

TITLE: Hybridized Meso-Macro Modelling of Flow in Resin Transfer Moulding with Non-Periodic Tailored Fibre Placement Geometries

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ABSTRACT:

Numerical simulations of resin-transfer moulding (RTM) are indispensable for evaluating the manufacturability of advanced composite parts. In conventional RTM models the governing flow equations are discretized on the macroscopic component geometry - typically with finite-volume or finite-element schemes - and the effect of the reinforcing fibres is introduced through an anisotropic permeability tensor obtained by homogenising a representative volume element (RVE) [1]. This Darcy–Forchheimer-type approach works well for periodic, homogeneous fibre architectures, but it breaks down when the reinforcement layout is non-periodic or deliberately tailored, as is the case with tailored-fibre-placement (TFP) roving patterns [2]. In such situations elements of the component cannot be represented by a single RVE and the construction of a full permeability tensor may even be unfeasible for a given mesh.

To address this limitation, a multiscale coupling framework is implemented that bridges the macroscopic RTM domain with a detailed mesoscopic description of the TFP architecture. The mesoscopic geometry is generated from a kinematic draping simulation of a prescribed TFP stitching pattern, yielding a digitized voxel-based material distribution with known fibre volume fraction and drape direction. [3] The coupling between the mesoscopic and macroscopic flow models is realized with the preCICE library [4], which uses joint boundaries to synchronise the pressure-velocity fields between a coarse macro-scale solver and a fine meso-scale solver that resolves flow in the actual voxelated roving geometry. Both the macro-scale and meso-scale solver are based on an in-house compressible, multiphase OpenFOAM fluid dynamics solver, custom developed for resin transfer moulding. [5] The mesoscopic model supplies locally resolved flow resistance without ever requiring an explicit macroscopic permeability tensor, while the macroscopic model provides the global pressure field and boundary conditions. The two solvers exchange interface fluxes and pressures iteratively until convergence, thereby reproducing the correct overall resin front evolution even in regions where conventional homogenisation approaches fail.

In this work, we present TFP geometries, that may require special attention, as they cannot be represented as an RVE and require mesoscopic simulations. We then explain the application of a coupling methodology used to implement such a multiscale simulation approach. Finally, we present a demonstration case, which illustrates the multiscale coupling approach. The conceptualized methodology is illustrated in Figure 1.

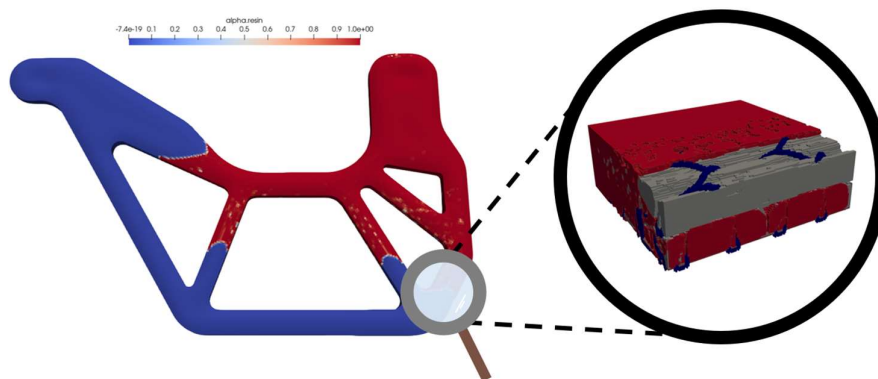


Figure 1: In this multiscale RTM simulation, a macroscopic geometry is infiltrated with a resin, the effects of fibres on the resin are homogenized using the Darcy-Forchheimer equation (left). Regions, where conventional homogenization approaches are ineffective, are coupled to the macroscale geometry and directly simulated on the mesoscale (right).

The abstract should (a) address **at least one of the core themes**, (b) not exceed two A4 pages of text, and (c) not exceed two further sides of A4 for Figures/Tables



References

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