EULERIAN APPROACH FOR COMPUTATIONAL FLUID-SOLID MECHANICS WITH CAPILLARITY ISSUES FOR RESIN INFUSION BASED PROCESS

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Introduction

Liquid Composite Molding (LCM) processes are competitive routes to elaborate composite structures with organic matrix, especially for large parts in aeronautics. These processes consist in infusing a liquid resin into a stacking of fibrous preforms on which a mechanical pressure field is applied. A thin non-deformable distribution medium is also included to ensure resin feeding. However, although these processes are efficient, they still remain hard to control. One of the main bottle necks arising in the process is the micro/macro void creations, which may significantly affect the quality of the final part. The macroscopic models [2] used to simulate and then optimize the process do not predict this phenomenon, because they do not include the multi-scale nature of the porous media, which is made from several yarns (tows of fibres at mesoscopic scale) that gather thousands of fibres (microscopic scale). The ultimate aim of the present work is to operate a scale transition to extract the mesocopical responses, *i.e.* at the scale of fibre tows, as functions of some process parameters such as pressure and velocity fields, in order to establish scenarios for porosity creation and growth of both mesocopical and microscopic scale. To achieve this, we recently introduced a local fluid-solid contact model at the microscopic scale, to study problems involving surface tension, capillarity and wetting effects between the fluid and fibrous solids, which are determinant in micro/macro void creation and evolution.

The basic model and numerical results

This work is based on an existing finite element fluid-solid framework for transient flows in deformable media at macroscopic scale, within an eulerian approach. At this scale, a monolithic approach [3] has been successfully investigated for coupling flows in purely fluid region, ruled by Stokes' equations, and an orthotropic porous region of low permeability (down to $10^{-15}\ m^2$) governed by Darcy's equations (Figure 1). The description of the moving coupling interfaces is performed with the Level-Set method. The mixed two-field (velocity/pressure) formulation of the flow is discretized using a continuous linear approximation. A Variational Multi-Scale method (Algebraic Sub-Grid Scale: ASGS) is used so as to verify the Brezzi-Babuska stability condition [3]. The approach has demonstrated its ability to simulate problems with complex geometry in severe regimes cases (low permeability, thin flow media) (Figure 1).
At the microscopic scale, the capillary effects between two immiscible fluids (air, resin) are firstly studied. Both fluids are supposed to be Newtonian and incompressible, thus governed by the Stokes' equations. The level set method is used to capture the fluid-fluid interface. To include the surface tension force at this interface, two methods are considered for computing the associated surface integral in an Eulerian approach: the Continuum Surface Force (CSF) method [1], where the surface integral is approximated by a volume integral, and the Surface

Local Reconstruction (SLR) method [4], where the surface tension term is explicitly computed over a locally reconstructed interface. Special attention is paid to reduce spurious velocities that appear at the fluids interface. Then the capillary effects are considered between the fluids and a solid, *i.e.* the wetting phenomena. We have implemented some methods to prescribe both the static contact angle and the slip condition of the contact line (Navier boundary condition) on the fluid/solid interface. These methods have been validated on some test cases of bubble dynamics (Figure 2). The aim is now to take into account the dynamic contact angle and its coupling with the Navier condition. This work is one of the numerical aspects of a project including also an experimental study of capillary effects of porous media [Pucci, Liotier, Drapier, FPCM12]. The ultimate objective is to be able to compare these numerical approaches with corresponding experimental results.

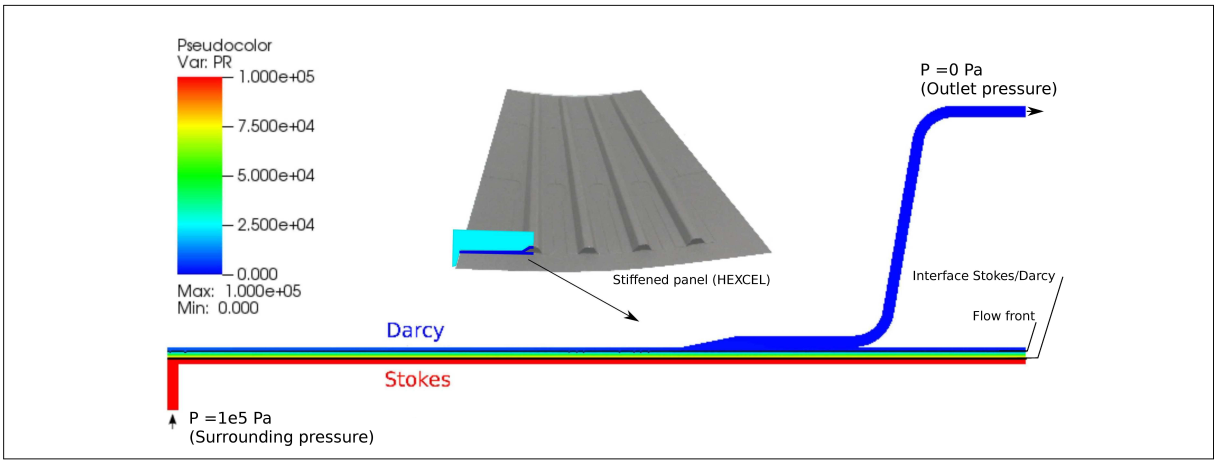
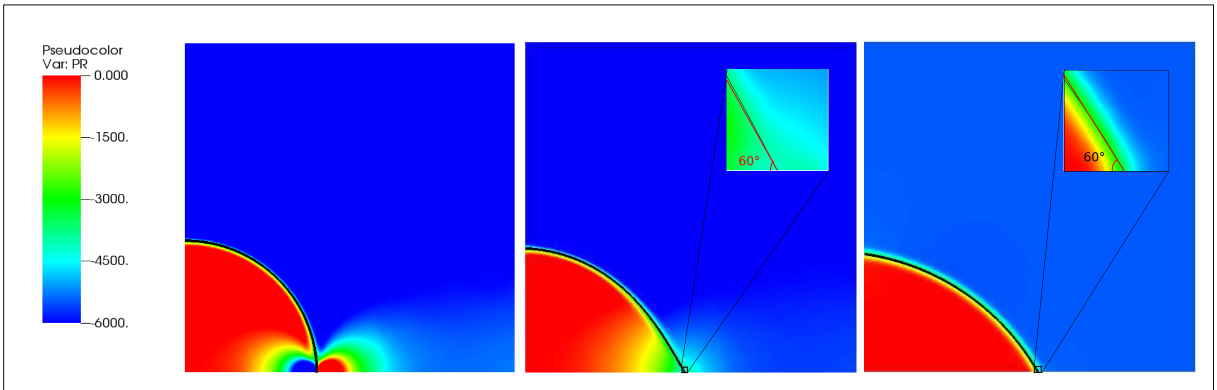


Figure 1: *Pressure fields in macroscopic scale simulation of resin infusion manufacturing process for a slice of stiffened panel.*



(a) t =0 s (b) t =0.01 s (c) t =0.05 s

Figure 2: *Discontinuous pressure fields in the simulation of bubble interface evolution with a contact angle of 60°.*

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