Transient seepage into low-permeability highly deformable orthotropic media for infusion-based composites processing

J. Bruchon*, **N. Moulin, and S. Drapier**

Hexcel-Mines Saint-Etienne Chair; SMS Division & LGF UMR CNRS 5307
Mines Saint-Etienne - Université de Lyon
e-mail: *bruchon@emse.fr, nmoulin@emse.fr and drapier@emse.fr

ABSTRACT

In order to reduce the manufacturing cost of aeronautic composite structures, while reaching a top quality control, wet-route processes are considered as ideal. More specifically, infusion-based processes present the highest potential, they consist in using vacuum to infuse a liquid thermo-reactive resin from a fluid bed across a stack of fibrous orthotropic preforms that undergo finite strains under the combined loading of atmospheric pressure and internal resin pressure [3]. However, controlling these processes is highly challenging, alternatively numerical simulation becomes mandatory and motivates the *Hexcel-Mines Saint-Étienne Chair for Advanced Numerical Modelling of Infusion-based Processing for New Generation Composite Structures* aiming at modelling from fibre (μm) to process (m) scale the infusion processes in a *HPC* framework.

Based on a holistic approach of the physics underlying these processes, during the last few years we have been working on coupling, firstly at the macro (process) scale, transient fluid flows with finite strains solid and porous mechanics, in isothermal conditions [3]. First, two different fluid flow regimes must be coupled on a fixed grid, representing the resin flows in both a highly permeable undeformable distribution medium (Stokes) used to create a resin bed, and low permeability ($\propto 1E^{-15}m^2$) fibrous orthotropic performs (Darcy). This is achieved using efficient *ASGS* Stokes-Darcy stabilized monolithic finite element formulations able to capture properly the fluid seepage into the preforms [1].

The second types of coupling deals with non-linear solid / fluid mechanics and fluid / level-set problems through weak coupling algorithms. Indeed, solid and fluid interact in two ways in the wet (saturated) preforms: the resin pressure will load the preforms and lead to a change in their porosity/permeability (controlling Darcy's fluid flow), and conversely will modify the overall wet preforms response against the external atmospheric pressure loading. Using a Terzaghi's equivalent stress, the non-linear wet preform response is easily built up, in an updated Lagrangian scheme, from the dry preform orthotropic non-linear response. This latter being also used for the dry preform - not yet filled in - response. Last, the level-set method used to capture the flow front is updated using the physical velocities, computed in the Stokes domain at the very beginning of infusion stage, and then in the Stokes-Darcy regions for most of the infusion stage.

Efforts are now ongoing to integrate local flows - capillarity- and also to minimise computation times with multitasking - *see* Mezher-Moulin-Bruchon-Drapier in this *Coupled Problems 2017*.

REFERENCES

[1] Abou Orm, L. and Troian, R. and Drapier, S. and Bruchon, J. and Moulin, N. Stokes/Darcy coupling in severe regimes using multiscale stabilization for mixed finite elements : monolithic approach versus decoupled approach. *Eur. J. Comput. Mech.*, (2014) **23**(3-4):113–137.

[2] Blais, M. and Moulin, N. and Liotier, P.-J. and Drapier, S. Resin-infusion based processes simulation : coupled Stokes-Darcy flows in orthotropic preforms undergoing finite strain. *Int. J. Mat. Form.* (2015) 1–12.

[3] Celle, P. and Bergheau, J.-M. and Drapier, S. Numerical Modelling of Liquid Infusion into Fibrous Media Undergoing Compaction, *Eur. J. Mech., A/Solids*, (2008) **27**:647–661.