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MoAM Research Group
Loughborough University

Developing 3D Fully Parametric Multi-Scale Computational Model for Nonwoven Simulations

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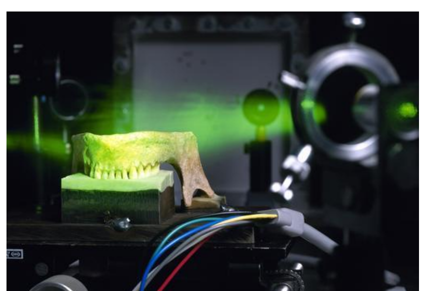
Outline

- Loughborough University
- Motivation
- Existing Numerical Models
- Our Contribution
- Material Characterization
- Computation of Material Anisotropy
- Developing 3D Fully Parametric Model
- Case Studies
- Conclusions

Loughborough University

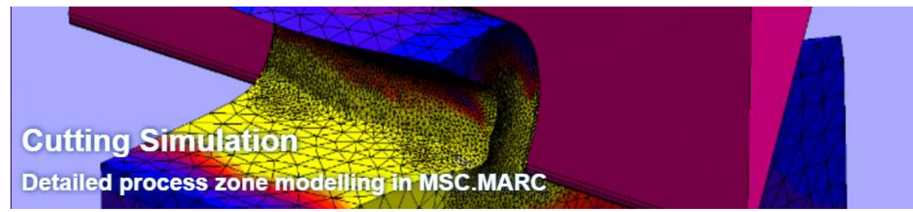
- Ranked 6^{th} in the 2018 Guardian University League Table.
- Winner of the Times Higher Education 'Best Student Experience' poll for five years running
- Ranked joint 1^{st} for 'Overall Satisfaction' National Student Survey (NSS) in 2017
- Awarded 'Best International Students Union of the Year 2014'
  National Union of Students (NUS)
  - *Mechanically Based Engineering = 3^{rd} (2008 and 2009)*



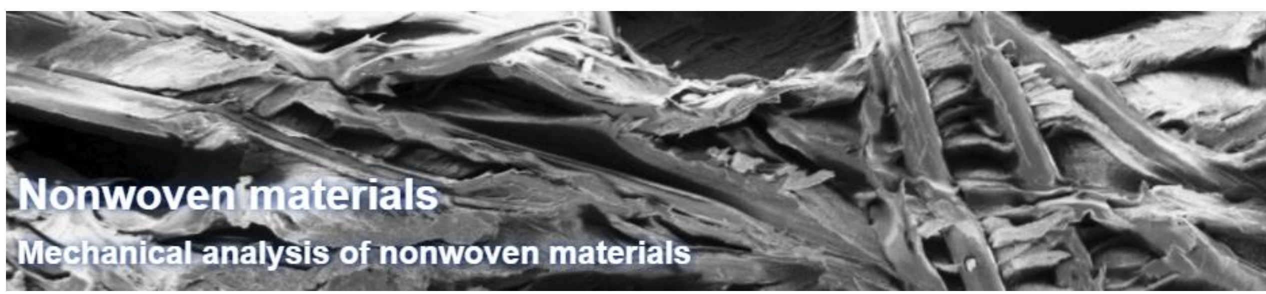
Mechanics of Advanced Materials Research Group (MOAM)

MoAM Research Group
Loughborough University

The Mechanics of Advanced Materials Research Group carries out multi-disciplinary research into the response of advanced engineering materials to various types of external loading and environmental conditions, using a combination of analytical, numerical and experimental techniques.



- More than 35+ publications on Nonwovens



Mechanics of Advanced Materials Research Group (MOAM)

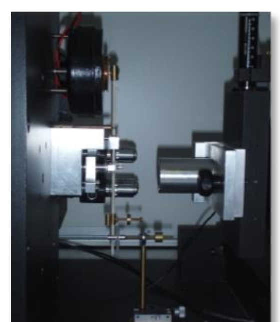
MSC Software

ABAQUS

MATLAB
The Language of Technical Computing
The MathWorks Inc.

Some of the Testing Facilities

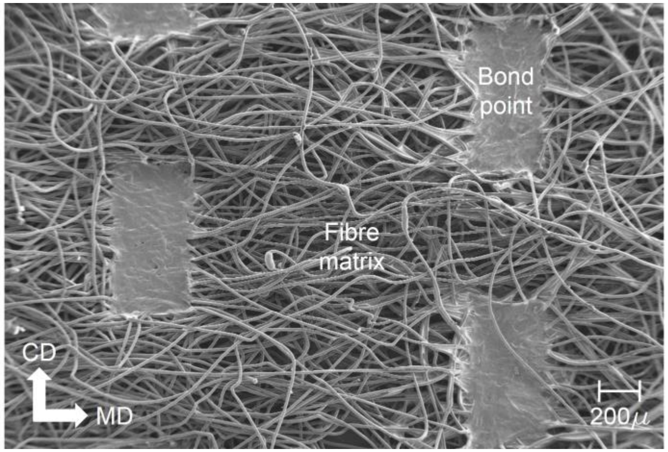
- Two servo-hydraulic machines up to 100 kN
- Impact fatigue testing system (based on CEAST RESIL IMPACTOR)
- Instron desktop machines up to 50 kN
- Instron Micro Tester 5848
- Thermosensorik GmbH Thermoelastic Stress Analysis system
- Atomic Force Microscope
- X-ray micro CT system
- Nano/Micro indenter
- Dynamic Mechanical Analyser TRITEC2000B
- Q-Sun XenonTest Chamber



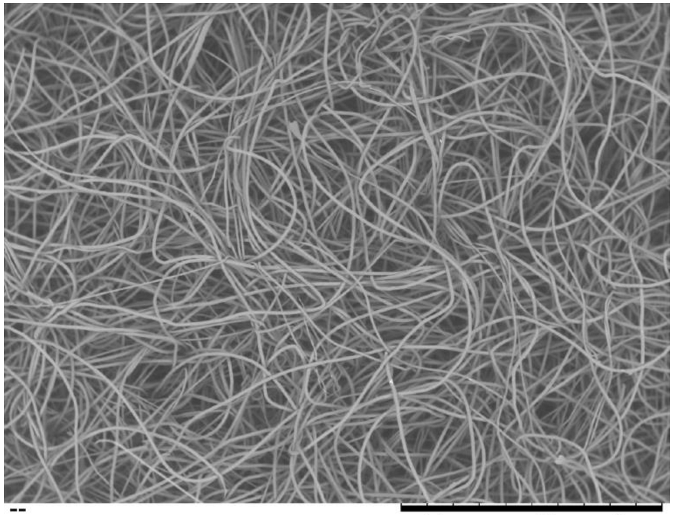
Motivation

Nonwoven Composites; Objectives and Deliverables

- Overall Objectives
  - Develop a multi-scale parametric numerical models to simulate mechanical and flow performance of nonwovens
- Overall Deliverables
  - Better understanding of micro-scale through-thickness mechanical behaviour of nonwovens
  - Simulating damage mechanisms
  - Parametric computational model for simulating compression performance and its effects
  - A clear methodology to design nonwovens considering mechanical performances before manufacturing to save time and cost



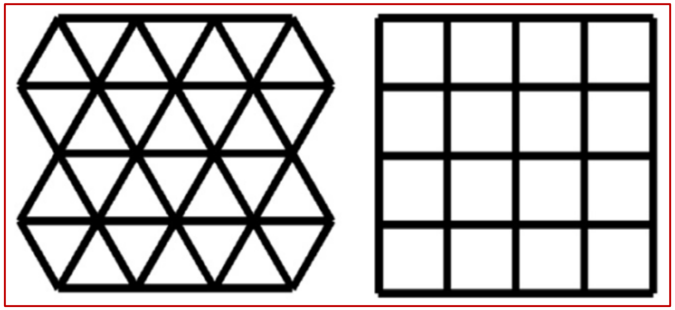
30gsm Point-bonded nonwoven



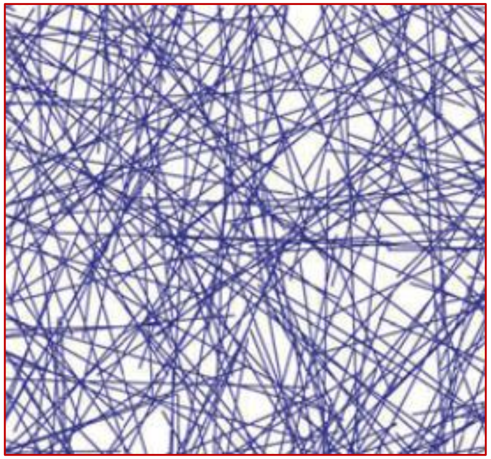
200gsm through air bonded nonwoven

Existing Numerical Models

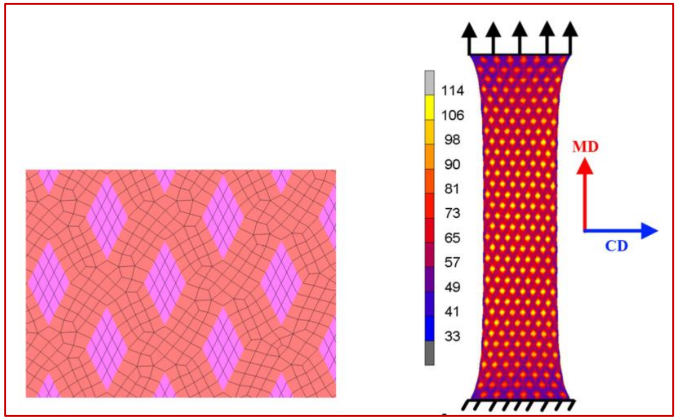
Quasi-continuum Models



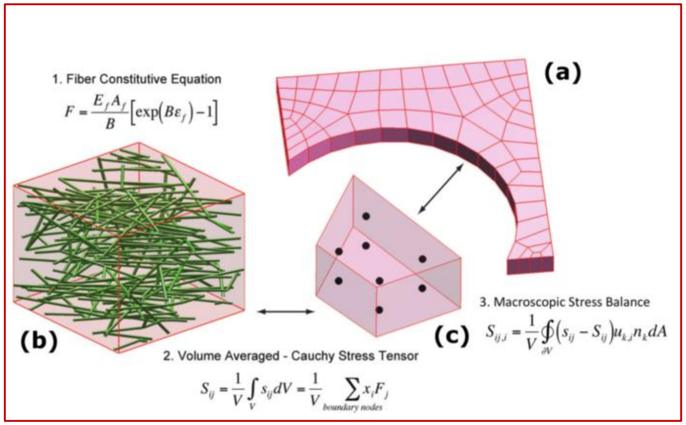
Discontinuous Models



Continuous Models



Hybrid Models



Ostoja-Starzewski, M., 2002. Lattice models in micromechanics. *Applied Mechanics Reviews*, 55(1), p.35.

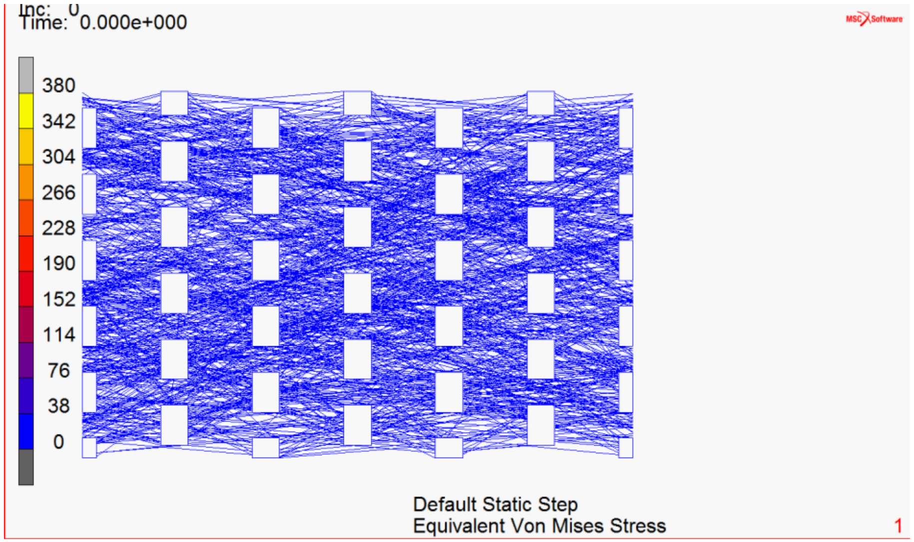
Ridruejo, A., Gonzlez, C. & Llorca, J., 2010. Damage micromechanisms and notch sensitivity of glass-fiber non-woven felts: An experimental and numerical study. *Journal of the Mechanics and Physics of Solids*, 58(10), pp.1628–1645.

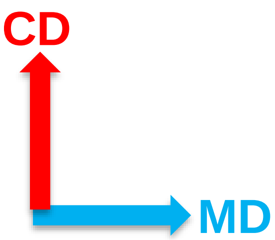
Demirci, E. et al., 2012. Numerical Modelling of Thermally Bonded Nonwovens: Continuous and Discontinuous Approaches. *Solid State Phenomena*, 188, pp.164–169.

Sander, E.A. et al., 2009. Image-based multiscale modeling predicts tissue-level and network-level fiber reorganization in stretched cell-compacted collagen gels.

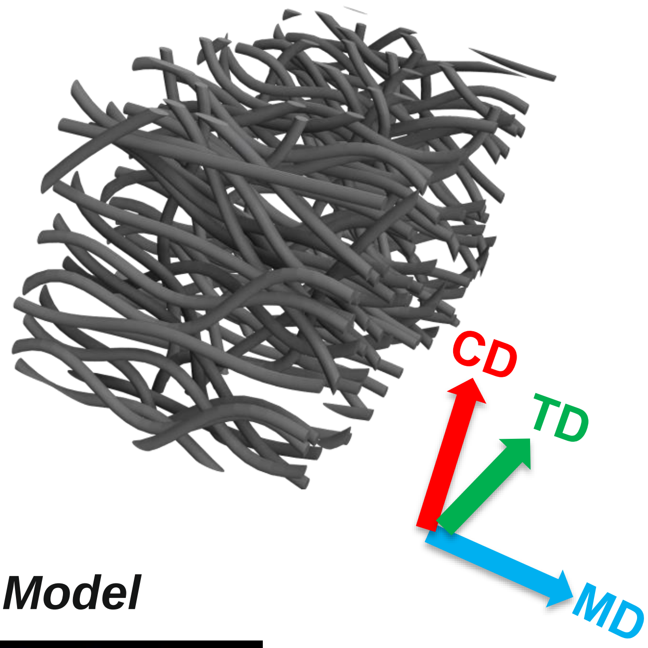
Our Contribution

Discontinuous Parametric Model

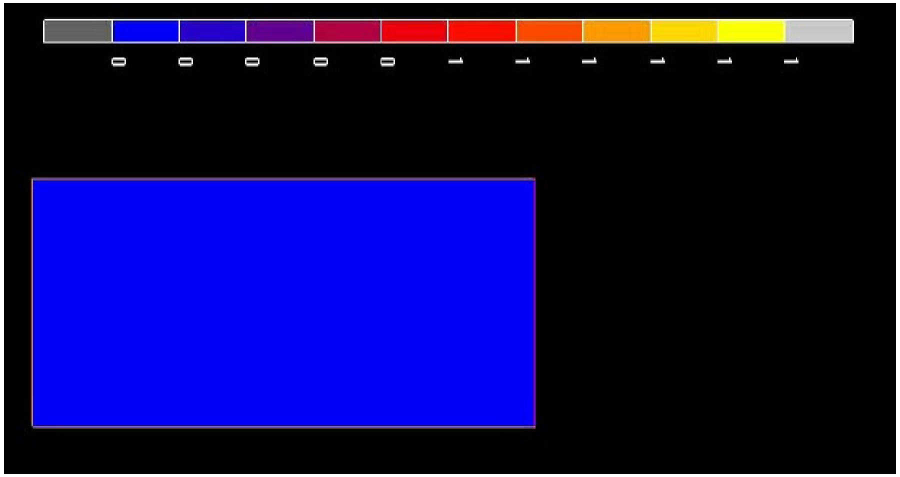


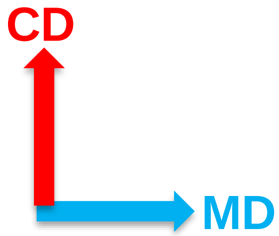


3D Parametric Model



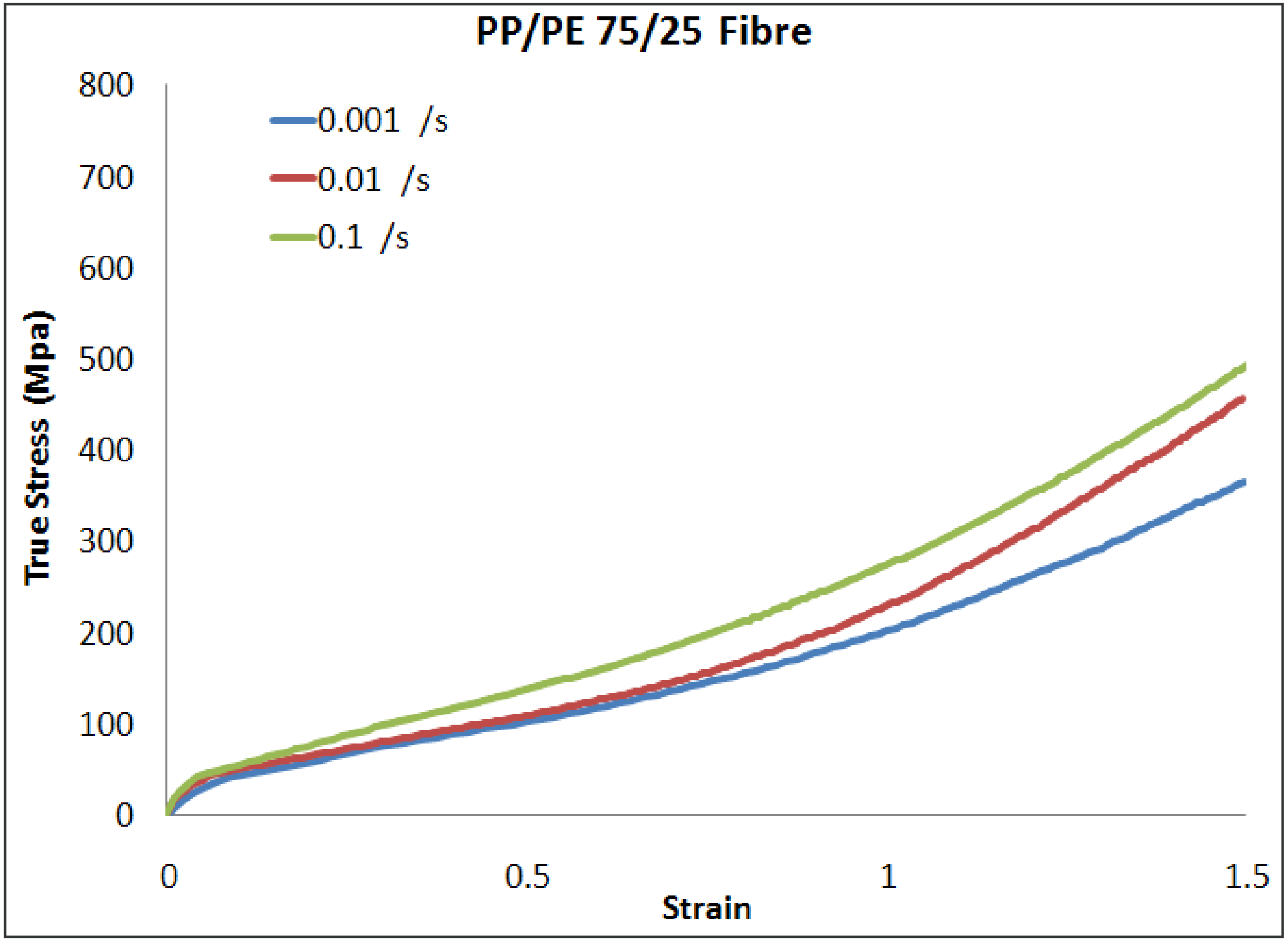
Continuous Parametric Model

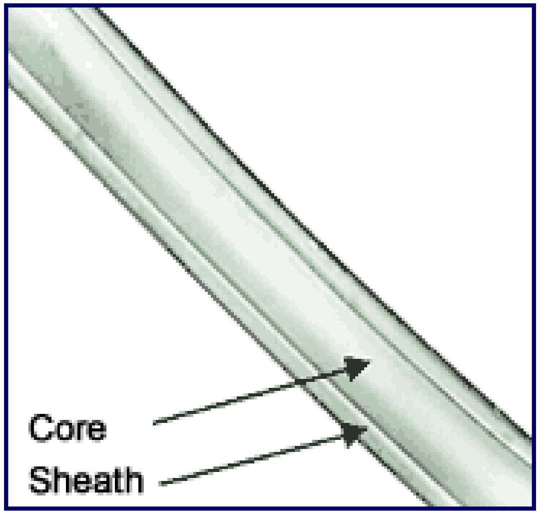




Material Characterization

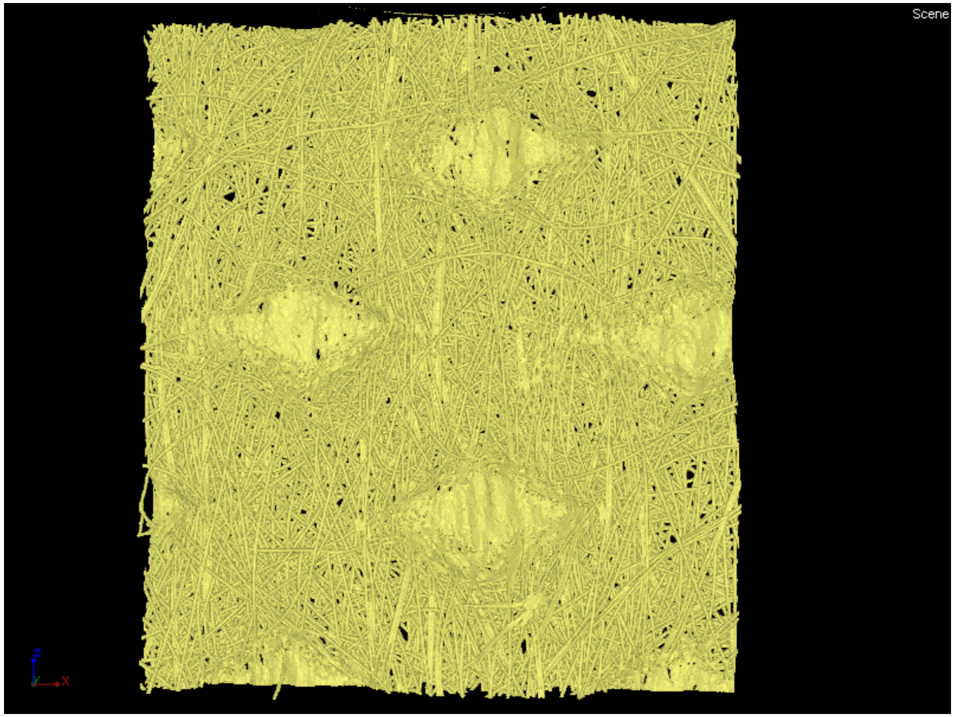
Single Fibre Tests



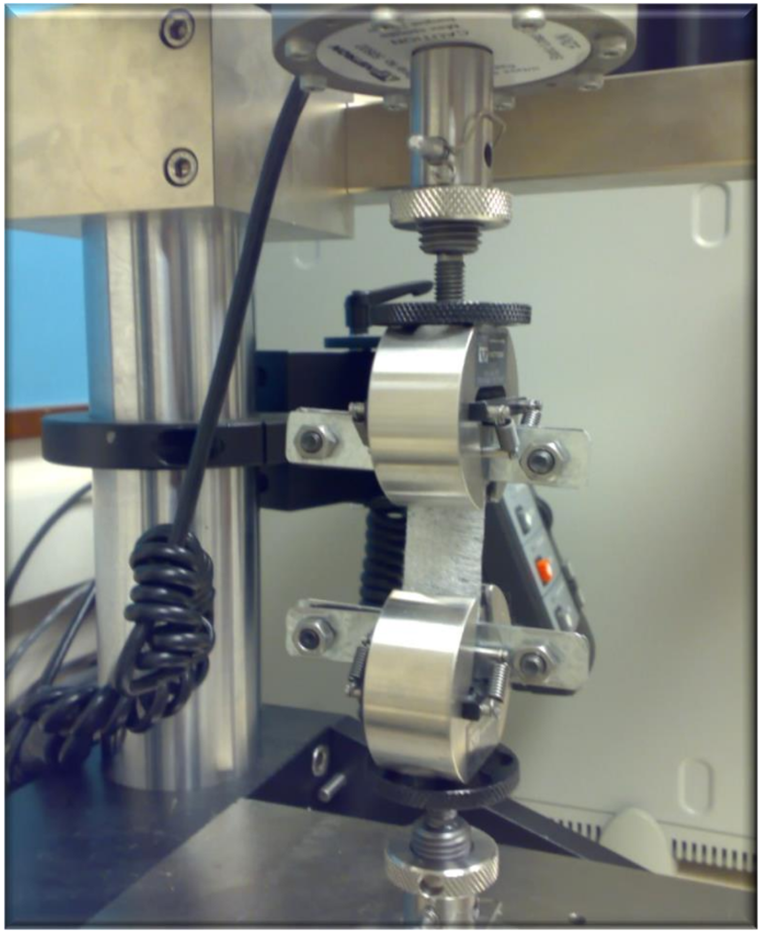


Tensile Test of PP/PE 75/25 bicomponent fibre for three strain rates

Material Characterization



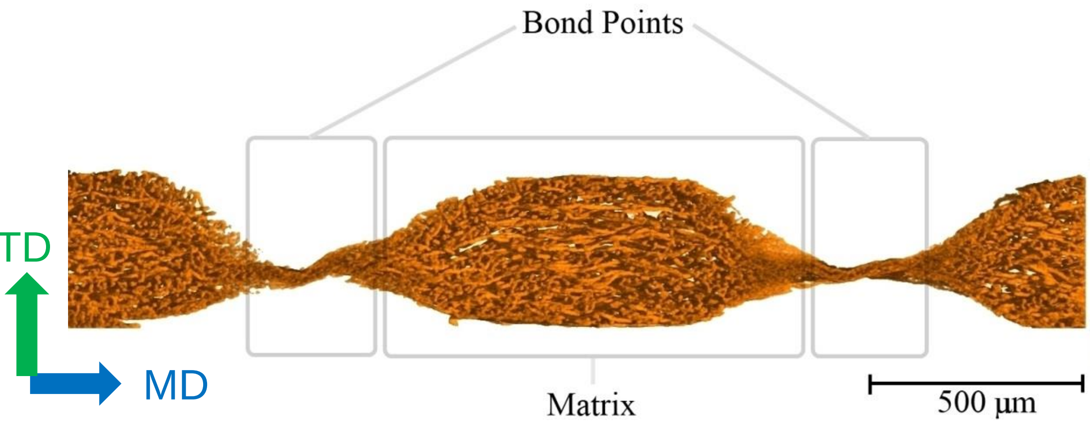
X-ray micro CT
(75/25 PP/PE 50 gsm)

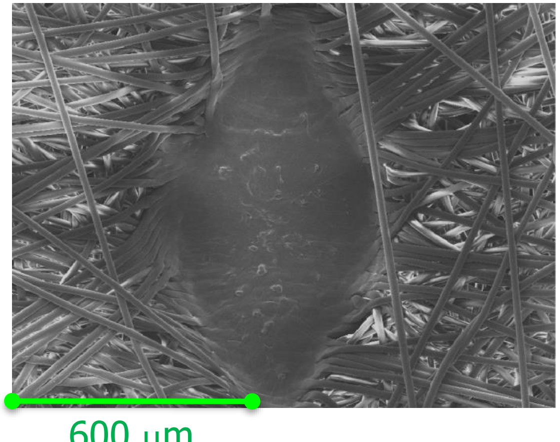


Instron® 5848 Micro Tester
with ±5 N Instron® loadcell

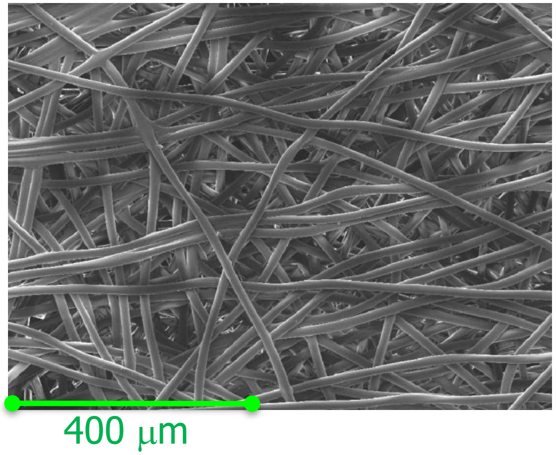
Computation of Mechanical Anisotropy

3D model (X-ray micro CT)



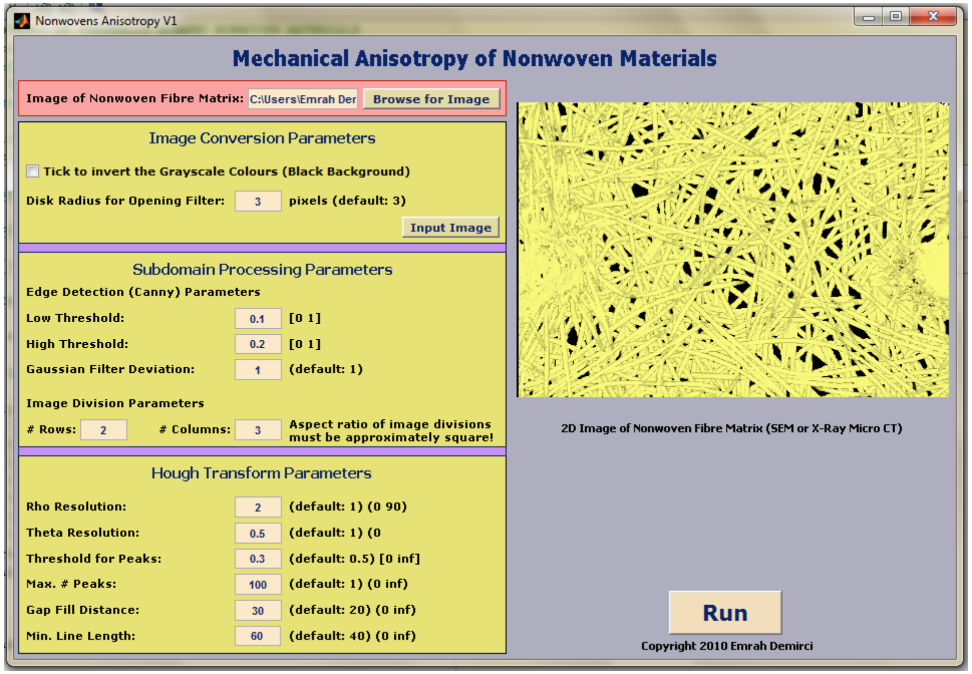


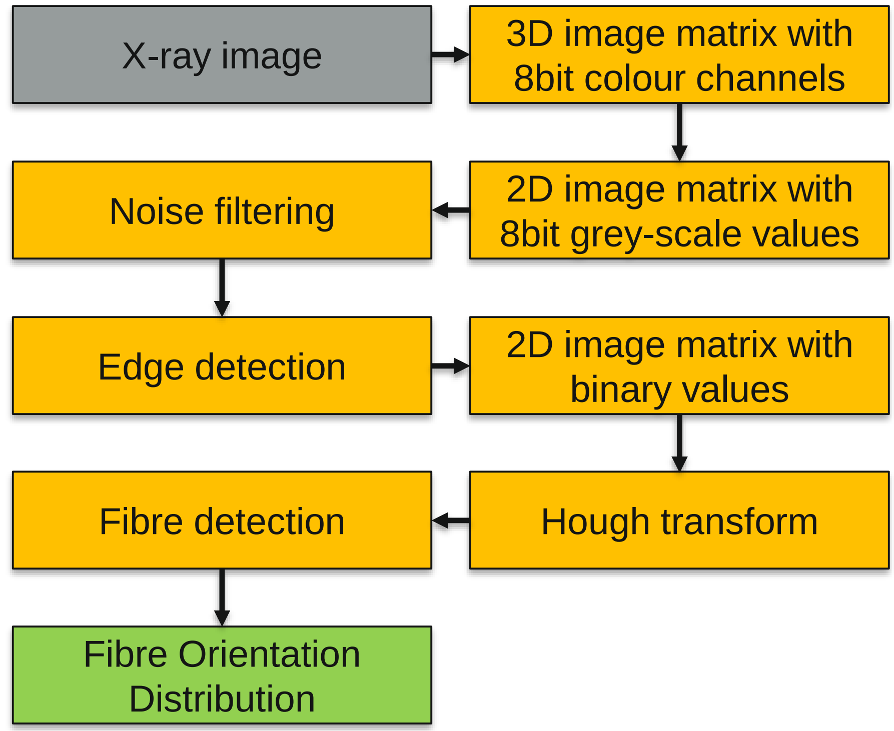
Bond point (SEM)



Computation of Mechanical Anisotropy

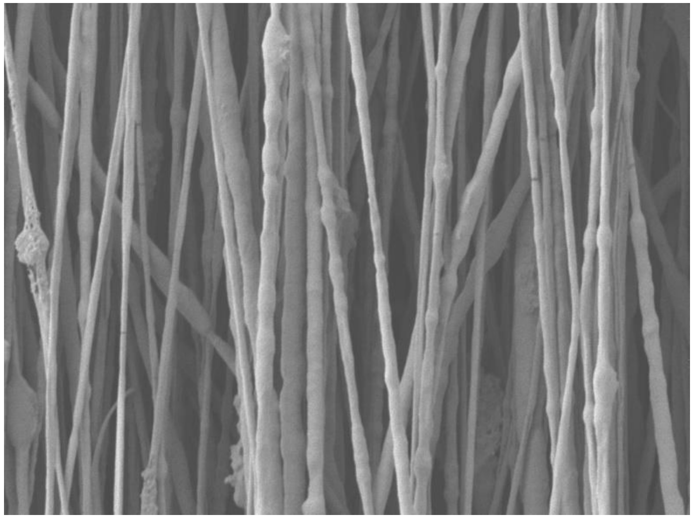
Detection of fibres

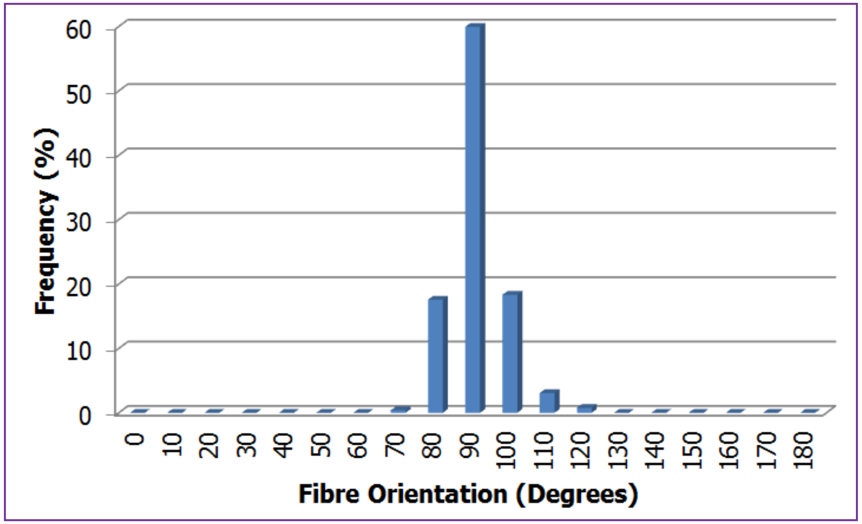


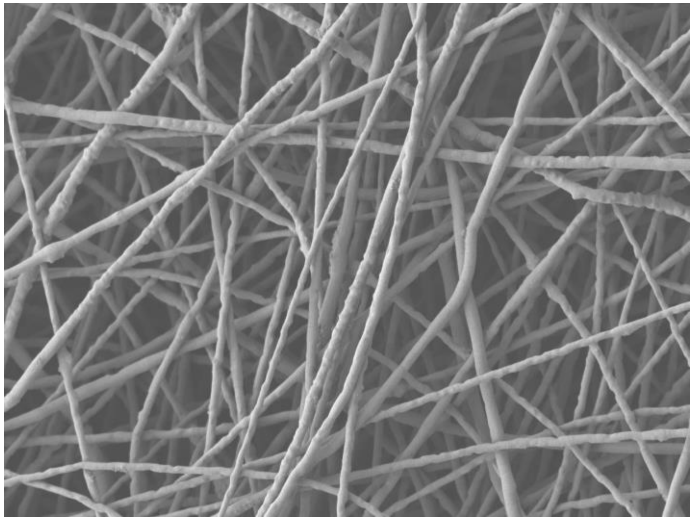


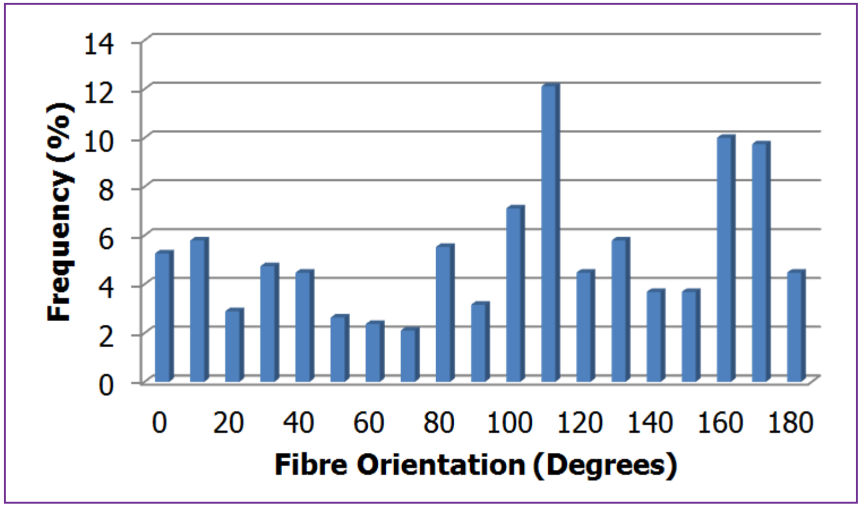
Computation of Mechanical Anisotropy

Detection of fibres

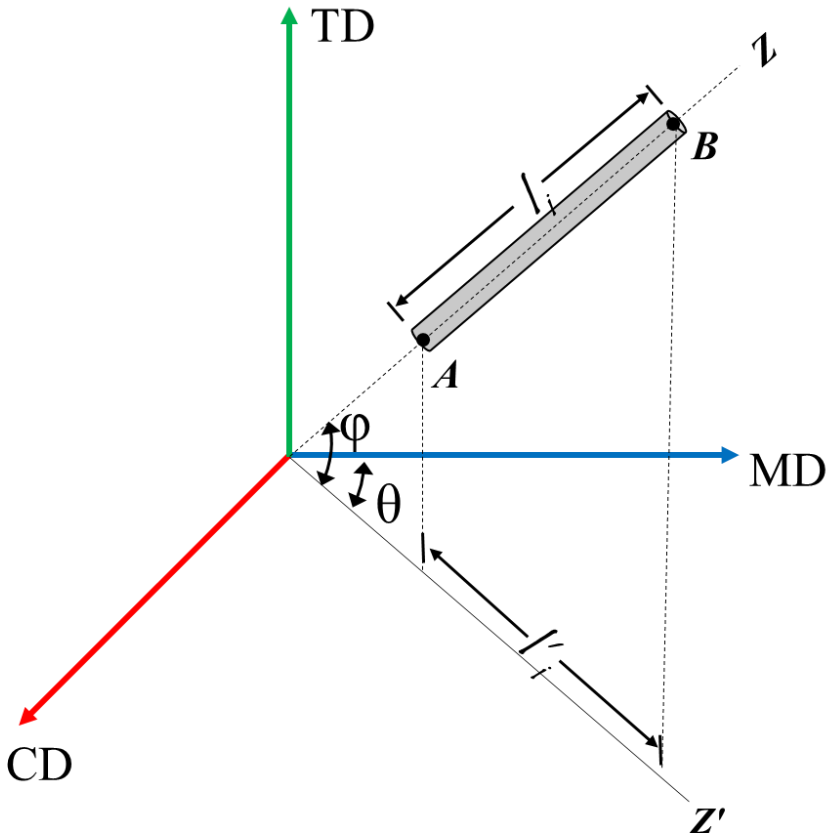




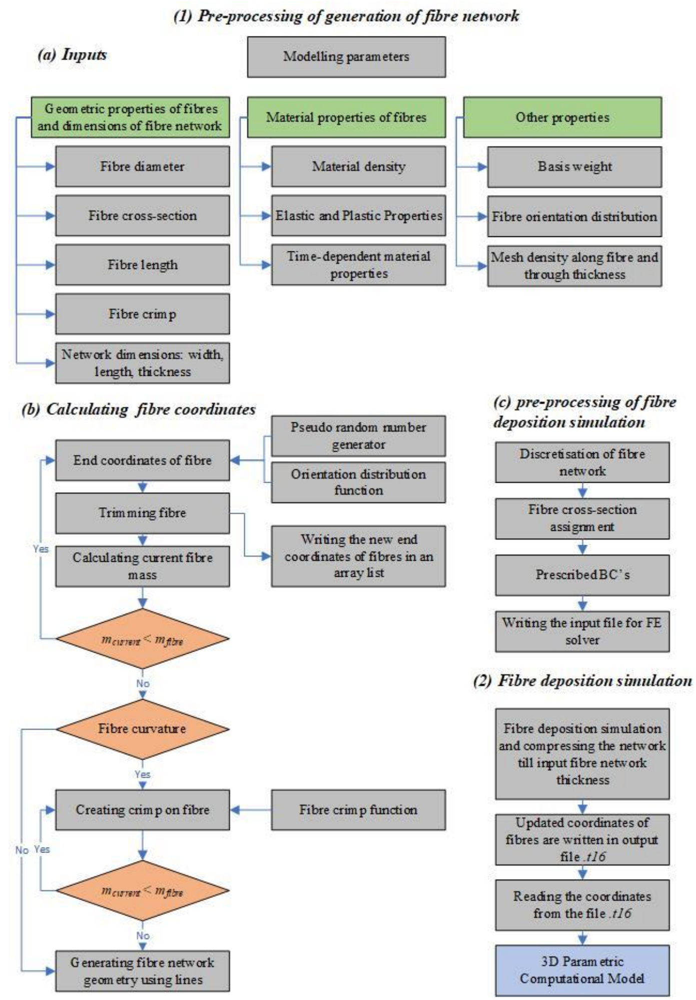




Developing 3D Parametric Computational



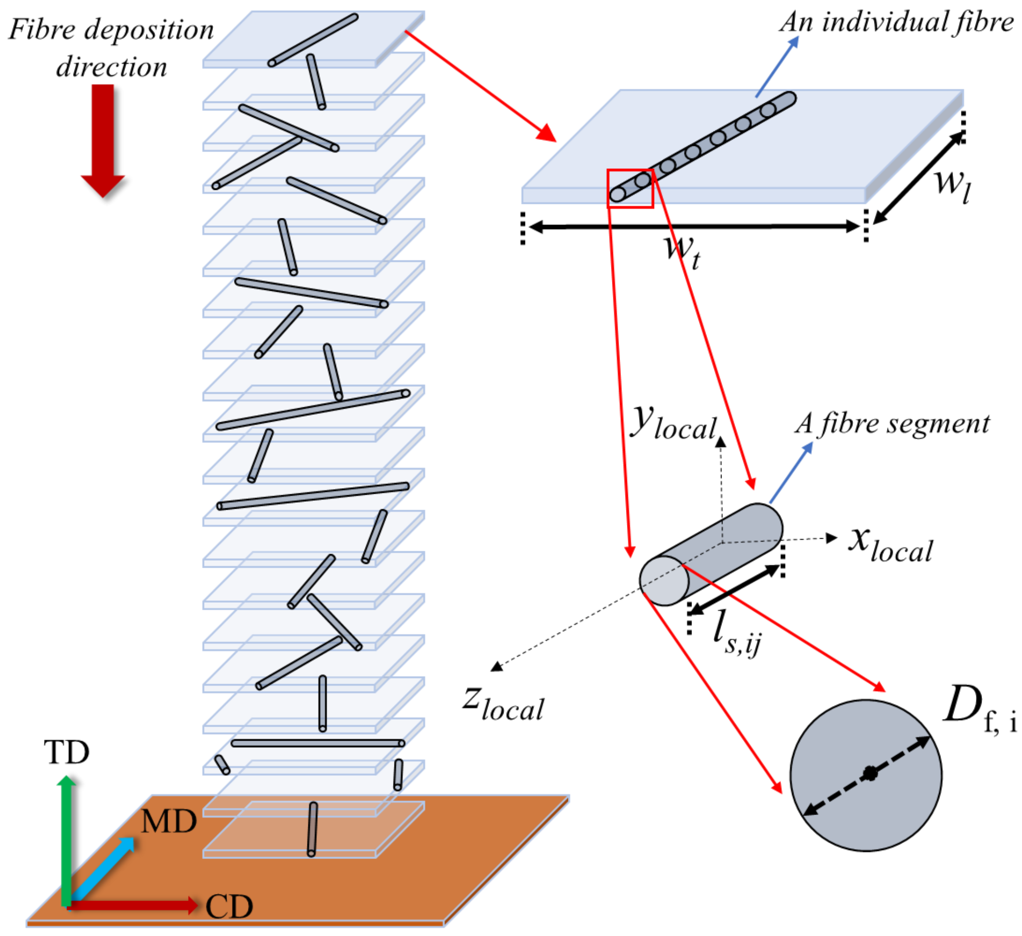
Alignment of a fibre



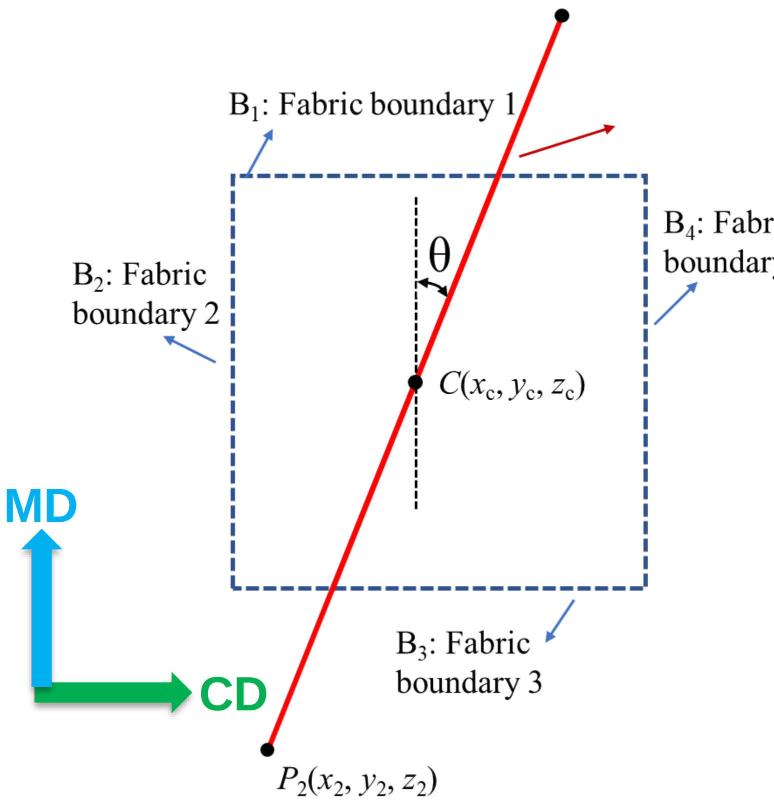
Outline of methodology for generating computational model

Developing 3D Parametric Computational Model

Fibre Deposition Simulation



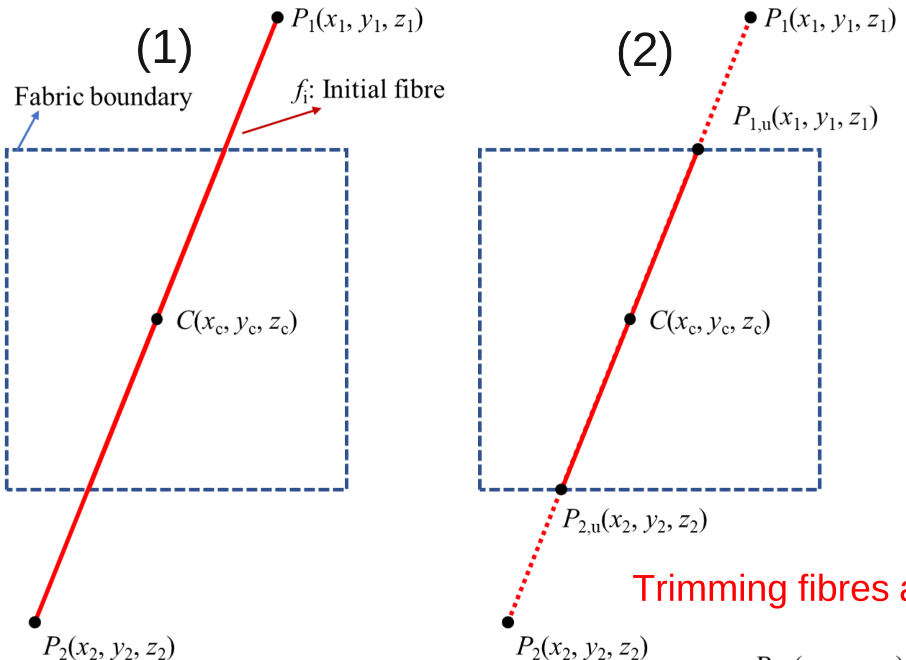
Fibre deposition

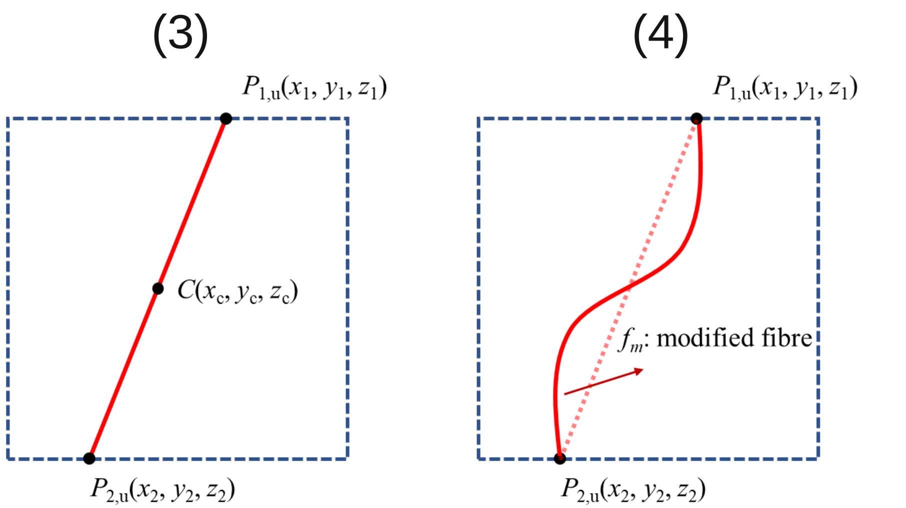


Placing single fibre

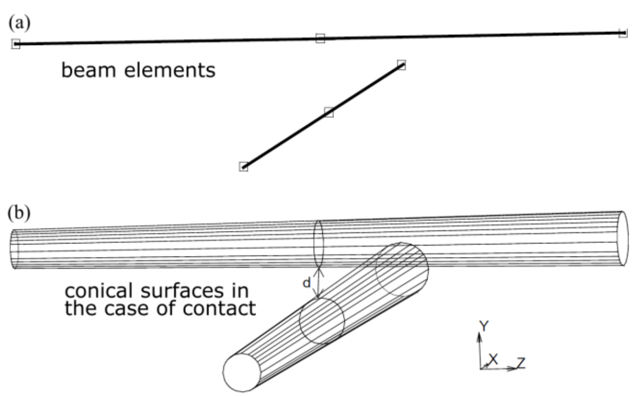
Developing 3D Parametric Computational Model

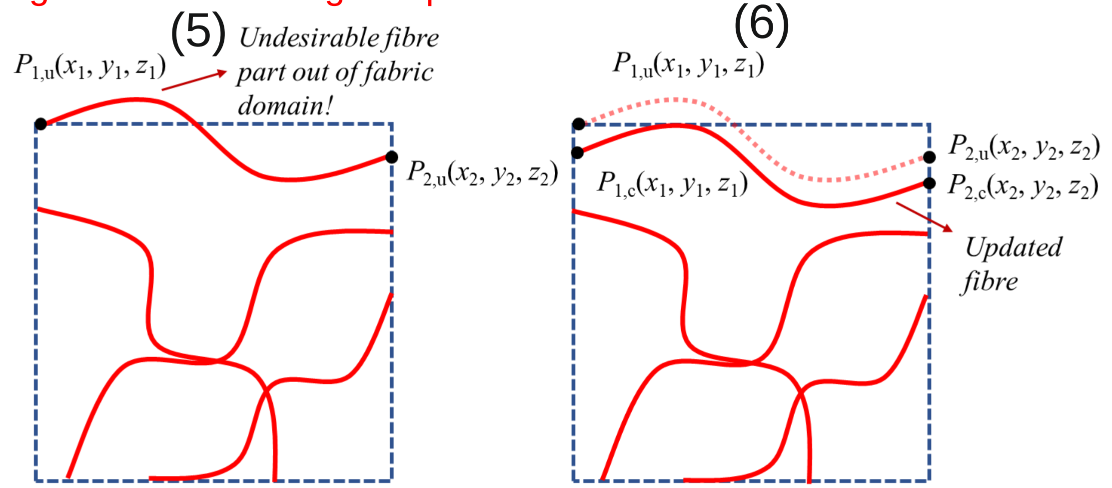
Fibre Generation, Trimming, and Crimp





Trimming fibres and adding crimp

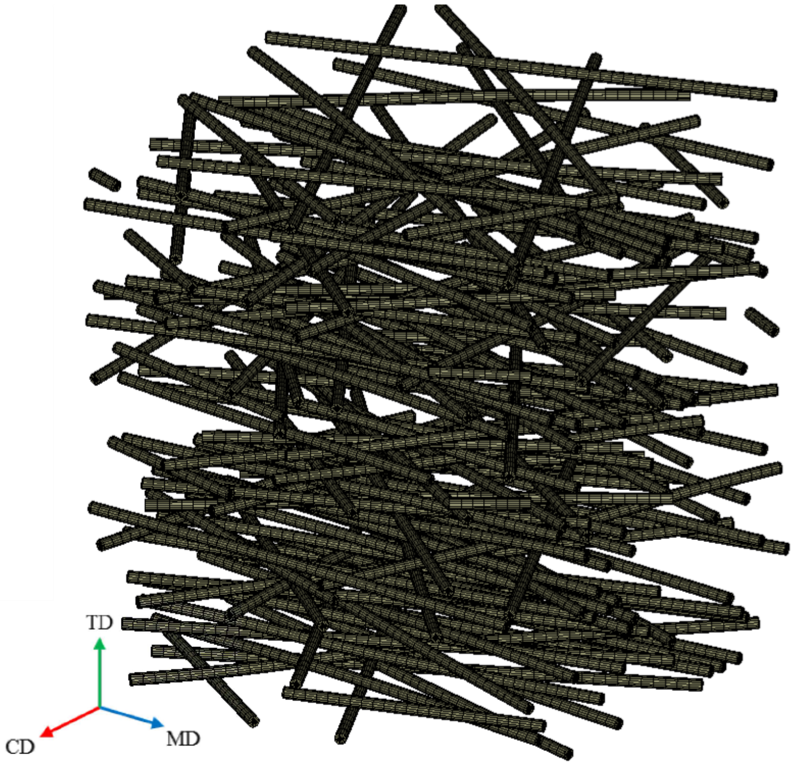




Repairing misplaced fibres

Developing 3D Parametric Computational Model

Resultant Deposited Network



Isometric view

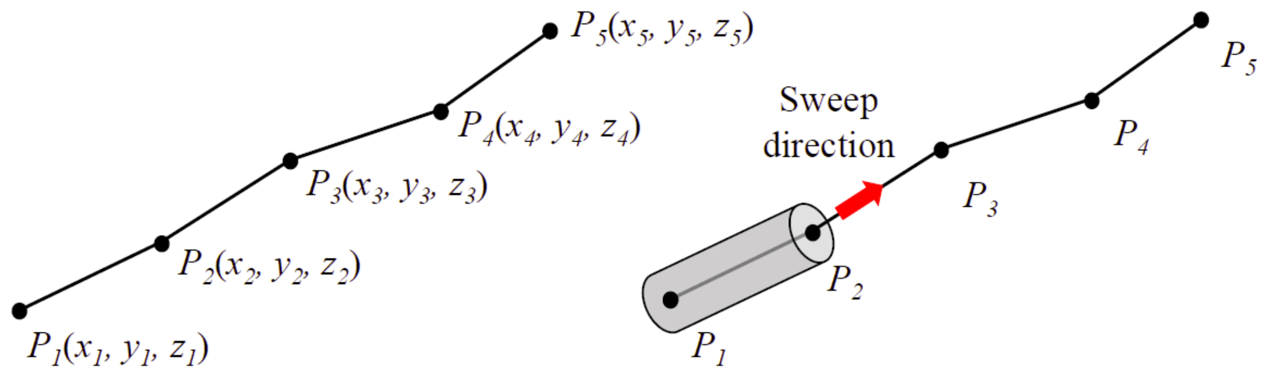
Side view

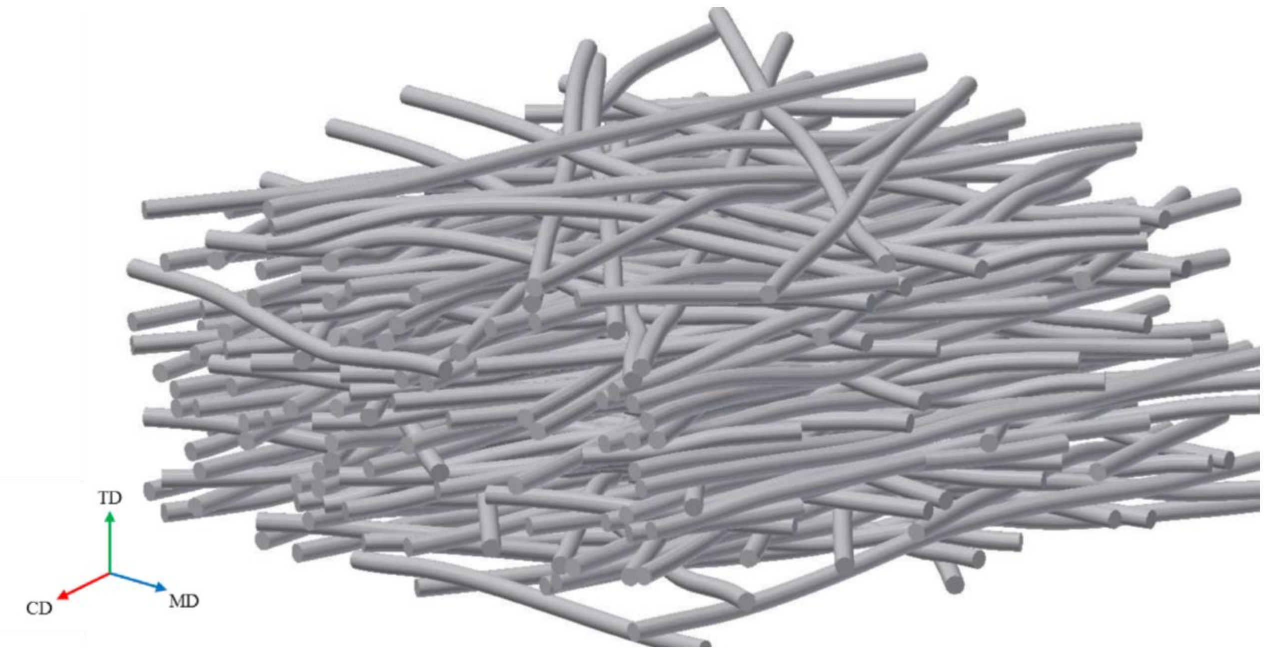
Developing 3D Parametric Computational Model

Converting FE model to CAD

AUTODESK® FUSION 360™

python™



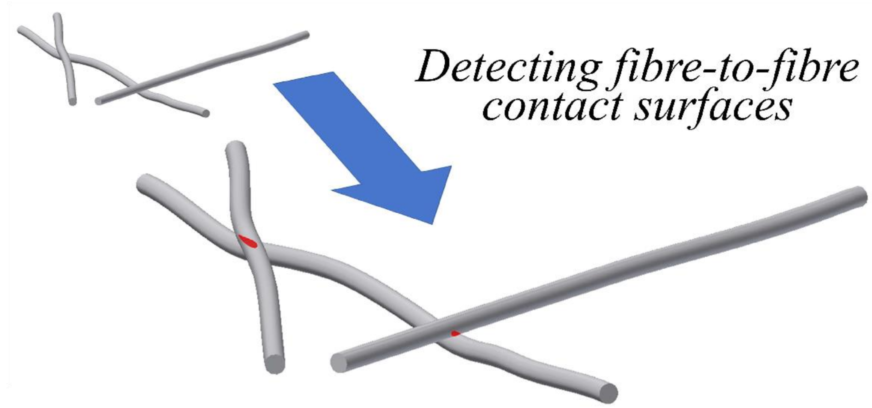


Isometric view

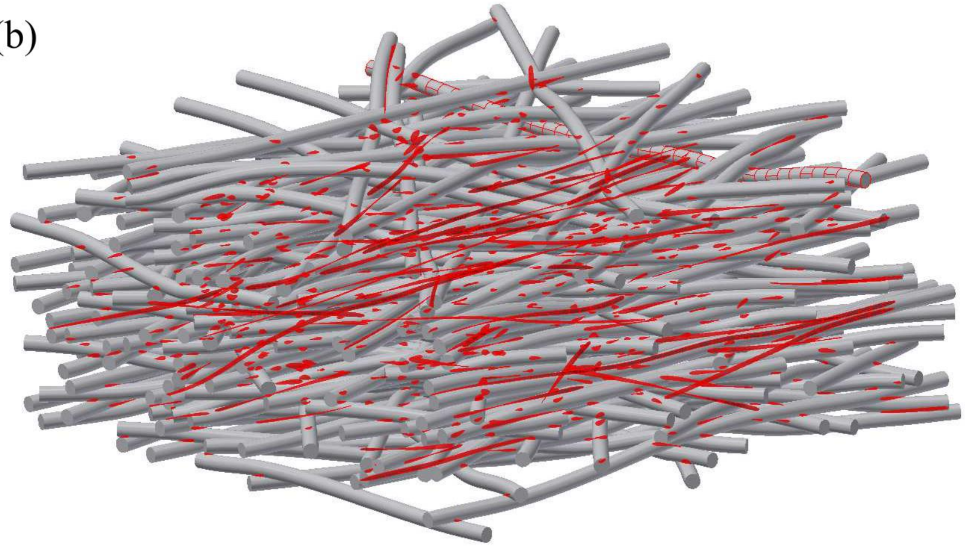
Developing 3D Parametric Computational Model

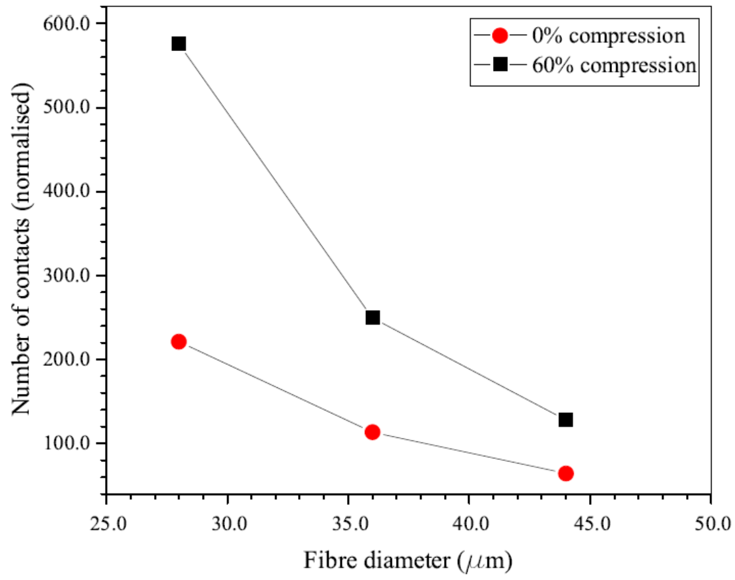
Detecting fibre-to-fibre contacts

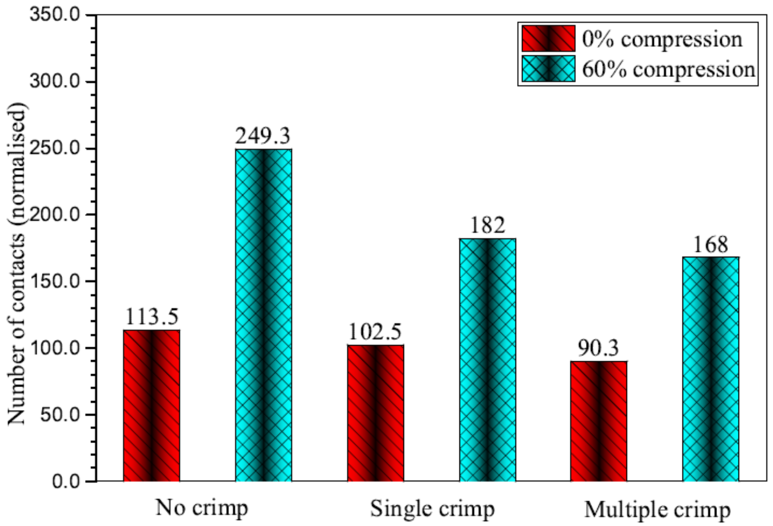
(a)



(b)

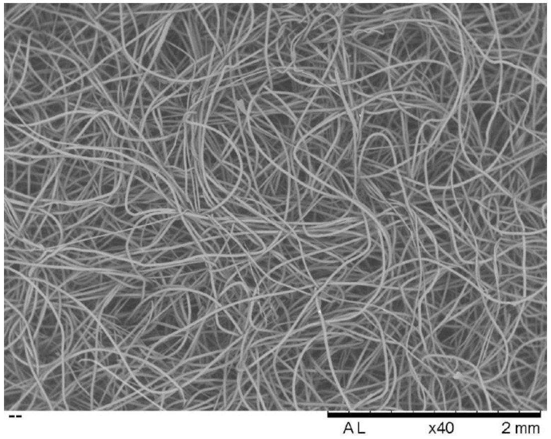


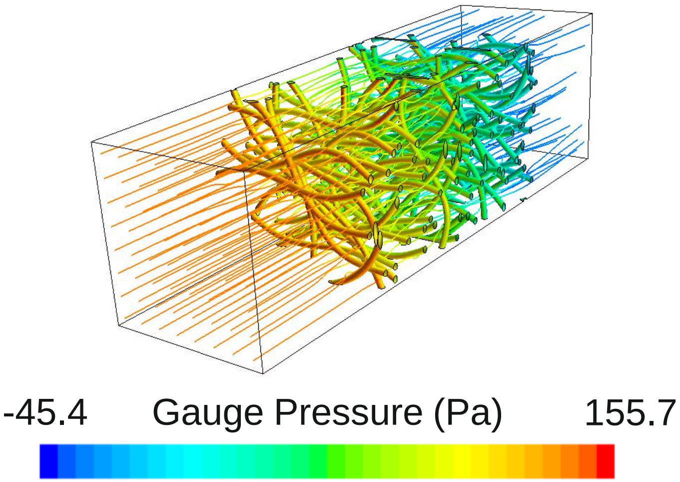


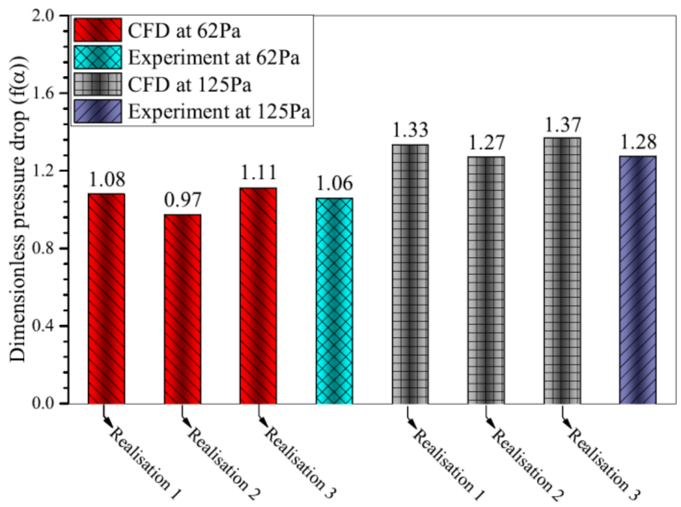


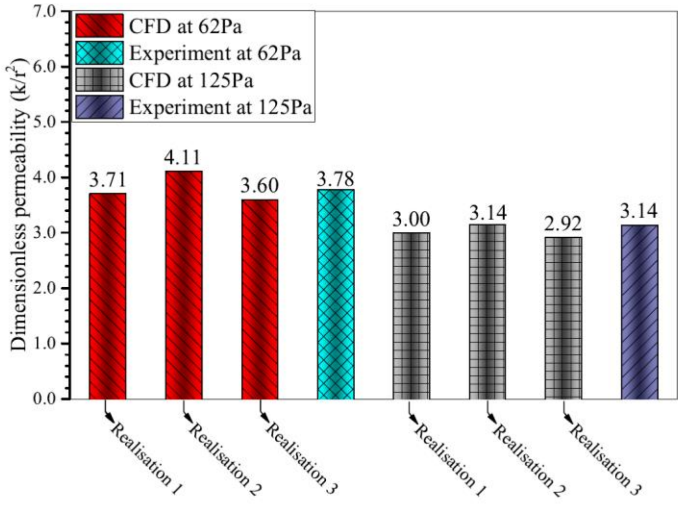
Case Studies

Case Study 1: Through-air Bonded Nonwovens



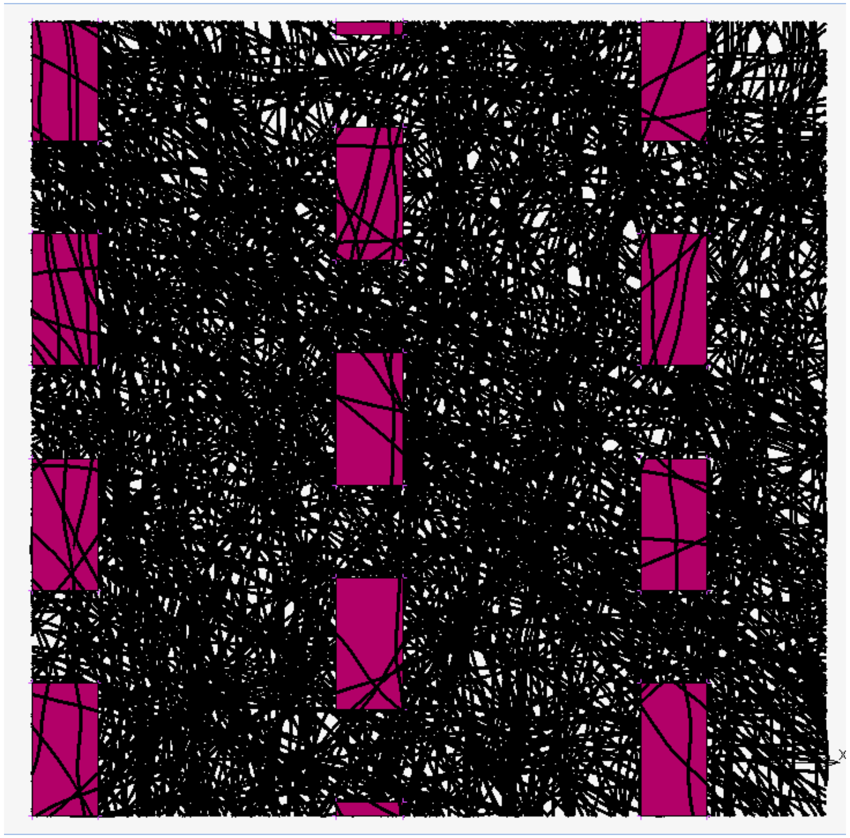


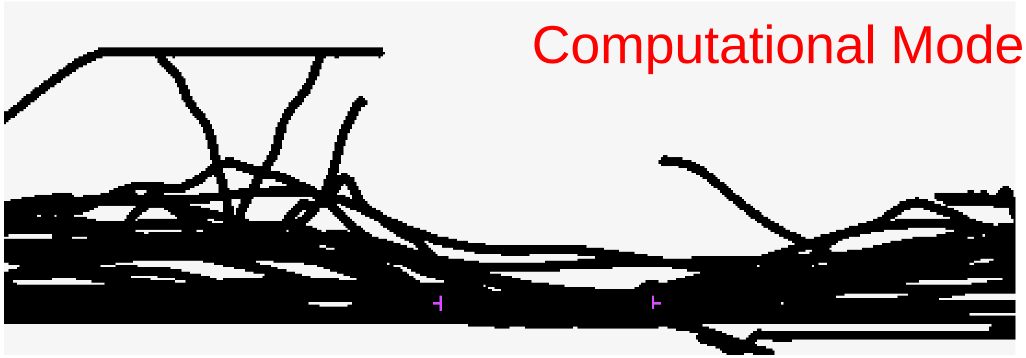




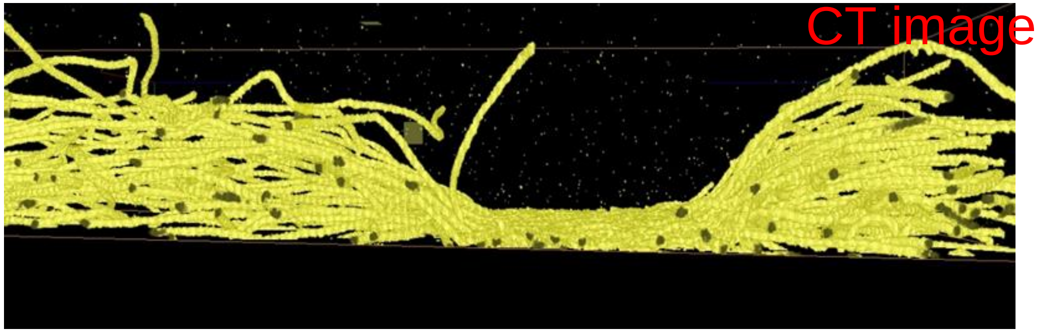
Case Studies

Case Study 2: Calendered Nonwovens





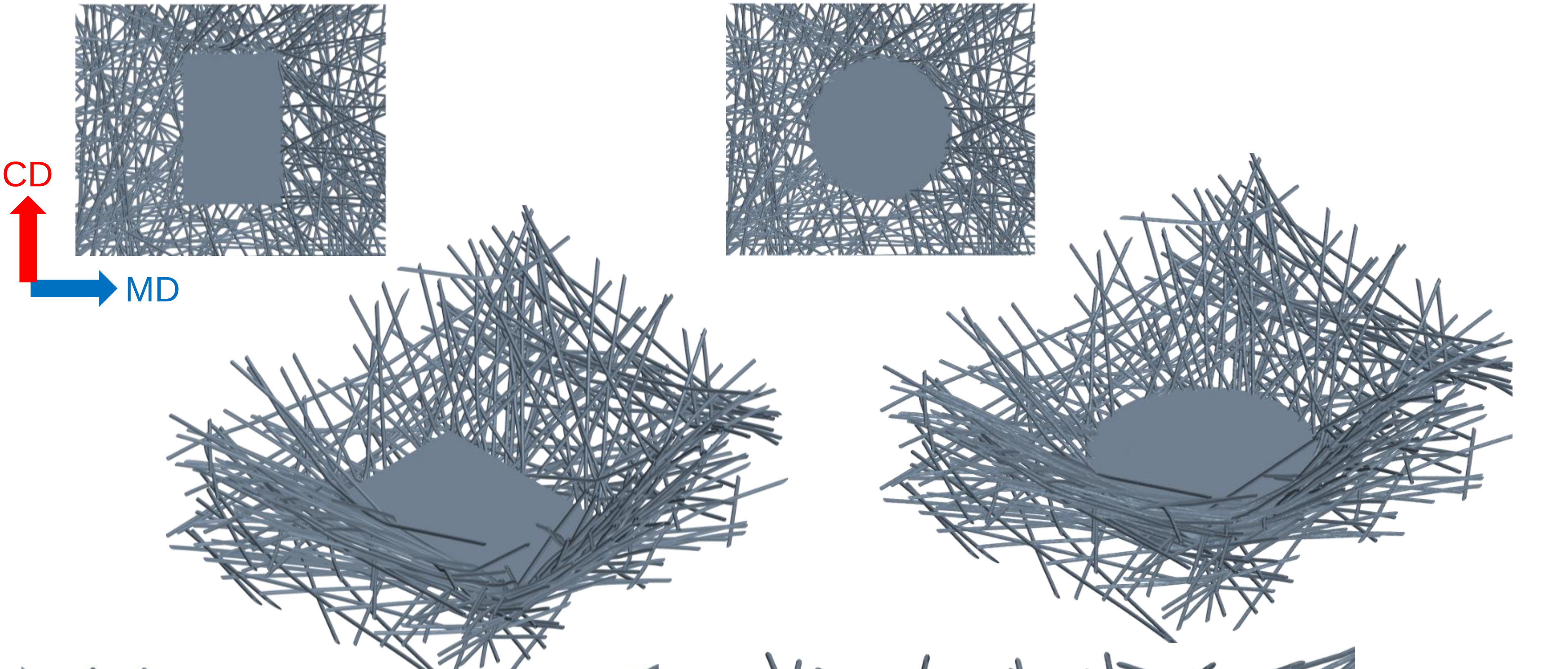
Bond point pattern showing thickness variations

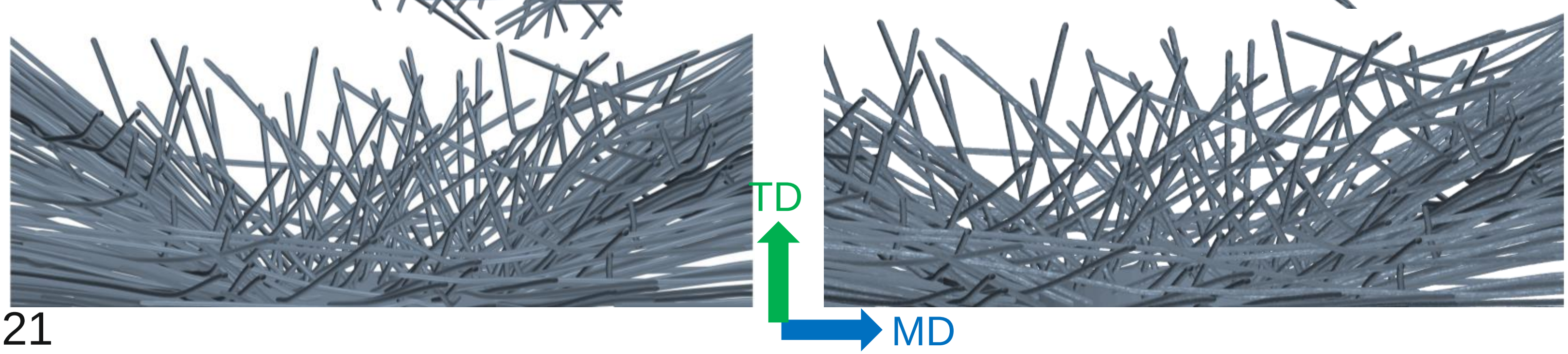


20 gsm thermally bonded calendered nonwoven (FE model)

Case Studies

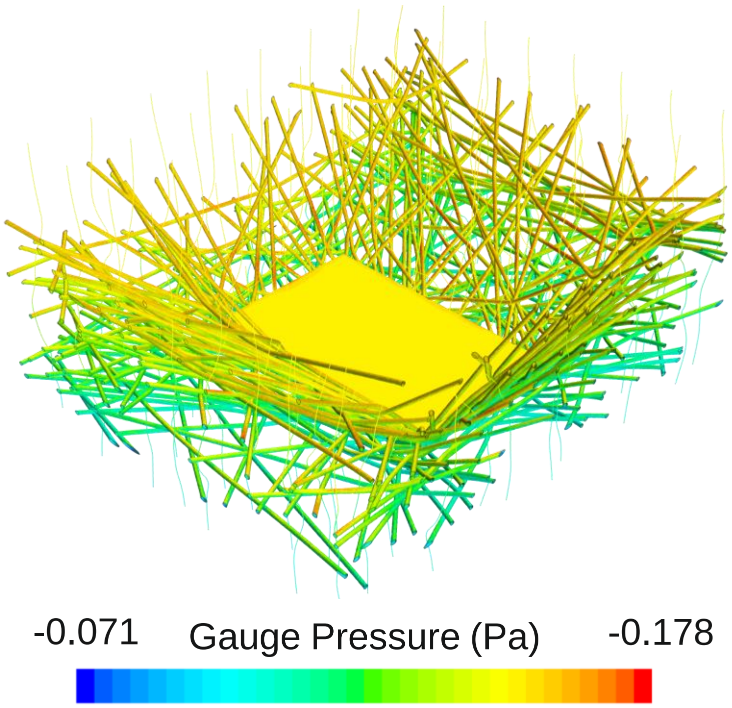
Case Study 2: Calendered Nonwovens



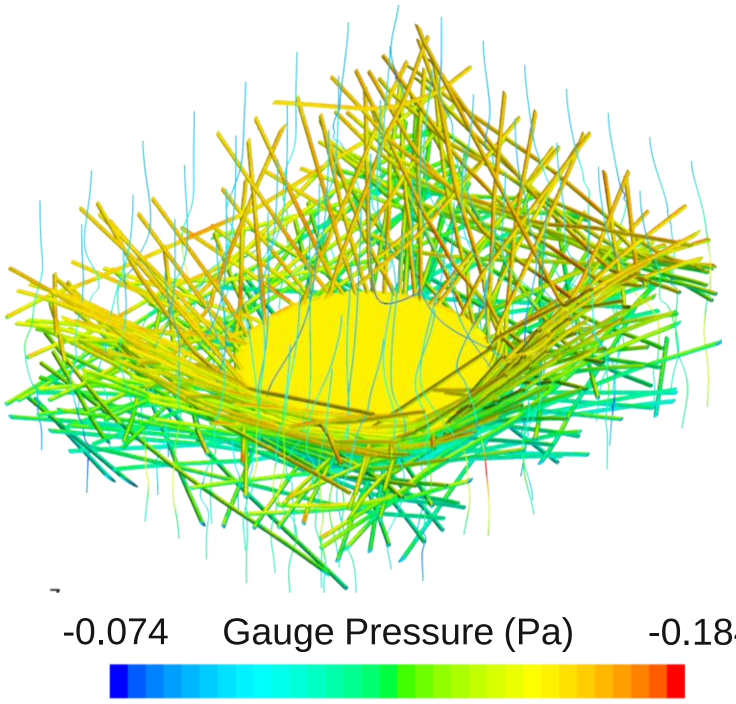


Case Studies

Case Study 2: Calendered Nonwovens



$\Delta P=0.122$



$\Delta P=0.124$

Conclusions

- The computational models developed with parametric approach is capable:
  - To predict the tensile, compression, and damage behaviours of the fabric under complex real-life loadings
  - To improve design robustness and reduce risk
  - To reduce product development time and cost
  - To study the effect of manufacturing parameters on tensile, damage, compression and flow performances.

Acknowledgements

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- the Nonwoven Institute, North Carolina State University, Raleigh, USA
- Wolfson School of Mechanical, Electrical and Manufacturing Engineering, UK
- MANN+HUMMEL GmbH, Ludwigsburg, Germany
- Reicofil GmbH & Co, Germany