Automated RTM of Multi-Component Resin Systems - Promise and Problems

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ABSTRACT

The objective of this research is to evaluate the state of the art in resin transfer molding (RTM) process technology and examine the influence of controllable process parameters on the thermal and mechanical behavior of composites manufactured from multi-component resin systems. This information will help determine the requirements of a multi-component resin transfer molding process and its suitability for production implementation specifically for aircraft primary structural components.

One objective of this research included the design, demonstration, and evaluation of an automated, supervisory, computer controlled RTM process. A second objective involved the selection and characterization of candidate materials for multi-component RTM of primary structural composites, with a focus on two-part resin systems with textile reinforcement. The goal of this work was to evaluate the feasibility and process error tolerance of this intelligent RTM process applied to two candidate resin systems. A study was performed to examine the effects of major process parameters including: variations in the resin component mix ratio, injection temperature, cure cycle modifications, and "aeration." This involved flat panel fabrication and a wide array of testing including physical evaluation, thermal analysis, and mechanical testing.

Significant progress has been made toward each of these objectives. Tests to date have concluded that while the resin injection equipment designed by Northwestern University as part of the Center for Intelligent Processing of Composites (CIPC) program sponsored by ONR has great merit in terms of the concepts being attempted and the potential for improved manufacturing reliability, as yet the system does not perform satisfactorily. Improvements need to made in terms of system reliability and robustness as well as functionality, particularly with regard to extreme resin mix ratios. For the materials evaluation component of this research two different resin systems were selected, but only one resin system has been evaluated. The cure kinetics of the resin were first characterized using thermal analysis to determine the processability of the resin as well as the basic thermo-mechanical properties of the resin. The resin system studied showed excellent processability over a wide range (even unrealistic) of process variations studied, the development of three-parameter cure model (time, temperature, and mix-ratio) is still ongoing. Finally the effectiveness of the automated, supervisory, computer controlled RTM process with the selected material system was evaluated by fabricating aerospace quality panels over a wide range of process variations. Thermal analysis, ultrasonic non-destructive evaluation (NDE), and mechanical testing were used to determine composite panel quality. The results of this work have demonstrated the potential of the automated RTM process while allowing us to work out many of the problems, furthermore the results of our mechanical tests on the composite panels show that the material system chosen is in fact very robust and relatively insensitive to moderate variations in the processing parameters.