Numerical Method to Predict Void Formation Inside Fiber Tows during the Liquid Composite Molding Process

Zuzana Dimitrovová and Suresh G. Advani
IDMEC / IST and DEM / UD

ABSTRACT

Liquid Composite Molding is a composite manufacturing process in which fiber preforms consisting of stitched, woven or braided bundles of fibers, known as fiber tows, are stacked in a closed mold and a polymeric resin is injected to impregnate all the empty spaces between the fibers. It is important to ensure wetting and saturation of all the fiber tows and regions in between them. Mold filling simulations do not usually address flow at the mesolevel in which one examines the movement of the resin inside a fiber tow in between individual fibers. Mesolevel analysis refers to study of resin flow in between individual 10-20 micron diameter fibers with the domain consisting of a fiber tow. The fiber tow is usually of the order of few millimeters as compared to the composite that is of the order of a few meters.

In flow across fiber tows, resin advancement in between the fibers in a fiber tow, is helped by strong capillary forces due to the microscale gaps but at the same time it must overcome a fiber arrangement with very low permeability. Therefore when the macroscopic front that impregnates the gaps between fiber tows envelopes the fiber tow, it will immediately wet only a thin film along the fiber tow circumference. The resin may find it easier to flow along the fibers inside a tow rather than across it. Thus, one would expect a complicated three-dimensional flow inside a fiber tow that could easily entrap voids that will be of the order of microns inside a fiber tow.

We have formulated the governing equations for free boundary flows around and inside a fiber tow and developed numerical techniques to address the movement of the flow at this scale. The simulation can track the advancement of the resin front promoted by both hydrodynamic pressure gradient and capillary action. The results clearly show that wicking flow plays an important role at the mesolevel and cannot be omitted. Voids creation is explained and temperature influence on the free front pattern is investigated.