IN SITU FLOW VISUALIZATION OF VOID MIGRATION DURING OUT-OF-AUTOCLAVE THERMOSET PREPREG PROCESSING

J. J. Gangloff Jr.[1], T. A. Cender[1], V. Eskizeybek[2], P. Simacek[1], S.G. Advani[1*]

[1] *Department of Mechanical Engineering and Center for Composite Materials, University of Delaware, Newark, DE, USA*
**Corresponding author's e-mail: advani@udel.edu*
[2] *Department of Materials Science and Engineering, Çanakkale Onsekiz Mart University, Çanakkale, Turkey.*

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Introduction

The presence of voids in composite laminates leads to significant degradation of materials properties. While high pressure processes – such as the autoclave – are well proven to deliver low porosity composite laminates, the composites industry is tending toward the use of vacuum bag only processes because of lower capital costs. To achieve low porosity laminates under the limitation of one atmosphere of pressure, voids must be removed from the system during processing. However, void migration in composites processing is a complex issue, which is still not well understood. This work presents an experiment, supported by analytical and computational modelling, that investigates how trapped voids in Out-of-Autoclave prepregs are transported to air pathways during processing.

Methodology

The experimental set-up – from Cender et al. (2013) [1] – was used to capture and record the *in situ* flow of resin and voids together through channels in the prepreg and into air pathways. A characteristic partially impregnated twill woven prepreg (Gurit ST94-RC303T with 6mm tow width) was used to study voids trapped within interlaminar regions. By changing processing parameters, such as pressure and temperature, bubble size and motion are correlated to the degree of resin impregnation and impregnation rates to investigate the behavior of entrapped voids and gage their propensity to migrate towards air pathways which are the dry cross-section regions within fiber tows. With the processing objective being low void content, process conditions are outlined to ensure enhanced migration of voids into air pathways within the prepreg. This is done by maximizing the velocity of voids with respect to the resin impregnation rate. In OOA processing, as a consequence of low consolidation pressure (1 atm), there is a higher propensity for void growth and entrapment. Thus, it is crucial to evacuate air or volatiles before consolidation.

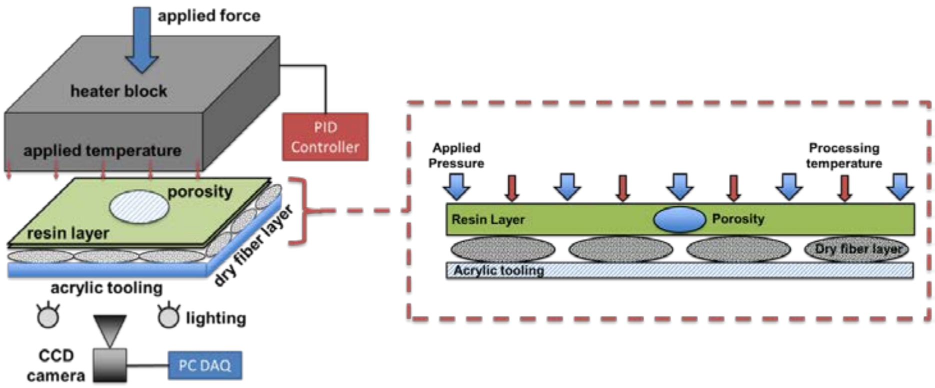

Figure 1: *Schematic of partially impregnated thermoset prepreg resin and void flow visualization setup adapted from Cender et. al. [1].*

Results

In Fig. 2, analytical and computational models (a & b) are shown and compared to (c) the model experimental resin flow front and bubble position in time inside an unsaturated fabric weave channel. By tracking the position of the resin flow front and bubble in time (Fig. 2d), while fitting a model, the process conditions influence the bubble mobility and can be tuned to direct the bubbles to reach the flow front before the complete channel saturation. The analytical model in Fig. 2a only considers a round bubble at terminal velocity in a changing pressure gradient, while the computational model (from Gangloff et. al. [2]) considers the additional effects of porous media boundaries (fiber tows) and dynamic bubble shape due to the changing channel pressure gradient.

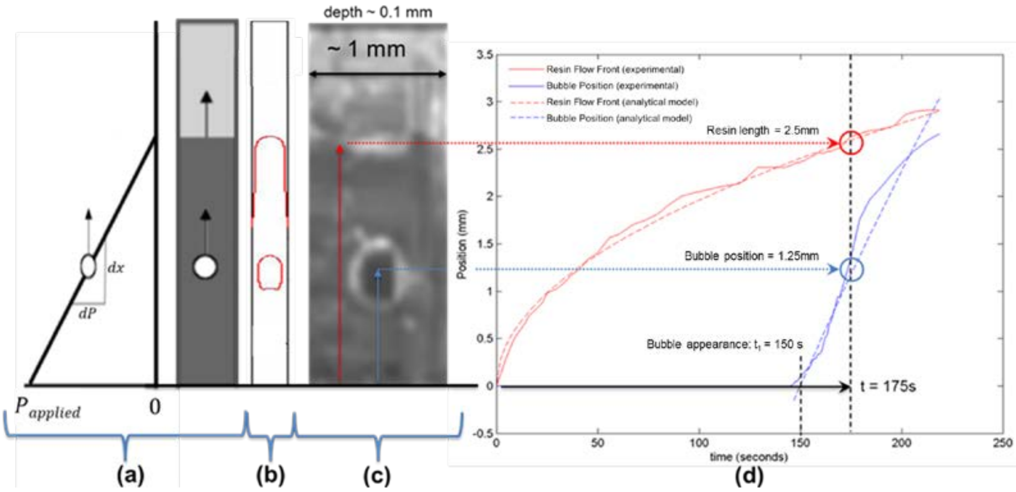

Figure 2: *(a) Analytical and (b) computational models are compared to (c) bubble and resin flow captured experimentally. (d) The position of bubbles and resin flow front are shown together along with a fit of the analytical to the data by only varying channel width and bubble radius.*

In order to remove voids from a laminate during processing, voids must coalesce with the resin flow front to be evacuated from the system. A pressure gradient in necessary in order to mobilize bubbles, and resin flow is necessary in order to induce a pressure gradient (i.e. resin flow is necessary for void motion). An important observation from this work is that voids will rarely migrate into the air pathways at the fiber tow centers once the intertow space in the fabric is saturated.

Summary

In this work, the void formation and transport dynamics in OOA process are studied to gain a global perspective on the process. The roles of applied pressure and temperature on advancing the degree of impregnation from the initial resin placement in partially impregnated prepregs are investigated. Process parameters can increase the bubble mobility and drive it to coalesce with resin front during flow.

Acknowledgements

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