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To cite this version:

Kevin Dugois, Stéphane Vincent, Didier Lasseux, Eric Arquis, Cédric Descamps. A macroscopic model for the impregnation process of composite material by a concentrated suspension. Euromat 2015, Sep 2015, Warsaw, Poland. hal-01172315

HAL Id: hal-01172315
https://hal-upec-upem.archives-ouvertes.fr/hal-01172315

Submitted on 7 Jul 2015

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A macroscopic model for the impregnation process of composite material by a concentrated suspension

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In order to improve thermal, mechanical behavior and weight of our turbine blades, we need to use a new composite material. The manufacturing process to obtain this composite is intricate and requires a fluid densification process consisted of two parts. Firstly, particles are introduced in the reinforcement thanks to a pressure-driven flow, where they're retained by a filtration membrane. By reducing porosity, we improve the capillarity infiltration of a melted metal which can react with particles (second part). In this present study, we carry out a model that can describe physics of particles' introduction in our material.

Given that we wanted to simulate flow at fibers scale and considering average particles' size is about a micrometer, we decided to use the volume fraction of particles \( \Phi \) to describe our colloidal suspension. Thus, suspension flow can be resolved with the Navier-Stokes equations of mass and momentum conservation. To evaluate the particle concentration field, a diffusion equation is introduced. Originally developed by Leighton \textit{et al} \cite{1}, then improved by Phillips \textit{et al} \cite{2} this equation describes the migration of particles in a sheared flow. At last, the viscosity dependence of volume fraction is given by Krieger \cite{3}:

\[
\mu(\Phi) = \left(1 - \frac{\Phi}{\Phi_{\text{max}}} \right) \eta \Phi_{\text{max}}
\]

Due to the filtration membrane presence, our process is similar to the dead-end filtration developed in microfiltration process \cite{4}. Thus, we easily observe the sieving mechanism with formation of a growing cake that can be seen as a porous media. In the cake, our model describes a macroscopic flow of aqueous fluid in a porous media composed of rigid spheres. Microfiltration process can also provide theoretical law over temporal evolution of the cake-layer thickness. Before testing our model over realistic geometries, it was evaluated with experiments \cite{5}. Then, our work consisted of two parts: 2D parametric studies and strong 3D simulations over RVE.

References


