Numerical Simulation of Resin Infiltration Process on 3D Fibrous Reinforcement at Multiscale

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Introduction

VARTM (Vacuum Assisted Resin Transfer Molding) process is one of the most significant process of composite material manufacturing. Compared with other processes, VARTM has numerous advantages such like good surface quality, low-cost, low COV emission and high efficiency. Resin infiltration is the key step of this process. Nowadays, the studies about numerical simulation of the resin infiltration on the 3D fibrous reinforcement at multi-scale mostly focus on the permeability estimation [1-3]. This work is interested in applying FEM (Finite element method) to study the transient flow front tracking based on 3D REV (Representative Elementary Volume) model including both woven and bidirectional fibrous structure at multi-scale. However, in the practical process of VARTM, both the flow outside tows and infusion intra tows include complex hydromechanics procedure, micro and macro voids formation greatly depend on transient situation.

For VARTM process, there is only one phase (resin) flow. In the region of inter tows, Navier-Stokes equation can be applied to simulate the free surface flow while Brinkman equation governs the flow intra tows. This single-phase method is suitable to describe the present challenges. Since Brinkman equation has been employed only to solve the single-phase coupling problem so far. At the meantime, it is indicated that this equation will cause numerous problems in two-phase porous flow. With the assumptions of considering resin as Newtonian fluid and inertial term ignored, the basic form of governing equation can be described as below in eq. 1 and eq. 2.

$$\nabla P + \mu \frac{1}{\boldsymbol{K}} \boldsymbol{u} - \mu \cdot \nabla^2 \boldsymbol{u} = 0 \qquad (1)$$

$$\nabla \cdot \boldsymbol{u} = 0 \qquad (2)$$

Where $\boldsymbol{K}$ is the permeability tensor of the porous structure, P is the pressure which drives the fluid, μ is the viscosity of the resin and $\boldsymbol{u}$ is the velocity vector of the resin. Eq. 1 is the Stokes-Brinkman equation, when $\boldsymbol{K}$ tends to be infinite in the free surface flow region, hence, the left hand term of eq. 1 turns to be 0 and Stokes equation is achieved.

Level set method is implemented to track the resin flow front. Two cases of transient flow front tracking on 3D bidirectional and woven fibrous architecture are presented in figure 1 and figure 2.

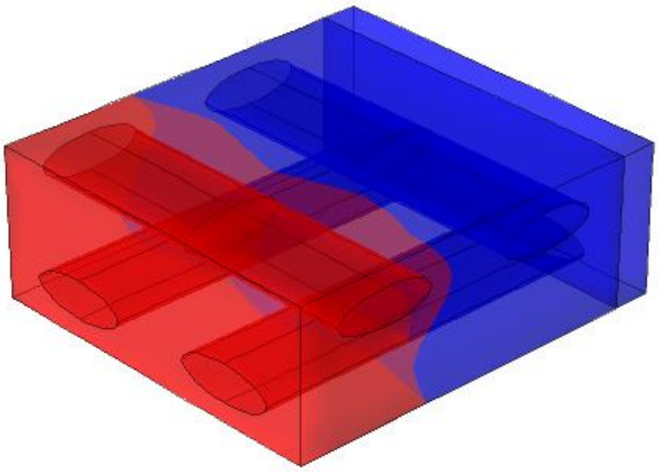

Figure 1: *Transient flow front tracking on 3D bidirectional fibrous architecture at multiscale*

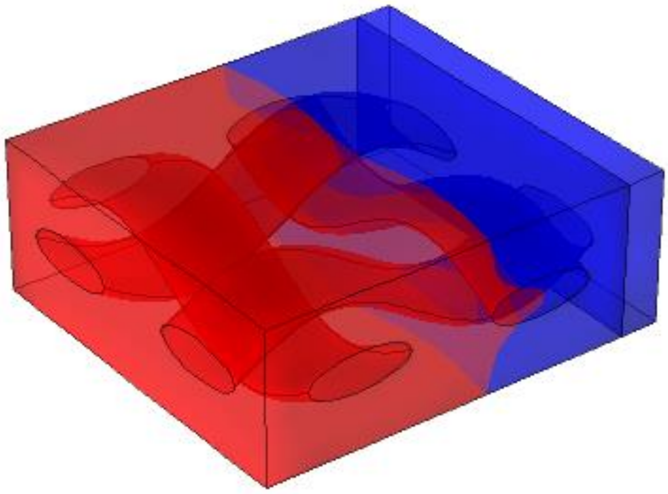

Figure 2: *Transient flow front tracking on 3D woven fibrous architecture at multiscale*

Infiltration ratio is defined to describe the situation of time-dependent infusion process as shown in figure 3.

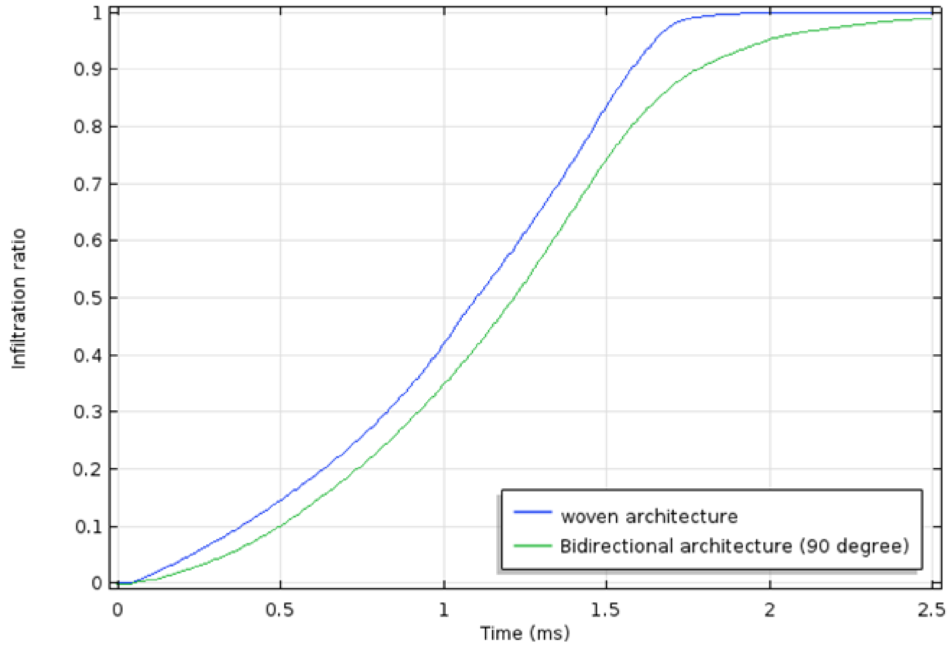

Figure 3: *Infiltration ratio as a function of time*

This work presents the resin infiltration process on 3D fibrous model at multiscale by adopting numerical simulation to track the transient resin flow front. The transient saturation during infiltration process can be studied by introducing infiltration ratio. Influence of structural parameters of the fibrous media, inlet pressure and resin property on the infiltration process is also discussed. All these results offer a better understanding of resin infiltration process on 3D fibrous reinforcement at meso-scale. Meantime, the appearance of defaults such like the formation of voids can be clear based on this model.

References

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