BACKGROUND

Reinforcements
- good structural properties
- strength
- stiffness
- low density

Matrix
- impact resistance
- protection against corrosion
- malleability
- toughness

But:
- Coupling of the two “ingredients” is key

At mold level:
Saturation = brightness

Void content variation:
- In time
- During process

Previously used:
C-scan
But, it shows void distribution:
- After injection
- After cure

MOTIVATION

FACT:
- Voids between fibers and between fiber tows diminish the structural properties of composite parts

NEED:
- A better understanding of
  - Micro-void formation and displacement
  - Role of capillarity

GOAL:
- Manufacture better parts through Liquid Composite Molding processes

APPROACH:
- Analytical model to account for capillarity and air displacement
- Experimental investigation
- Numerical approach using the Lattice Boltzmann Method (LBM)

EXPERIMENTAL: ONLINE MONITORING OF PREFORM SATURATION

Observation:
- Vinyl ester and glass have similar refractive indexes
- Saturated fiber tows “disappear”

Consequence:
- Visualization of saturation status during an RTM injection in transparent mold

RESULTS – TOW SATURATION VS. TIME

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SATURATION VS. INJECTION PRESSURE (7, 15, 30 psi)
NUMERICAL: LATTICE BOLTZMANN METHOD (LBM)

Flow of multi-phase fluids through porous media is difficult to simulate using computational fluid dynamics because of:

- Complex geometry
- Surface tension effects
- Gas compressibility effects

Alternative: Lattice Boltzmann Methods, a class of techniques based on meso-scopic particles to simulate fluid flows.

Advantages:

- LBM is suited to simulate flows around complex geometries
- Multi-phase flows
- Easily implemented on parallel machines

LBM - FEATURES

Flow is simulated through the collective behavior of a population of particles

Broad range of applications:
- Interface between phases
- Contact angles at a solid boundary
- Large density ratios between phases

Collision / propagation of particles simulate flow

Gas pocket (void) moving through an array of obstacles (porous media)

RESULTS – BUBBLE RAISING DUE TO BUOYANCY

The code simulates distinctly wetting and non-wetting behavior

- Qualitative results seem reasonable
- Instabilities occur present at the solid / liquid / gas contact line

RESULTS - RESIN IMPREGNATION OF FIBER TOWS

Wetting

Non-wetting

ROADMAP

- Gravity (buoyancy)
- Complex geometries
- Boundary conditions

Experimental

- RTM setup designed for online monitoring of tow saturation
- Technique established to determine variation of saturation with capillary effects

FUTURE WORK

- Contact angle between solid / liquid / gas

Experimental

- Monitor saturation of one fabric layer
- Monitor saturation of individual tows

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