THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Centre for Advanced Composite Materials

Textile Simulations for Virtual Composite Materials Manufacturing

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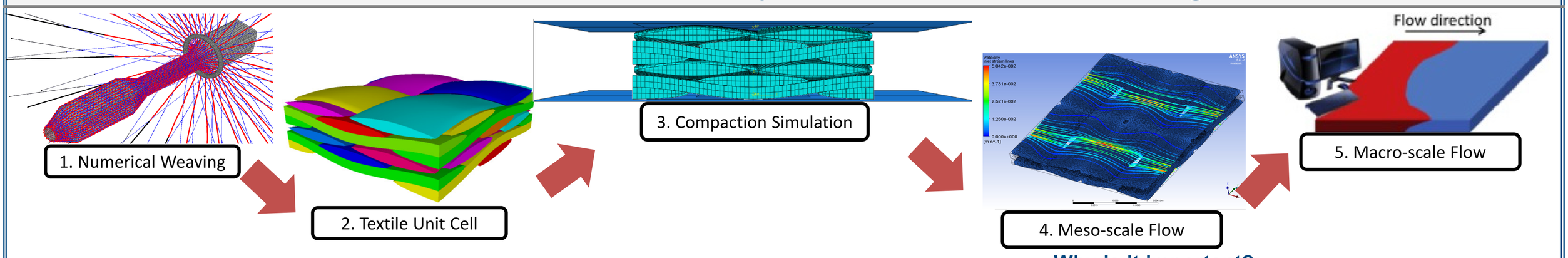
Introduction to Virtual Composite Materials Manufacturing



What is virtual composite materials manufacturing?

It is a complete multi-physics simulation of composite manufacturing from raw materials to end product. The flow chart above describes the virtual manufacturing of a fibre reinforced polymer composite part using the Resin Transfer Moulding (RTM) technique.

Why is it important?

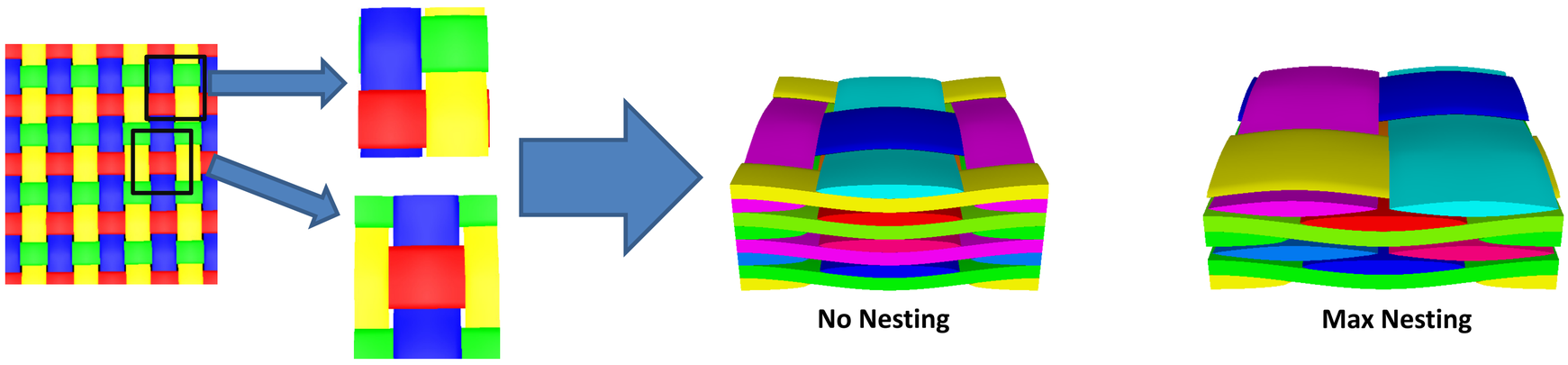
1. Powerful feasibility studies verify whether the proposed composite products can actually be manufactured.
2. Computer simulation is more cost effective and faster than experimental based trial and error.
3. Near optimum manufacturing parameters can quickly be determined which leads to efficient manufacturing and high quality end products.

Aim: Numerically characterize the textile preform (steps 2 to 4 above)

Focus on Numerical Characterization of Textile Preform

Creation of Textile Unit Cell

A **textile unit cell** is the smallest repeating structure of textile preform. The analysis conducted on the unit cell level is extrapolated to represent the whole textile structure.

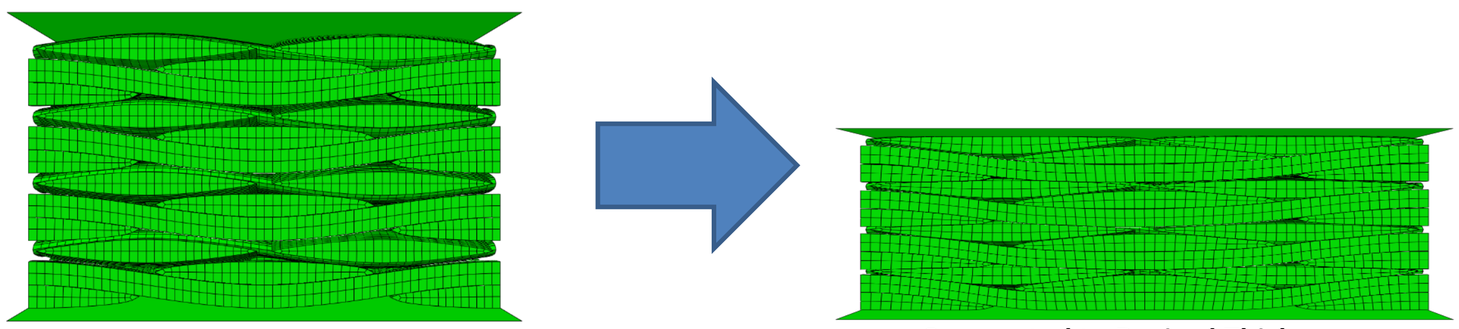


No Nesting

Max Nesting

Compaction Simulation

A **compaction simulation** is conducted on both single and multi-layer textile unit cells to obtain the deformed geometries of the unit cells. This step is vital to obtain realistic flow geometry used in the next step.

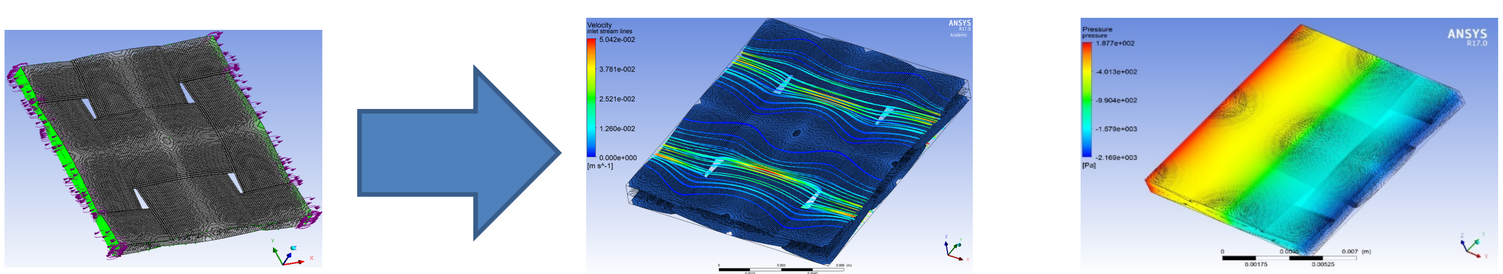


Not Compacted

Compacted to Desired Thickness

Flow Simulation

A **flow simulation** is conducted to the deformed textile unit cells. A pressure gradient is imposed forcing the fluid to flow in the desired direction. The mass flow rate is then extracted and used to predict the meso-scale permeability in a single direction.



Impose Pressure Gradient in the Direction of Interest

The Resultant Flow Streamlines

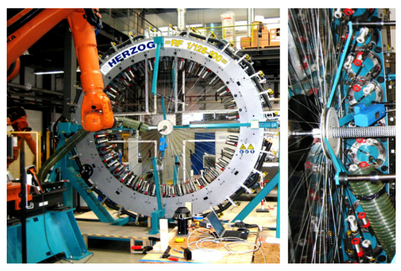
The Resultant Pressure Contour

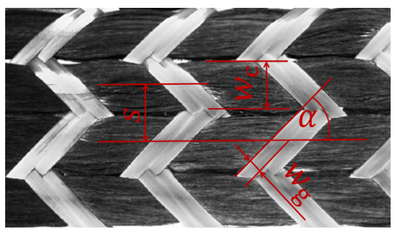
Application to Braided Fibre Composite Products

Braided textiles offer high conformability and damage resistance. Advanced braiding techniques allow for the production of near net-shaped fibre preforms for complex shape composite parts. These positive traits make braided textiles ideal reinforcements for polymer-based composites. Virtual manufacturing offers promising possibilities:

1. Assessment of varied braiding patterns.
2. Mandrel design optimization.

These design enhancements lead to improvements in both manufacturability and end product mechanical properties.





Conclusions

Advanced numerical simulations have been conducted as part of the complete virtual composite materials manufacturing.

1. Averaged textile unit cells have been generated to make use of the repeating nature of textile fabric.
2. Compaction simulations have been conducted to a relevant fibre volume fraction to obtain realistic flow geometry.
3. Flow simulations have been performed on the compacted textile unit cell to obtain permeability along the direction of interest.
4. The predicted permeability enables macro-scale flow simulations to predict the flow behaviour during actual product manufacturing. This enables fast determination of optimum manufacturing parameters which leads to lowered production cost and improved part quality.

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