

Process Development Methods for Managing Volatile-Induced Defects in a Blended Infusion Resin

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Abstract:

The demand for high-temperature composites is driving the development of new polymer matrix materials. Copolymerization, or the blending of multiple resins, can lead to materials that retain desirable constituent properties while avoiding major shortcomings. However, it can also complicate in-process behavior.

In this plenary, we present a process development methodology for a blended benzoxazine-epoxy copolymer for which performance and cost envelopes can potentially bridge the gap between BMIs, epoxies and phenolics. The blended chemistry imparts desirable properties. However, it can also result in volatile release and void formation during resin transfer molding (RTM). To study this issue, we employed a multi-part methodology that combined fundamental material and process analysis with the development of practical manufacturing solutions.

We characterized resin behavior using thermal analysis as well as novel methods for studying volatile release, including real-time infrared spectroscopy. We also clarified the mechanisms of volatile-induced porosity using a lab-scale RTM tool that allows *in situ* monitoring and visualization. Results indicated that a solvent was the primary volatilizing species, and that maintaining a minimum resin pressure can prevent bulk void nucleation. However, the results also showed that volatile-induced surface porosity, which can easily be mistaken for trapped air, can form after infiltration. Despite sufficient pressure, surface porosity arises due to the coupled effect of cure shrinkage, cavity pressure loss, and spatial variations in temperature and resin properties.

These fundamental insights directed our work towards two feasible mitigation strategies for volatile-induced porosity. We modified the formulation of the resin to reduce volatility, demonstrating a consequent reduction in defects. Concurrently, we developed a model to predict mold cavity pressure as a function of temperature, resin properties, thermal expansion and cure shrinkage. We also used the model to identify optimized cure cycles that modulate in-process behavior to maximize the time in which cavity pressure can be maintained.

Overall, the talk will demonstrate the benefits of an integrated process development methodology combining fundamental and applied study of resin chemistry and process mechanics, and highlight the distinctive behavior of a blended resin matrix system.