UNIVERSITY OF DELAWARE
CENTER FOR
COMPOSITE MATERIALS

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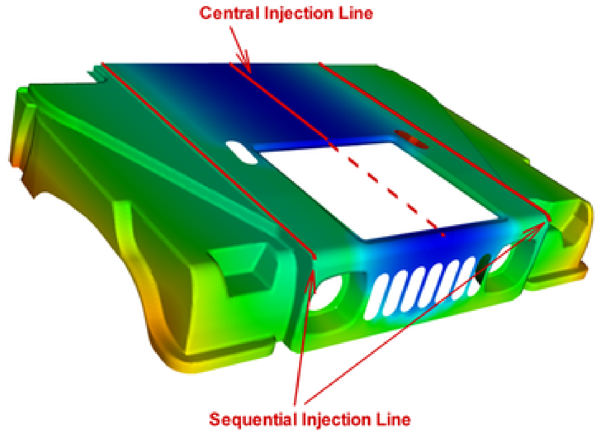
LIQUID INJECTION MOLDING SIMULATION

Liquid Injection Molding Simulation (LIMS) is a software tool that simulates the mold filling stage of resin transfer molding (RTM) and related processes by modeling flow through porous media by Finite Element/Control Volume Method. It provides a cost-effective way to verify and optimize mold design by providing a "virtual" mold filling process to avoid time- and resource-consuming trial and error in physical reality. LIMS has been successfully used to design and simulate intelligent or adaptive filling processes that utilizes sensors mounted on the part and controllable injection hardware, either as a stand-alone program or as a simulation engine for other programs.

LIMS Features

The simulation allows the user to monitor flow progression, pressure distribution, and inflow rates during the mold filling process. Various inlet parameters, including location, can be changed during the simulated filling. A number of other effects, such as "race-tracking" - the tendency for resin to flow much differently around corners where draped preforms have folded - can also be modeled.

The built-in scripting interpreter allows the user to tailor the simulation to address additional issues. Scripts can access the parameters during the simulation and modify them as needed. It is even possible to modify the material data during the simulation. This allows the user to simulate complex filling schemes such as using adaptive controls. For example, the evaluation of fiber tow saturation through a set of scripts is available with LIMS distribution



Simulation of Sequential VARTM injection into an Automotive Hood Component

The program offers three interface options:

1. The provided graphical user interface (LimsUI) allows the user to modify the model parameters, run simulation and view the simulation results. It is tailored to the particular needs of resin flow modeling. It allows user to perform the most common operations, including creation of the distribution network, by point-and-click. It automatically generates scripts and runs the simulation for the most common scenarios.
2. The command console allows power user to fully harness the LIMS BASIC interpreter either by directly typing the commands or by loading scripts. This offers the user access to the full power of the simulation engine. It possible to create complex scripts to model LCM process variations, introduce optimization and process control and easily execute LIMS from other programs.
3. For those interested in utilizing the simulation engine interactively within their own code, LIMS can connect to their platform using MPI interface to exchange commands and data during simulated process.

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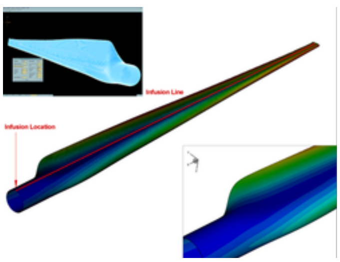
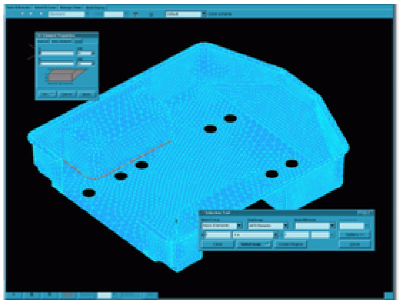
Specific Capabilities

- The incremental solution algorithm provides fast simulated filling. Problems with a few thousand degrees of freedom solve within seconds on usual personal workstation (~3GHz Intel i7).
- The mold geometry may be a three-dimensional solid, a three-dimensional (2.5D) shell, or any combination of both.
- One-dimensional channel elements may be added to mesh geometry to simulate systems of injection tubes or race tracking.
- Two dimensional surface may be added to three-dimensional mesh to model highly permeable distribution media. LimsUI allows user to add such features to the pre-existing mesh.
- Multiple injection gates, vents, and sensors are allowed and can be modified as the filling simulation progresses, for example to open and close injection gates and vents as needed.
- The user may control the simulation through a built-in programming language. The program can monitor the filling and simulate on-the-fly control.



Simulation Flow Patterns during Wind Blade Infusion

- All the solution data is available to the interpreter during the simulation. This effectively represents a large array of sensors which can be used to design or verify mold filling control strategies, as gates and vents can be adjusted in response to signals sent by these sensors.
- Material data may be modified on the fly, allowing the user to model processes, such as Compression Resin Transfer Molding (CRTM).
- Finite outlet pressure and dry spot prediction is available.
- Output of the results is available at any time during execution of the program. One may either take the over-all snapshot in any given instant, or track the individual values of interest through the filling process.
- MPI Based interface is available to pass commands and data between other programs and LIMS or multiple instances of LIMS.
- Graphical user interface is tailored toward the specific needs of liquid composite molding. It facilitates modifications of preform properties, generation of additional race-tracking, and distribution media geometry, execution of filling simulation(s) and the display of results.
- Input files can be prepared in several programs (including Open Source GMSH).
- Available input converters provide possibility to prepare data in additional programs and include



LimsUI Graphical User Interface. A racetracking channel is being added to a mesh of automotive trailer.

- phenomena like the fabric deformation during preforming
- Output is available through its GUI, TECPLOT package or GMSH postprocessor.

System Requirements

- The program has been developed as cross-platform engine and Windows based GUI. It is actively tested on Windows 10 and 11.
- Command-line port of simulation engine for Linux is tested and available on request.
- MPI enabled simulation engine is available on both Windows and Linux.
- The system requirements depend on the type of application. For two-dimensional problems, the requirements are very low. For realistic 3D models a few gigabytes of RAM are needed as the program uses direct solver. To use the graphical user interface the computer must support OpenGL.

sites.udel.edu/lims

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