Available online at www.sciencedirect.com
ScienceDirect
Composites: Part A 37 (2006) 1815–1830
composites
Part A: applied science and manufacturing
www.elsevier.com/locate/compositesa

Simulation of active flow control based on localized preform heating in a VARTM process

R.J. Johnson, R. Pitchumani *

Composites Processing Laboratory, Department of Mechanical Engineering, University of Connecticut, 191 Auditorium Road, Unit 3139, Storrs, CT 06269-3139, United States

Abstract

Defects in parts produced by the vacuum assisted resin transfer molding (VARTM) process are often attributable to the formation of voids during the mold filling stage of the process. These defects can be eliminated through the use of active control schemes to steer the flow to follow a desired path. This paper builds upon previous work of the authors [Johnson R, Pitchumani R. Induction heating assisted permeation enhancement for the VARTM process. In: Proceedings of the 34th international SAMPE technical conference. Maryland; 2002. p. 250–61; Johnson R, Pitchumani R. Enhancement of flow in VARTM using localized induction heating. Compos Sci Technol 2003;63(15):2202–15] and explores the innovative idea of using induction heating as a means of locally reducing viscosity to counteract the effects of spatial permeability variations in preform layups. Feedback of flow front locations during the filling stage of the VARTM process is used together with a numerical process model to arrive at decisions on the trajectories of the induction coil, and the coil voltage, so as to maintain a uniform flow progression without exceeding a prescribed maximum temperature limit. In the present study, various control strategies are explored in a simulation environment to arrive at an optimal scheme for practical implementation. Results of studies demonstrate that the control scheme is capable of improving the flow uniformity, as measured by the root mean squared (RMS) error relative to an ideal uniform fill by as much as 88% in comparison to an uncontrolled mold fill, while simultaneously maintaining acceptable material temperatures throughout the filling process.

Keywords: A. Polymer-matrix composites (PMCs); C. Computational modeling; E. Resin flow; E. Resin transfer moulding (RTM)

1. Introduction

Vacuum assisted resin transfer molding (VARTM) is an attractive and affordable method of producing large-scale composite structures. As is common across liquid molding processes, in general, part defects often arise during the mold filling stage of this process, where a reactive resin is drawn into a porous preform placed in a single hard sided mold through the use of vacuum. As the resin is drawn through the preform by the pressure gradient, the fluid preferentially follows the path of least resistance governed by its viscosity and the permeability of the preform material. The relation between flow velocities, permeability, pressure gradient, and viscosity is governed by Darcy's law [3,4]. Designing the process so as to achieve uniform and complete fiber saturation is imperative for fabricating quality products. Furthermore, despite an optimum process design, process and material parameter uncertainties as well as real time and run-to-run variabilities cause deviations from the design targets [5]. Robust fabrication therefore calls for online and real-time control strategies that ensure reliable fill in the face of practical variabilities.

Flow control in resin transfer molding processes has been the subject of several recent investigations. Nielsen and Pitchumani [6,7,8] presented model-based control schemes for the resin transfer molding process, including controls for both flow rate controlled and pressure controlled injection systems. They used neural networks [6,8] and real time numerical process simulations [7] to actively control the RTM process. One of the control strategies used online

* Corresponding author. Tel.: +1 860 486 0683; fax: +1 860 486 5088.
E-mail address: r.pitchumani@uconn.edu (R. Pitchumani).

1359-835X/$ - see front matter
doi:10.1016/j.compositesa.2005.09.007