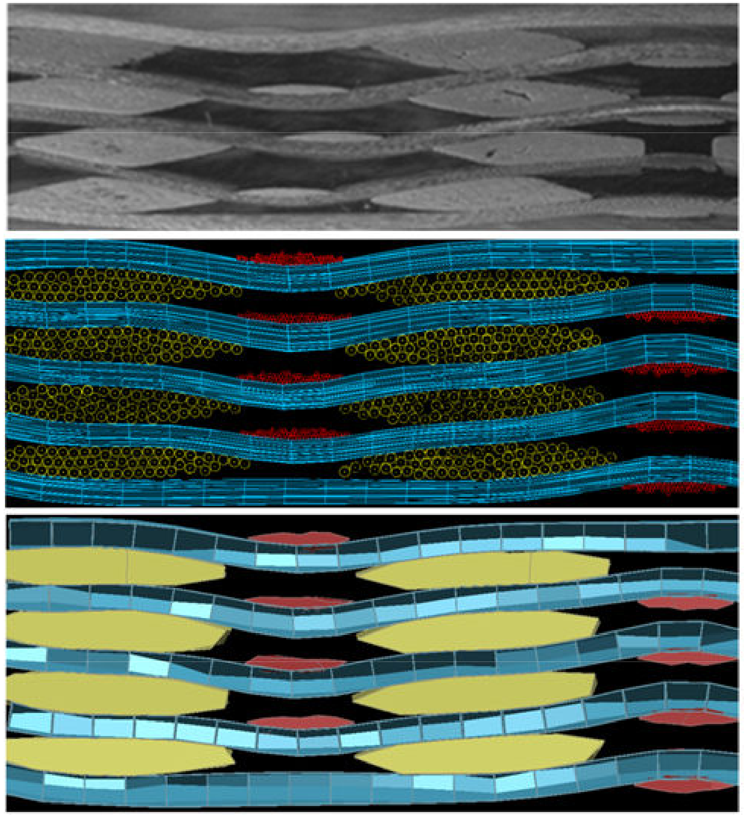
Digital element

Proposed model

Orthogonal fabric

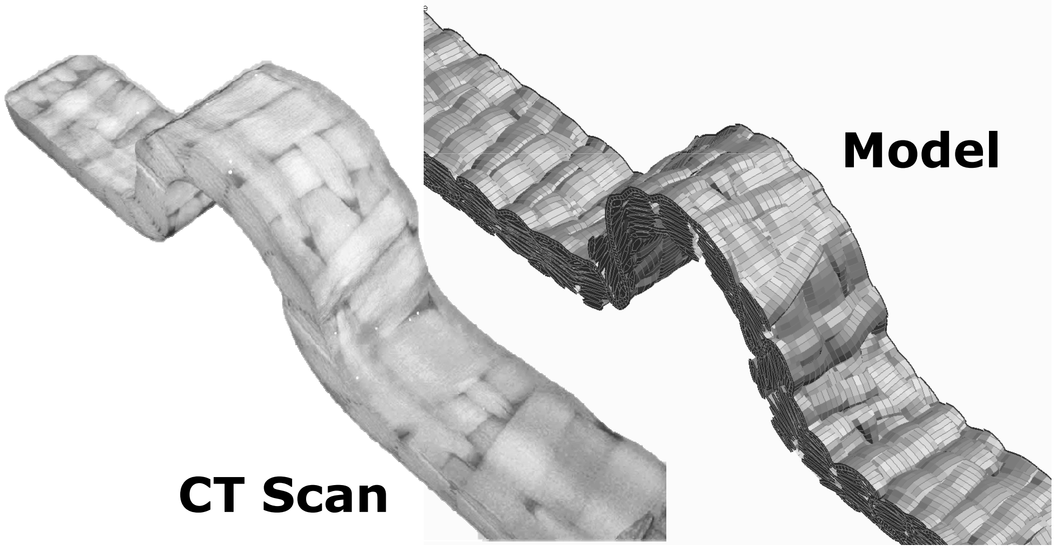


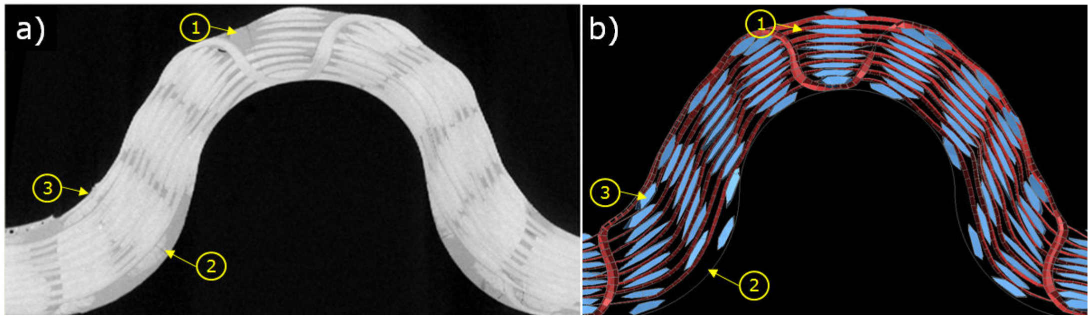
Layer to layer interlock fabric



Macro scale kinematic models

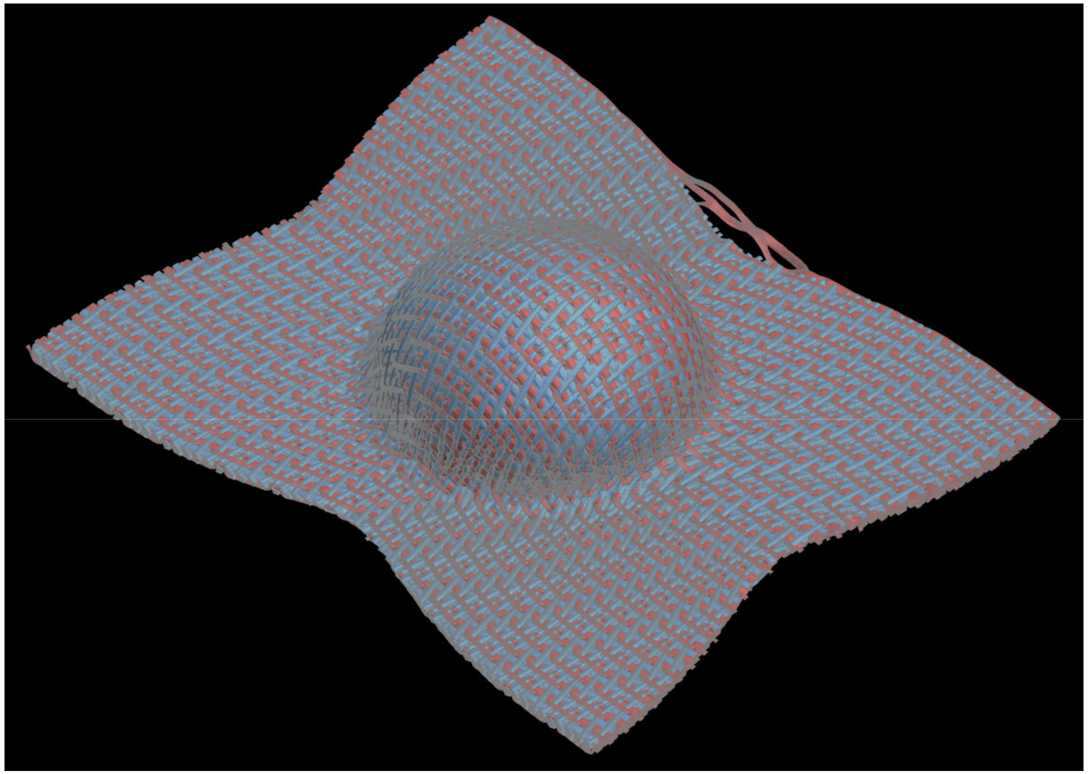
Feature Scale Models





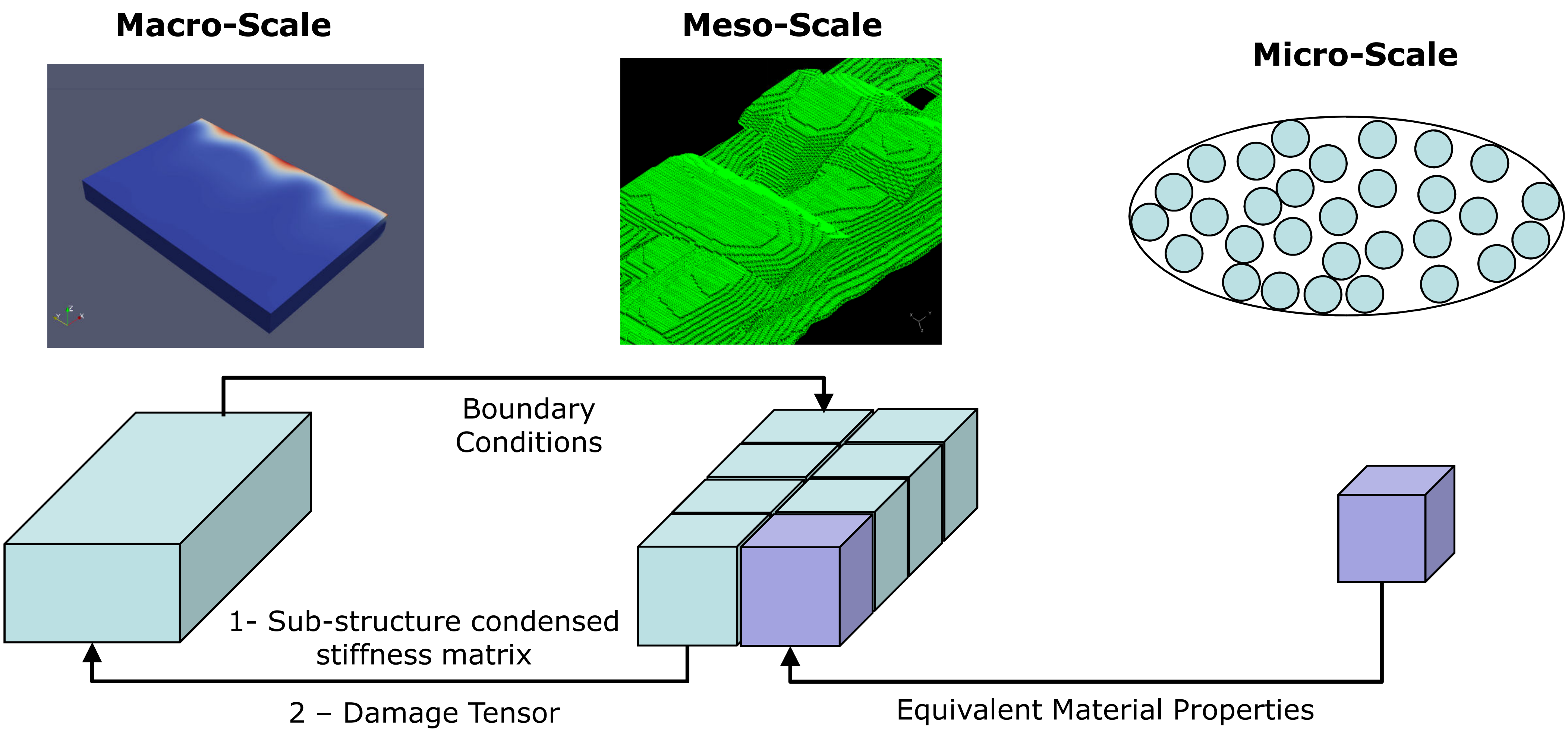
- Full scale fabric models can be built using tessellation based on unit cell geometries from the previous stage.
- These models can be used to simulate macro scale compactions on rigid or flexible tool

Full Scale Models



Multi-scale Mechanical Modelling

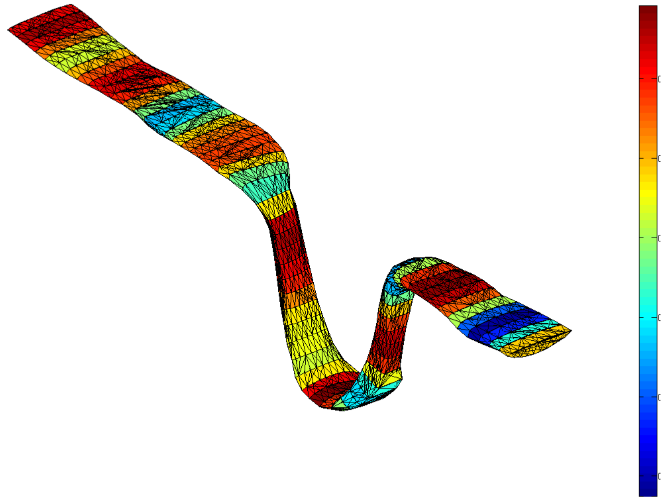
The proposed multi-scale mechanical modelling framework:



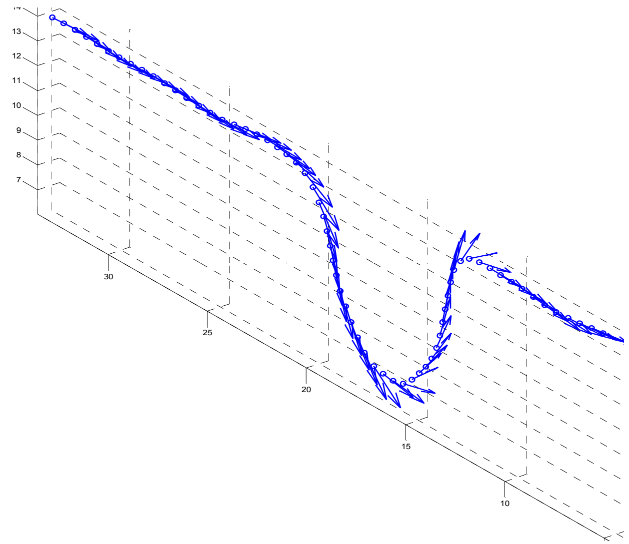
Meso Scale Mechanical Models

- Material properties such as intra-yarn volume fraction and material axis are extracted from the kinematic models.
- Using triangulation each integration point in a Voxel mesh is assigned properties.
- These models can accurately capture the behavior of 3D and 2D multilayer woven materials

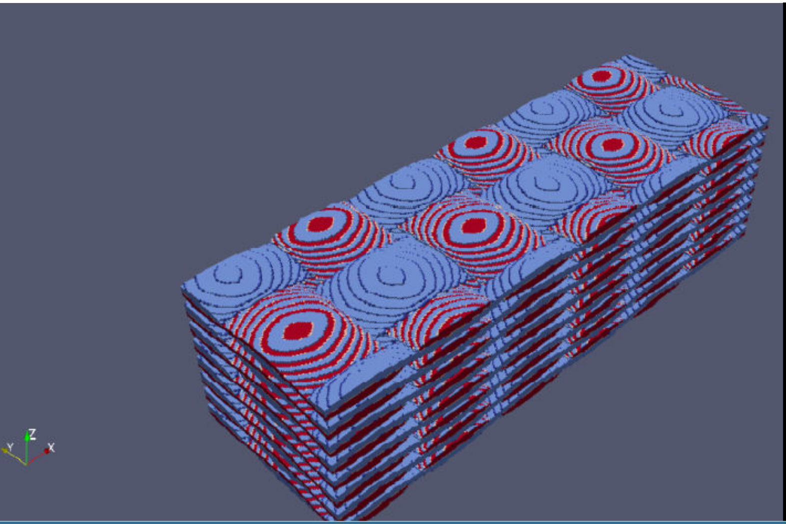
Intra-yarn Vf



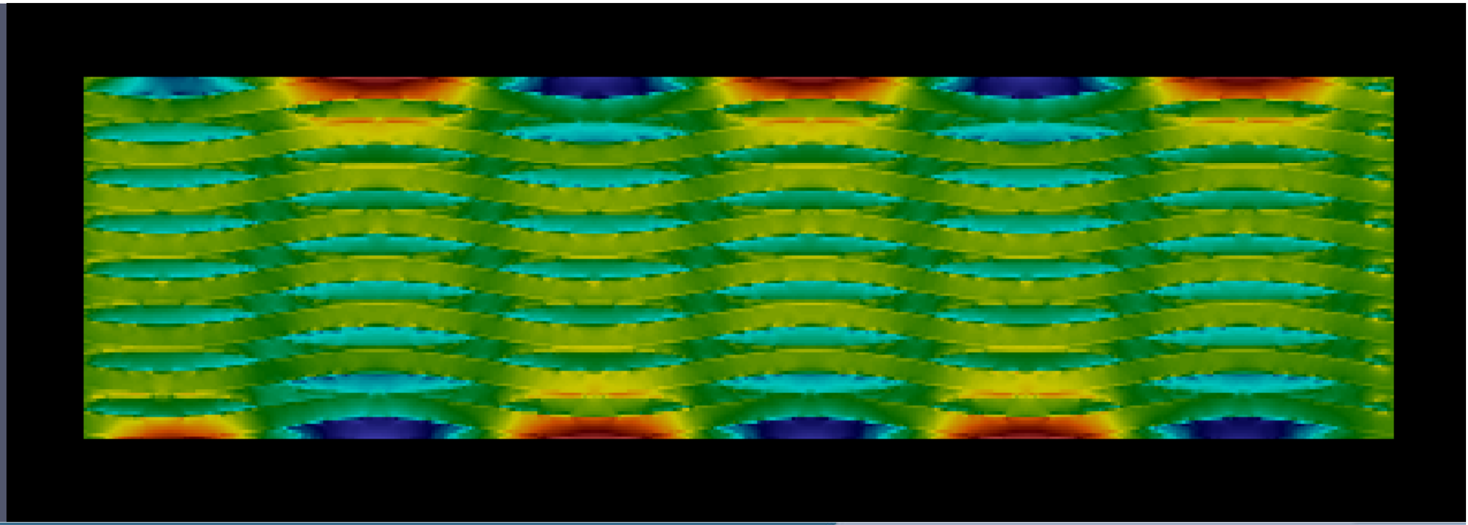
Material Axis



Material Mapping

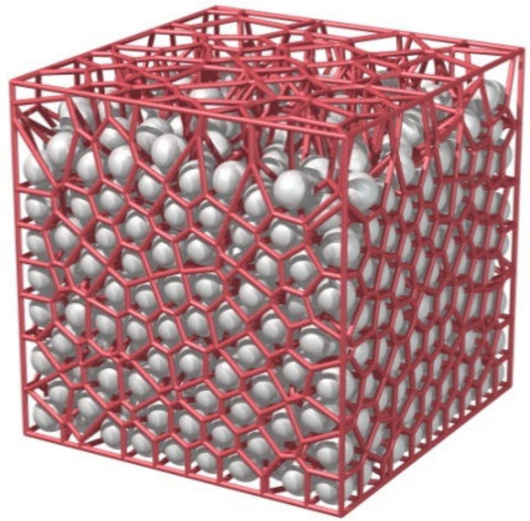


Stress Distribution in Fibre direction , 24 million DoF

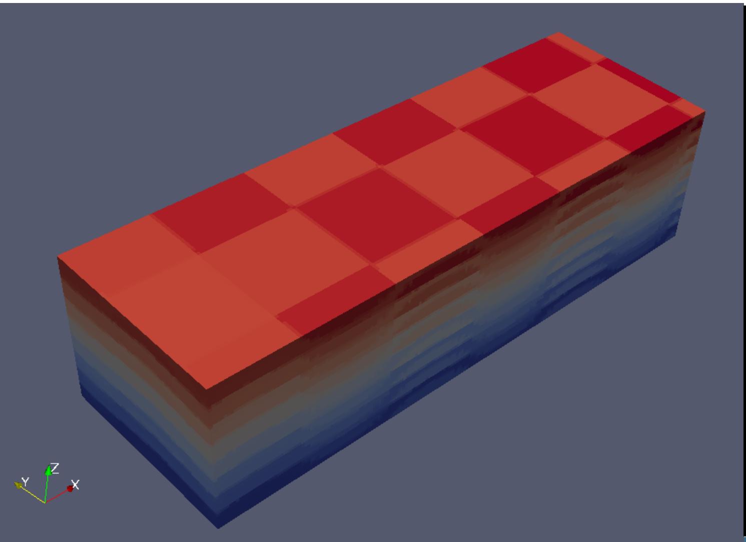


Macro Scale Mechanical Models

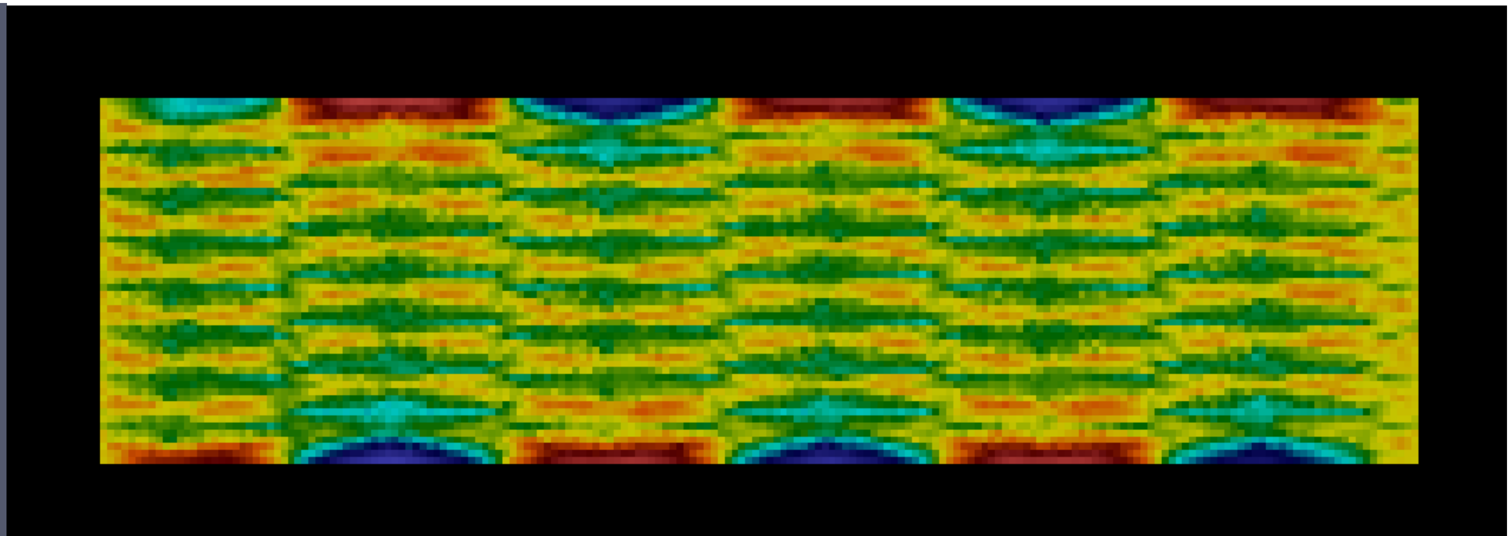
- A computationally efficient modelling approach is needed for macro-scale mechanical models.
- Voronoi tessellation is used to divided the 3D woven material into cells. Each cell is assigned a fabric geometry point.
- Volume averaging of material properties is carried for each cell.
- A low fidelity model is then built using the Voronoi cells.



Material Mapping



Stress Distribution in Fibre direction ,1.98 million DoF



The way forward:

- Develop a Lagrangian multipliers based multi-scale modeling technique which integrates both the macro/meso in a single multi-scale model.
- Introduce progressive damage modelling capabilities to the meso-scale models.
- Conduct a set of experiments to verify the completed 3D woven modelling framework.

Acknowledgment:

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Questions ?