Void Formation at Mesolevel during the Liquid Composite Molding Process

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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. Mesolevel analysis refers to study at the order of a fiber tow which 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 advance in intra-tow spaces, although helped by quite strong capillary pressure, must overcome a fiber arrangement with very low permeability. Therefore only a thin strip along the fiber tow circumference is filled when the primary resin front envelopes it. If the resin is not forced to flow across the single fibers inside the tows, it will naturally choose the easier direction, i.e. along the fibers in this case.

In flow along fiber tows, intra-tow permeability is much higher and moreover capillary action is twice as strong as in flow across the tows. Therefore resin advance in intra-tow spaces can be promoted as much as in inter-tow spaces and as a consequence two situations may arise, wicking flow front inside the fiber tow can be either advance or delay with respect to the primary front in the inter-tow spaces, which also pre-determinates the location and shape of the emerging voids.

Numerical simulations at the mesolevel are conducted by incorporating the governing equations for free boundary flows around and inside a fiber tow into a set of subroutines. 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.