

Vacuum Infusion Processing (VIP)

UD-CCM Toolbox for Intelligent Processing

For more than a decade, the Office of Naval Research has invested more than \$8 million at the University of Delaware Center of Composite Materials (UD-CCM) to lead the transition to 21st Century multifunctional composites and manufacturing technologies for Naval Ship and Air systems. Through basic and applied research, the UD-CCM's Advanced Materials and Intelligent Processing Center (AMIPC) has led the effort to transition Vacuum Infusion Processing (VIP) technologies to industry for both government and commercial projects. AMIPC has created an invaluable toolbox of virtual design, manufacturing, and QA/QC tools engineered to bring improved affordability and quality to liquid molding processing.

Simulation And Design Tools

AMIPC virtual design tools evaluate both the infusion and curing processes, and include both analytical and finite

Benefits of UD-CCM Expertise in Vacuum Infusion Processing

- Virtual design tools allow rapid prototyping development
- SMARTMolding automation allows process control and QA/QC
- TDR sensing enables distributed resin flow monitoring and accurate cure measurements
- Leverage expertise through workshops, consulting and prototyping

element (LIMS) based simulation capabilities. These tools incorporate the fundamental understanding of compaction, tow saturation, and other material behavior inherent in VIP and have been applied to optimize gate locations and material selection (e.g. the high-permeable distribution media).

Moreover, they are used for on-line control and to understand the mechanisms of process and product quality variations. Complemented with commercially available software such as FiberSim, LS-DYNA, and Patran, the virtual design tools are fully integrated for rapid re-engineering to manufacturing. The system has been applied to numerous components, including composite hoods, a composite twisted rudder, and other commercial and military applications.

Process Development

AMIPC has developed and evaluated numerous VIP variations. UD-CCM's developments include the Co-Injection Resin Transfer Molding (CIRTM) and membrane-based infusion process (patent pending). Channel and interlaminar flow media based processes have been evaluated and scale-up has been successfully demonstrated in-house or in conjunction with industrial partners. UD-CCM's process

21st Century Manufacturing Toolbox

Simulation & Design Tools

- Automated Permeability Workcell
- Liquid Injection Molding Simulation
- Dimensional Tolerance Simulation
- Design Tool
- Sequential Injection Design
- Material Database

Process Development

- Process Sensors
- Automation and Control
- Co-Injection Resin Transfer Molding
- Elevated Temperature VARTM
- Delay Line Concept
- VARTM Supervisory Software Development
- Sequential Injection

Quality Assessment

- Defect Detection
- Part Database
- Embedded Sensors

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and material developments have enabled one-step processing of thick-section components (demonstrated on a 4-inch thick graphite/aramid mine blast kit) and elevated temperature processing of high performance resin systems. New resins have been developed that allow room-temperature processing for composites that meet high-temperature service requirements. UD-CCM's Intelligent Process Control system (IPC), called SMARTMolding, provides manufacturers with an impressive assortment of benefits, including repeatability, dimensional control, waste reduction, increased productivity, reduced labor, and lower overall cost. Modeling and simulation, sensing and control, and experimental validation and automation form the nucleus of IPC components.

Quality Assessment

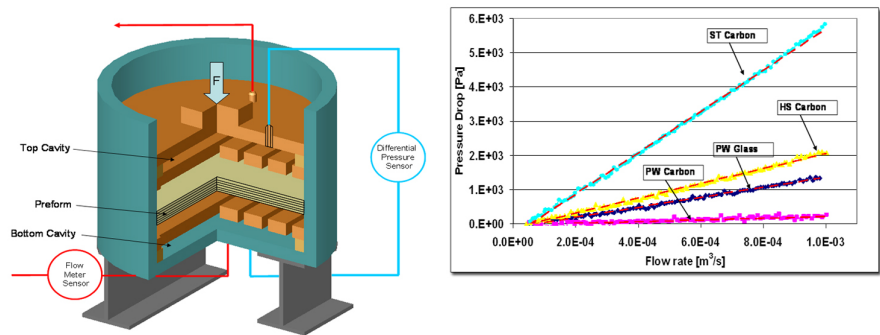
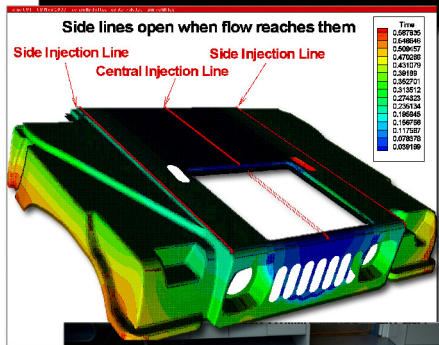
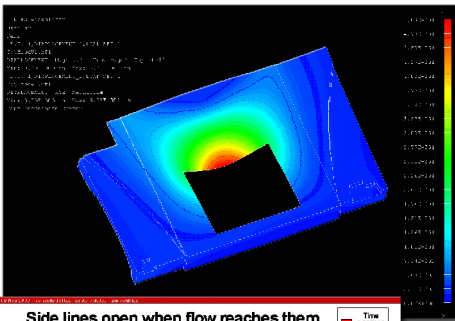
UD-CCM regards QA/QC of both process and in-service performance evaluation as an integral part of the next generation of composites applications.

SMARTMolding provides a complete electronic record of the process history. Collaboration with NSWC (Caderock, MD) and the U.S. Naval Academy (Annapolis, MD) has produced a structural identification system based on vibration analysis (SIDER) that identifies defects in large composite structures.

This technology has been applied in numerous applications, including a composite highway bridge made with VIP (located in Delaware), various topside ship structures and composite integral armor.

Leveraging Our Expertise

Suppliers and manufacturers can easily leverage UD-CCM expertise by taking advantage of our workshops, consulting and prototype development services. Workshops impart invaluable hands-on learning of state-of-the-art VIP. For participants, complimentary lectures and laboratory sessions provide the theoretical and practical understanding to successfully implement the process in-house or to improve a current manufacturing practice. UD-CCM's consulting and prototype development services find genuine solutions for unique application challenges. Most importantly, UD-CCM continually updates its growing network of SMARTMolding Beta Sites with the newest advances in technology.



$\Delta P \sim Q$ \rightarrow 1D-Darcy's Law can be applied \rightarrow $v = \frac{Q}{A} = -K \frac{\Delta P}{\eta \cdot h}$