Stokes capillary driven flows in fibrous media

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ABSTRACT

Numerical simulation is a crucial asset for high performance composite manufacturing. When a liquid resin infuses reinforcements made of carbon fibres, voids may be created which will affect the final part. Those voids appear due to the competition between capillary effects and viscous effects. This study is part of an industrial chair with, the Hexcel company aiming at modelling and optimising infusion processes for new generation of structural composites.

This study will focus on the capillary effects investigated at the fibre scale. The two fluids (air-resin) Stokes problem is solved using a finite element method. The fluid problem is solved with linear approximations for both velocity and pressure. Though this approximation does not satisfy the Ladyzenskaia-Babushka-Brezzi stability condition, hence an *Algebraic SubGrid Scale* method [?] is used to ensure the existence and uniqueness of the solution. Furthermore, the front of resin is followed by a *level-set* function [?] which is convected by the flow velocity at each increment of the staggered coupled approach.

There are three interfaces, first between the fibres and the resin, second between the fibres and the air, and third between the resin and the air. At each interface the jump of the normal stress gives rise to a capillary force substituted into the weak form of the Stokes equations as a Neumann condition. Modifications using the Laplace-Beltrami operator [?] yield a new expression allowing to include the mechanical equilibrium of the triple line into the weak formulation. This method has the advantage to avoid to impose the contact angle, which is not an intrinsic parameter. Besides there are pressure and gradient of pressure jumps at each interface. The linear approximation for the pressure field is not well suited to capture those behaviours and the pressure space has to be enriched. Therefore discontinuous shape functions [?] are used on the elements cut by the interface and are eliminated by static condensation prior to assembly of the system.

Finally as first test-case, a fluid wicking up against a wall and between two plates is considered. The input parameters of the problem are viscosities, densities and the three surface tensions of cellulose plate(s) immersed into diiodomethane and air. The case of a meniscus against a wall has a known analytical solution while the shape of the meniscus between two plates will be compared with other numerical approximations.

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