MODELING TRANSPORT PHENOMENA IN LIQUID COMPOSITE MOLDING: COUPLED APPROACH

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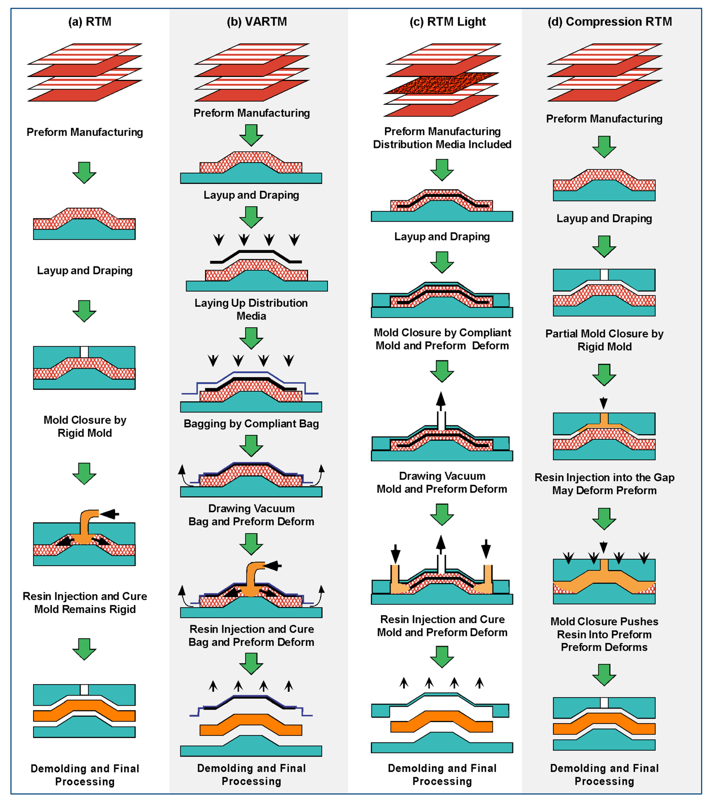
Introduction

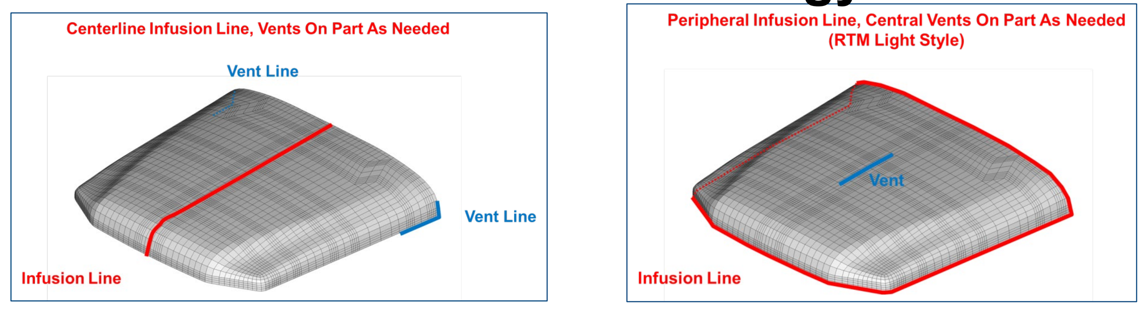
- Modeling Transport Phenomena in LCM Is Important
- Transport and Growth Dynamics of Volatiles Strongly Influence the Porosity of Final Part
- Resin Pressure and Flow Controls Volatile Transport
- Volatile Motion and Growth Influence on Flow is Limited
- Developed Approach Separates:
  - Resin Flow (Infusion) Simulation based on LIMS Package
  - Transport of Volatiles in Discrete Forms
  - Transport of Volatiles Dissolved in Resin
- The Approach is Extensible to Other Transport Phenomena

Liquid Injection Molding



Variety of Processes

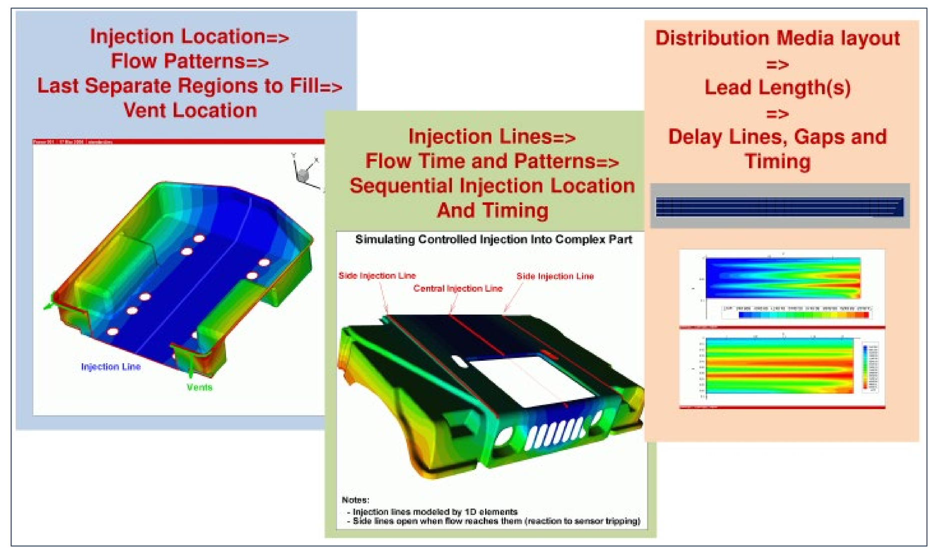
Flexible Infusion Strategy



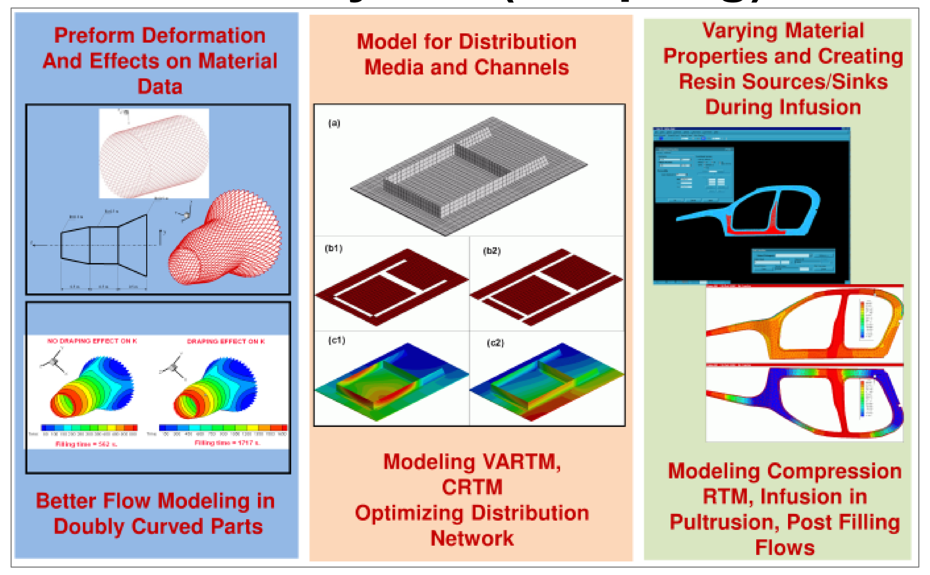
Process Simulation Necessary to Make Good Choices

LIMS Package and Current Applications

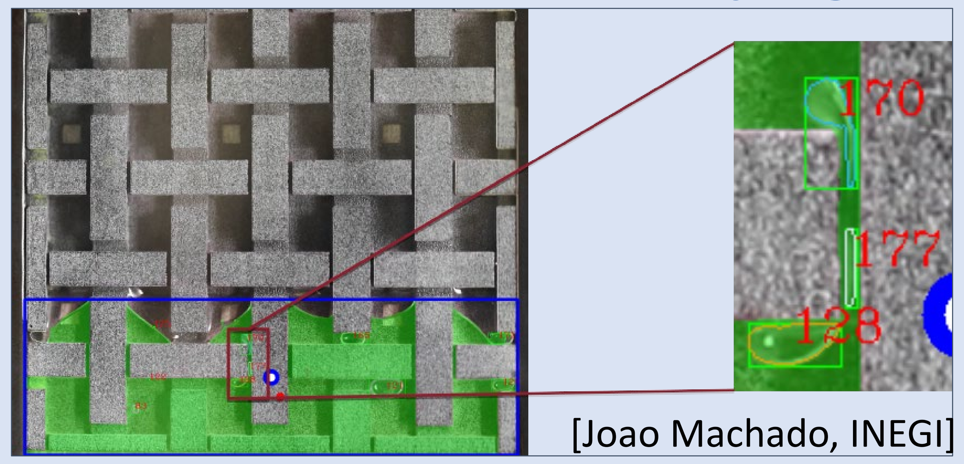
Infusion Process Design



Expandable Process Physics (Scripting)



1. Resin Flow Modeled Satisfactorily
2. Bubbles (Volatiles) Move in Resin
3. We Need to Model That Coupling…



[Joao Machado, INEGI]

… But Use Separate Model (Efficiency Reasons)

Governing Equations

FLOW: $\langle \boldsymbol{v}_f \rangle = -\frac{\boldsymbol{K}}{\eta} \cdot \nabla p \;\Rightarrow\; \nabla \cdot \left(\frac{\boldsymbol{K}}{\eta} \cdot \nabla p \right) = 0$

ENERGY: Usually In But What if Multiple Reactions? Boundary Conditions?

$$(\rho C_p)_{ef} \frac{\partial T}{\partial t} + (\rho C_p)_f \langle \boldsymbol{v}_f \rangle \cdot \nabla T = \nabla \cdot (\boldsymbol{k} + \boldsymbol{K}_D) \cdot \nabla T + \eta \langle \boldsymbol{v}_f \rangle \cdot \boldsymbol{K}^{-1} \cdot \langle \boldsymbol{v}_f \rangle + \sum_i \phi \alpha_i H_i \frac{\partial \alpha_i}{\partial t}$$

CONVERSION: Multiple Equations?

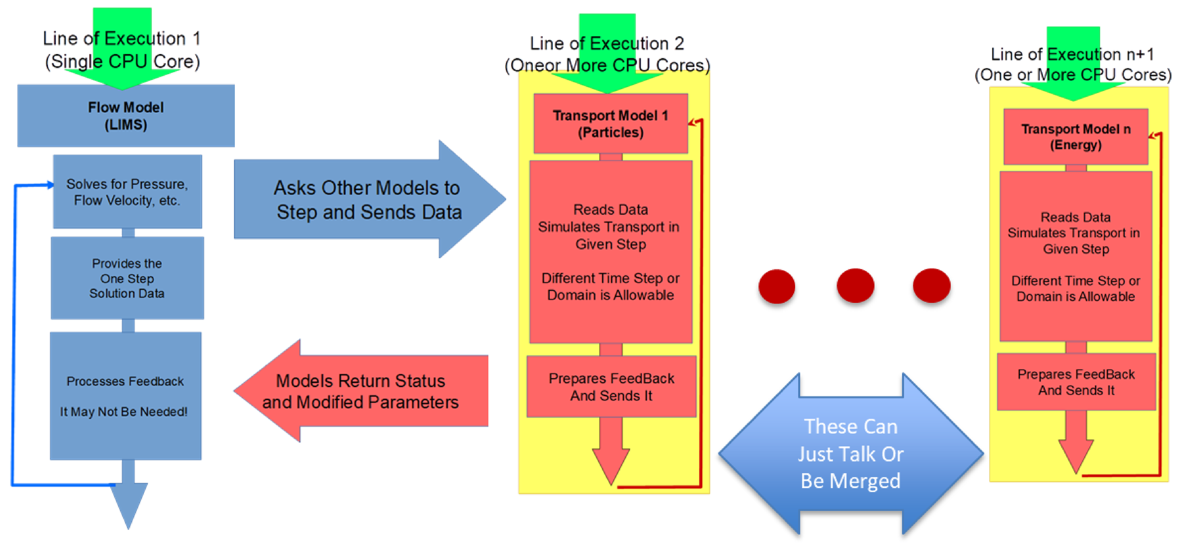
$$i = 1\ldots : \phi \frac{\partial \alpha_i}{\partial t} + \langle \boldsymbol{v}_f \rangle \cdot \nabla \alpha_i = \nabla \cdot \phi (\boldsymbol{D} + \boldsymbol{D}_D) \cdot \nabla \alpha_i + \phi \dot{R}_{\alpha_i}$$

DISCRETE BUBBLE or PARTICLE: $i = 1\ldots : \boldsymbol{v}_i = \boldsymbol{U} . \boldsymbol{v}_f = \frac{1}{\phi} \boldsymbol{U} . \langle \boldsymbol{v}_f \rangle = -\boldsymbol{U} . \frac{\boldsymbol{K}}{\phi \eta} \cdot \nabla p$

DISSOLVED VOLATILES: $i = 1\ldots : \phi \frac{\partial c_i}{\partial t} + \langle \boldsymbol{v}_f \rangle \cdot \nabla c_i = \nabla \cdot (\phi \boldsymbol{D}_{ci} \cdot \nabla c_i) + \phi \dot{c}_i$

Needs Flow Data But Limited Influence on Flow

Flow and Transport Models: Parallel Coupled Execution



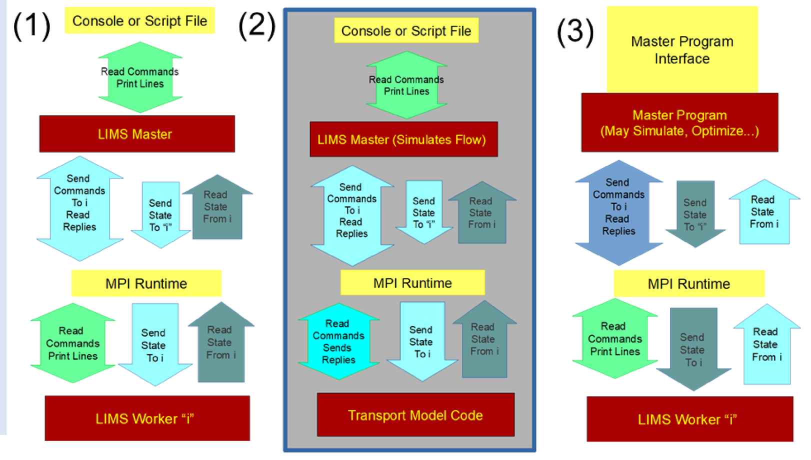
Coupling Through MPI as Implemented in LIMS and New Code

- LIMS Will Read Either Console or from MPI Text As Command Stream
- LIMS Can Send Commands Through MPI and Read Output Printed to MPI
- LIMS Can Send or Retrieve Simulation State

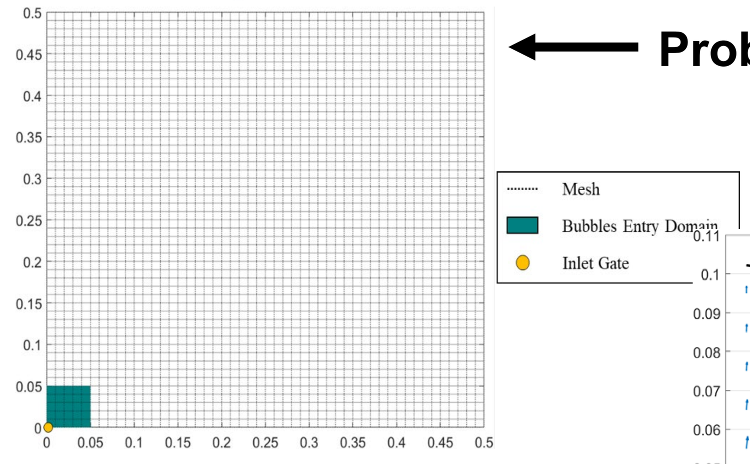
THREE SCENARIOS

1. LIMS Can Cooperate with LIMS
2. LIMS Can Control Other Simulation Code (Our Case: The Additional Code or Codes Simulate Transport)
3. LIMS Can Be Controlled By Other MPI Enabled Program

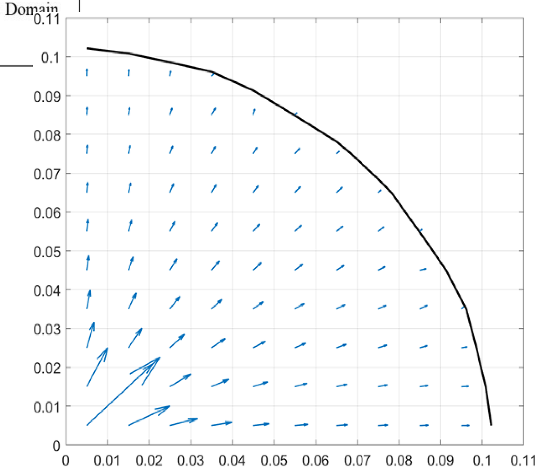
NOTE: The Existing Solution is Win 32 Only and Data Exchange is Inefficient



Moving Volatiles: Simple Case

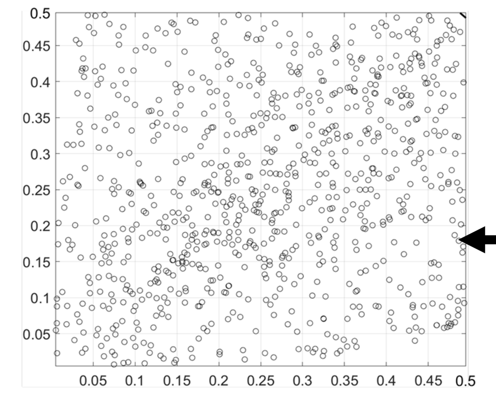


Problem Setup



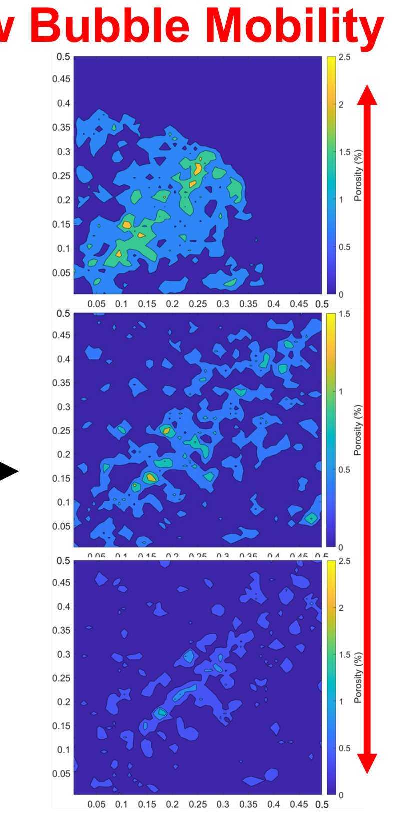
Flow Front (LIMS)
Velocity (Transport Code)

Low Bubble Mobility

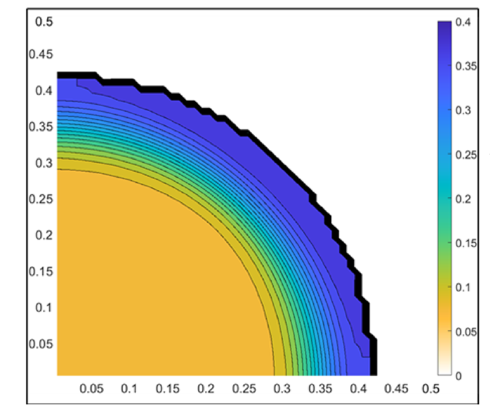


Tracking Multiple Bubbles

Porosity of Filled Part

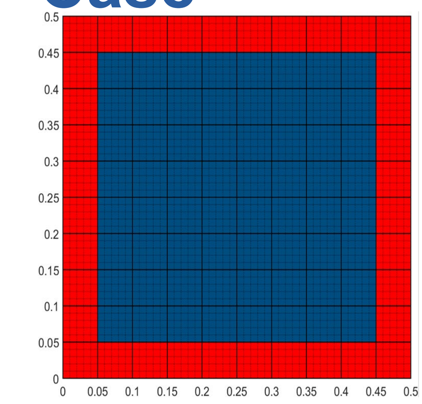


Tracking Dissolved Volatiles



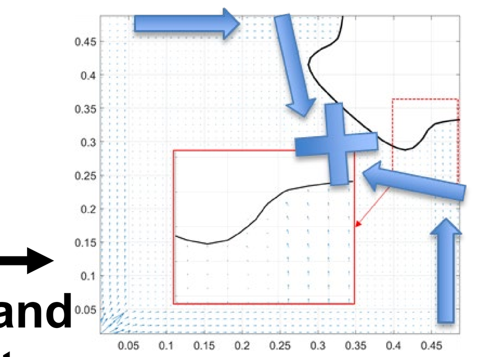
High Bubble Mobility

Moving Volatiles: Race tracking Case

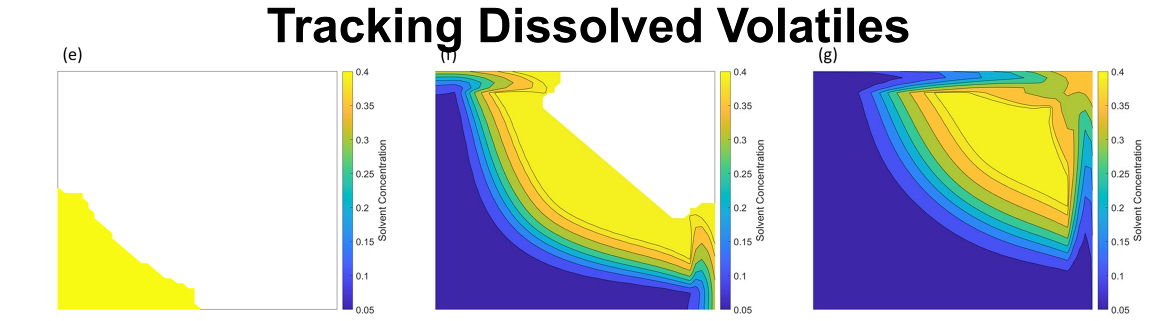


Problem Setup

Flow Front and Velocity Pattern

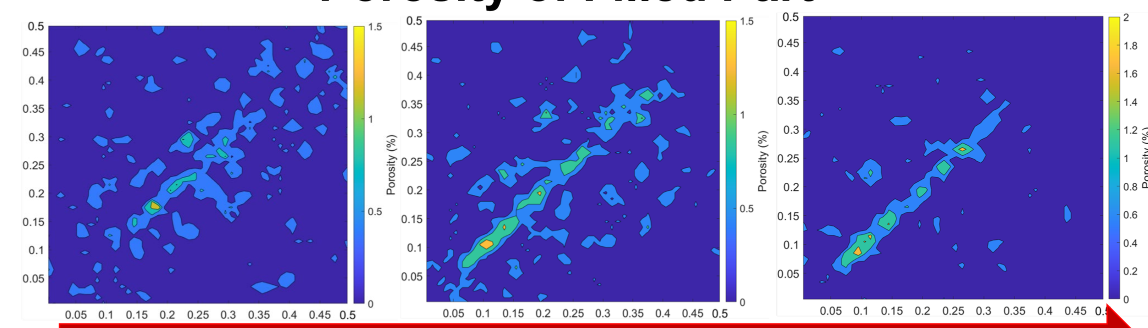


Tracking Dissolved Volatiles



t=507 s | t=2959 s | t=4184 s

Porosity of Filled Part



Stronger Racetracking

Conclusions

- Proper Software Basis for Transport Simulation Using LIMS Was Implemented
  - LIMS Communication through MPI Interface
  - Generic Executable Code for Transport Simulation
- Proof of Concept Transport Models Were Implemented for Bubble/Particle Tracking and Dissolved Volatiles Convected with Flow
- Benefits Of Such Approach Include Easy Parallelization, Code Stability and Simplicity and Fast Development and Modification Cycle of Models Based on Novel Governing Equations
- LIMS MPI Communication Offers Other Uses, for Example for Optimization on Parallel Systems

Acknowledgements

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