Multigrid & Network Approach based Permeability Prediction

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Introduction

Resin Transfer Moulding (RTM) is a production method for near-net shaped composite products. Often, Non-Crimp Fabrics (NCFs) are used, but accurate permeability prediction models of NCFs, required for RTM flow simulations, are unavailable yet.

Objective

Prediction of the macro scale permeability of NCFs, while accounting for geometry and flow characteristics on micro scale.

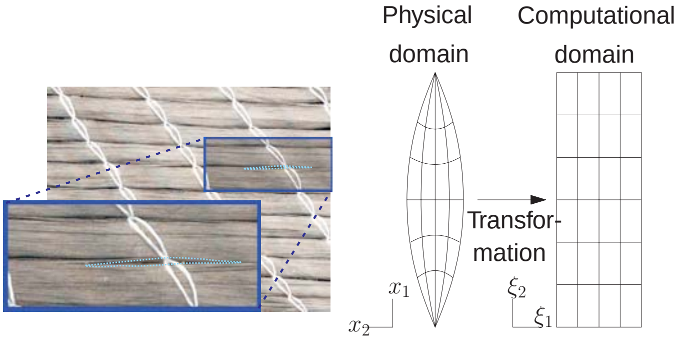

Figure 1 : Non-Crimp Fabric micro scale geometry showing rhomboidal flow domain, which are discretised using a bipolar coordinate transformation.

Methods

The permeability model consists of three parts:

- Geometric description of the flow domain [1,2].
- An efficient flow solver for micro level domain.
- Network model, bridging micro scale flow and macro scale permeability prediction.

The high length–width ratio and rhomboidally shaped domains cause numerical problems in the outer edges of the domain. A coordinate transformation, here a bipolar mapping, can help to overcome these problems (Figure 1).

Multigrid method are chosen as a solver for the micro flow, combining sufficient accuracy with low computational requirements. Relaxation of the approximate solution on different grid sizes (typically doubling the number of grid points in each dimension) enhances the global convergence of the solution.

The solutions of the single flow domains on micro level are combined in a network (Figure 2), representing the actual structure of the NCF. The flow domains communicate in overlapping regions, which can be abstracted directly from the NCF geometry. The computed transfer functions between the pressures and flows at the interaction points between overlapping flow domains are used in a network model.

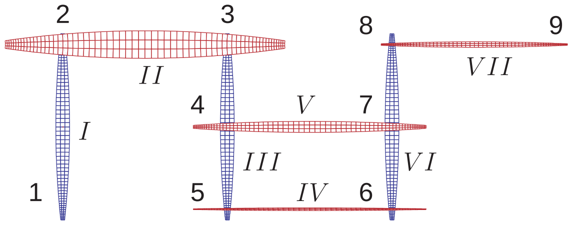

Figure 2 : Network of flow domains; Roman numbers: domains, Arabic numbers: overlapping regions.

Results

Figure 3 shows the velocity profile of the top of a flow domain. No-slip conditions are assumed at the boundaries of the flow domain, apart from the three overlap regions, as can be recognised in Figure 3. Integration of the velocity over the area of these in- or outflow region yields the flow, allowing the computation of the transfer functions between the different regions.

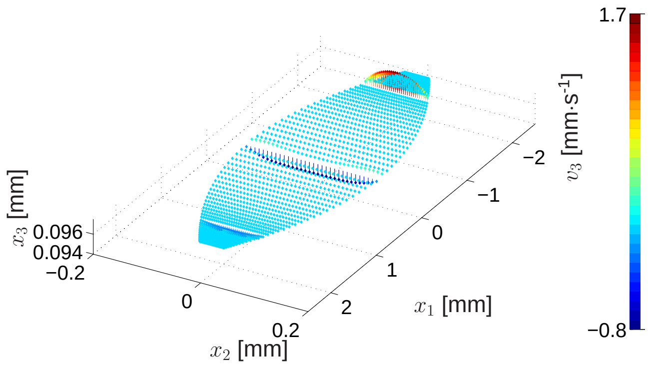

Figure 3 : Velocity at the top plane of the domain.

Further Research

A generalisation of the approach and the geometrical description of the micro geometry will enhance the applicability of the method and the development of a designers tool to predict the permeability of arbitrary Non-Crimp Fabrics.

References

1. Loendersloot, R. et al., Permeability Prediction of Non-Crimp Fabrics Based on a Geometric Model, ECCM-11, 2004.
2. Loendersloot, R. et al, A Permeability Prediction For (Un)Sheared Non-Crimp Fabrics, FPCM-7 2004.