An Adaptive Fully Implicit Residual-Based Variational Multi-Scale Formulation for Multiphase Flow

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ABSTRACT

Void type defects created during liquid composite molding processes have a major influence on the performance of composite parts used for instance in the aeronautic industry [1]. Numerically, the void content in a part can be related to processing parameters by modelling resin flow through the composite.

Resin flow is modelled in this work using a fully implicit Residual-Based Variational Multi-Scale (RBVMS) formulation [2]. The Navier-Stokes equation is solved using stabilized finite elements with quadratic interpolation for the velocity and linear for the pressure. The interface is modelled using the level-set method with quadratic interpolation, which involves a level-set advection equation that is fully coupled to the Navier-Stokes equation using a Continuum Surface Force (CSF) model for surface tension [2]. Consistent linearization and robustness of the fully coupled formulation with all RBVMS stabilization terms is achieved using local numerical differentiation and automatic time-step control.

Added to the resin/air interface that is modelled using the level-set method, interfaces between yarns or fibres and the resin and the air must also be modelled. In this work, a conforming-nonconforming mesh generation and adaption algorithm [3], [4], coupled to appropriate error estimators, is used to achieve this goal. Solid phases such as yarns or fibres are meshed in a pre-processing step from real microstructure images acquired using e.g., tomography. This is done by first iteratively refining a non-conforming mesh close to interfaces using a curvature-based error estimator, and then fitting interface elements to obtain a conforming mesh of these interfaces [3]. This conform meshing strategy is not employed for the resin/air interface due to its fast motion and complex topological changes. Instead, a dynamic adaptive strategy using an anisotropic error estimator is proposed to keep elements refined close to the interface. This strategy is inspired from Hessian-based error estimators for linear interpolation [5], but extended to deal with the quadratic interpolation used for the velocity and the level-set function.

Simulations of resin flow through two-dimensional unidirectional fibre composites and three-dimensional woven fibre composites are proposed to illustrate the capabilities of the proposed numerical model. Air bubbles entrapment is considered with a close attention.

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