

STOKES-DARCY FLUID FLOW SIMULATIONS WITHIN 3D INTERLOCK – EXPERIMENTAL AND NUMERICAL PATH TO TAKE INTO ACCOUNT THE INTRA-YARN CAPILLARY EFFECTS

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Abstract

Resin Transfer Molding (RTM) is a widely used process in composite material manufacturing, involving the compaction of a fibrous preform, here a 3D interlock, to achieve targeted Fiber Volume Fraction (FVF), followed by impregnation with liquid resin. Dual scale flows within and between homogeneous equivalent porous yarns must be modeled for predicting impregnation schemas and defects. At the mesoscopic scale, fabric unit cells are characterized by yarn morphology and intra-yarn FVF fields.

The dual-scale nature of fabrics significantly affects saturated and unsaturated fluid flows, especially due to capillary phenomena within yarns, which are modeled as an addition to Darcy's law via a capillary pressure. The effect on the effective value of the calculated permeability has yet to be assessed. The aim of the numerical approach is to develop a robust numerical framework for simulating fibrous medium impregnation at the mesoscopic scale [1- 2] and then to compare the results with experimental characterizations.

Accurate description of resin flow within porous yarns requires locally oriented intra-yarn permeability tensor fields and capillary stress tensor (the "orthotropic capillary pressure" [3]) at the resin-air interface. Additionally, pressure enrichment is introduced at the fluid front, represented by a level set function, to capture pressure discontinuity in Darcy domains.

Saturated and unsaturated permeability have to be compared and understood. At the scale of the equivalent homogeneous medium, could an equivalent capillary pressure (determined using a capillary rise experiment) be added to the pressure difference of the saturated permeability in order to recover the unsaturated permeability?

Experimental estimations of permeabilities have been performed at different scales (yarn and preform), regimes and test liquids are ongoing [4]. To evaluate the approach that will be applied at the scale of the yarn in 3D Interlocks, simulation of filling of a cavity complying to the standard ISO 4410:2023 [5] were made, applying estimated or calculated capillary pressures.

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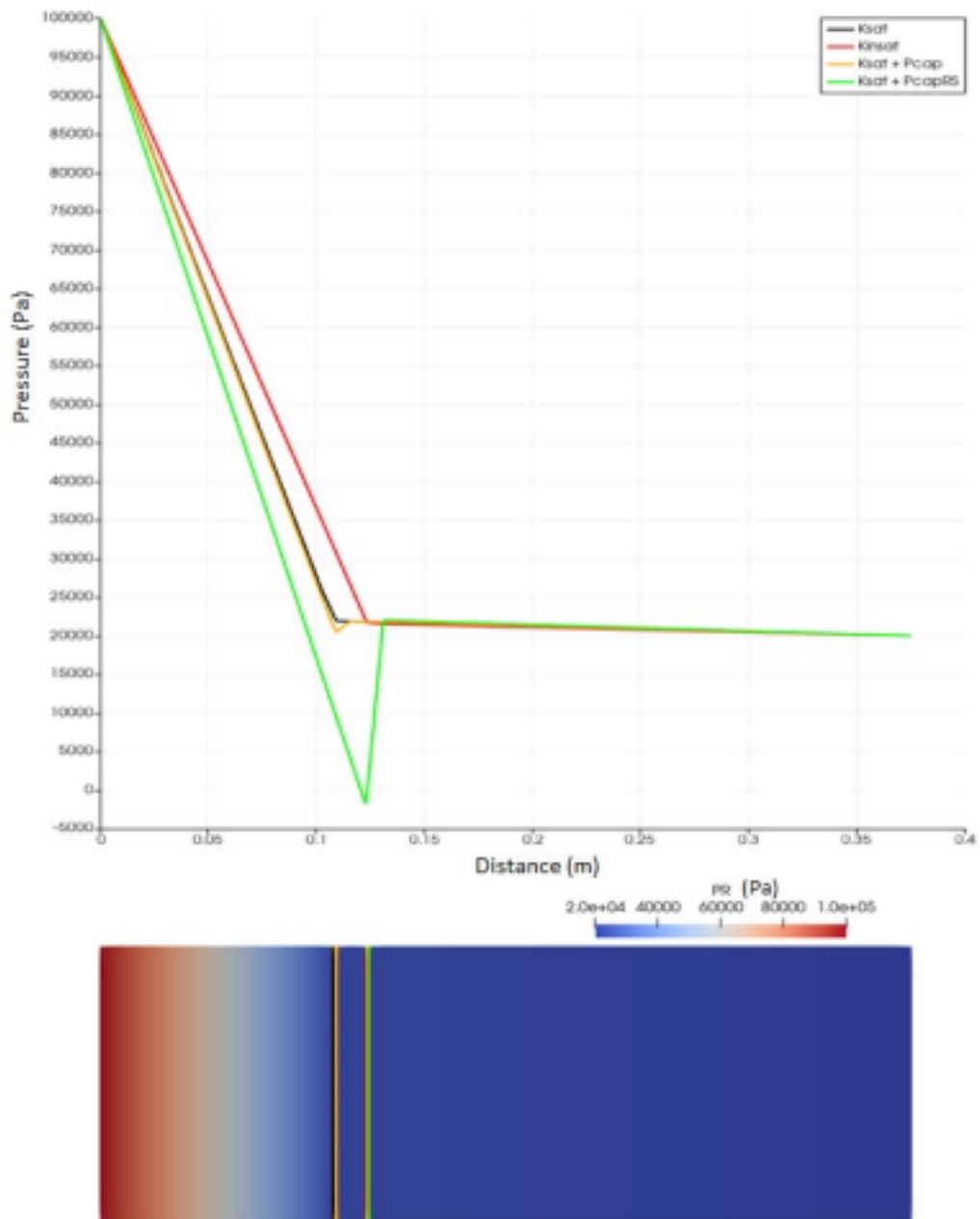


Figure 1. Filling simulation of a cavity complying to the ISO with different conditions and calculation of capillary pressure – visualisation of the numerical pressure gradient for different values of permeability and capillary pressure à the flow front (top) – visualisation of the flow front position and pressure gradient (down)

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