Non-Isothermal Injection Molding with Resin Cure and Preform Deformability

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Many composite materials are manufactured using industrial processes, usually named Resin Transfer Molding, Structural Resin Injection Molding or Squeeze Casting, which essentially consist in injecting a metallic, ceramic or polymeric melt in a porous preform of reinforcing elements. At the end of the production cycle, the liquid matrix, which should uniformly fill up the whole preform, solidifies holding the reinforcing elements together and enabling the transfer of the major stresses and loads to the solid preform.

In the literature, these processes are usually modeled assuming that the solid preform is rigid, though non negligible deformations are mentioned or put in evidence by several authors [1], [2], [3], [4]. In fact in several practical situations the pressure gradient driving the flow is large enough to significantly compress the reinforcing network, especially ahead the advancing infiltration front, and this alters the preform permeability. This is particularly evident near the injection port where the liquid matrix penetrates the preform , since a fiber-free region may form there. At this point the liquid prefers to flow around the preform rather than through it.

In addition, from an industrial point of view, it is important to have a model which allows to monitor deformation and stress states in the solid preform, to quantify the inhomogeneous characteristics of the final products and revel in advance the possibility of damages in the reinforcing network, which may lead to material failure.

¿From these observations, the necessity of including deformations in models aimed at simulating composite material manufacturing is clear. So we have developed a model simulating the non-isothermal injection molding process, always allowing deformation of the solid preform during the application of pressure and temperature cycle. In addition, while infiltrating the resin undergoes an exothermic crosslinking chemical reaction. The problem presents then the formation of three time-dependent domains, the first one occupied by the liquid only, the second one by the solid preform wet by the curing resin and the third one consisting of the uninfiltrated solid preform. It is assumed that sharp fronts divide the three domains. If this might be plain for the interface dividing the pure liquid and the wet preform, i.e. one borders of the problem, it implies a simplification of capillary phenomena at the interface between the saturated and the dry porous medium. This assumption, often called slug-flow approximation, is reasonable when the applied pressure is much larger than the capillary pressure. This requirement is satisfied by most composite materials manufacturing processes.

Though the model specifically refers to the industrial processes mentioned above, the basic idea can be applied to other industrial processes involving infiltration in deformable porous materials, e.g. sponge-like materials.

References

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