Process Modelling of Textile Composites
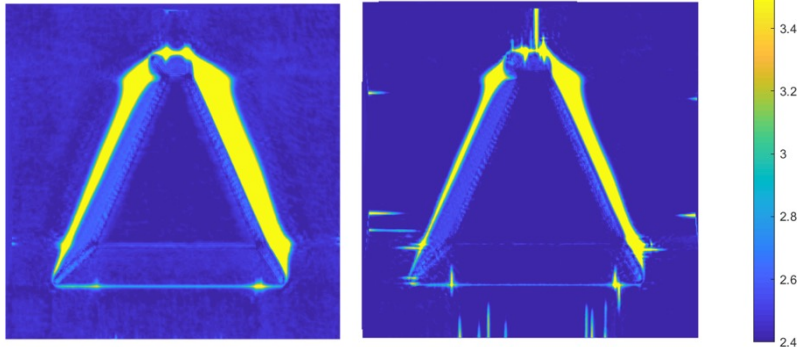
Adam Thompson

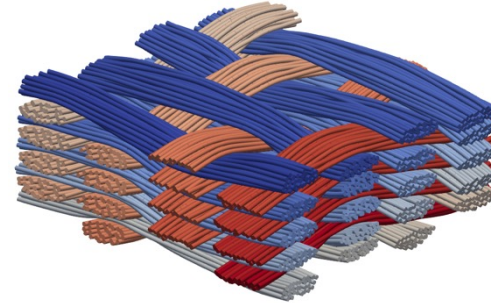*Research Fellow*

bristol.ac.uk/composites
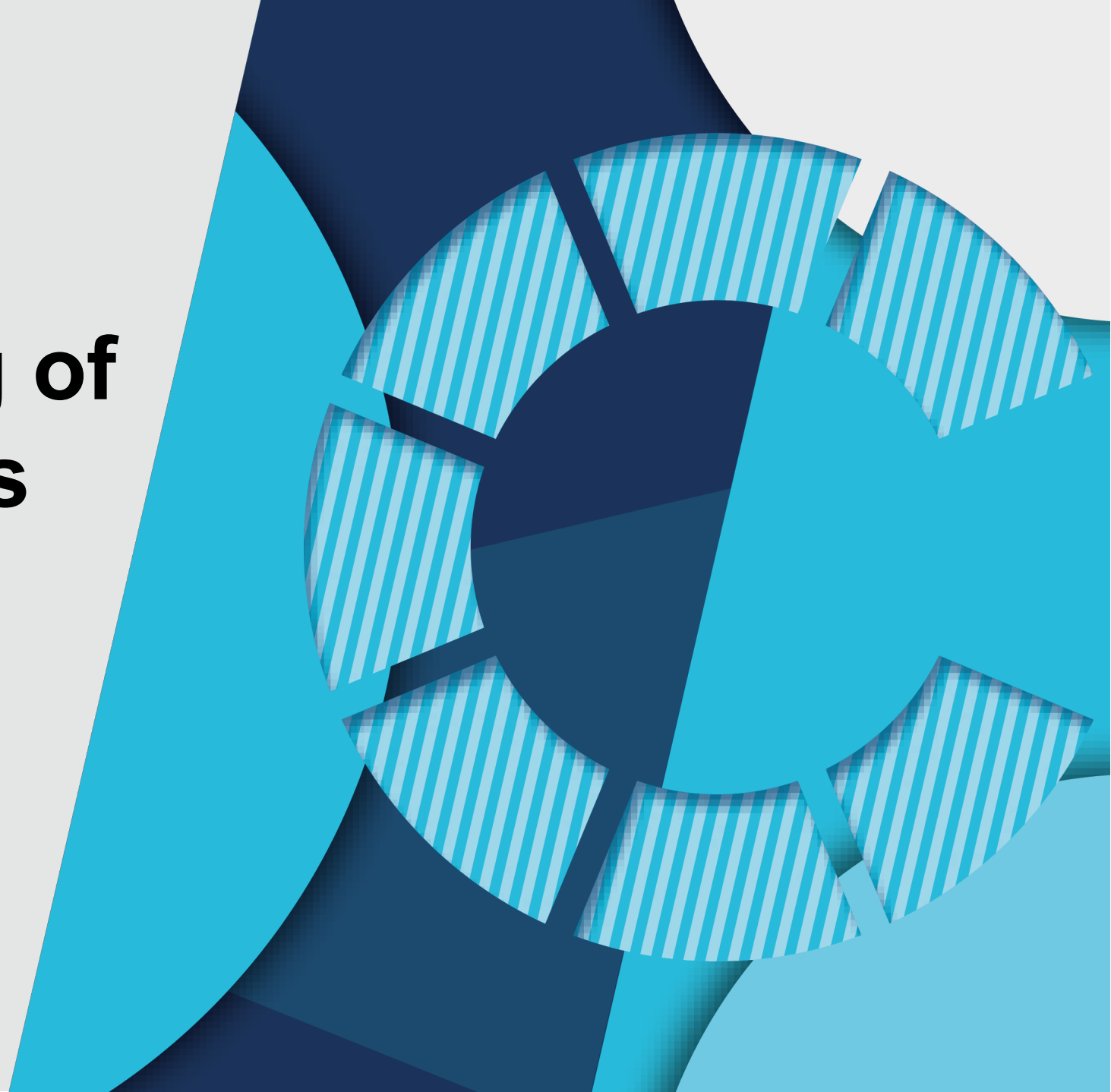
Overview

Macro-scale Forming

- Dissemination
- Collaboration
- Industrialisation

Software: SimTex

- Developments
- Dissemination

What's Next?

Composites: MadeFaster

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Macro-Scale Forming

DefGen Outputs

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Modelling defect formation in textiles during the double diaphragm forming process

Adam J. Thompson *, Jonathan P-H. Belnoue, Stephen R. Hallett

Bristol Composite Institute (ACCIS), University of Bristol, Queen's Building, University Walk, Bristol, BS8 1TR, UK

Contents lists available at ScienceDirect
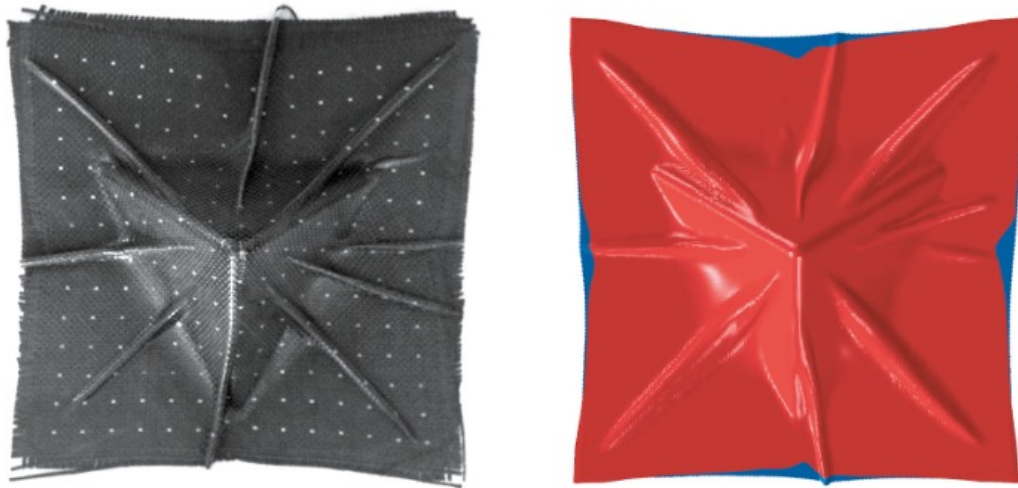
Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Numerical modelling of compaction induced defects in thick 2D textile composites

Adam J. Thompson *, Joseph R. McFarlane, Jonathan P.-H. Belnoue, Stephen R. Hallett

Bristol Composite Institute (ACCIS), University of Bristol, Queen's Building, University Walk, Bristol BS8 1TR, UK
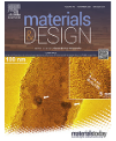

Inter-layer penetration

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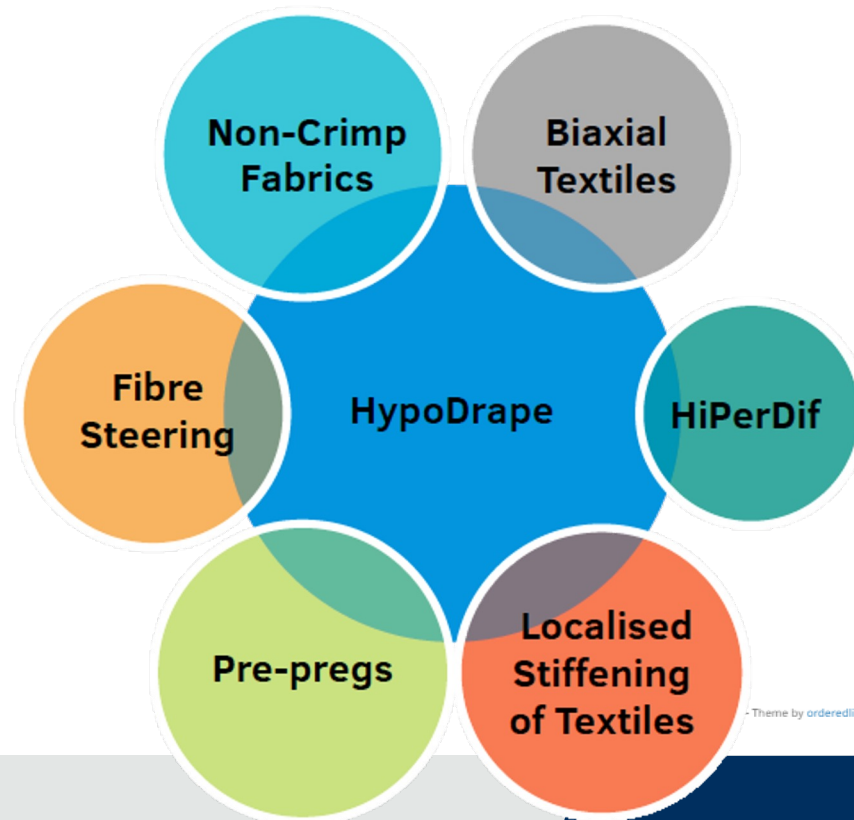
Bristol Composites Institute
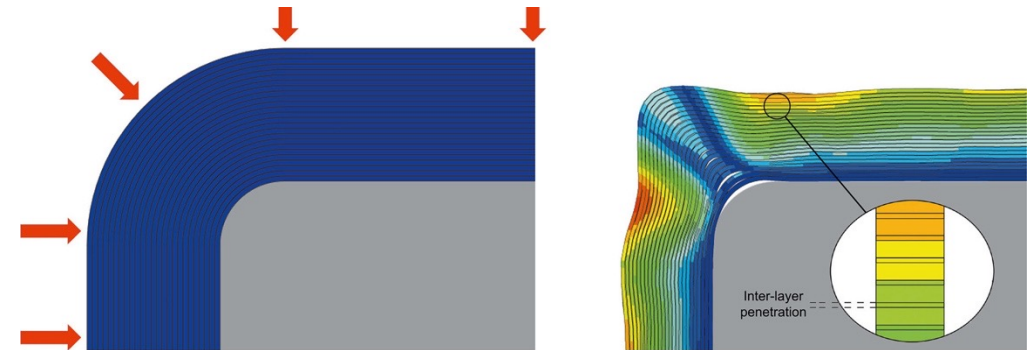
HypoDrape

User material subroutine for Abaqus to capture the kinematic behaviour of fibres during forming.

Used as the foundation for a number of projects within SIMPROCs

Released in 2020 via BCI process modelling Github page:

- 30 subscribers world wide
- Currently in use by Airbus and NCC
- Led to 2 successful international collaborations

Bristol Composites Institute

a c c i s
ADVANCED COMPOSITES COLLABORATION FOR INNOVATION & SCIENCE

Bristol Composites Institute (ACCIS), University of Bristol, UK

View My GitHub Profile

HypoDrape

Hypodrape is a usermaterial subroutine (VUMAT) for Abaqus/Explicit used to define the mechanical constitutive behaviour of biaxial textile materials for simulating fabric drape and forming.

The related work was conducted at the University of Bristol under the EPSRC funded research grant: Centre for Innovative Manufacturing in Composites project "Defect Generation Mechanisms in Thick and Variable Thickness Composite Parts – Understanding, Predicting and Mitigation" (DefGen), grant reference no. EP/I033513/1.

Access

To receive access to the HypoDrape repository, please send a short email to accis-github@bristol.ac.uk to let us know your interest.

Access is granted on the condition that you agree for us to contact you about your use of the software.

You can click here for a template.

Additional details

A full technical description of the model coded in the VUMAT is provided in:

- A.J. Thompson, J.P-H. Belnoue and S.R Hallett, "Modelling defect formation in textiles during the double diaphragm forming process" Composites Part B: Engineering, in press.

Demonstrations of the model capabilities are illustrated in:

- A.J. Thompson, J.R. McFarlane, J.P-H. Belnoue and S.R Hallett, "Numerical modelling of compaction induced defects in thick 2D textile composites" Materials & Design, under review.

For more information please contact the Bristol Composites Institute (ACCIS): accis-github@bristol.ac.uk .

Graphical Abstract

https://accis.github.io/archive/HypoDrape/
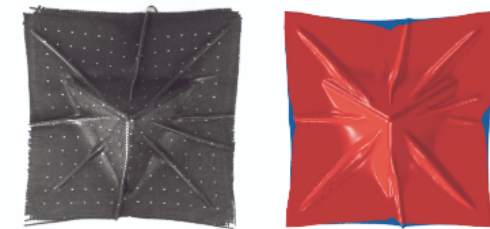
Collab. #1

Rashidi A, Milani A.S, University British Colombia

Extension to pre-impregnated textiles including:

- inter-ply shear behaviour
- consolidation behaviour

Resulting model was able to capture:

- consolidation induced wrinkles over single curvatures
- evolution of wrinkles during forming through to consolidation in large ply stacks

The collaboration lead to a publication

After forming

After consolidation

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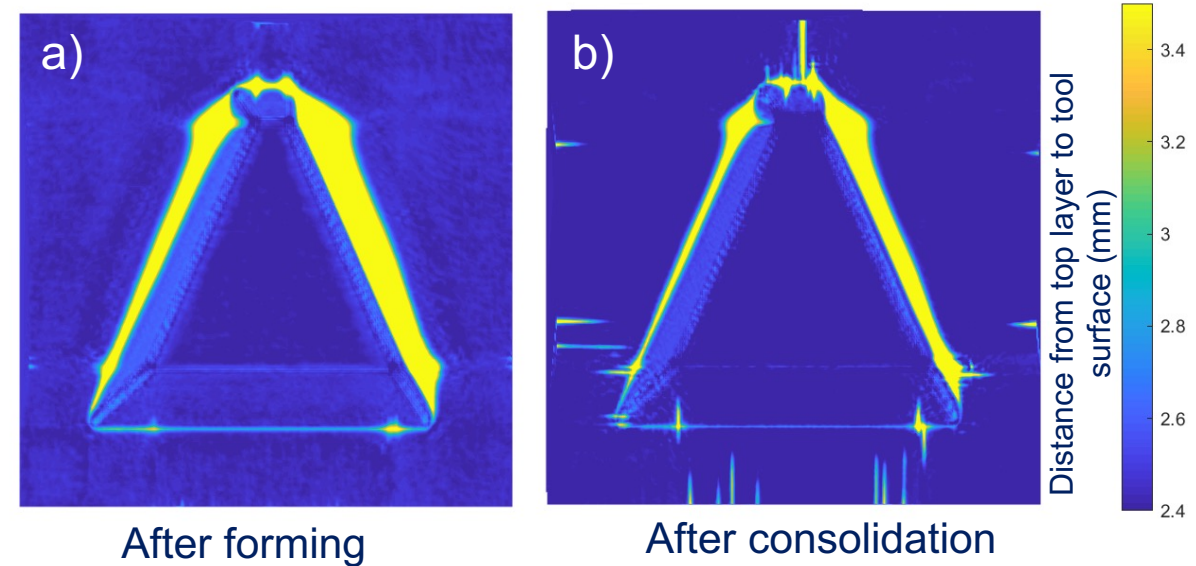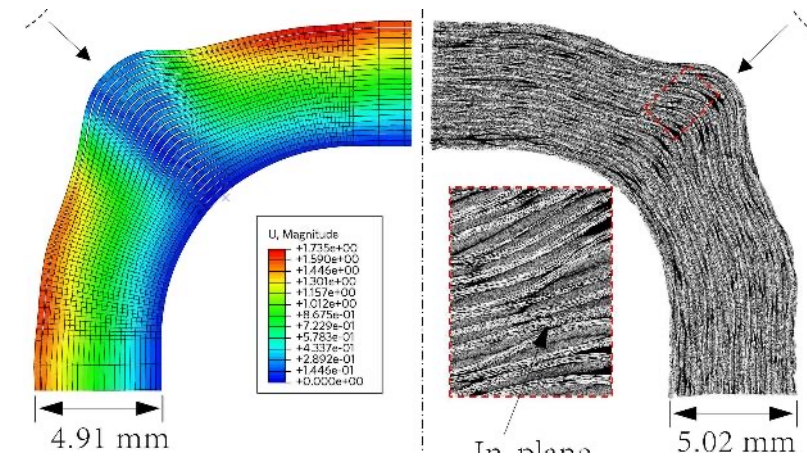
Collab. #2

Broberg P, Bak B.L.V, Lindgaard E, Aalborg University

Extend model to include:

- nonlinear bending stiffness
- inter-ply cohesion/tack

Resulting model was able to predict wrinkle positions and their representative size

Productive collaboration which lead to enhanced capability

Before visit

After visit


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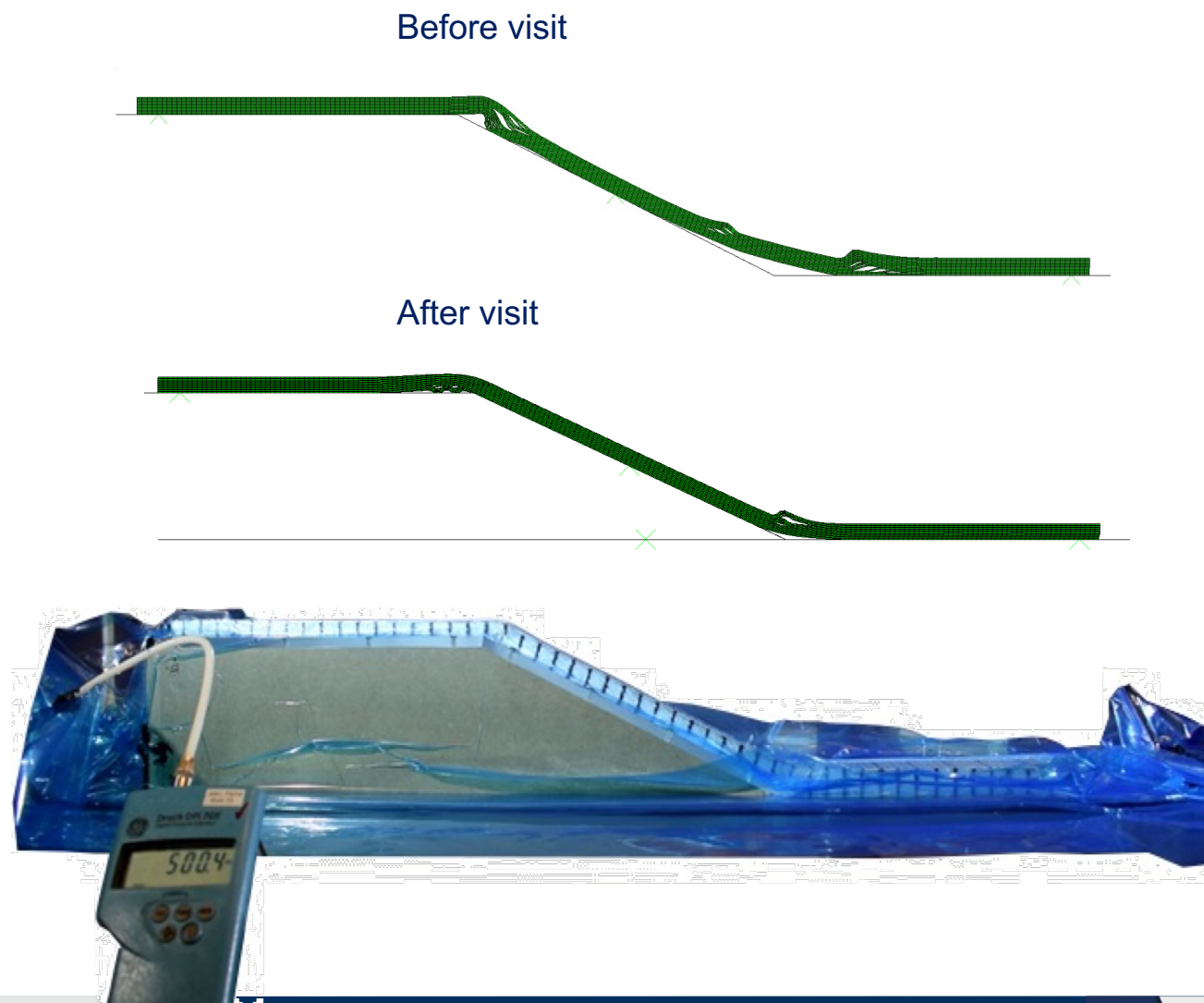
Forming of NCFs

Williams L, Airbus, BCI

Textile constitutive models are typically adopted for modelling NCFs but unable to capture intra-ply slippage present in these materials.

Introduction of new contact model which captures the intra-ply slip behaviour present within an NCF.

Contact model includes a no separation condition imposed by stitch yarn, while permitting fibre-aligned tow sliding
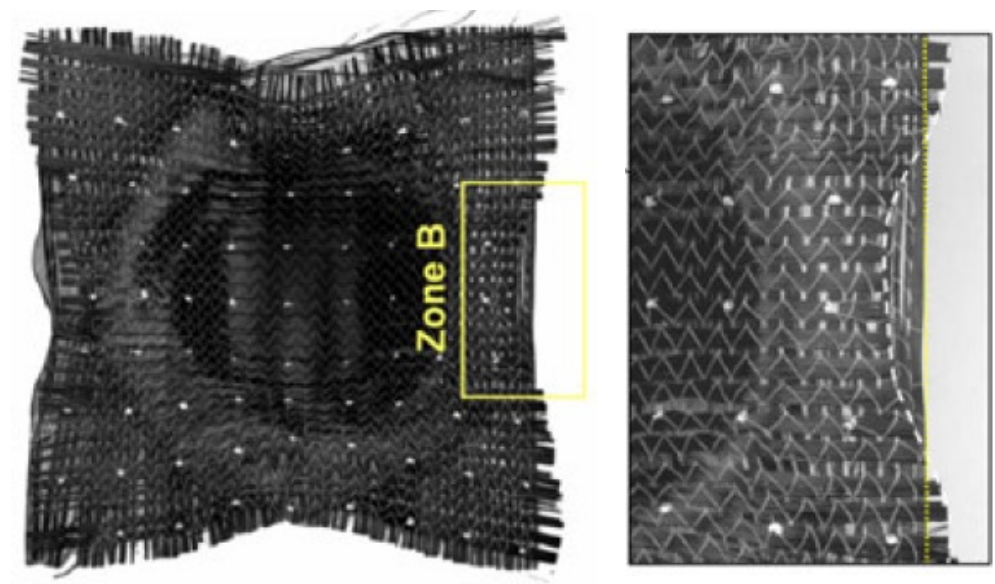
Triaxial NCF at formed at different orientations

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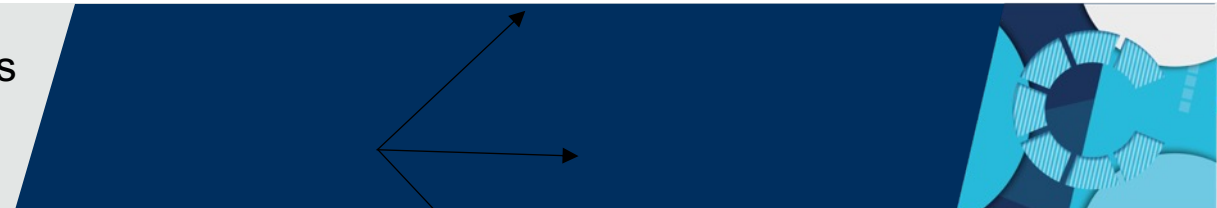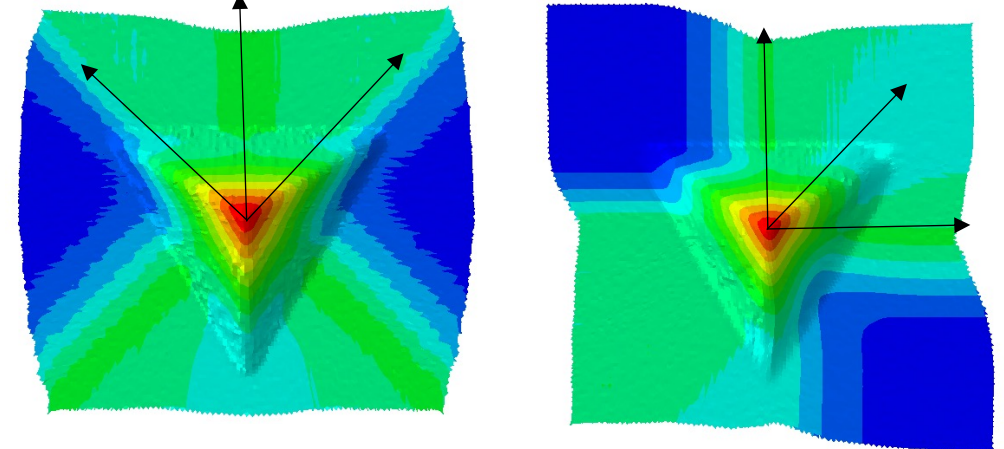
Industrialisation

Williams L, Airbus, BCI

Constructing work flows to simplify the model build, run and post-processing of results.

Developing methods to stabilise simulations and make their ease of use akin to kinematic methods.

Allows users to see the formability of a part and identify possible regions of concern early in design stage before full definition of manufacturing process.

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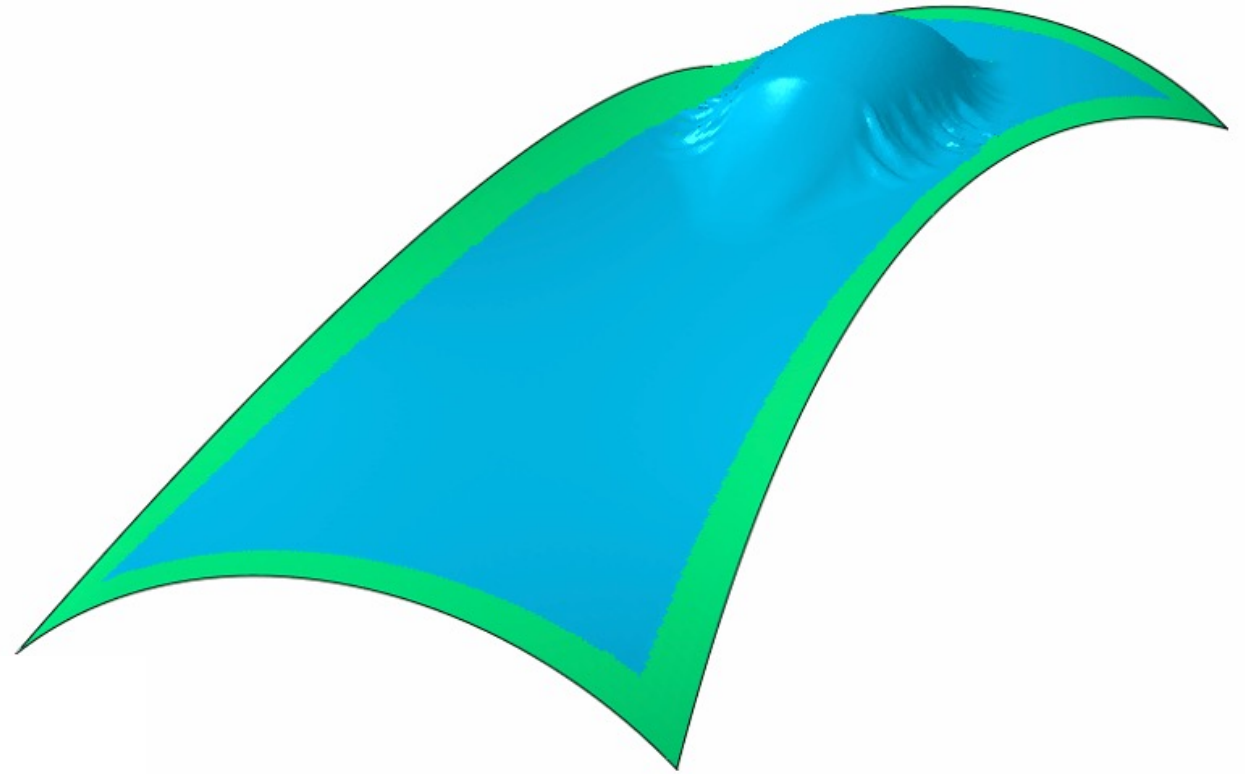
Process Optimisation

Chen S, Alan Turin Institute, BCI

Rapid prediction tools required to explore variability in manufacturing processes and optimise manufacturing parameters.
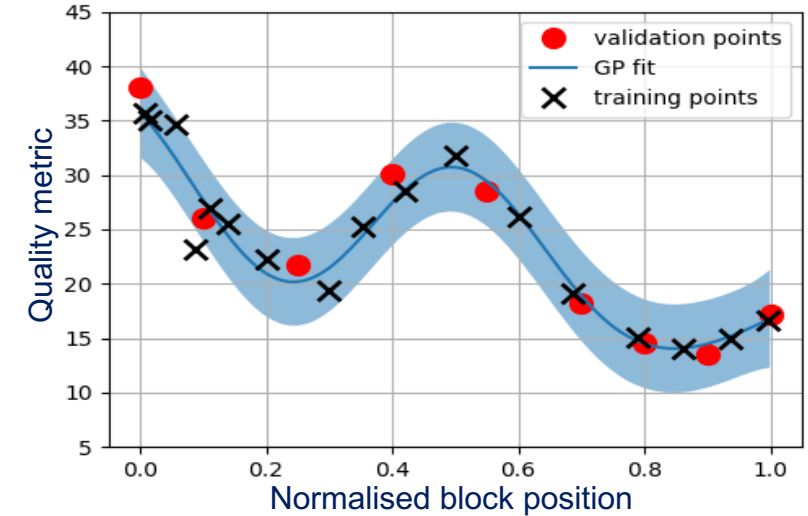
Training a Gaussian Process to emulate computationally intensive models is a promising solution.

Once trained the Gaussian Process emulator is used for the optimisation.
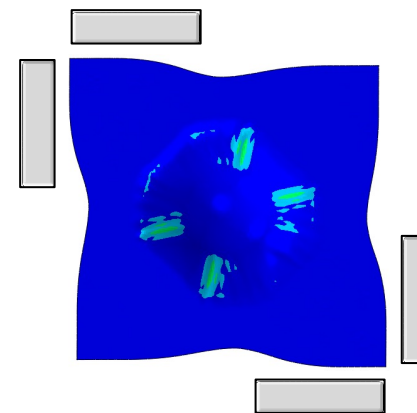
Build training dataset
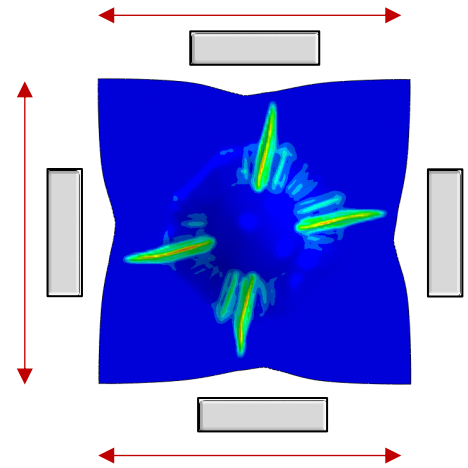
Train GP

Optimised result

Perform optimisation using GP

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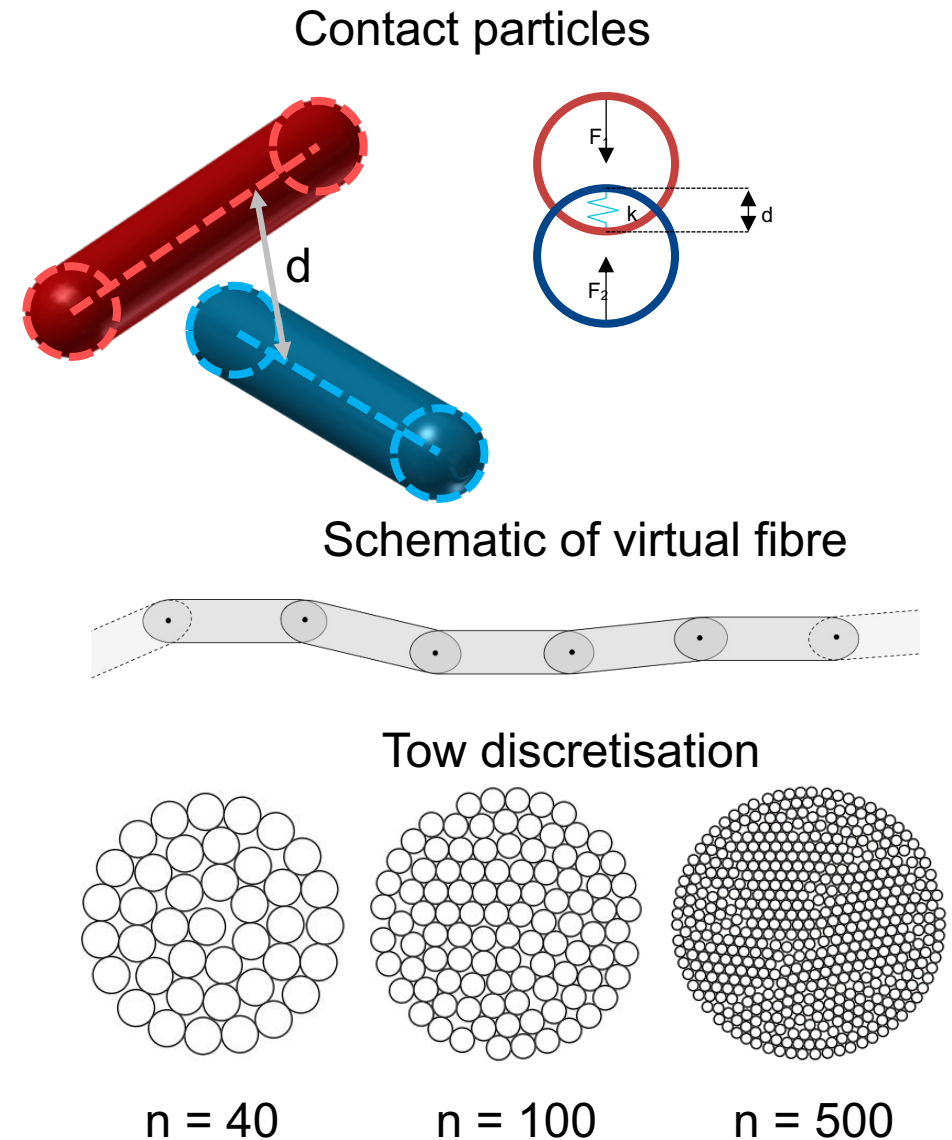Bristol Composites Institute

SimTex

What is SimTex?

Bespoke finite element solver developed for creating realistic virtual textile architectures

Focuses on efficient resolution of contact between spherocylindrical particles

Virtual fibres represented as chains of these particles

Arrays of virtual fibres used to represent fibrous tows

Contact particles

Schematic of virtual fibre

Tow discretisation

n = 40   n = 100   n = 500

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What is SimTex?

Textile unit cells built from basic textile design information:

- Weave architecture
- Number fibres per tow
- Fibre diameter

Tension applied to virtual fibres, simulating tension during weaving process.

Resulting model captures realistic fibre paths and cross sectional shapes

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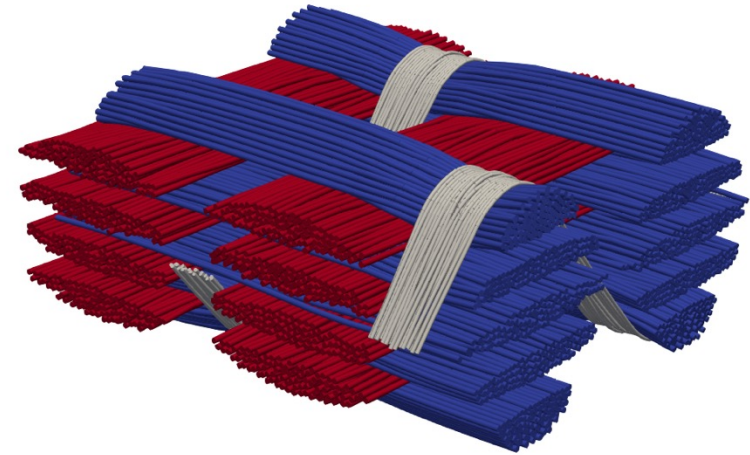
SimTex PrePost

Primary purpose of SimTex is to provide realistic geometries for mechanical performance modelling.

SimTex PrePost provides functionality to build and run mechanical models and perform numerical homogenisation.

Released to Rolls Royce Plc and is now being actively used for the design and analysis of jet engine components.

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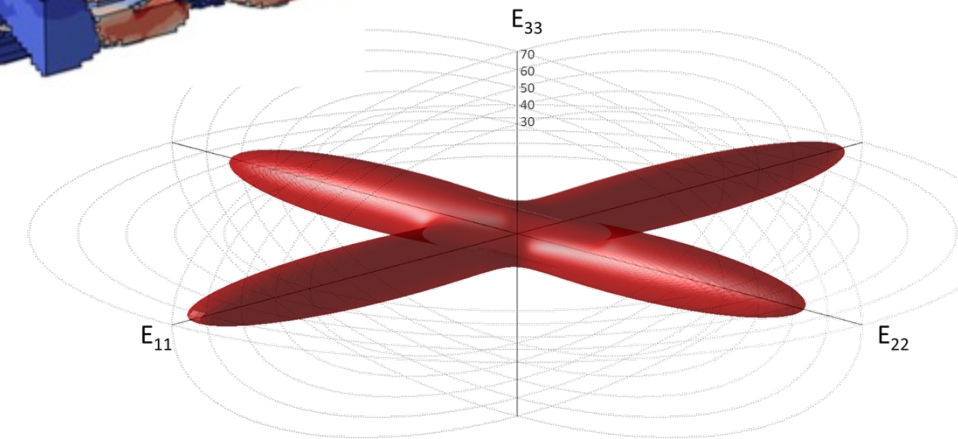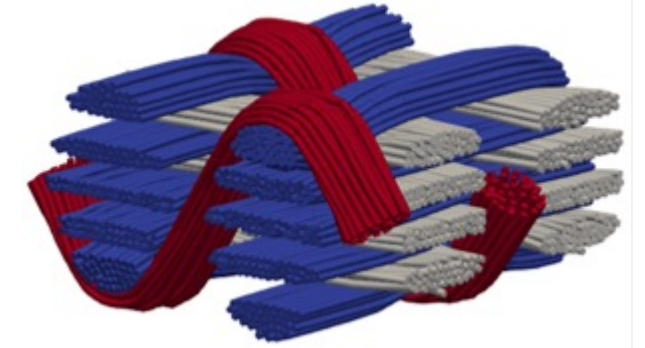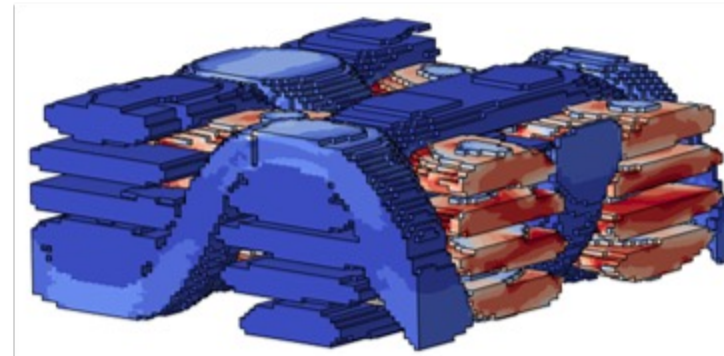
Why SimTex?

Comparisons with commercial FE codes showed SimTex to achieve the same result in ~ one seventh of the time.

Improvements down to more robust and efficient contact algorithm.

Removing constraints of working in COTS tools allowed more novel ideas to be implemented which also improved speed ups.

Further speed ups achieved by working with RSE's to refactor and optimise code base.

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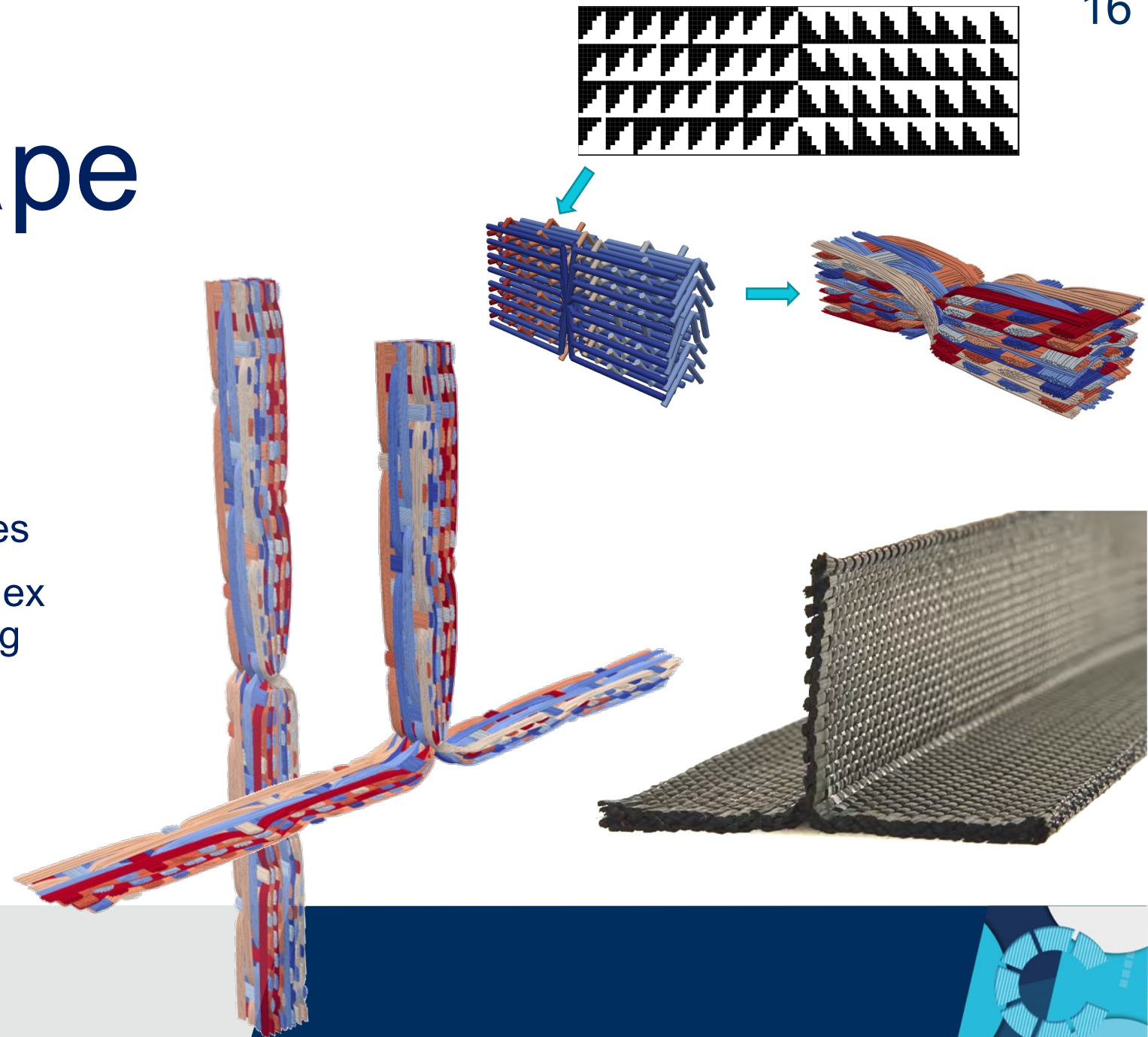Bristol Composites Institute
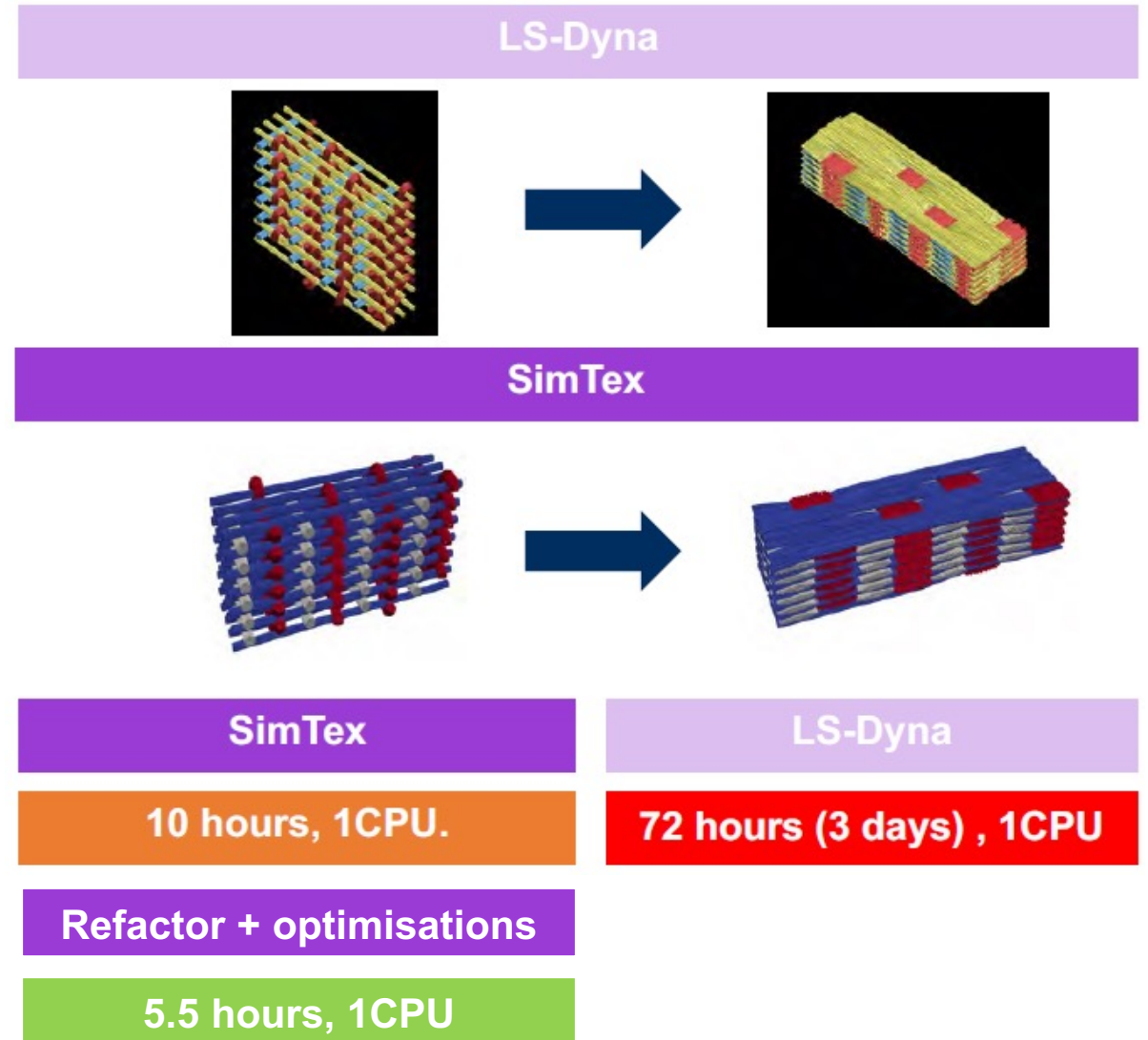
Near-net shape

Integration of final component features into internal architecture:
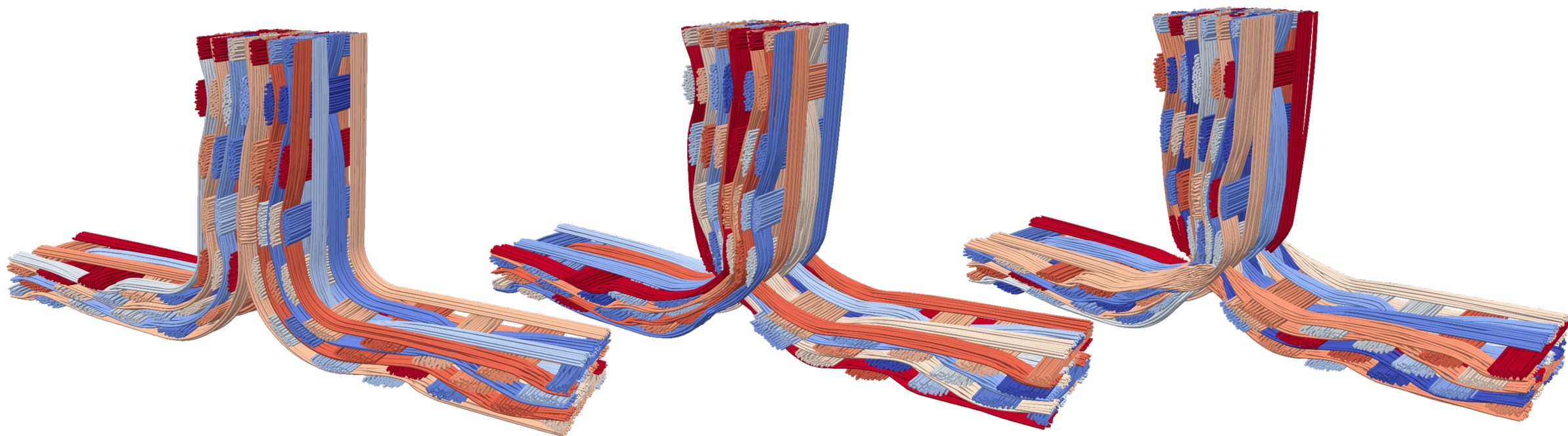
- Ply drops
- Bifurcations

Significant challenge for modelling as size and complexity of textiles increases

Introduced methods to deal with complex tightly woven features and for achieving final part shape without unwanted artefacts

Near-net shape

Braiding

Introduced beam to surface contact to capture tow-mandrel interaction

Virtual bobbins – elements pulled from source under a given tension to simulate tow pulled off the bobbin

Same technology applicable to other manufacturing process such as explicit modelling of weaving and filament winding

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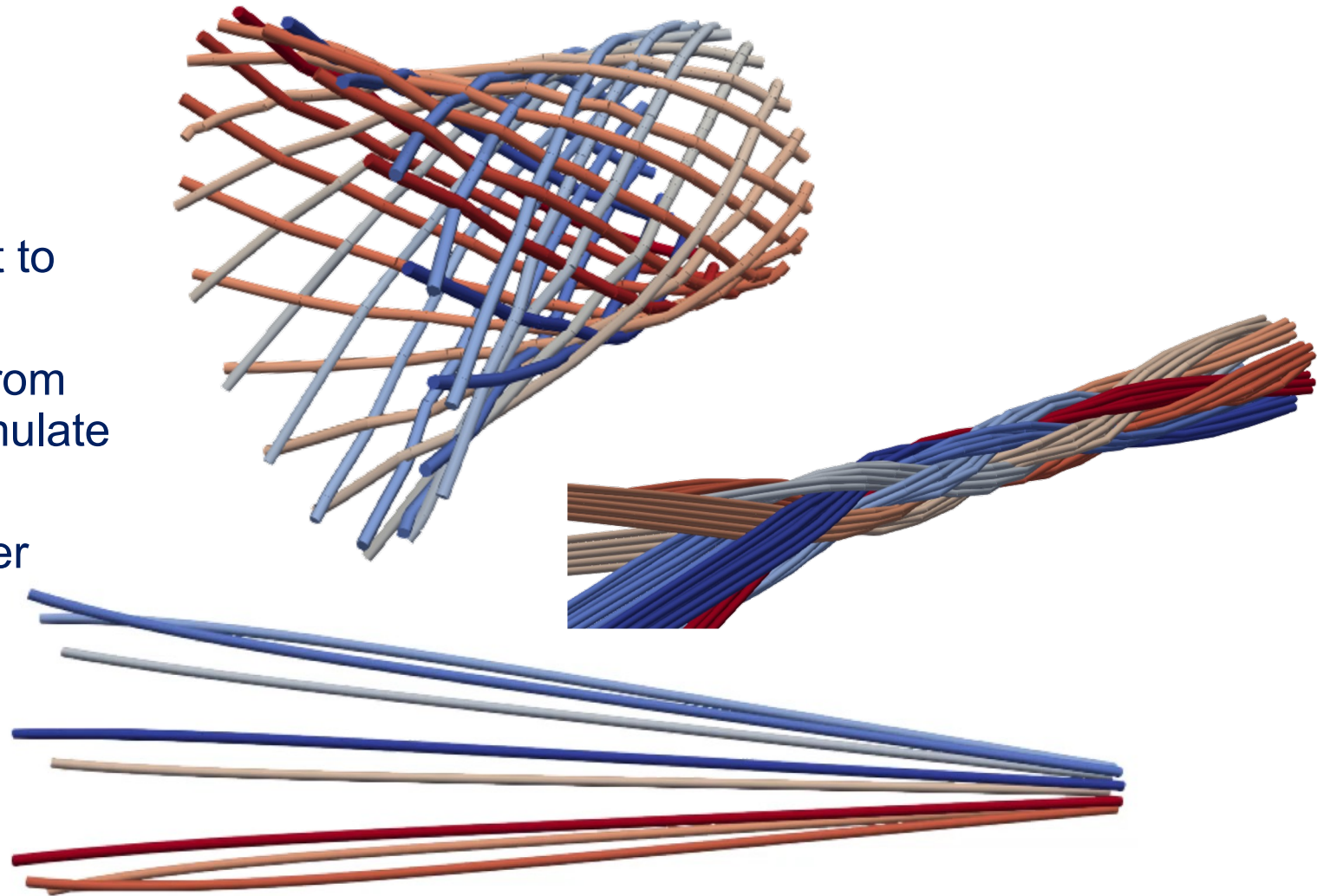
What's next?

Composites: MadeFaster

Rapid, physics-based simulation tools for composite manufacture

Providing simulation capability to capture variability in process and material.

Extending SimTex to consider a greater range of manufacturing processes.

Use dimensional reduction techniques to reduce complexity while retain predictive capability.

Result: ability to capture statistical spread of likely outcomes instead of a single deterministic result.

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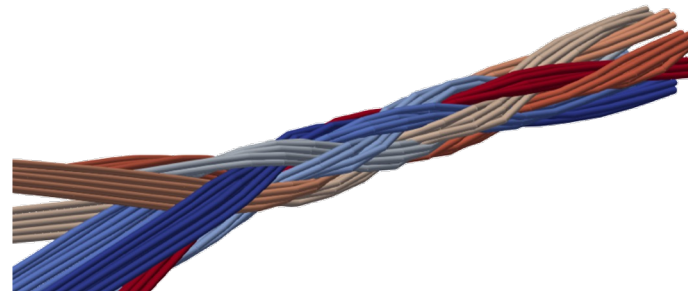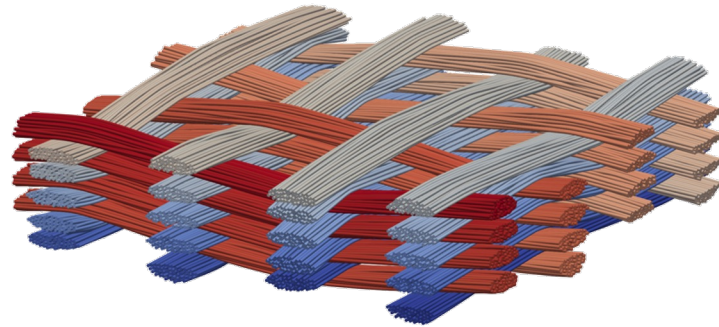
Credits

Laurence Kedward

Kate Gongadze

Ric Sun

Stephen Hallett

Dmitry Ivanov

Matt Edwards

Siyuan Chen

Jonathan Belnoue

Michael Pei

Mark Turk

Lachlan Williams

Jordan Jones

Bassam El Said

Peter Foster

Meng yi Song

Yi Wang

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Thank You

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