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Homogenisation of Fluid Flow Equations in Textile Microstructures and Numerical Permeability Prediction

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We aim at a fast and accurate prediction of the permeability of textile microstructures, which is an important parameter for optimising the manufacturing of composites with textile reinforcements. New materials with textile microstructures are used in an increasing number of high-performance products. In the manufacturing process, Resin Transfer Moulding (RTM) is used, which is the low-pressure injection of resin into a closed cavity filled with fibre preforms. Practical experiments aim at the enhancement of resin flow through the fibre preform to reduce voids, bubbles and injection time. An alternative to the time- and money-consuming experiments is offered by the numerical simulation of fluid flow in the fibre preforms which allows for the virtual testing and optimisation of different mould designs and textiles.

However in most cases, the large discrepancy between the textile microscale and the composite macroscale renders a direct numerical simulation of fluid flow in the pore microstructure impossible due to computational complexity reasons.

A way to deal with this problem is to upscale the analytical equations of fluid mechanics that hold on the microscale to laws on the macroscale by e.g. averaging or analytical homogenisation methods [**?**]. The so derived macroscopic equations take the microscale only by effective parameters like the permeability into account and are thus numerically easier to handle for simulation purposes.

If the textile yarns are impermeable, the homogenisation of the Navier-Stokes equations yields Darcy's law on the next coarser scale. On the other hand, if the yarns are permeable, we have to couple the Navier-Stokes equations in the fluid domain with Darcy's law or Brinkman's equation in the porous part [**?**, **?**]. In order to explicitly avoid complicated interface conditions between them, Angot et al. [**?**] employ the so-called Navier-Stokes/Brinkman equations as a penalized version of the Navier-Stokes equations for scalar permeabilities.

The contribution of this work is as follows: we shortly discuss the homogenisation of the Navier-Stokes equations in textiles and extend the Navier-Stokes/Brinkman equations to account for non-scalar textile permeabilities, which are of practical interest. We numerically solve the resulting homogenised problems and the Navier-Stokes/Brinkman equations in three dimensions and compare the results to a direct numerical simulation of the Navier-Stokes equations on the microscale. Further, we present an extension to two-phase flows and compare our textile permeability predictions with experimental data.

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