Missouri S&T

Center for Transportation Infrastructure and Safety

Development and Characterization of Multifunctional Composites

by

V.G.K. Menta

A National University Transportation Center at Missouri University of Science & Technology

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16. Abstract

This project is aimed at graduate research training of students interested in pursuing careers in transportation areas. Financial support will be provided to recruit eight new graduate students interested in pursuing their doctoral degrees in transportation areas each year. These students can pursue their doctoral studies in any department at Missouri S&T. In departments where a master's degree is the highest degree awarded, students pursuing their master's degree with thesis option will be considered. Areas as stated in the goals, interests and objectives of State Departments of Transportation and Missouri Department of Transportation in particular will be considered for support in this project.

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FINAL REPORT
MISSOURI S&T – NATIONAL UNIVERSITY TRANSPORTATION CENTER
ADVANCED MATERIALS, TRANSITION-STATE FUEL VEHICLE
INFRASTRUCTURE AND NON-DESTRUCTIVE TESTING TECHNOLOGIES

Sequential #: R203 - 00016751

Project Title: UTC Graduate Research Assistantship for V. G. K. Menta (Ph.D Student) - Development and Characterization of Multifunctional Composites

Principal Investigator: K. Chandrashekhara, Professor, Department of Mechanical and Aerospace Engineering

Project Duration: 8/1/2007-7/31/2008 (Year 1)

Amount: $ 22,940

Project Summary (Year 1)

A low-cost Vacuum Assisted Resin Transfer Molding (VARTM) process has been developed to manufacture Fiber Reinforced Polymer (FRP) composites. In VARTM, a fiber preform is placed into a one-sided mold and the mold is vacuum sealed. Resin is then drawn into the mold by vacuum to infuse the preform. Resin flow is assisted by microgrooves built into a distribution medium placed beneath the vacuum bag. After full infiltration of the resin has been achieved, the mold is heated to the curing temperature and the part is solidified. The process has certain advantages such as low cost one sided hard tooling, net shape manufacturing of large complex parts, and high fiber volume fraction. Physics based process simulation tools is be used for the optimization of the injection locations and resin infusion during the process. This process can be used to manufacture complex shapes and multifunctional composites. A multifunctional structure is a unique design approach with the composition of structures performing several functions beyond carrying mechanical loads. It involves integration of several functions such as flame resistance and impact resistance. Physical and mechanical tests are performed to evaluate the performance of the manufactured parts.

Manufacturing and Characterization of VARTM Composite Parts

VARTM is rapidly emerging as a viable method for the manufacture of high-quality composites. The VARTM process offers several advantages such as lower tooling cost, net shape manufacturing of large complex parts and low emission of volatile chemicals. Manufacturing of quality parts using the VARTM process is dependent on various parameters such as location of resin inlet, flow medium and vacuum ports. In comparison to the conventional autoclave process, VARTM process uses atmospheric pressure. Also, pre-impregnated tapes are not required.

The permeability of the preform, fiber architecture, the presence of fabric crimping and other factors have an influence on the resin infusion into the fabric. In VARTM process, as the flow front progresses the preform can compress under the deformable bagging material resulting in change in fiber volume fraction and permeability values. Variations in permeability can lead to formation of dry spots and non-uniform flow during infusion. Simulation of vacuum infusion process is a necessary tool to optimize the process parameters and to minimize the costly and time-consuming trial-and-error processes. The ability to simulate the resin flow prior to the actual manufacturing process will be helpful to identify potential void formation zones and the time to complete the infusion, which are critical when using resins with limited pot life. Using simulation tool, many key infusion process parameters such as preform compaction, the location and number of resin inlet and vacuum ports can be determined in advance. A three dimensional process simulation tool has been developed for the VARTM process. This model has been used for the optimization of the resin inlet and vacuum ports. Figure 1 shows the flow front for a flat panel.

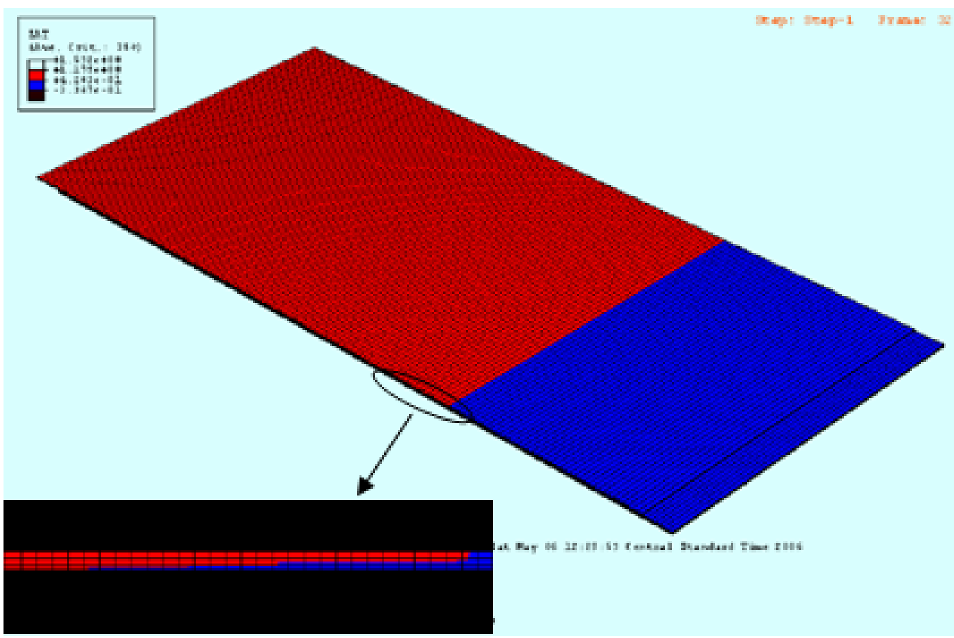
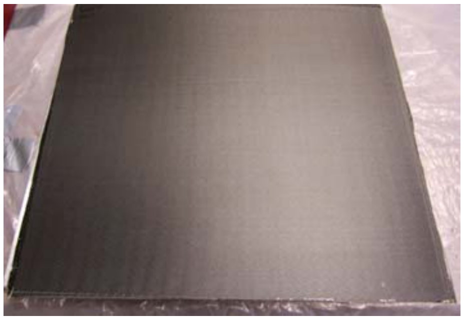


Figure 1. Progress of the Flow Front

Flat and hat stiffened carbon/epoxy panels have been manufactured using the VARTM process. Figure 2 shows the parts manufactured using the VARTM process. Flexural test were conducted on flat and stiffened panels. Figure 3 compares the load vs deflection for flat panel, single stiffened panel and double stiffened panel. The experimental results for bending have been validated using structural finite element analysis. The experimental results were in good agreement with finite element simulation.



Flat Panel

Single-Stiffened Panel

Double-Stiffened Panel

Figure 2. Composite parts manufactured using the VARTM process

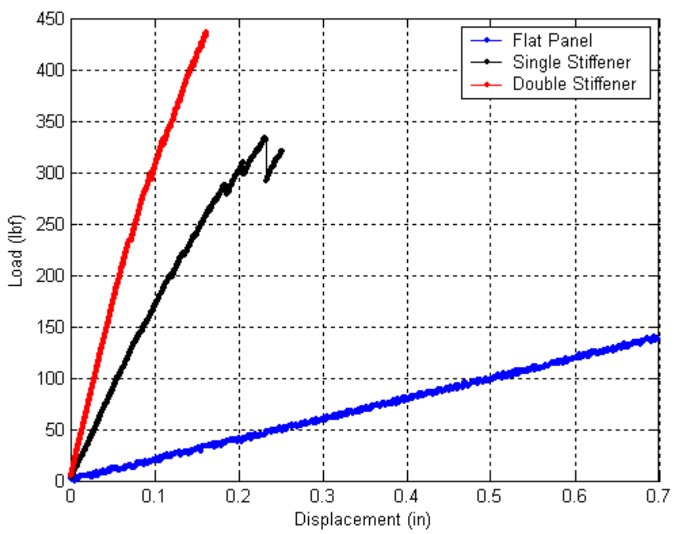


Figure 3 Load vs displacement for flat and stiffened panels