

Optimizing Bio-Inspired Flow Channel Design on Bipolar Plates of PEM Fuel Cells

Comsol Conference 2010

Boston

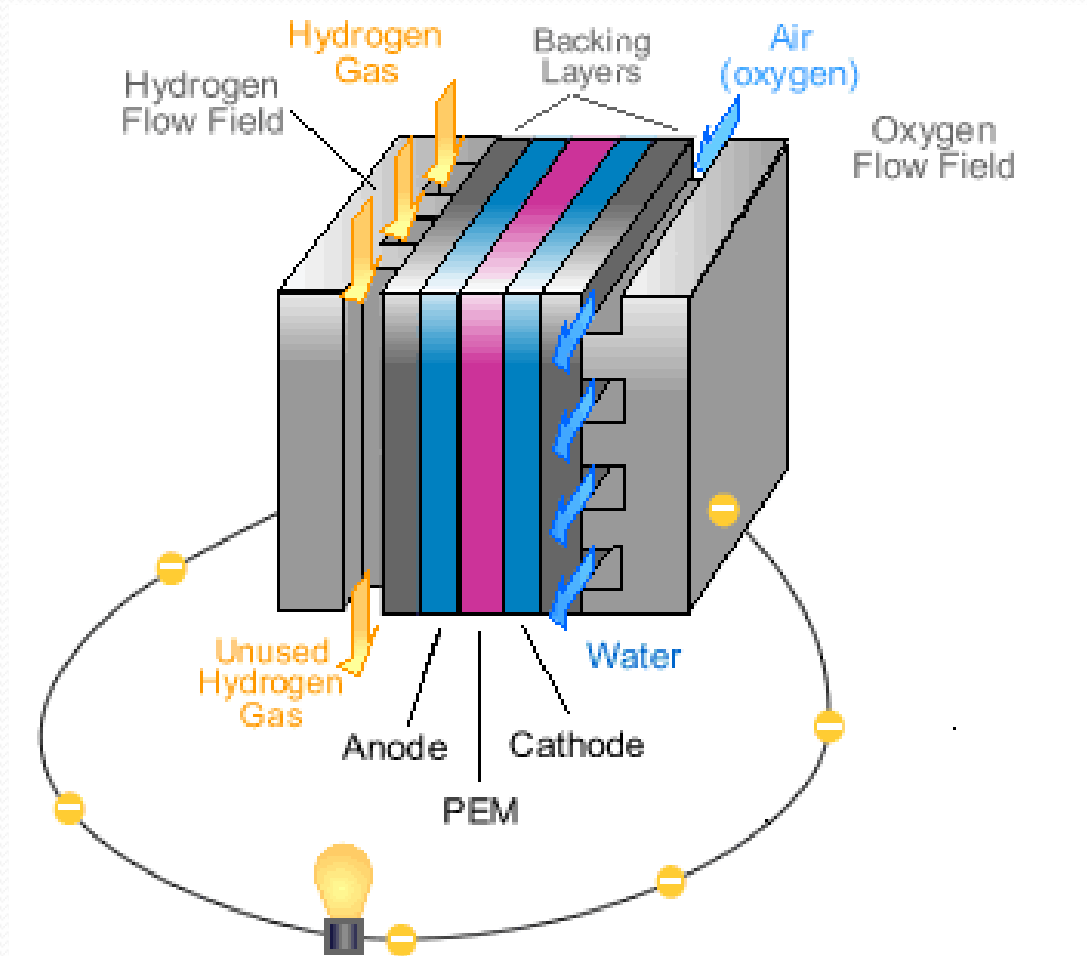
James Peitzmeier

10/7/2010

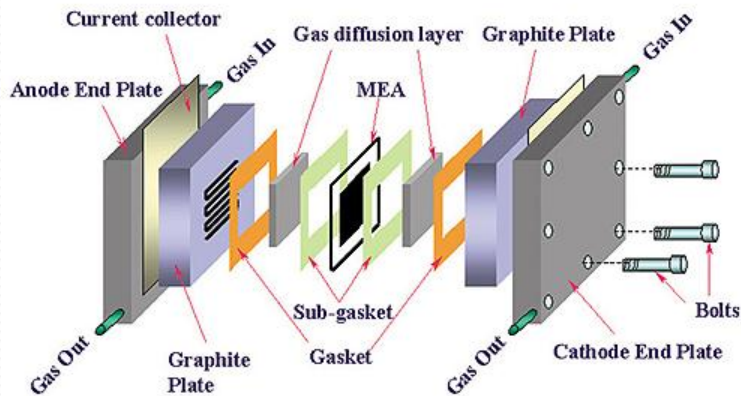
Presentation Outline

- Background on PEM fuel cells
- Concept and Problem Statement
- Analytical Model
- Comsol Model
- Iterative Model
- Results
- Future work

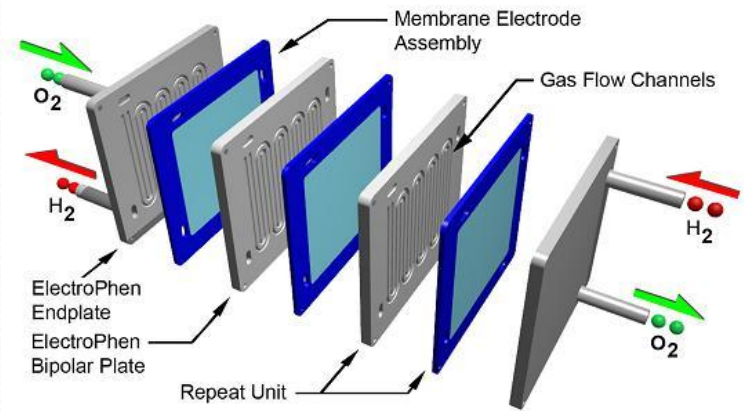
PEM Fuel Cell: Basic Components



Bipolar Plates



Increase Power

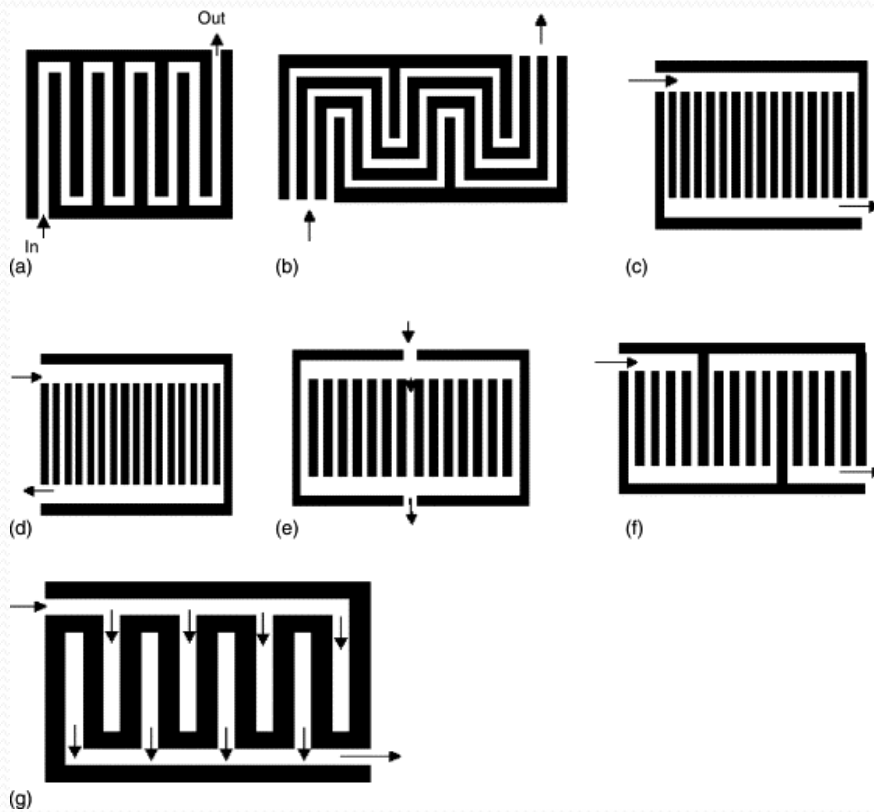


- Single fuel cell is limited to ~ 0.6 V and ~ 0.7 W.
- To increase power, stack many cells in series using bipolar plates

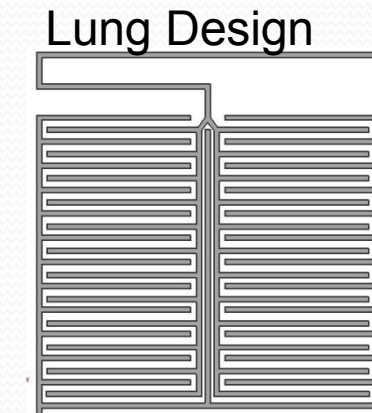
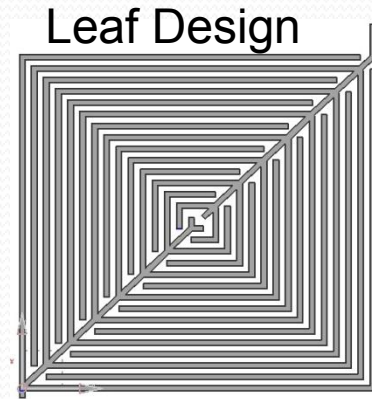
Bipolar plate functions

- Electrically conductive: transfers electrons to current collectors
- Thermally conductive: heat removal
- Physical support of stack
- Distribute hydrogen and oxidant evenly
- Remove excess water

Flow patterns on bipolar plates



Existing conventional flow pattern

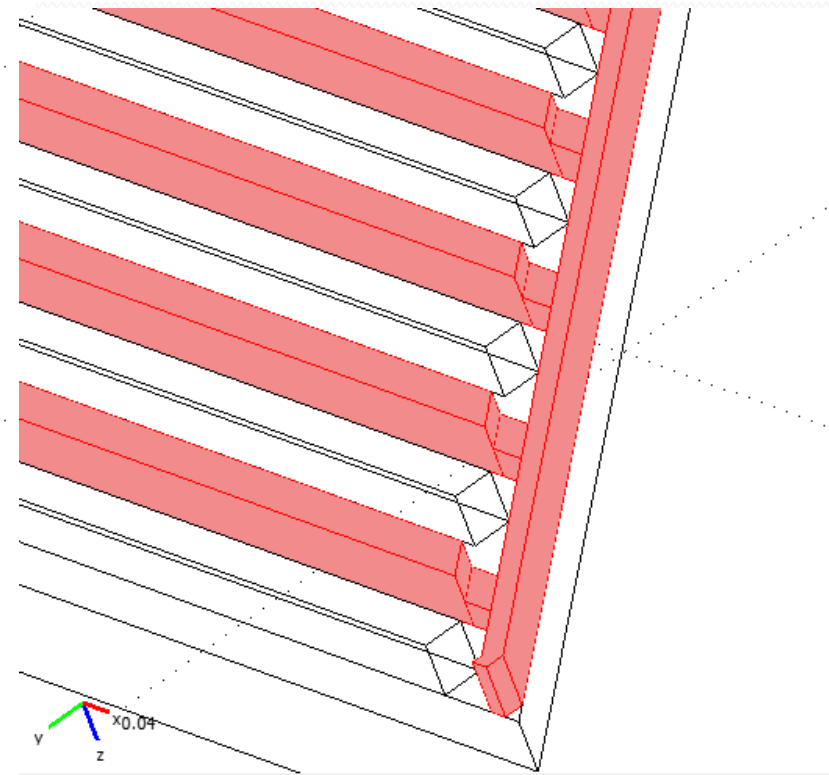
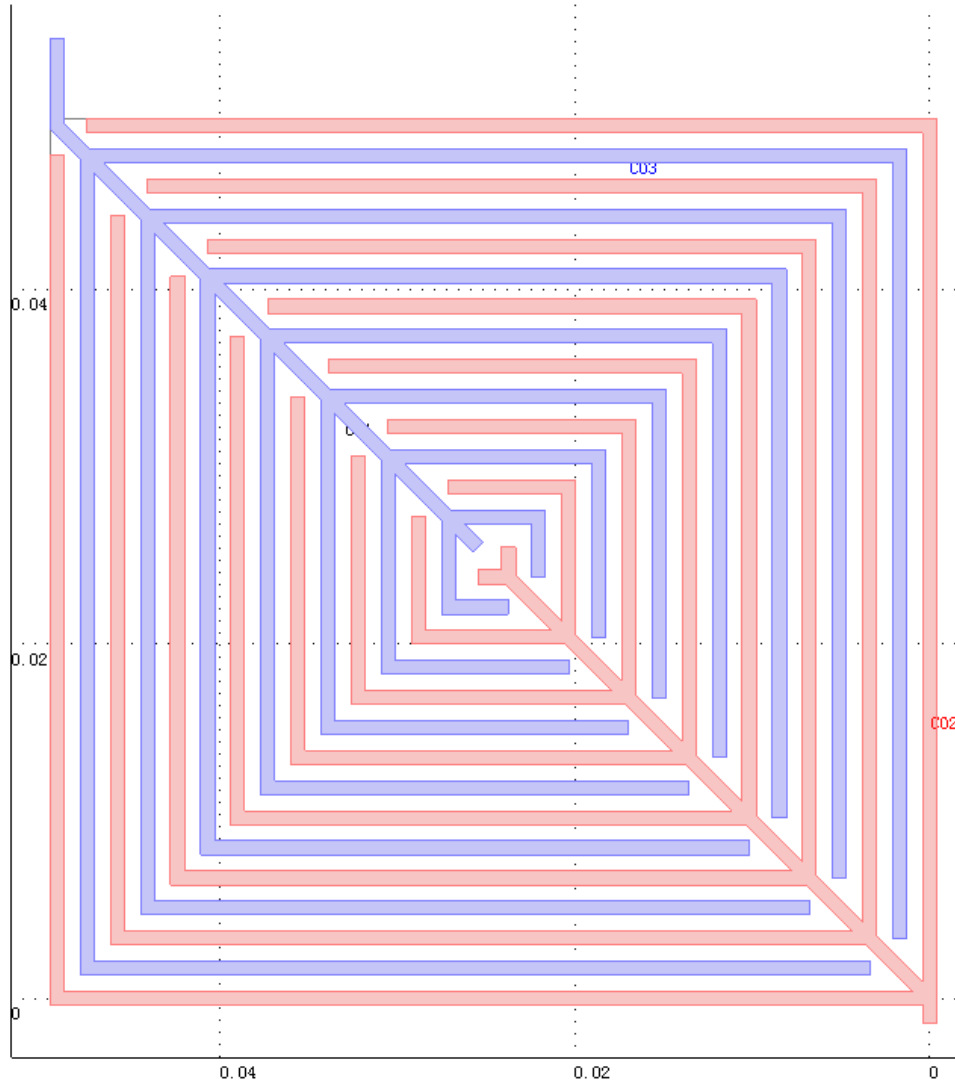


Bio-inspired Design

Objective

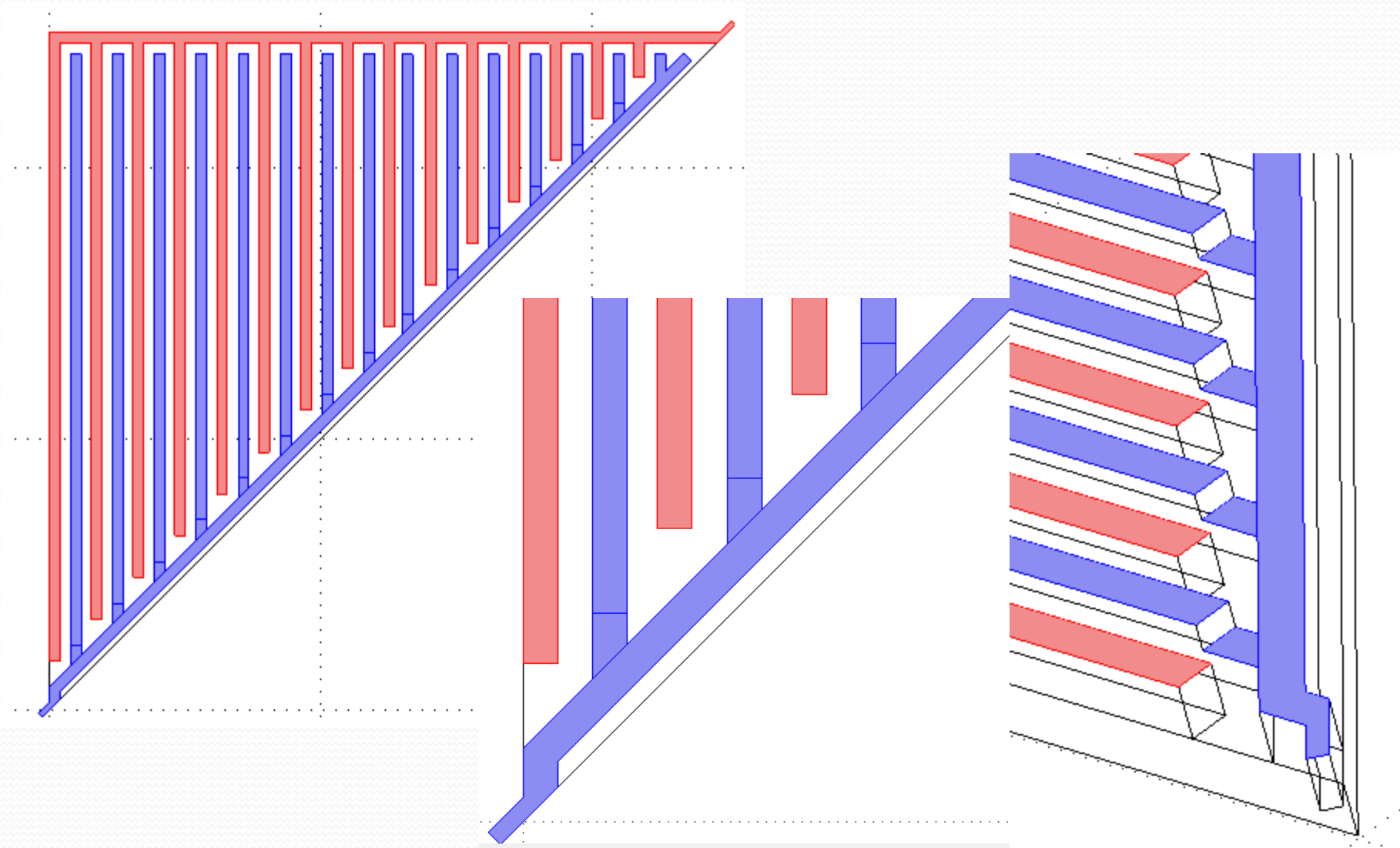
- To optimize the bio-inspired flow pattern design by adding the gates to each channel
 - Uniform flow distribution
 - Low pressure drop from the inlet to outlet

Leaf Design (1)



(1) J. Kloess, X. Wang, J. Liu, Z. Shi, and L. Guessous, Investigation of bio-inspired flow channel designs for bipolar plates in proton exchange membrane fuel cells, *J. Power Sources*, **188**, 132-140 (2009)

New lung design

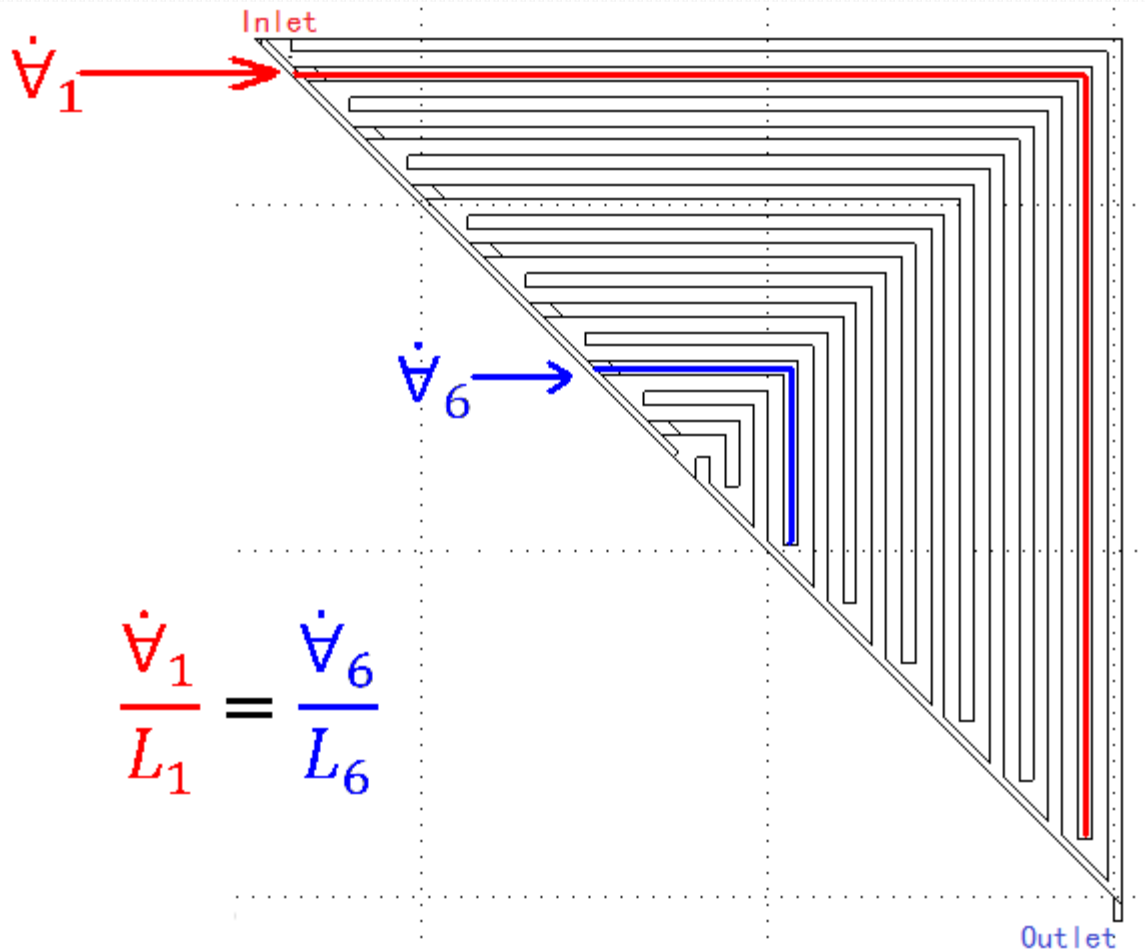


Methodology

- Analytical analysis
- Numerical Simulation
 - Comsol-Flow dynamics
 - Matlab-Optimization

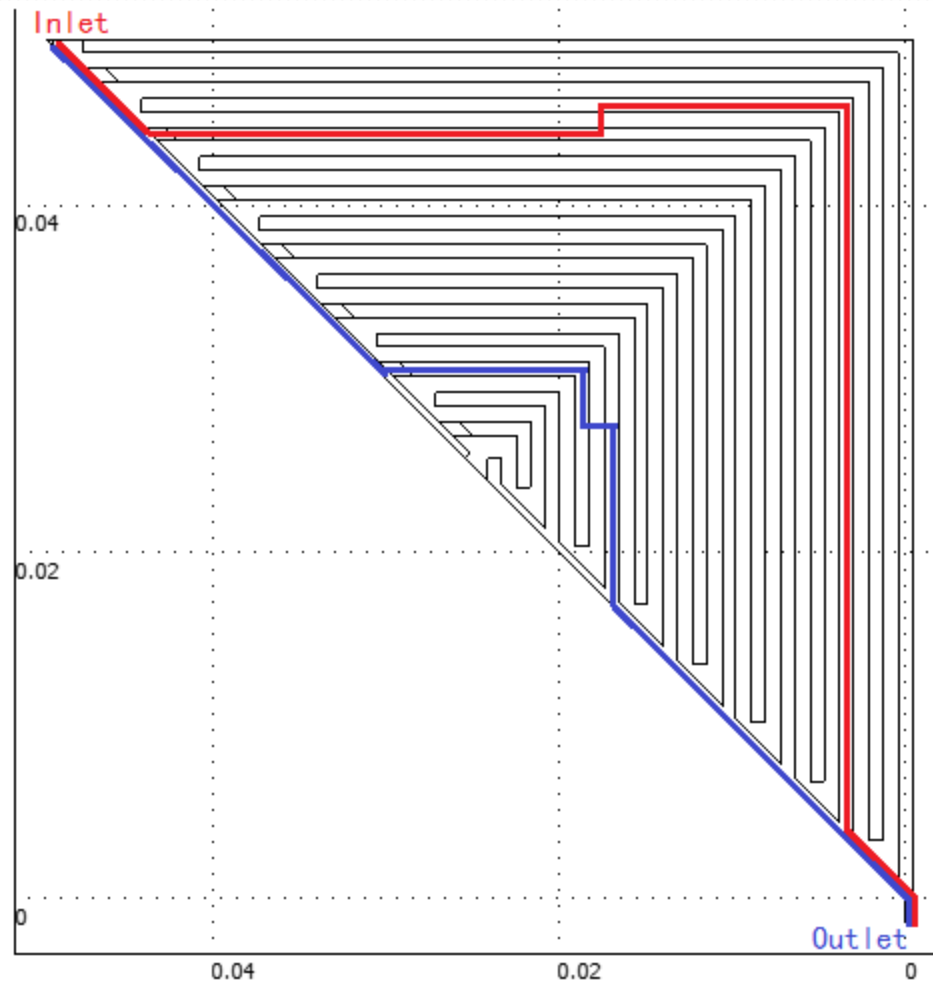
Analytical Model: Basic Ideas

Volumetric flow rate proportional to channel length



Analytical Model: Basic Ideas

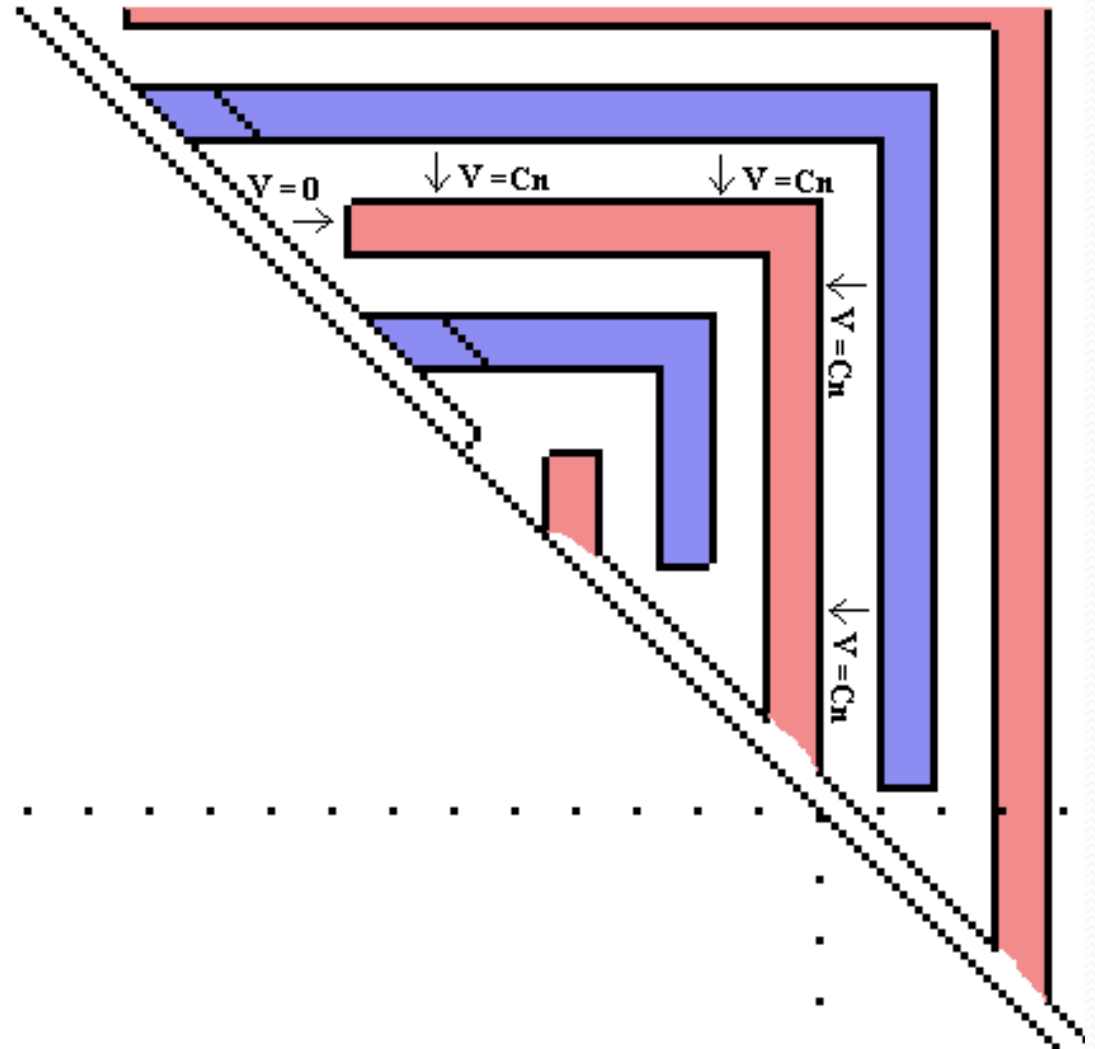
Change in pressure across any path must be equal



Analytical Model: Basic Ideas

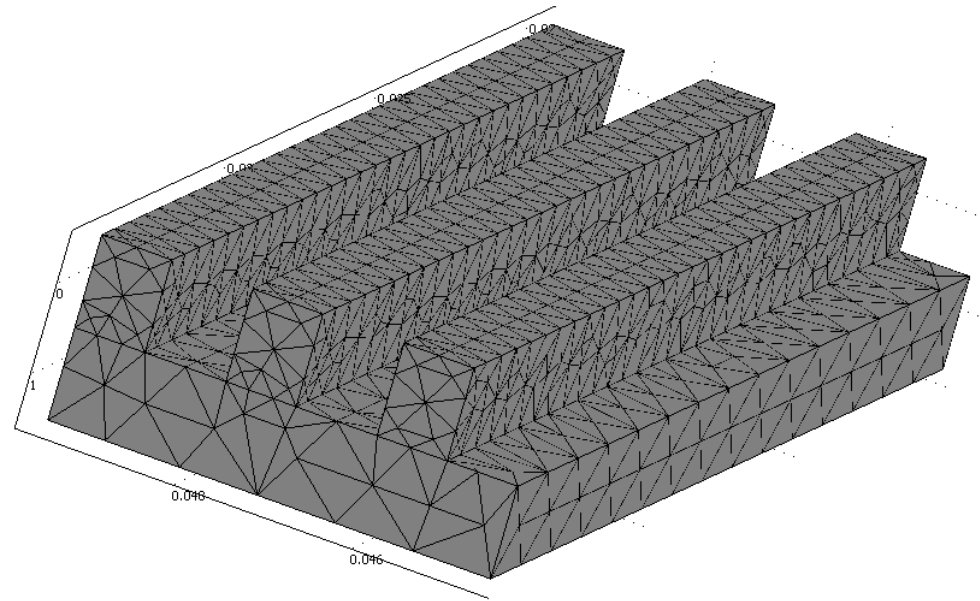
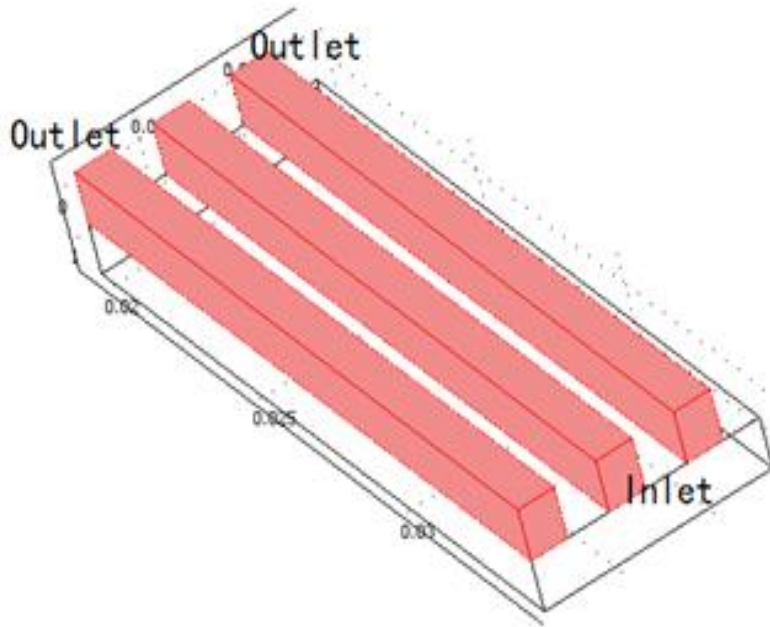
Assumptions

- Velocity in GDL between a inlet outlet pair is constant for the length of the channel
- Flow from runner to channel is negligible



Mesh Independence:

Model

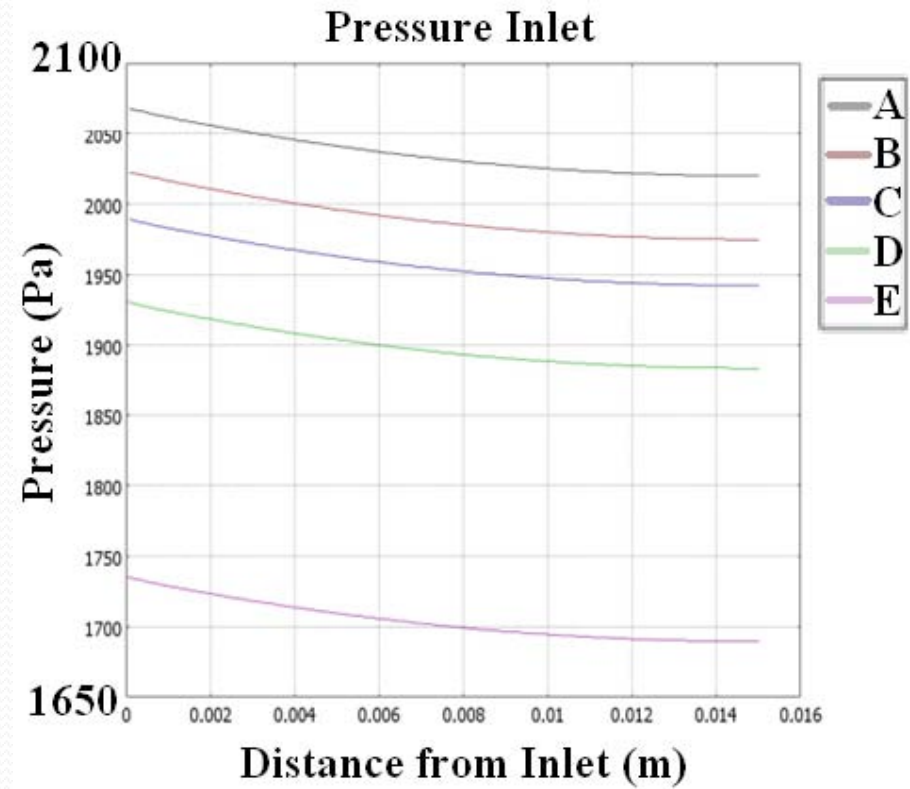
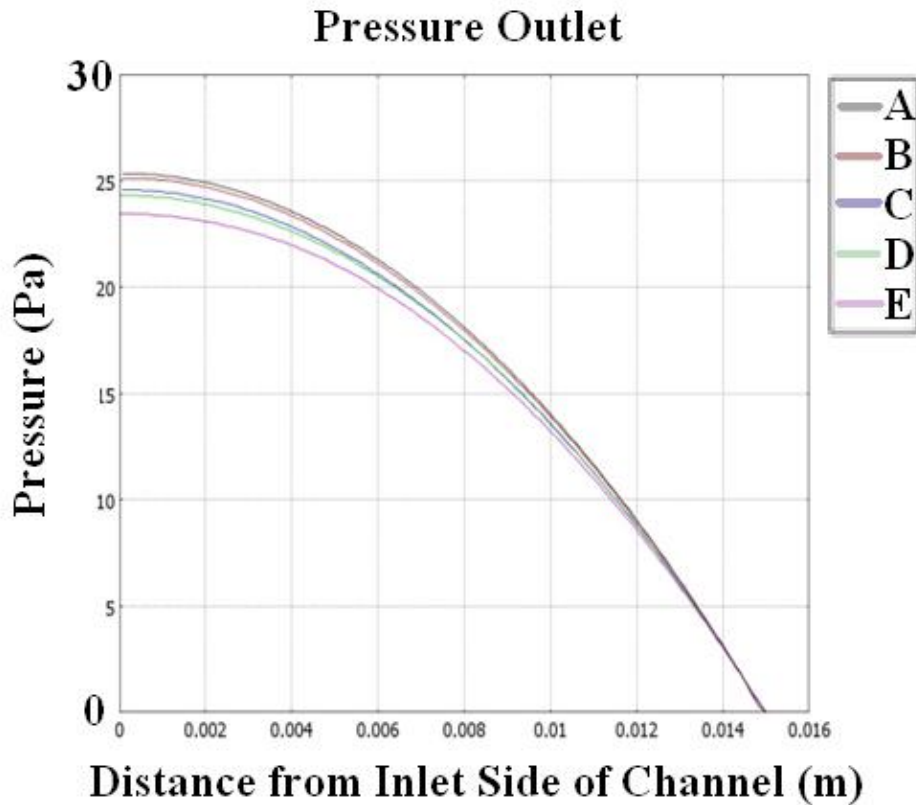


x 1e-3

- Model, 1 inlet, 2 outlets and GDL

- 3rd most refined mesh, mesh C
- This mesh is used in testing

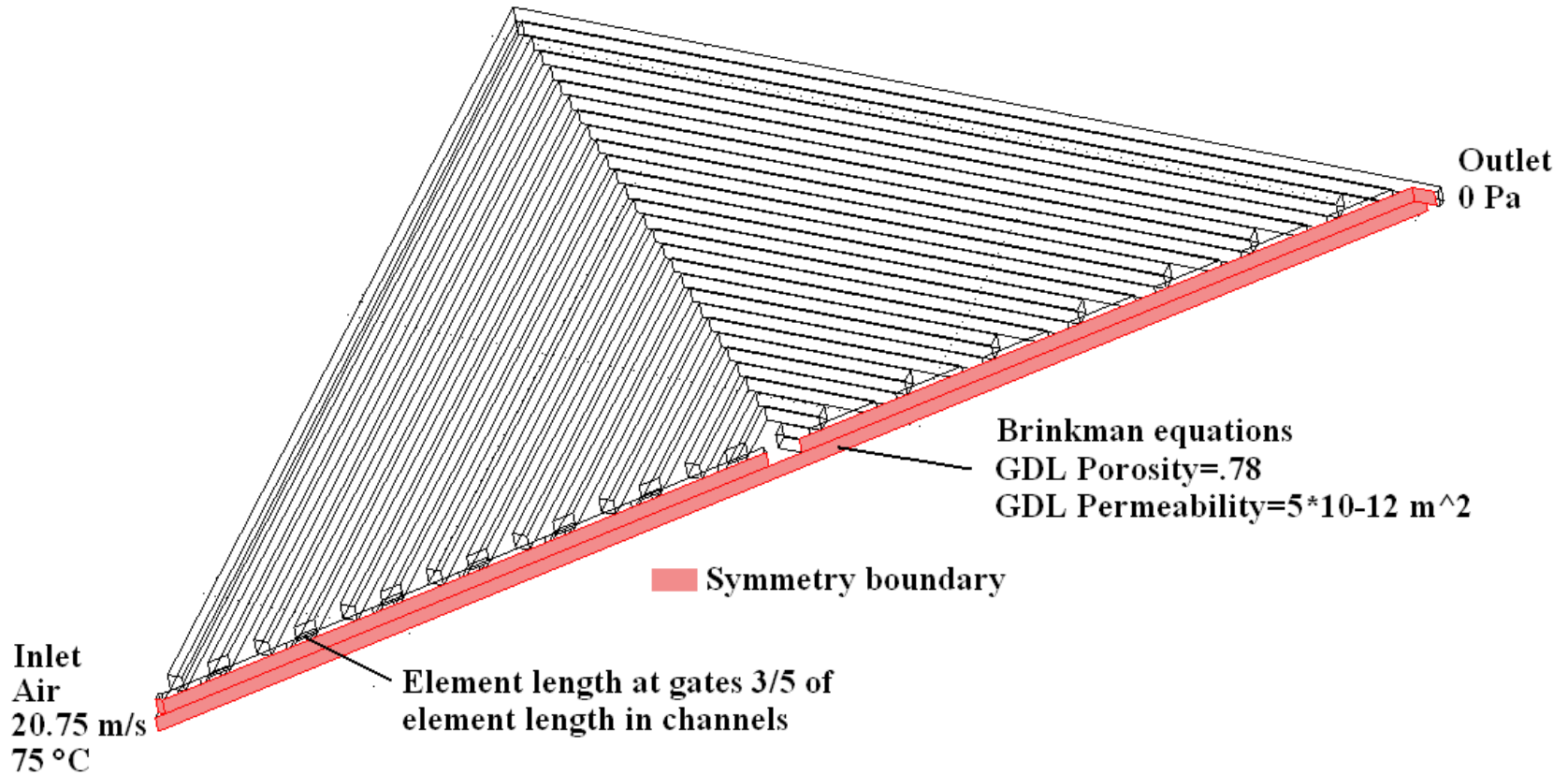
Mesh Independence: Results



Velocity towards catalyst in GDL also considered

Comsol Model

Using Incompressible Navier Stokes Equations

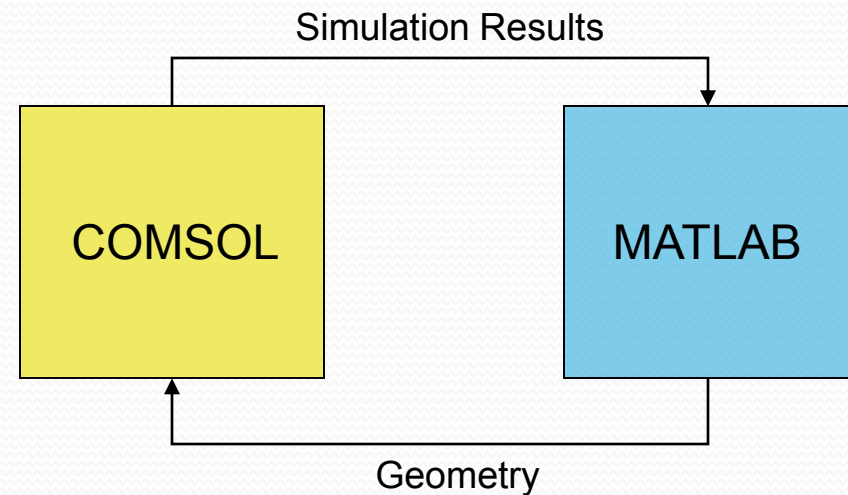
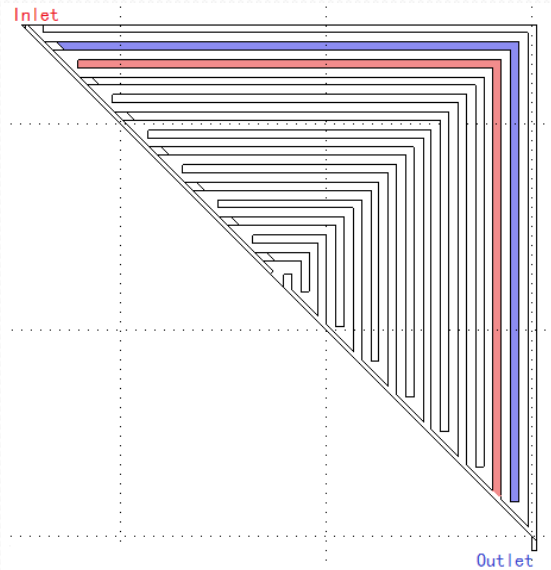


Limitations

- No water generation or removal
- No mass flow through PEM

Iterative Model: Comsol Side

Solve model, return channel pressure values



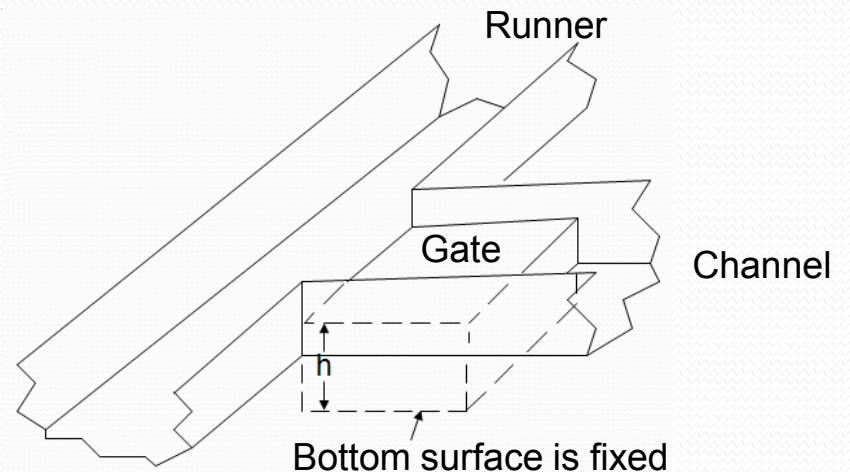
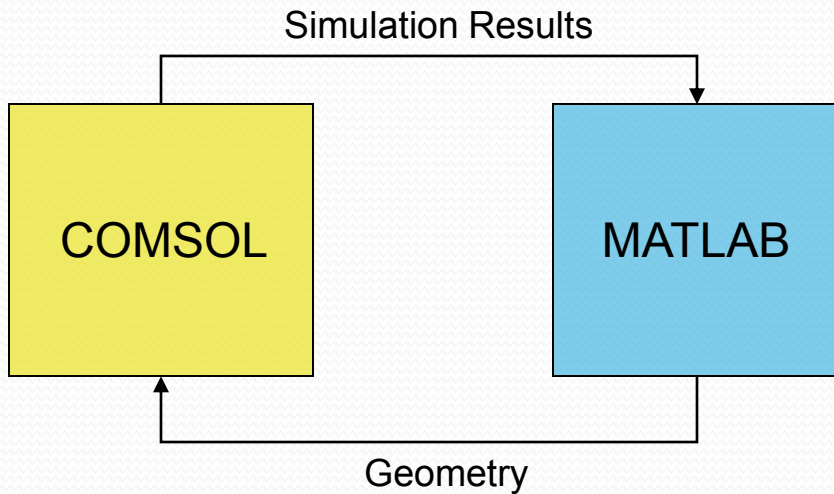
- Pressures for pairs of inlet and outlet channels are returned to Matlab

- 1 pair per gate is considered

Iterative Model: Matlab side

Modify gates to balance difference in pressures

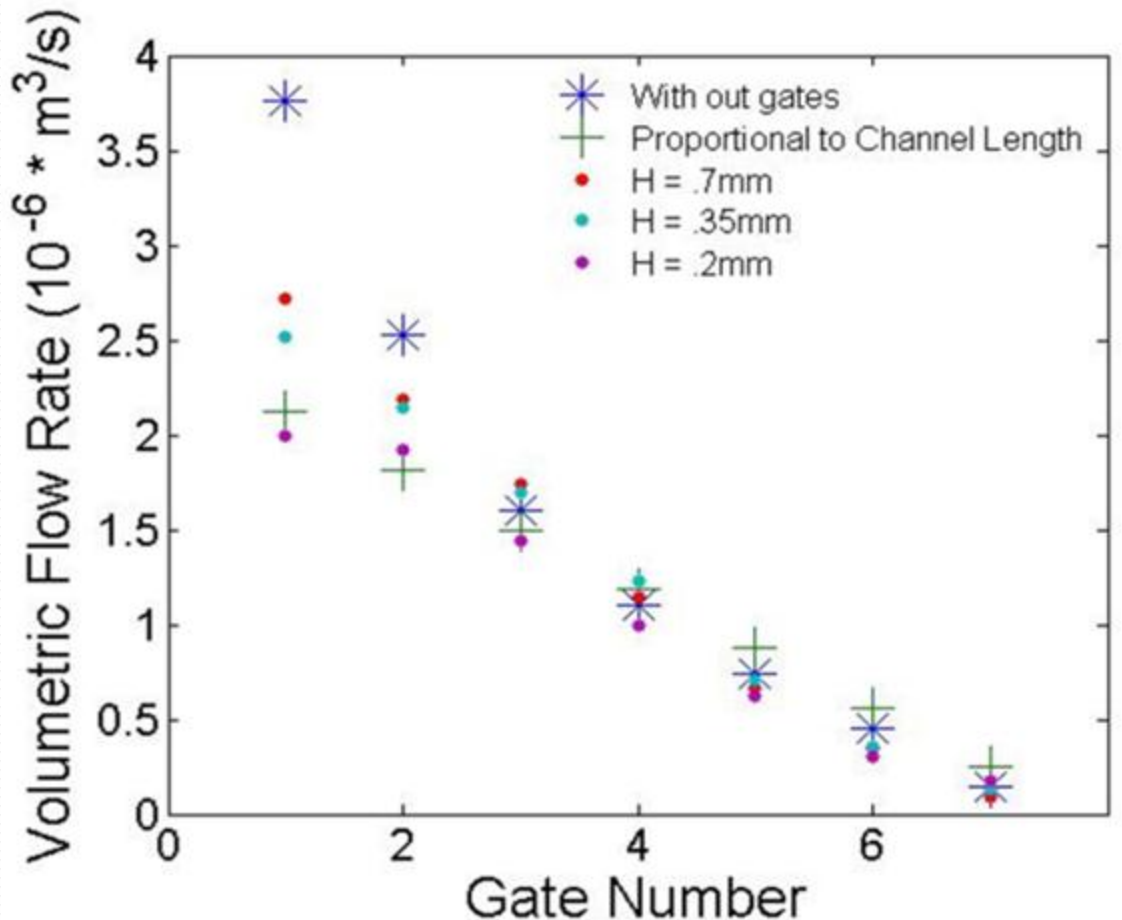
- Matlab modifies geometry and topography of the gates
- The goal is to find a geometry that will produce a constant pressure difference between inlet and outlet pairs



Analytical Model: Results

Flow rates through Gates

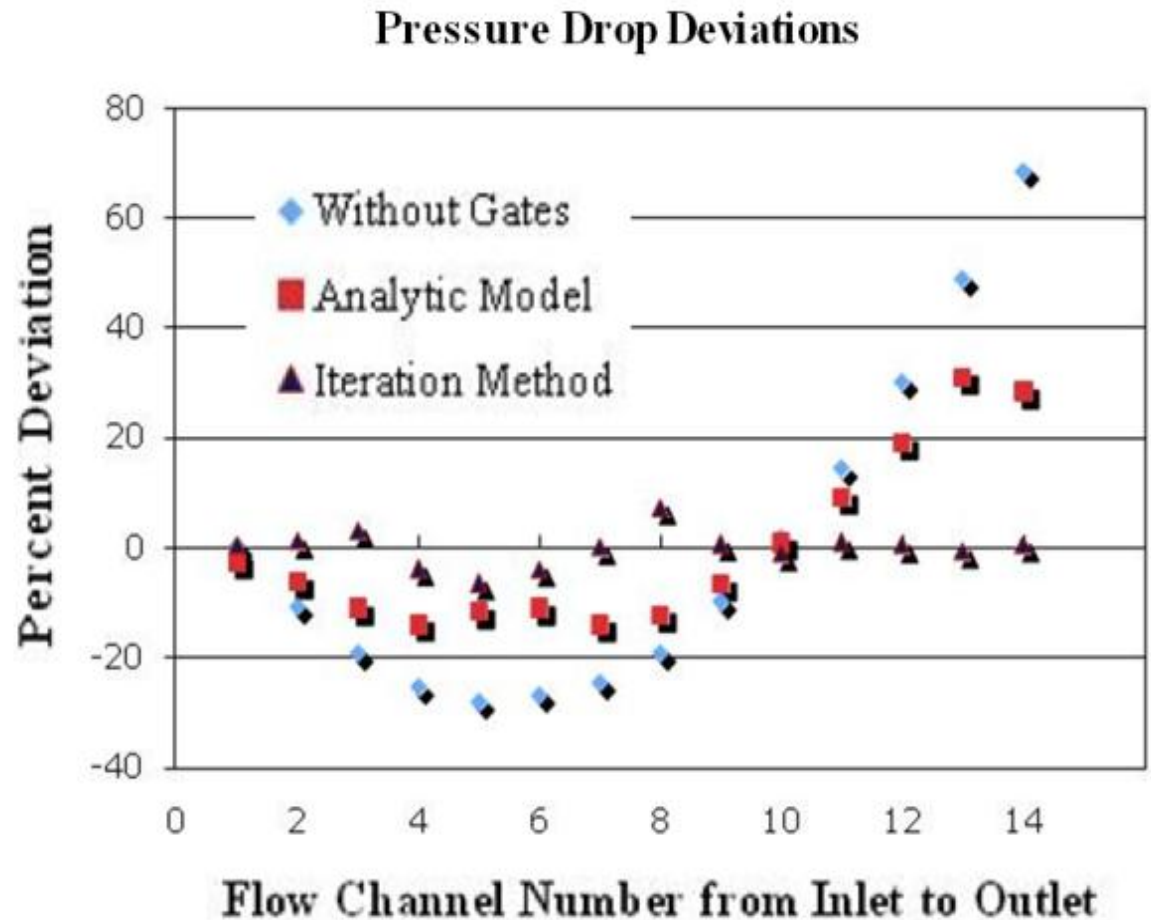
- H is a tunable parameter
- Model balances measured parameter



Iterative Model: Results

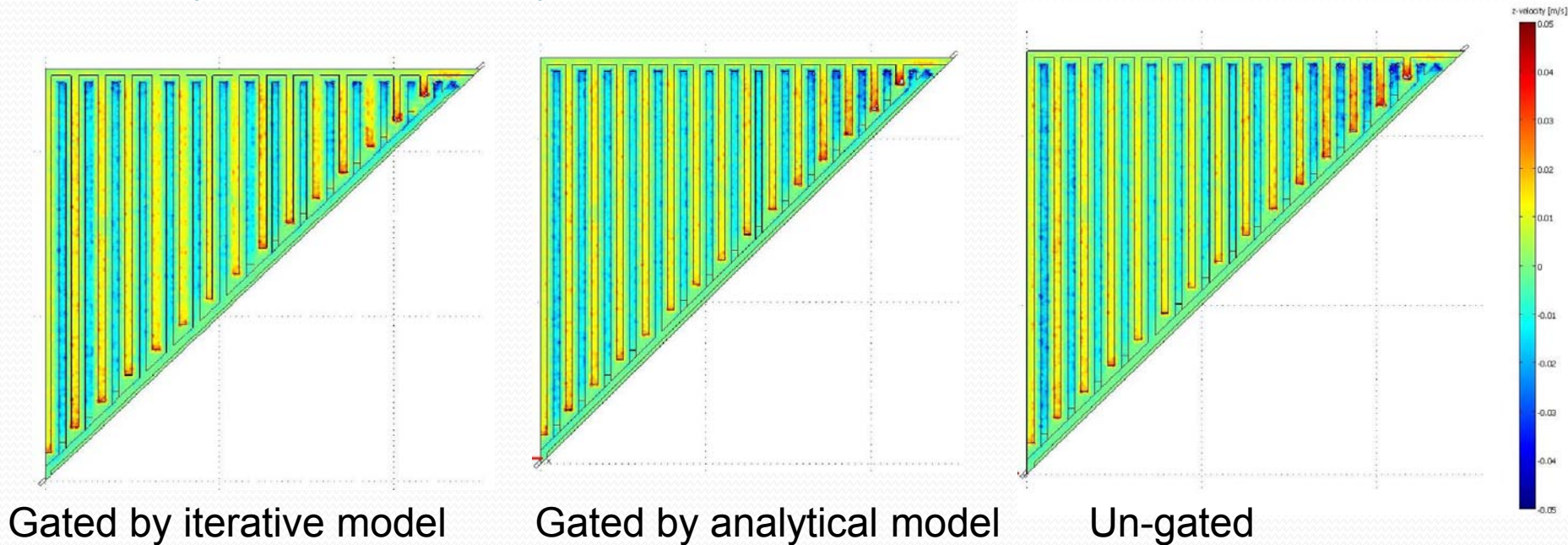
Flow rates through Gates

- Model improves measured parameter



Lung Model: Results

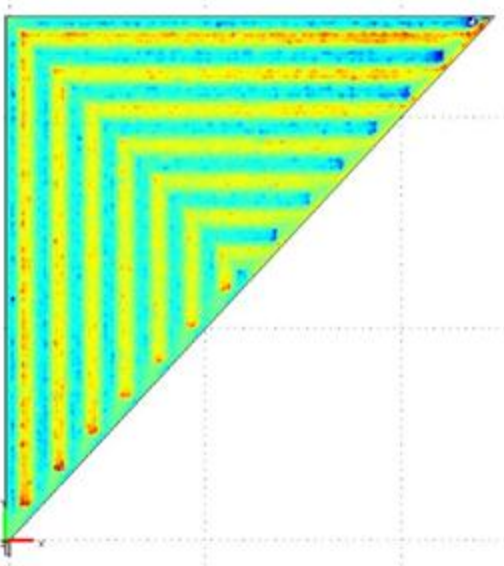
Velocity towards catalyst



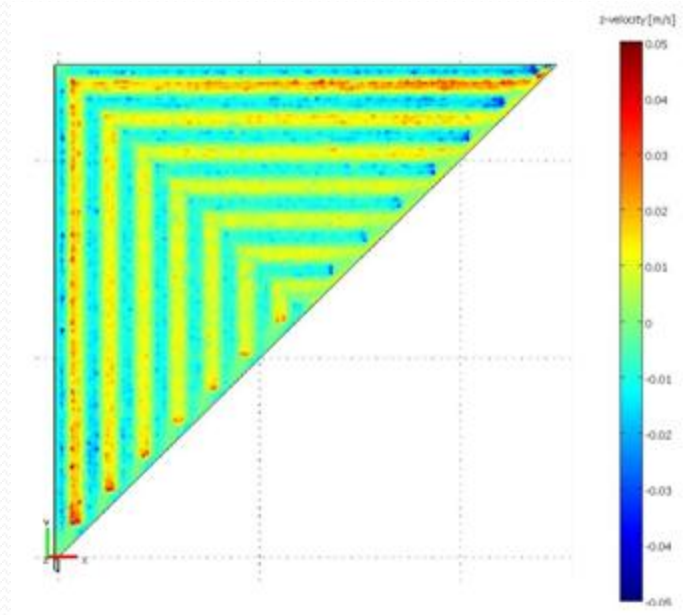
- Minimal change
- Hot spots at end of inlet channels and beginning of outlet channels

Leaf Model: Results

Velocity towards catalyst



Gated by analytical model

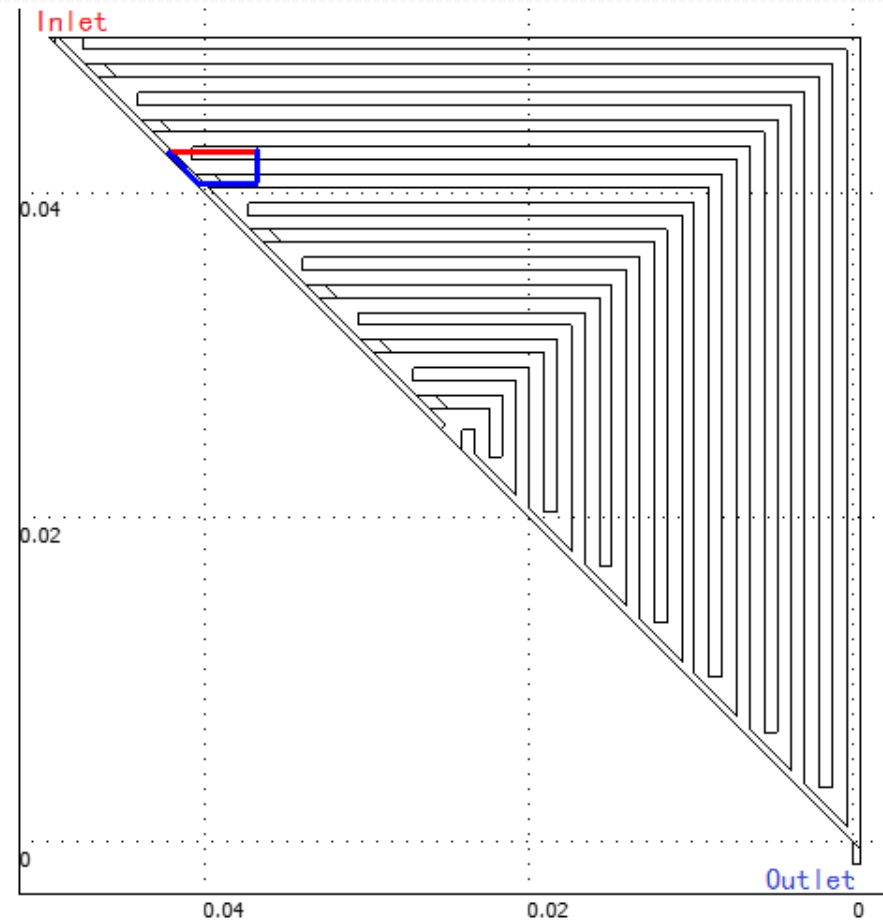


Un-gated

- Minimal change
- Hot spots at end of inlet channels and beginning of outlet channels

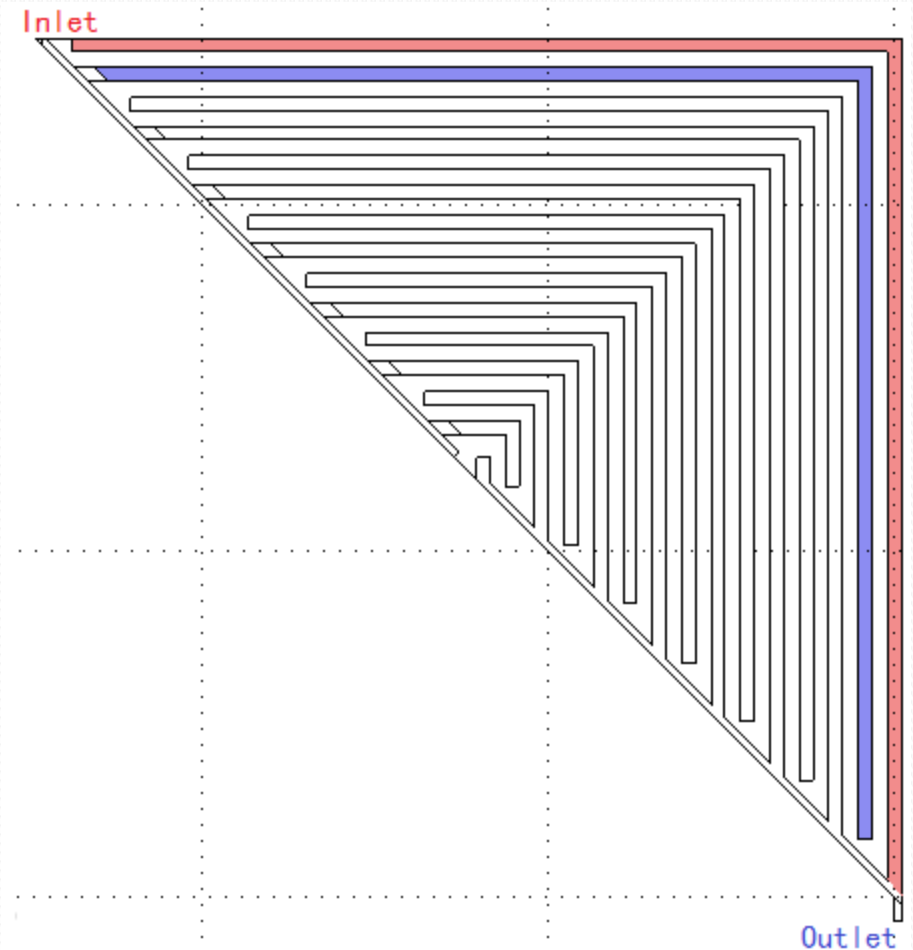
Future Work: Analytical Model

- The path from the runner to the outlet has the same pressure drop as the path through the gate
- Flow rate through red path will be prescribed



Future Work: Iterative Model

- Account for flow between 1st inlet channel and 1st outlet channel
- Account for flow through GDL between runners and channels



Questions?



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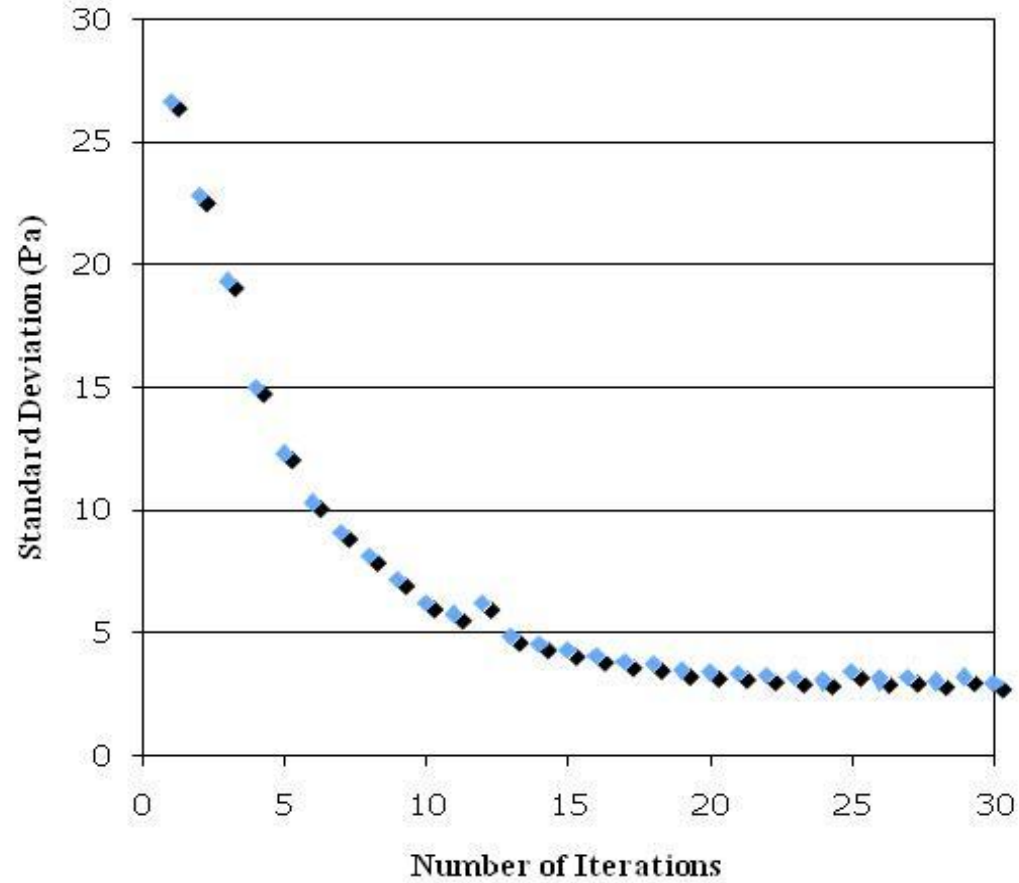
Co-Authors: Steven Kapturowski, Dr. Xia Wang



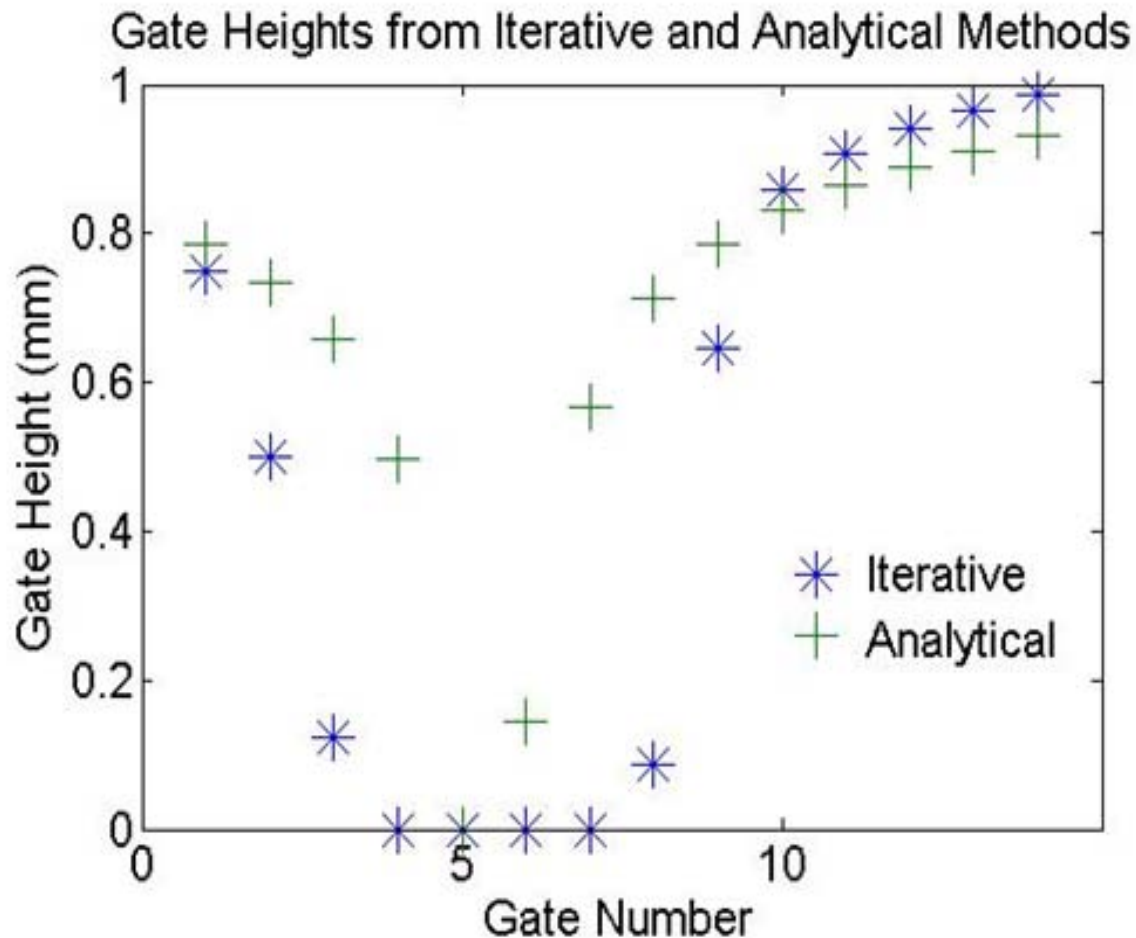
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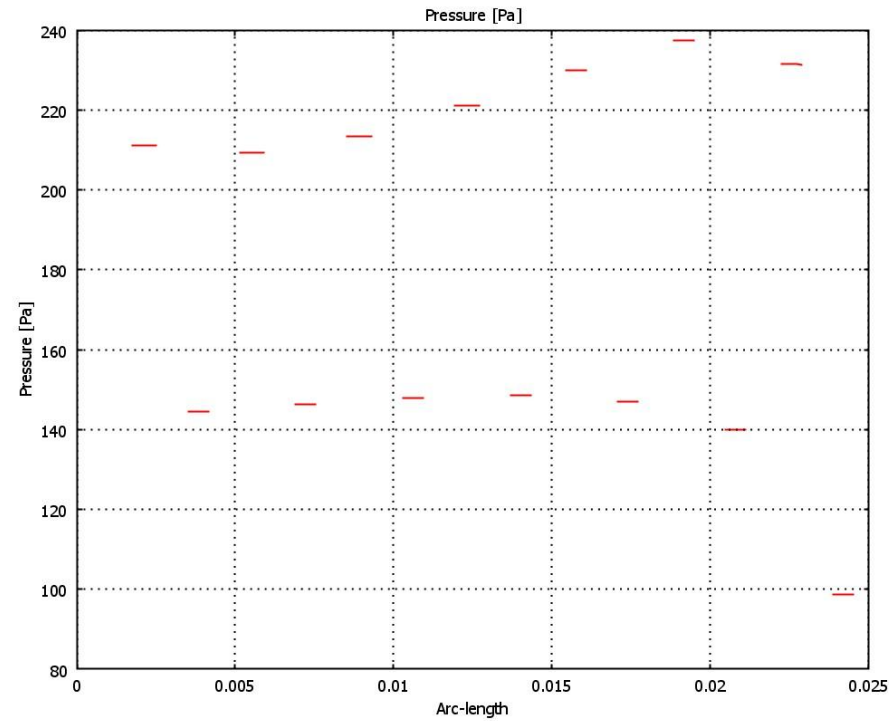
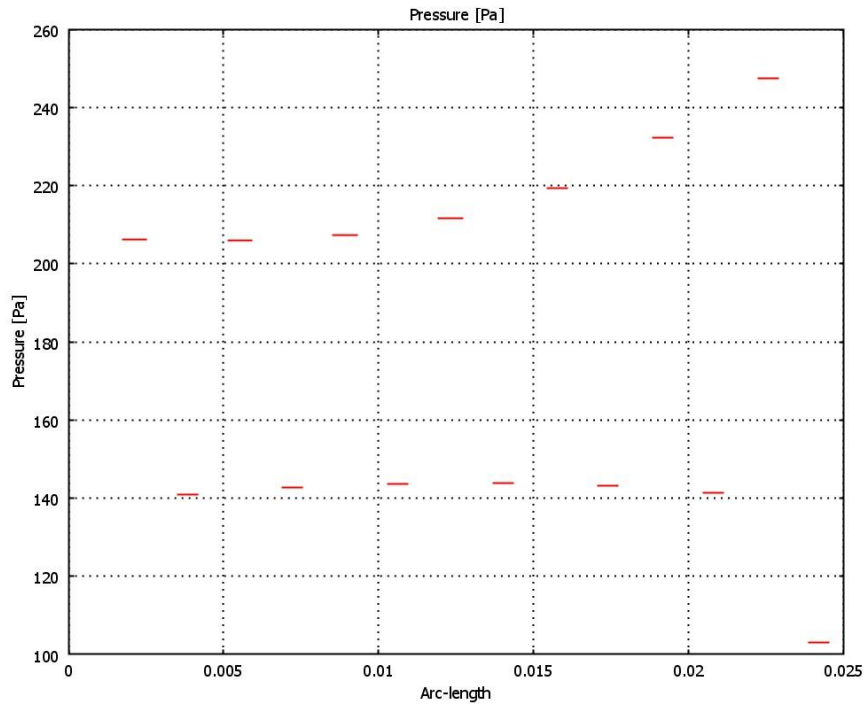
Iterative model convergence



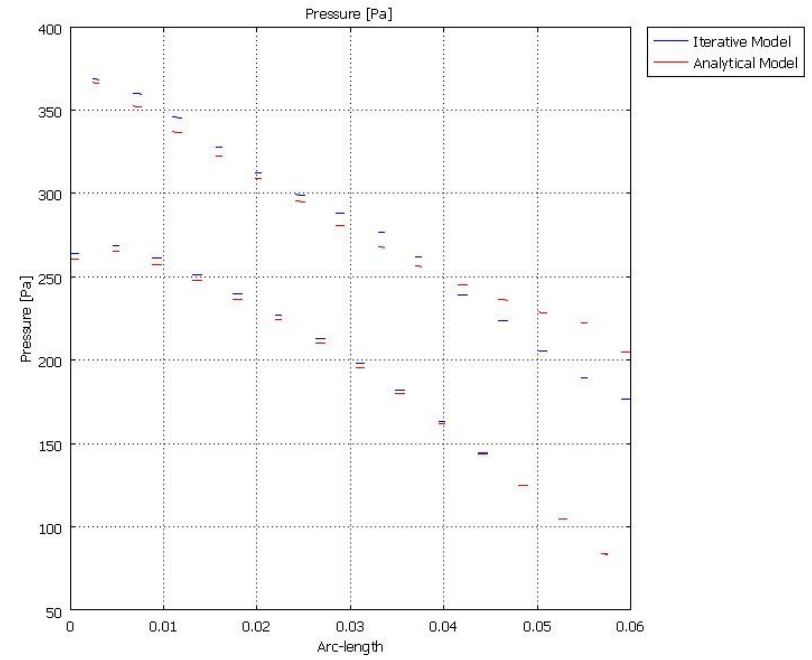
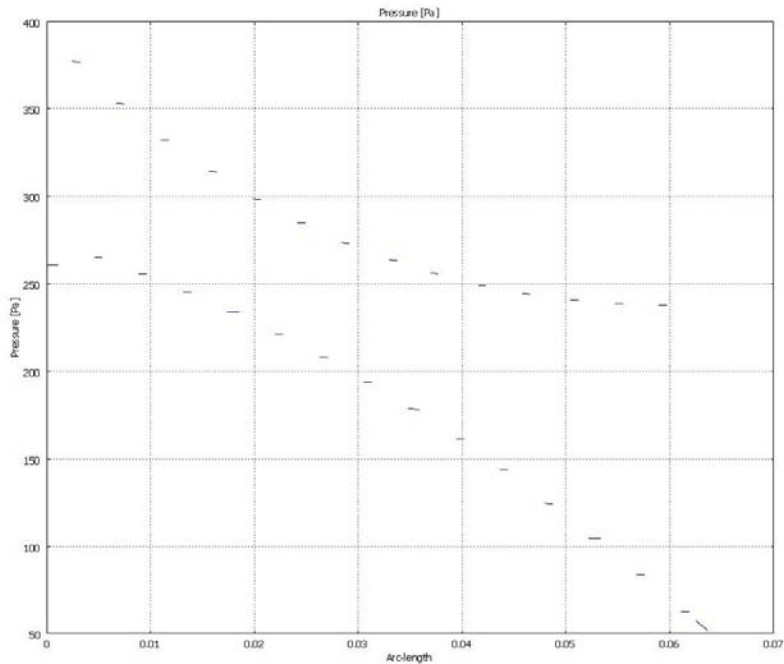
Gate Heights for lung design



Leaf Pressure at inlets and outlets



Lung Design Pressures at inlets and outlets



Velocity magnitude in GDL

