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Numerical simulation at macro- and mesoscopic scales of flow in porous media taking into account capillary effects

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Numerical modeling of fluid flow in multiscale porous media is an emerging approach to simulate composite material manufacturing such as resin infusion-based processes. Fibrous reinforcements are made up of fiber bundles. This dual-scale porous architecture causes the fluid flow to be non-uniform between intra-tow and inter-tow spaces during the manufacturing process. Consequently, impregnation defects and void formation may occur due to the competition between viscous and capillary forces. In fact, the pressure jump generated by the capillary pressure at the flow front can reach up to 0,32bar [3]. Our aim in this work is to develop a robust numerical framework to simulate fibrous media filling at various scales where capillary forces are assumed to play a key role.
At macroscopic scale, the fibrous reinforcement is described by an homogeneous medium and the flow is subsequently formulated using Darcy equations. Numerical strategies such as variational multiscale stabilization [2] and local pressure enrichment [1] are respectively required to ensure the consistency of the finite element model and to properly capture the pressure discontinuity. The model is subsequently validated using the method of manufactured solution.
Thereafter, this numerical model is extended to the mesoscopic simulation of the transverse flow in order to assess the effects of the capillarity at the fiber bundles scale. The flow in the fiber bundles is formulated using Darcy equations while Stokes equations modeled the surrounding flow. A monolithic approach is performed for Stokes-Darcy coupling. Finally, the numerical results are correlated with experimental studies in order to understand void formation and transport mechanisms at mesoscopic scale.

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