Upscaling transient flows in fibrous multi-scale structures for infusion-based stochastic process modelling of composite structures

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Resin infusion-based processes are promising routes for the production of primary composite structures. However, manufacturing such structures for aeronautics is still a challenge which requires to fill-in further gaps in terms of quality, to reach the 1% max void content targeted in ever increased production rates (60 aircrafts/month in 2020/25 for the next generation of single aisle aircraft). As a world leader in composite materials production for aeronautics, Hexcel is funding a 2.2 M€ industrial chair at Mines Saint-Etienne, a long time partner, for developing leading edge simulations capabilities for aircraft manufacturers. Since 2015, mandatory developments for setting robust numerical and experimental modellings of the underlying hydro-poro-mechanical phenomena in play have been achieved, and require now to gain insight into the physics of flows in fibrous multi-scale architectures.

Indeed, a continuous effort over the last years has permitted to build a unique in-house holistic framework to model these processes (see https://www.mines-stetienne.fr/en/author/drapier/research-topics/) which can be cast as a **polymeric resin impregnating highly deformable orthotropic preforms undergoing finite strains under external and internal fluid pressure driving forces**. Owing to the developed stabilized numerical schemes, the representation of **coupled transient flows tightly combining across scales (Stokes, Darcy, capillary effects)** is now secured.

The aim of the present PhD work is twofold: 1/ to setup a **physically sound approach** in order to **upscale flows from the constituent scale towards the ply and then the macro scale,** through a multi-scale approach of the fluid flow in the **dense fibrous orthotropic network under consideration,** and 2/ to use **deep learning techniques** to feed **stochastic** models with **experimentally assessed variability**.
The PhD work should then start from full-field simulations of flow in micro-structures, including **surface tension effects**, both in **saturated** and **transient** regimes, to model flows in fibre bundles (plies) as well as between the transition regions of dis-aligned bundles. **Homogenization techniques** will be first settled in a rigorous framework, based on recent works in the field of porous media flows, to estimate permeabilities and capillary pressures in the bundles. **Computed surface responses** will be assessed also, especially for transition zones between the fibre bundles. In both cases the resulting characteristics will be used to feed upscale simulations where homogeneous equivalent media ruled by Darcy-like response are considered. Then, a complementary approach may consist in considering, in full-field simulations, **stochastic distributions** of properties originating from fibre/ bundle-scale disorders or other potential process-induced variability. Enriched with intrinsically variable experimental data, such full-field models results will feed **deep learning systems** to produce **stochastic data-driven surrogate** models which may be interrogated on the fly in macroscopic simulations.

Partner : Hexcel Corporation.

Profile sought :
1 – mechanics or applied physics (solid, fluid, porous media), applied mathematics,
2 - numerical skills.
Skills in C++ programming/HP Computing and stochastics will be a plus.
Applicants should be fluent in English, if not in French.

Funding : 3-years term contract at 1600 € net salary per month (including social insurance).

Recruitment : continuous applications will be examined until proper candidates will be appointed

Applications (CVs+transcript of records+references) should be sent directly to Prof. J. Bruchon bruchon@emse.fr