



CECAM Bulletin C05-06

VARTM Variability and Substantiation

Principal Investigator(s): D. Heider , C. H. Newton, J.W. Gillespie, Jr., Center for Composite Materials, University of Delaware

Background

Vacuum-Assisted Resin Transfer Molding (VARTM) has the potential advantages of relatively low cost with sufficiently high volume fractions of reinforcement and can be readily applied to large-scale structures. VARTM is an infusion process where a vacuum draws resin into a one-sided mold. A cover, either rigid or flexible, is placed over the top to form a vacuum-tight seal. However, for many aircraft applications, VARTM does not currently provide sufficient repeatability or control of variability. Such variability is commonly observed when processing with the VARTM process. In order to produce VARTM parts of aircraft quality on a routine basis, the variability must be understood.

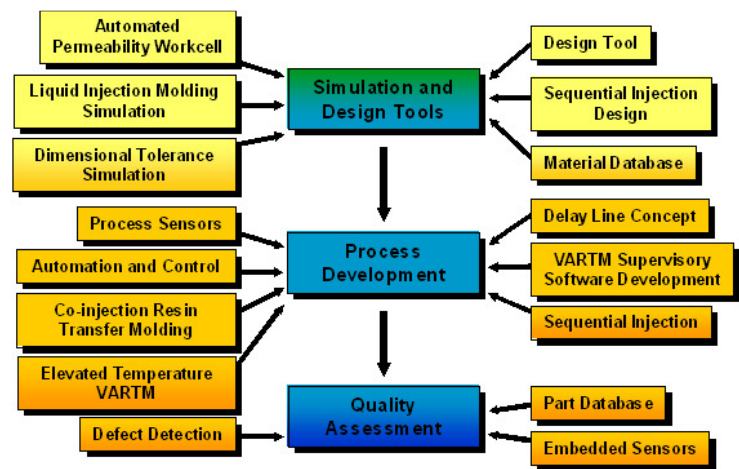
Objectives

The long-term objectives are repeatability equivalent to autoclave processing with specific properties (property/weight) that are close to autoclave processed part levels at a lower cost.

There are many factors that influence the variability of the final part. The factors that play a major role in the cause of this variation need to be identified and the causes and effects of changes in these factors understood. Three main VARTM process variations will be considered:

1. The SCRIMP process, patent owned by TPI Composites, is a vacuum infusion process using a high-permeability layer to rapidly distribute the resin on the part surface and then allow through-thickness penetration;
2. The CAPRI process, patented by The Boeing Co., is a SCRIMP variation where vacuum debulking and a reduced pressure difference is used to minimize thickness gradients and resin bleeding;
3. The VAP process, patented by EADS, is when an air-permeable membrane is used on top of the distribution media to allow continuous and areal venting reducing void content and creating a robust process variant.

We are using and developing advanced simulation tools including Liquid Injection Molding Simulation (LIMS), a comprehensive simulation software for mold filling, to explore a variety of filling scenarios and provide for the investigation of the influence of various processing conditions in VARTM and the SMARTMolding Intelligent Process Control (IPC) system. This approach enables material, process, and part traceability



UD-CCM's Tool Kit of VARTM Capabilities

along with semi-automated material lay-up, automated resin mixing, and resin infusion and control of dwell times and cure cycles. The automation capabilities enable monitoring of cycle times for all processing steps, sensing of the important process parameters through embedded sensors and QA/QC of the complete process.

The present work is developing an understanding of the sources of variability in VARTM processing. The primary sources are linked to variation in thickness, fiber volume fraction, and void content. Work at CCM as part of the FAA Center of Excellence leveraged with the Office of Naval Research Advanced Material Intelligent Processing Center is showing that the VAP and the CAPRI process produce significant reductions in both thickness variation and void content. The program has developed experimental characterization work cells to evaluate the effect of debulking on fiber volume fraction and permeability and to characterize and optimize membranes for various aerospace resin systems. Models capable of predicting thickness variations dependent on processing have been developed and incorporated into CCM's tool kit for VARTM

capabilities. Together, the fundamental science approach can optimize the process setup and predict variability for the various VARTM process variations.

Two industrial partners are supporting the on-going efforts and include W.L.Gore & Assoc. GmbH and Cytec Engineered Materials Inc. The capabilities developed in this program are being used to optimize processing approaches for current and future aerospace components.