Modeling Multiscale Resin Impregnation In A Bidirectional Composite Laminate

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COMSOL CONFERENCE 2015 PUNE

COMSOL Conference, Pune
October 29, 2015

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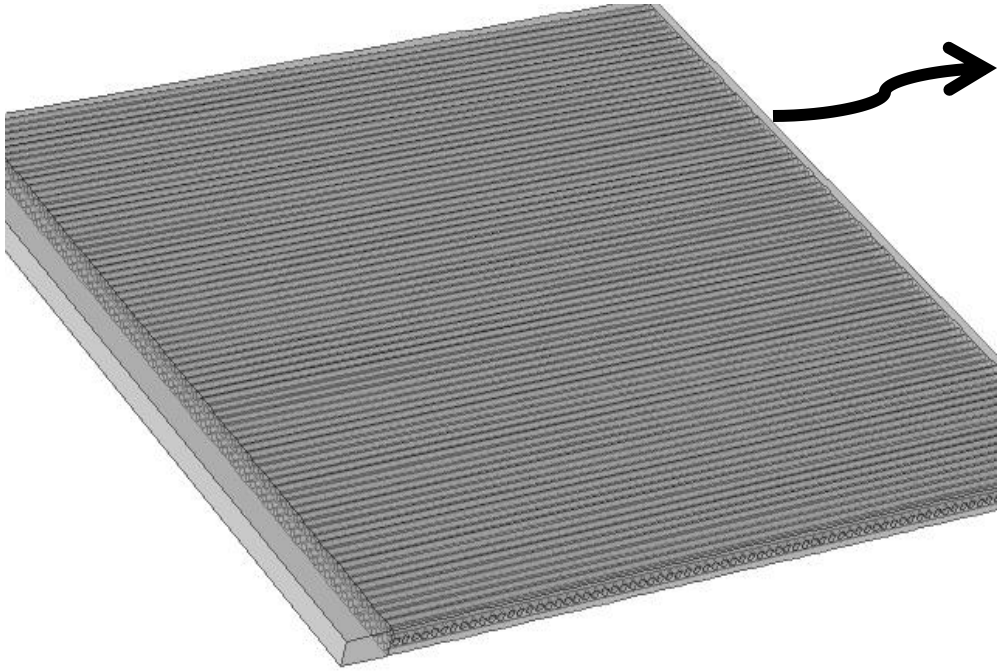
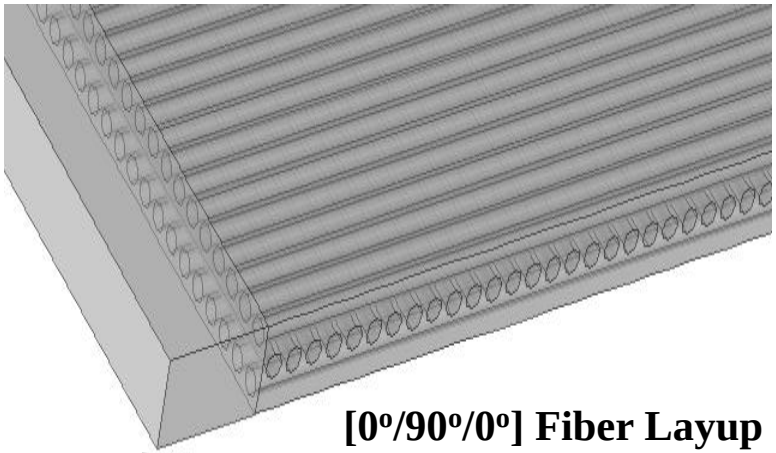
Background

- Experimental resin infusion process by Vacuum Assisted Resin Transfer Molding (VARTM) results in certain void content in the composite laminates.
- This is detrimental to the mechanical properties of the composite.
- Studying the resin flow front progression can yield insights into the void formation and hence an optimum method can be developed to minimize them.
- The ability of COMSOL Multiphysics to solve fluid flow along with interface tracking was effectively used to study this.

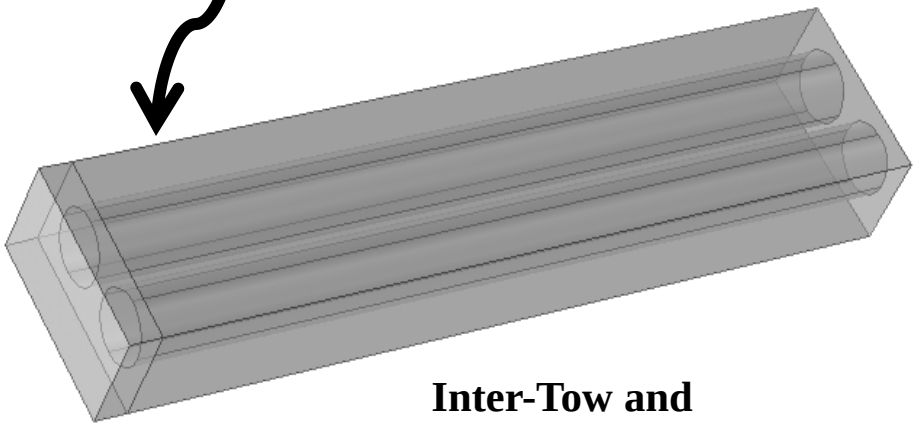
3-D Bidirectional Fabric



Laminate



[0º/90º/0º] Fiber Layup



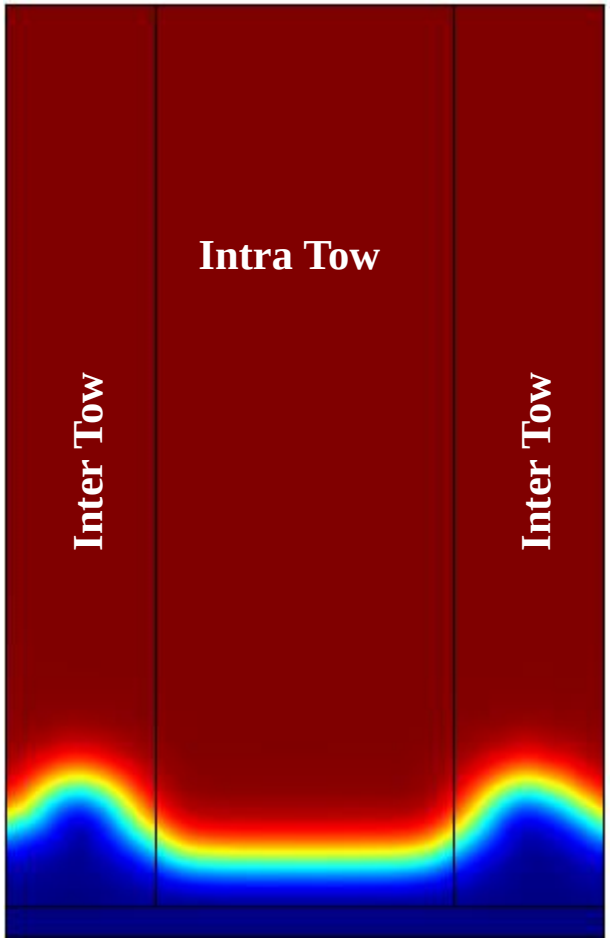
Inter-Tow and
Intra-Tow regions

Carbon Fibre Fabric Properties

Tow Designation	12K Carbon Fiber
Fabric Dimensions	30 cm x 30 cm
Fiber Volume Fraction	0.48
Tow Porosity	0.48
Tow Diameter	782 µm
Fibril Diameter	5.148 µm
Longitudinal Permeability	4e-13 m^2
Transverse Permeability	9e-14 m^2

Dual Scale Resin Infusion

- Resin flow through fabric
  - Inter-Tow Flow
  - Intra-Tow Flow
- Two primary driving forces
  - Hydrodynamic pressure gradient
  - Capillary effects
- Under higher applied pressure
  - Hydrodynamic pressure gradient dominates
- Under lower applied pressure
  - Capillary effects dominates



2 D Unidirectional fabric with resin flow fronts

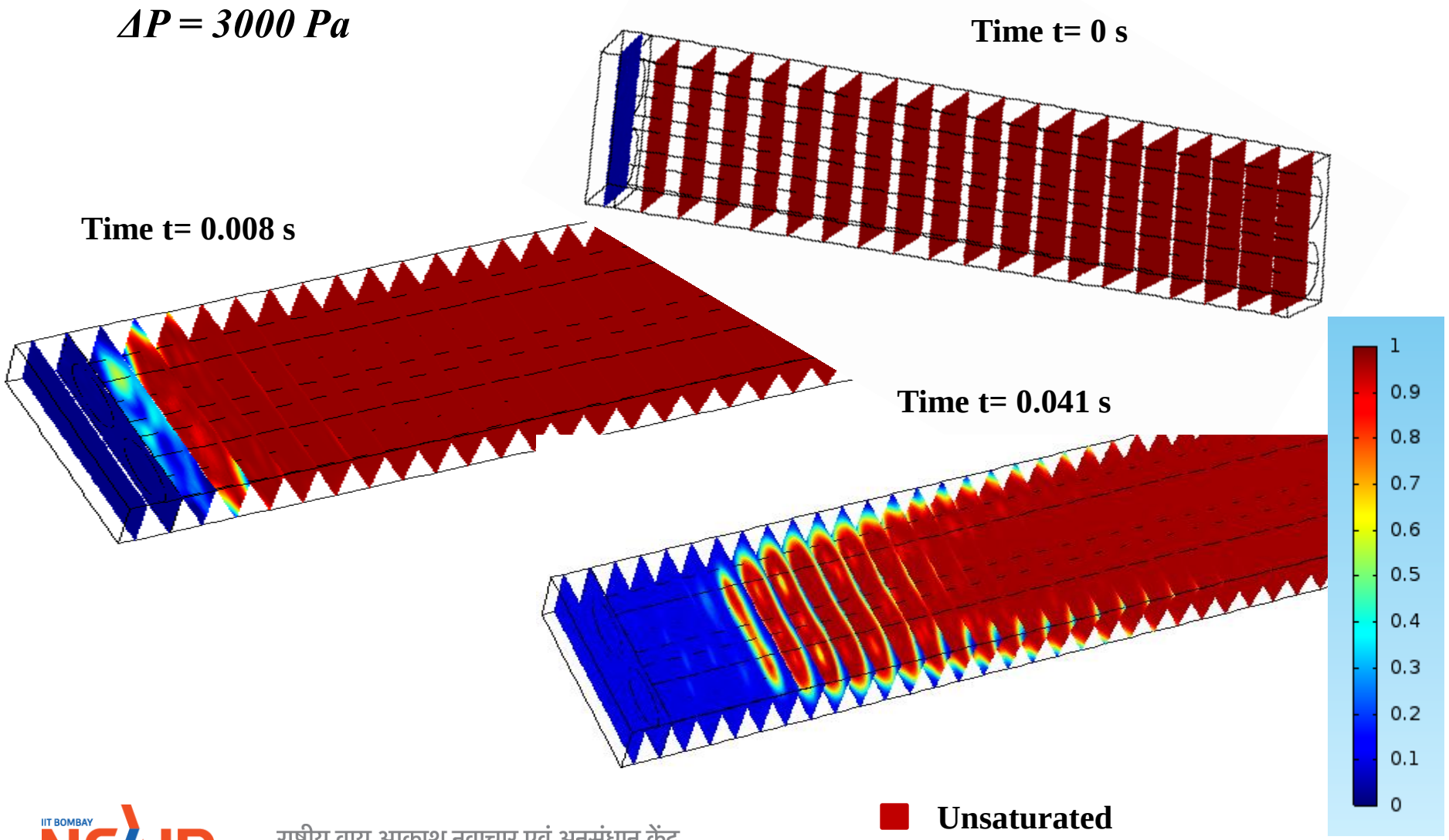
Physics and Model Parameters

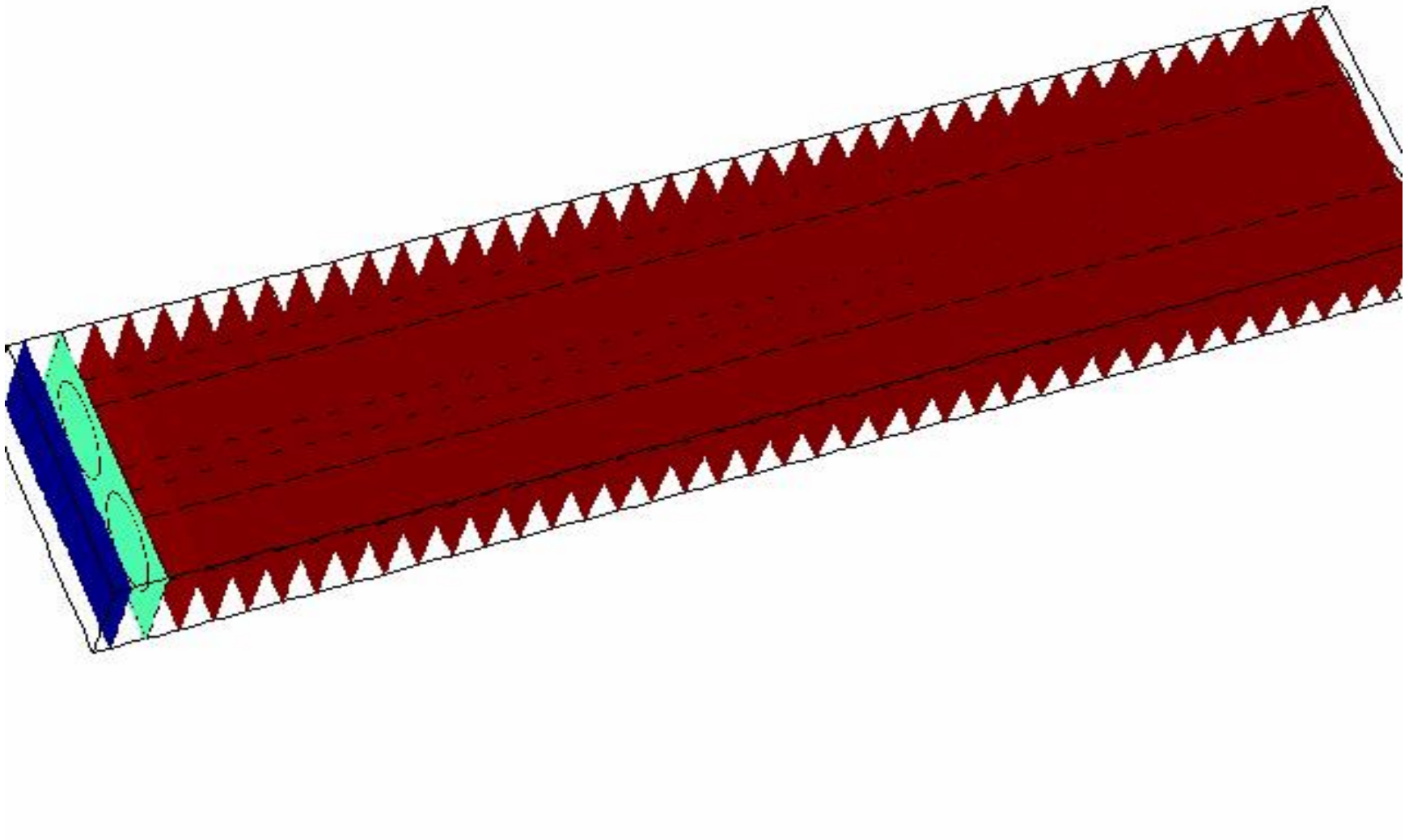
- The inter-tow flow is modeled as Stokes flow while the intra-tow flow is a porous flow modeled using Brinkman's equation.
- The Creeping Flow module with porous media enabled is used to model this dual scale flow in COMSOL Multiphysics 5.1.
- The Level Set method is used to track the flow front progression in these regions.
- Time Dependent analysis was carried out.

Modeling Conditions

- **Initial Conditions :**
- Velocity = 0
- Pressure = 0
- **Boundary Conditions :**
- Pressure Inlet
- Pressure Outlet
- No slip walls
- **Resin Properties :**
- Resin Type : Epoxy
- Density : 1200 Kg/m^3
- Viscosity : 0.157 Pa.s

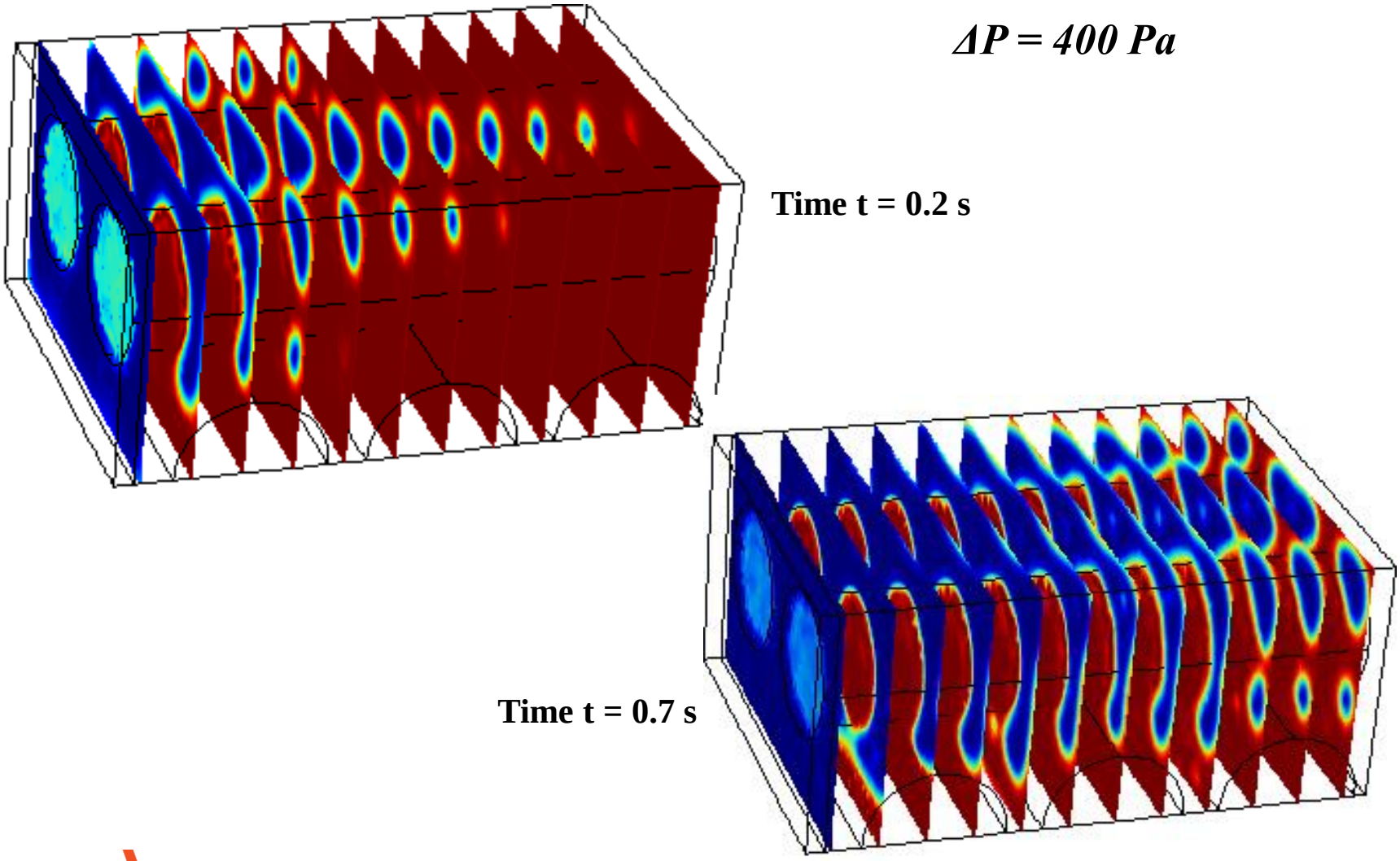
Unidirectional Fabric Inter Tow Lead

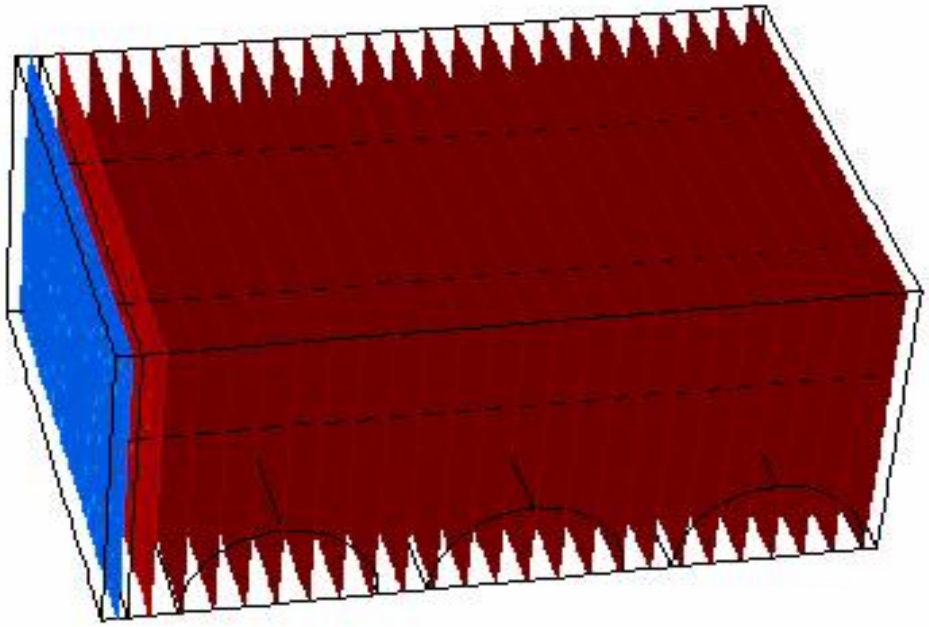




Unidirectional Fabric Inter Tow Lead

Bidirectional Fabric Inter Tow Lead





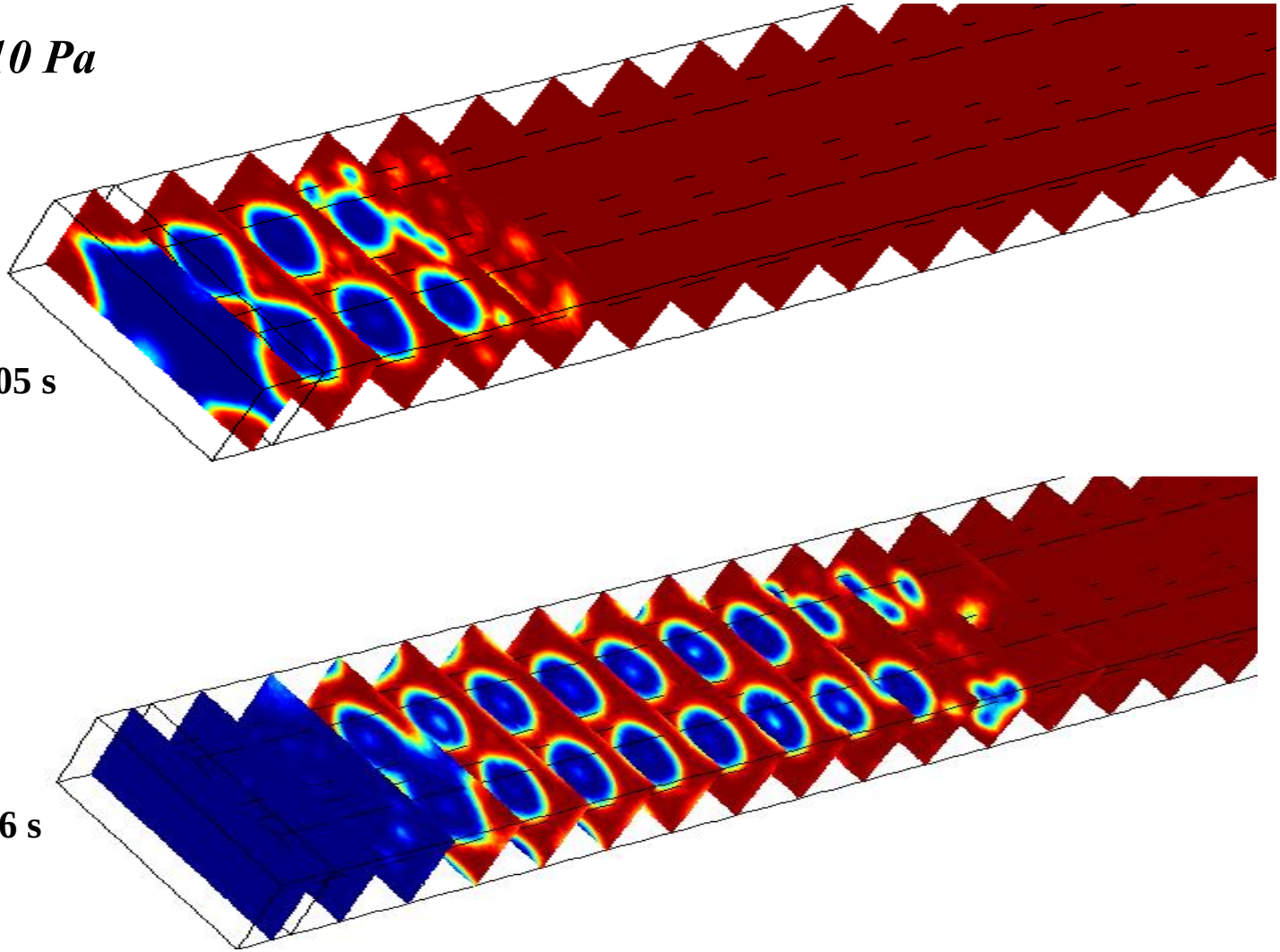
Bidirectional Fabric Inter Tow Lead

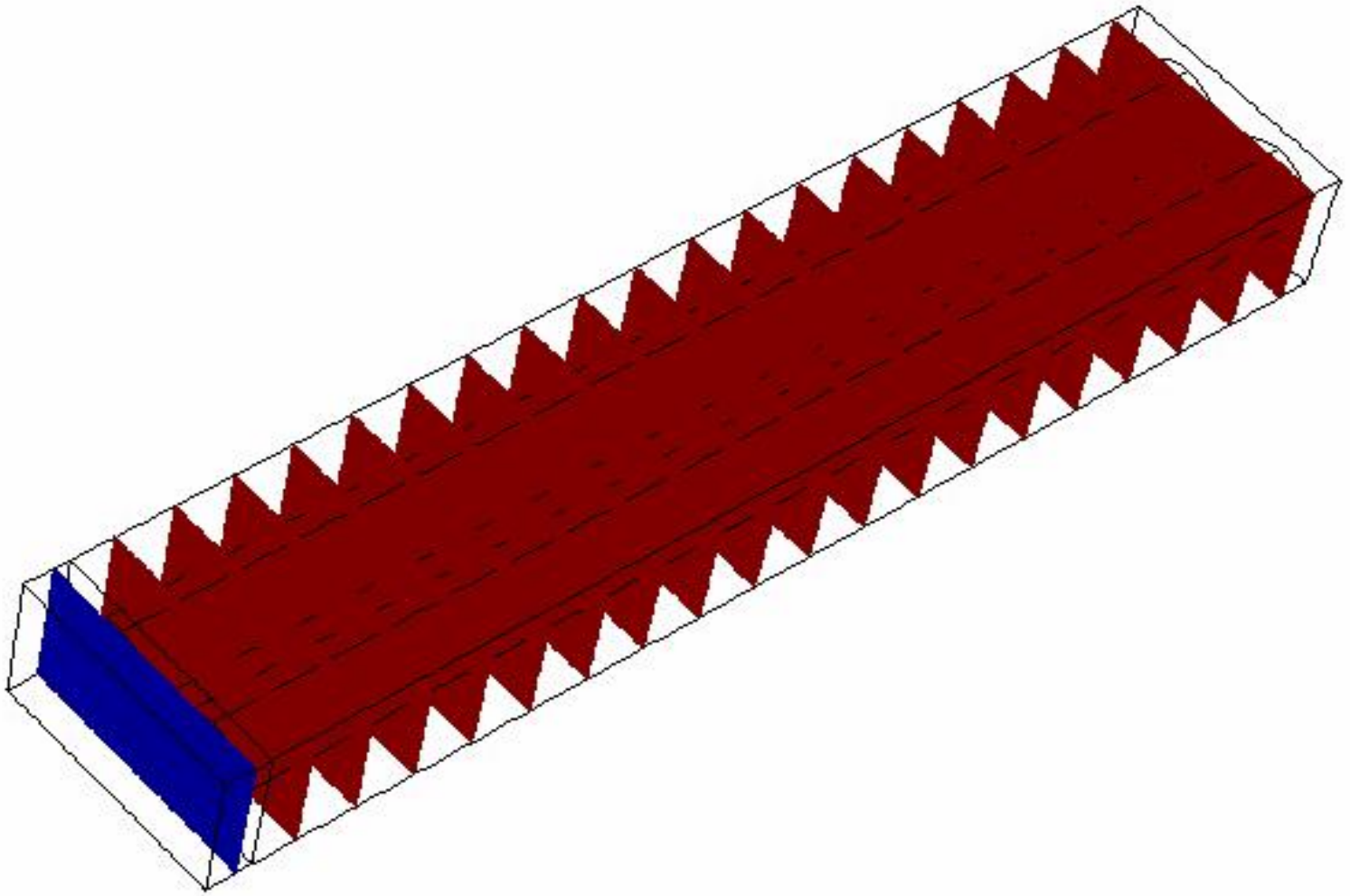
Unidirectional Fabric Intra Tow Lead

$\Delta P = 10$ Pa

Time t = 0.05 s

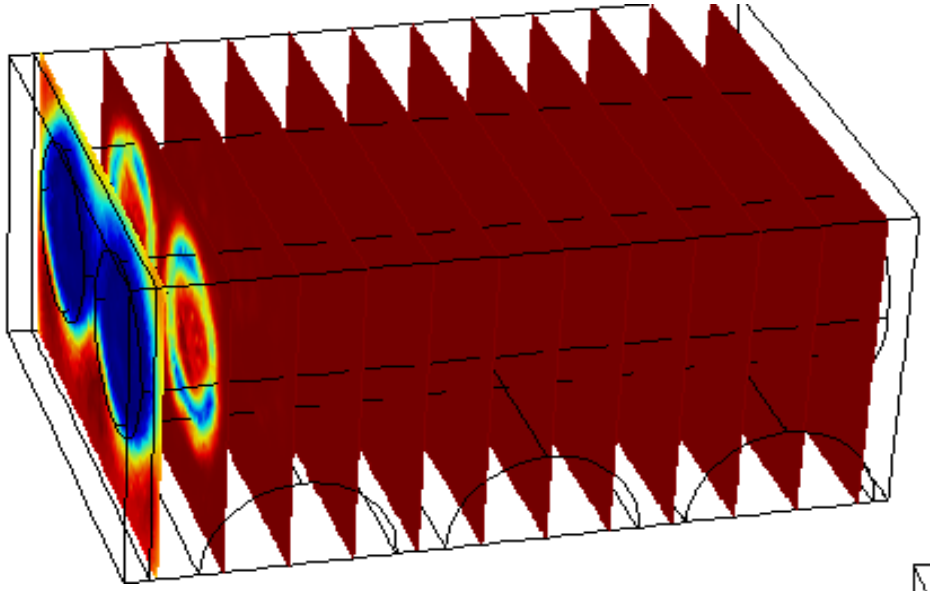
Time t = 0.16 s





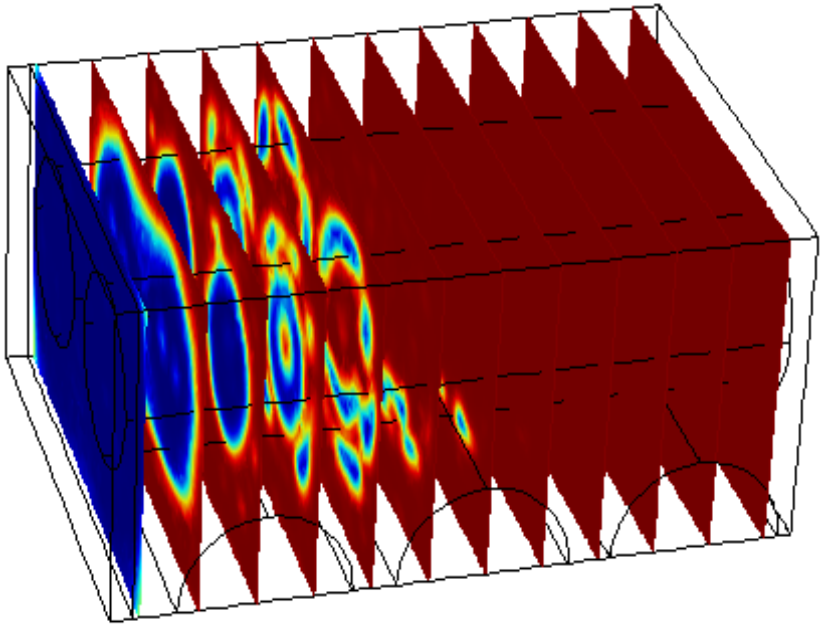
Unidirectional Fabric Intra Tow Lead

Bidirectional Fabric Intra Tow Lead

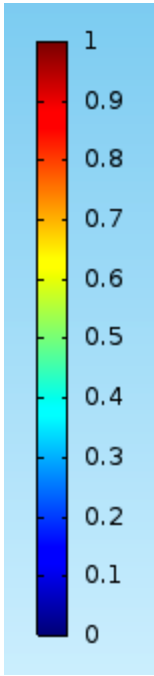


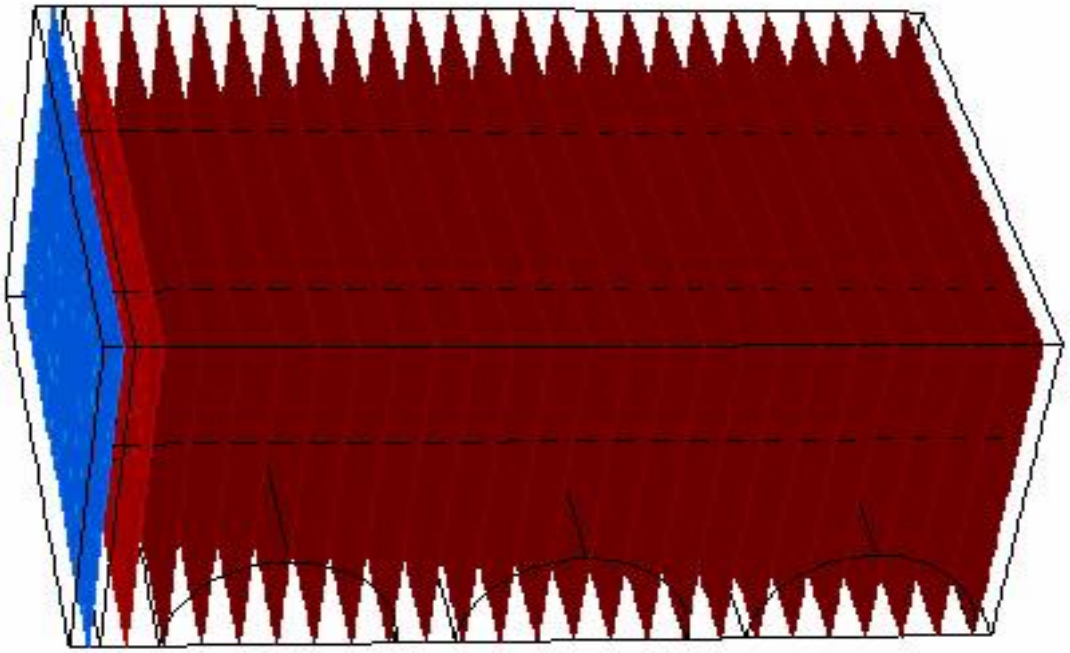
$\Delta P = 2\ Pa$

Time t = 5 s



Time t = 20 s





Bidirectional Fabric Intra Tow Lead

Further Research

- Incorporate resin curing kinetics.
- Time and saturation dependent inlet conditions.
- Multiple inlets and outlets.
- Different inflow conditions.
- Testing for various fiber and resin combination.
- Modeling with woven fabric.
- Developing an algorithm for achieving uniform flow front.
- Experimental validation of the model.

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Thank You

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