



Stochastic modeling of nonisothermal flow during resin transfer molding

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Received 9 October 1998; received in revised form 2 December 1998

Abstract

Resin Transfer Molding (RTM) offers the potential to manufacture reinforced thermosetting composites of complex geometries cost-effectively, and at high throughputs. Strong uncertainties inherent in the process, however, stymie robust production of quality composites via this route. Although a number of numerical models have been developed over the years to describe the process, a thorough and systematic analysis of the parameter uncertainties has been the subject of little attention, and forms the focus of this study. This paper presents a stochastic model to investigate the effects of process and material parameter uncertainties on the nonisothermal filling process during resin transfer molding. The analysis is performed in terms of four dimensionless parameters that concisely represent the process physics, and provide for a generalized applicability of the study over a wide range of processing configurations. Parametric studies are conducted to identify optimum values of the dimensionless quantities that minimize the fill time, while simultaneously minimizing the output parameter variabilities. The results of the study provide valuable insight towards robust manufacture of composite materials. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

Resin Transfer Molding (RTM) is a liquid composite molding technique that is increasingly being used in the commercial manufacture of reinforced thermosetting composites. In the basic isothermal process, a catalyzed resin is injected into a closed mold cavity which has a pre-placed fiber stack, called the *preform*, at room temperature [1]. After the resin has completely permeated the preform, the mold walls are subjected to high temperatures in order to initiate complex cross-

linking chemical reactions called *cure*. Cure leads to an increase in the viscosity of the resin, and eventually the resin *gels* to form a structurally hard composite product. In the nonisothermal variants of the RTM process, the resin, the mold walls, and the fiber stack are all maintained at different temperatures, and the temperature field inside the mold changes continuously as the resin flows. Nonisothermal mold filling has the potential to result in shorter processing cycles, since heating the resin leads to a decrease in its viscosity, and hence to faster resin flow. It is to be noted, however, that heating the resin also initiates the cure reactions that might cause gelling before the mold is completely filled. Complex nonlinear interactions among the governing phenomena are thus characteristic of the process.

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