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Flow control using localized induction heating in a VARTM process

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Abstract

Voids formed during the mold filling stage of the vacuum assisted resin transfer molding (VARTM) process become defects in the fabricated parts. Active flow control is one way to eliminate these defects by guiding the flow along a desired path during the mold filling stage of the process. Building upon previous work of the authors [Johnson R, Pitchumani R. In: Proceedings of the thirty-fourth international SAMPE technical conference, MD, USA, vol. 34(1); 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; Johnson R., Pitchumani R. In: Proceedings of the fourteenth international conference on composite materials, CA, USA; 2003, Paper# 0861; Johnson R, Pitchumani R. Simulation of active flow control based on localized preform heating in a VARTM process. Compos Part A-Appl Sci Manuf, in press doi:10.1016/j.compositesa.2005.09.007], this paper presents implementation of an active flow control using induction heating as a means of locally reducing viscosity to counteract the effects of nonhomogeneity in the permeability of preform layups in a prototype VARTM process. Feedback of flow front locations during the filling stage of the 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. A flow front following control strategy is implemented in a lab-scale experimental setup and tested on several preform layups exhibiting spatial permeability variation, as well as in the case of preforms with mold inserts. Results of these studies demonstrate that active flow control is capable of reducing the fill time, improving the flow front uniformity throughout the duration of the mold fills, and eliminating dry spot formation.

Keywords: Induction heating; A. Carbon fibres; E. Resin transfer moulding (RTM)

1. Introduction

Vacuum assisted resin transfer molding (VARTM) is an attractive and affordable method of fabricating composite products. In this process, a fibrous reinforcement material, termed preform, is placed onto a single hard sided mold and sealed with a vacuum bag. The system is subject to vacuum through the exit vents, and catalyzed resin is drawn from the inlet ports through the porous preform material. Part defects often arise in the filling stage when the flow follows the path of least resistance entrapping a void in a region of local low permeability or when the last location within the mold to be filled is not adjacent to an exit vent. Thus, achieving uniform fill and complete fiber saturation is essential to fabricating quality products. Despite an optimum process design, process and material parameter uncertainties as well as real time and run-to-run variabilities can cause deviations from design targets [5]. Therefore, reliable fabrication must employ real-time process control to realize uniform and complete fill in spite of practical unpredictabilities.

Several researchers have recently reported investigations of flow control in resin transfer molding (RTM) processes. Walsh and Mohan [6] reported a control using real-time flow sensing to determine the optimum time to activate a second resin inlet mid fill as a means of compensating for low permeability in the VARTM process. Heider, et al.,

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