FEM simulation and Monitoring of resin flow in Liquid Molding processes

V. Antonucci1 , A.Calabrò, F. De Nicola2, M.Giordano1, L.Nicolais1, C. Vitiello2
1 CNR-Institute for Composite and Biomedical Materials, P.le Tecchio 80 - 80125 Napoli – Italy 2 CIRA scpa, Advanced Technologies and Materials Lab, Via Maiorise - 81043 Capua (CE) - Italy

ABSTRACT

Liquid Molding processes are promising and attractive low cost techniques for the manufacturing of high performance polymer based composite materials. The processing cycle involves the impregnation of a dry fiber mat by a thermoset polymer resin which is injected into a closed mold in the case of the RTM process or can be pre-shaped in film form under the fibers in the case of RFI technology. After complete infiltration, the resin reacts to form a cross-linked polymer network (cure reaction) giving the composite consolidation. Thus, due to the complex nature of the process, the processing modeling and characterization coupled to a proper control should aid the design of the processing parameters and enable the manufacturing of high performance parts. In this study, the non-isothermal resin infiltration during the RTM process has been analyzed and characterized experimentally. In particular, the resin flow through the fibers has been described by the Darcy law and introducing the degree of saturation, the percent of void effectively occupied by the resin within a control volume, as variable in order to account for the moving boundary nature of the problem. The numerical simulations have been performed by a finite element software that was developed and conceived as an open simulation platform in which it is possible to insert different kind of models able to describe the behavior of the most important process variables (degree of cure, temperature, pressure, viscosity) and to investigate the control strategy to improve the efficiency of process manufacturing. The flow and balance equations have been solved by using a fixed mesh grid and an explicit time step scheme. The stability of the solution was ensured by applying the Courant-Friedrichs-Lewy condition. The numerical diffusion along the flow direction was minimized by using the “internal nodes” method which provides also higher accuracy on the degree of cure solution due to the use of a bigger number of nodes compared with the effective number of nodes of the mesh. The resin advancement through the fiber mat was measured experimentally by several fiber optic sensors embedded preliminary through the reinforcement. The use of the non intrusive fiber optic sensors allowed both the in-situ characterization of the fiber reinforcements and the real time monitoring of the resin flow during the experimental infusion tests demonstrating the capability and the reliability of the model.