

Computational Modeling of Fluid and Particle Flows in Rock Fractures

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Outline

➤ Applications

- Enhanced Oil Recovery, Reservoir Engineering

➤ Flow through Rock Fractures

- CT Scanning of Rock Fractures
- Geometric Features of Fractures
- Numerical Simulation of Flow through Fractures
 - LCL Model
 - Fluent
 - OpenFOAM

➤ Conclusions

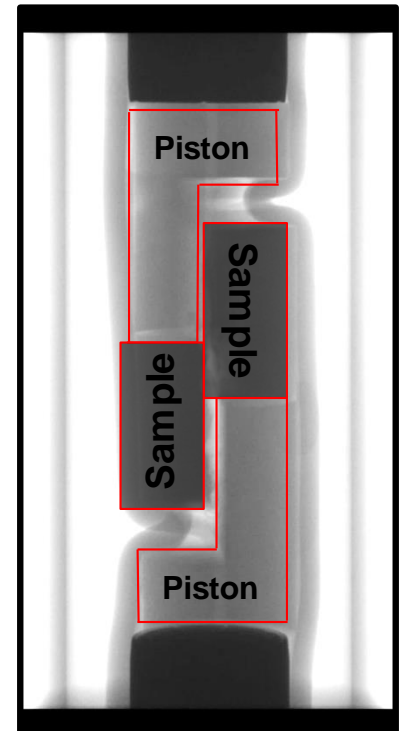
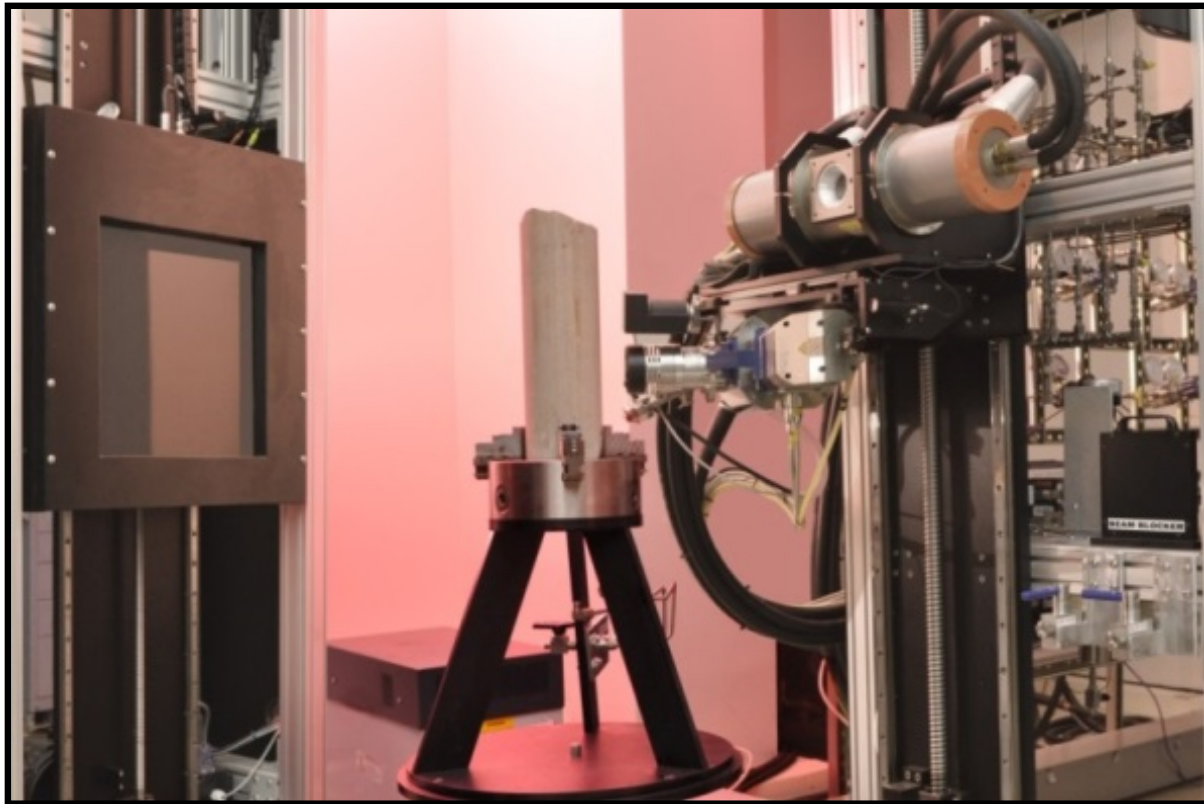
Objectives

- Improve efficiency of geological CO₂ sequestration in depleted oil fields and brine saturated fields.
- Provide a better understanding of two-phase flow patterns during CO₂ sequestration.
- Develop a better understanding of the displacement of oil or brine by CO₂.

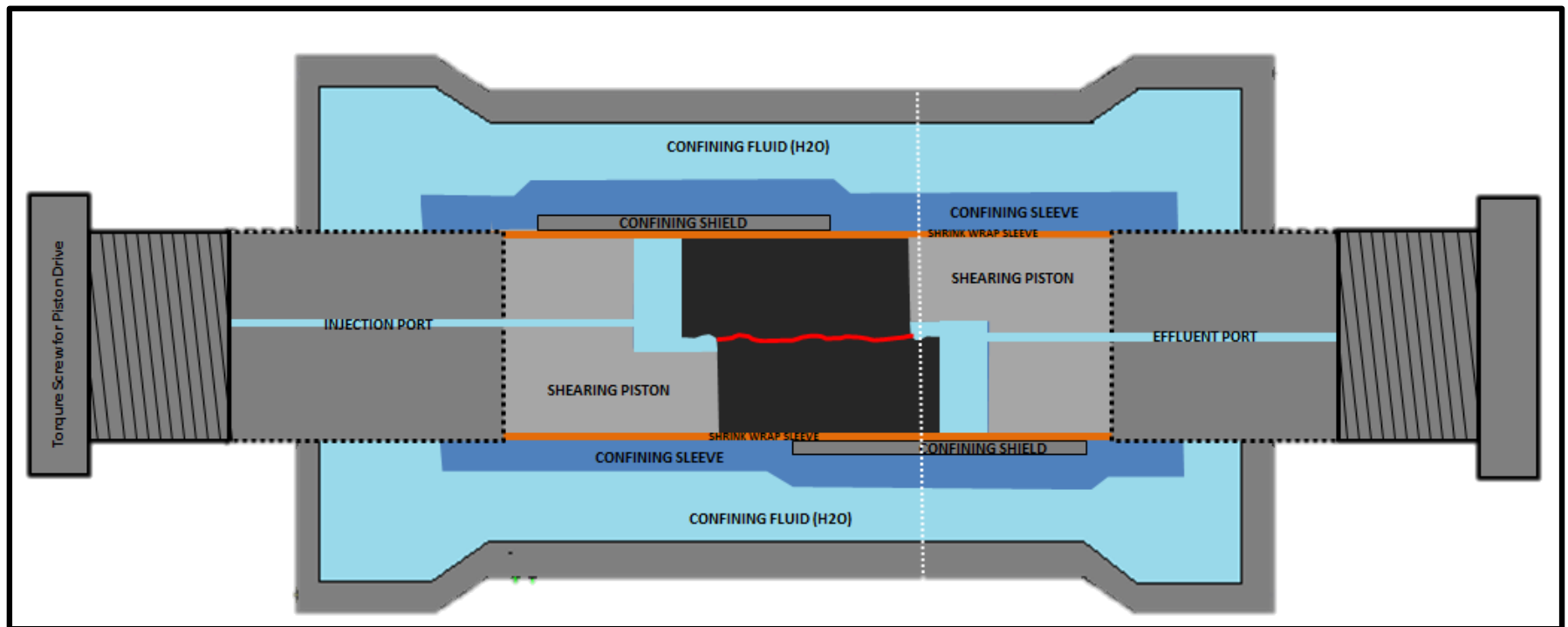
Shearing Apparatus

- Modified Hassler core holder to shear in discrete steps
- Industrial CT scanning and permeability measurements at each shear step

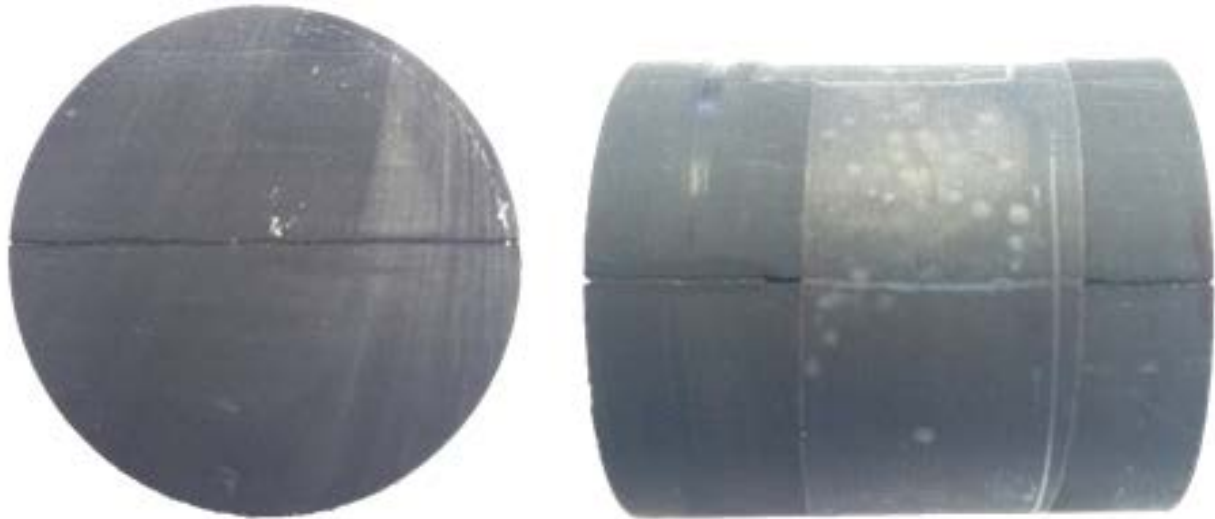
Shearing Apparatus



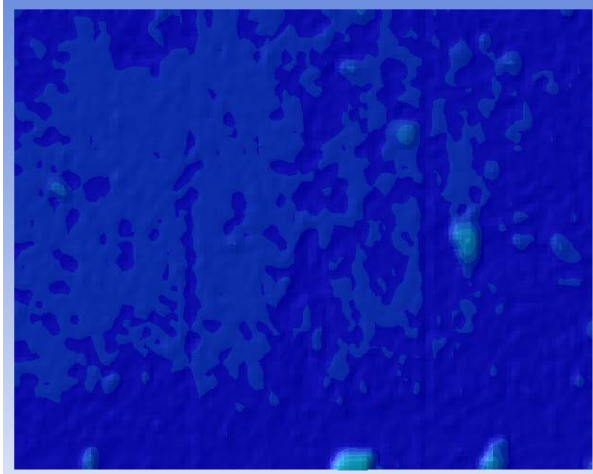
Permeability Measurements



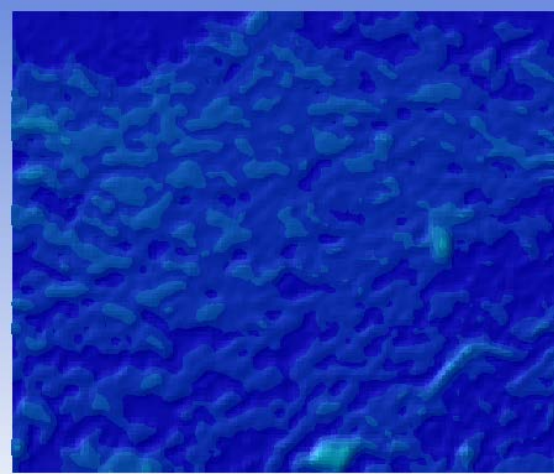
Marcellus Shale Sample



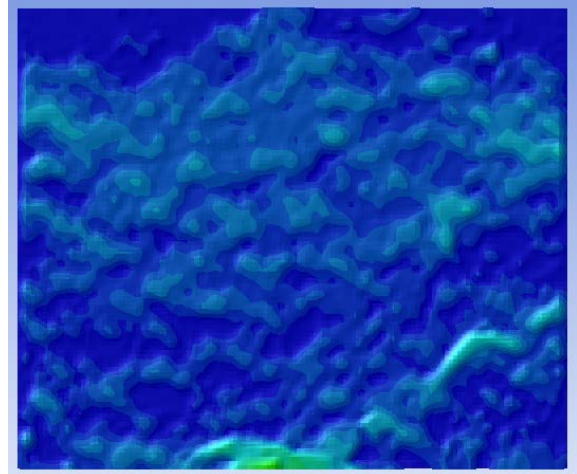
Aperture Map (m)



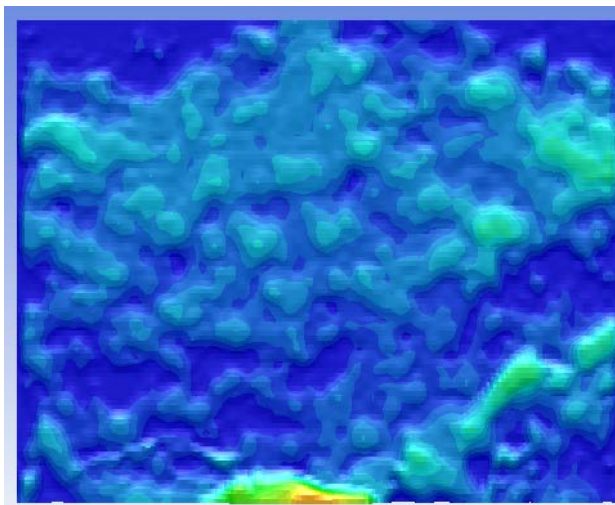
IS-6_0_ApertureMapRB-10AVG



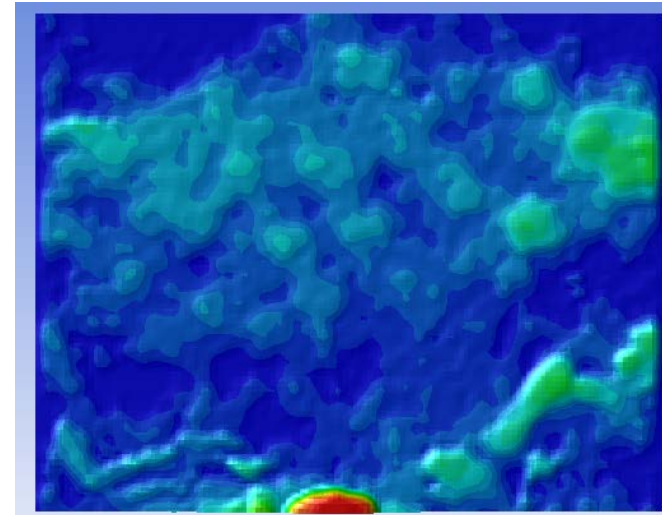
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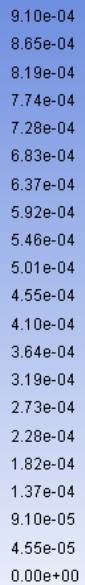
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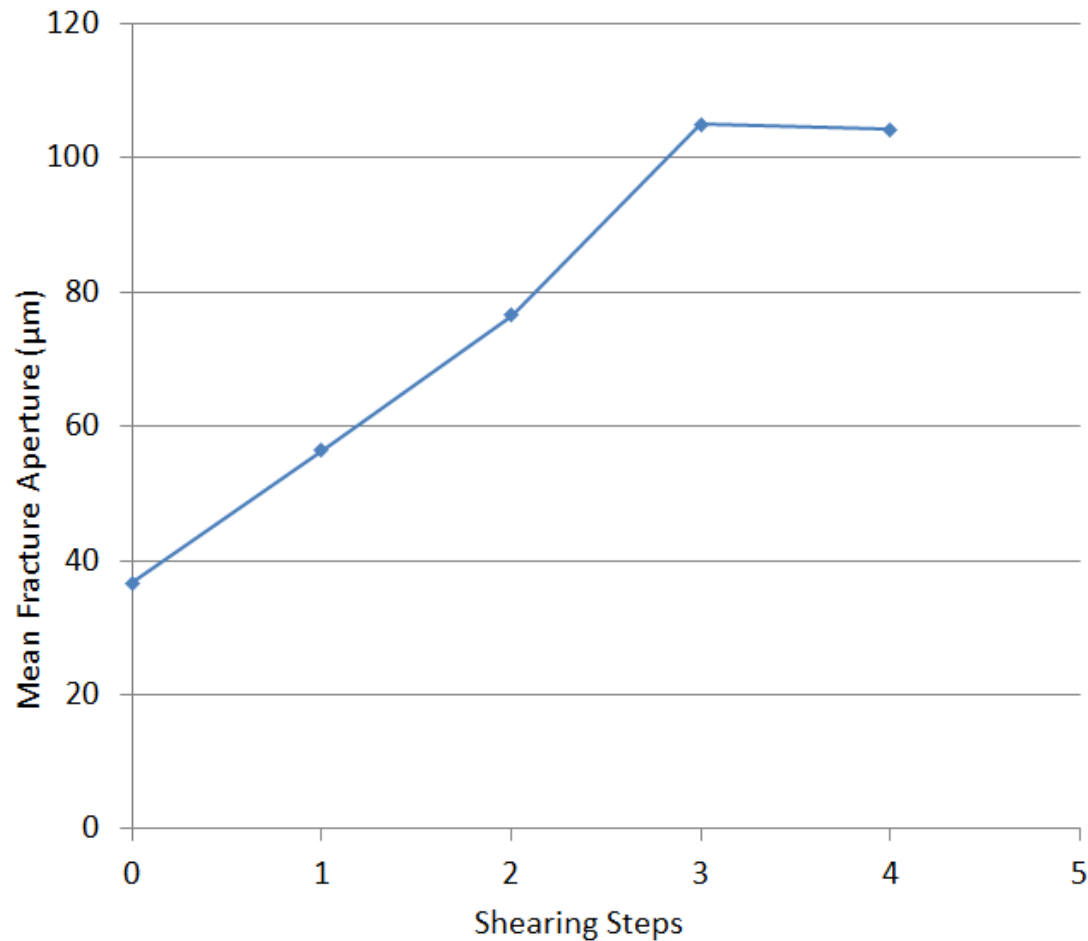
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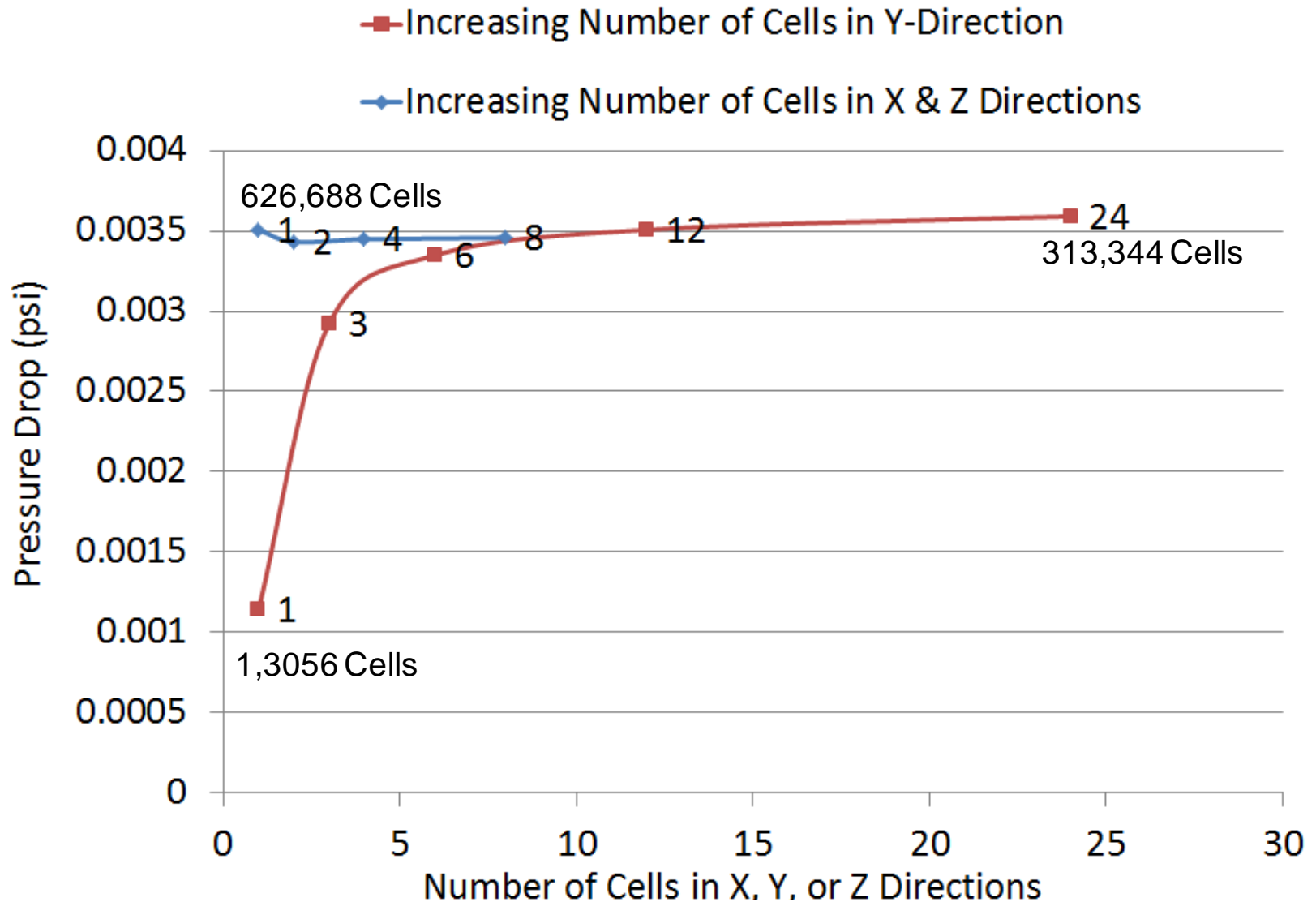
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Mean Fracture Aperture

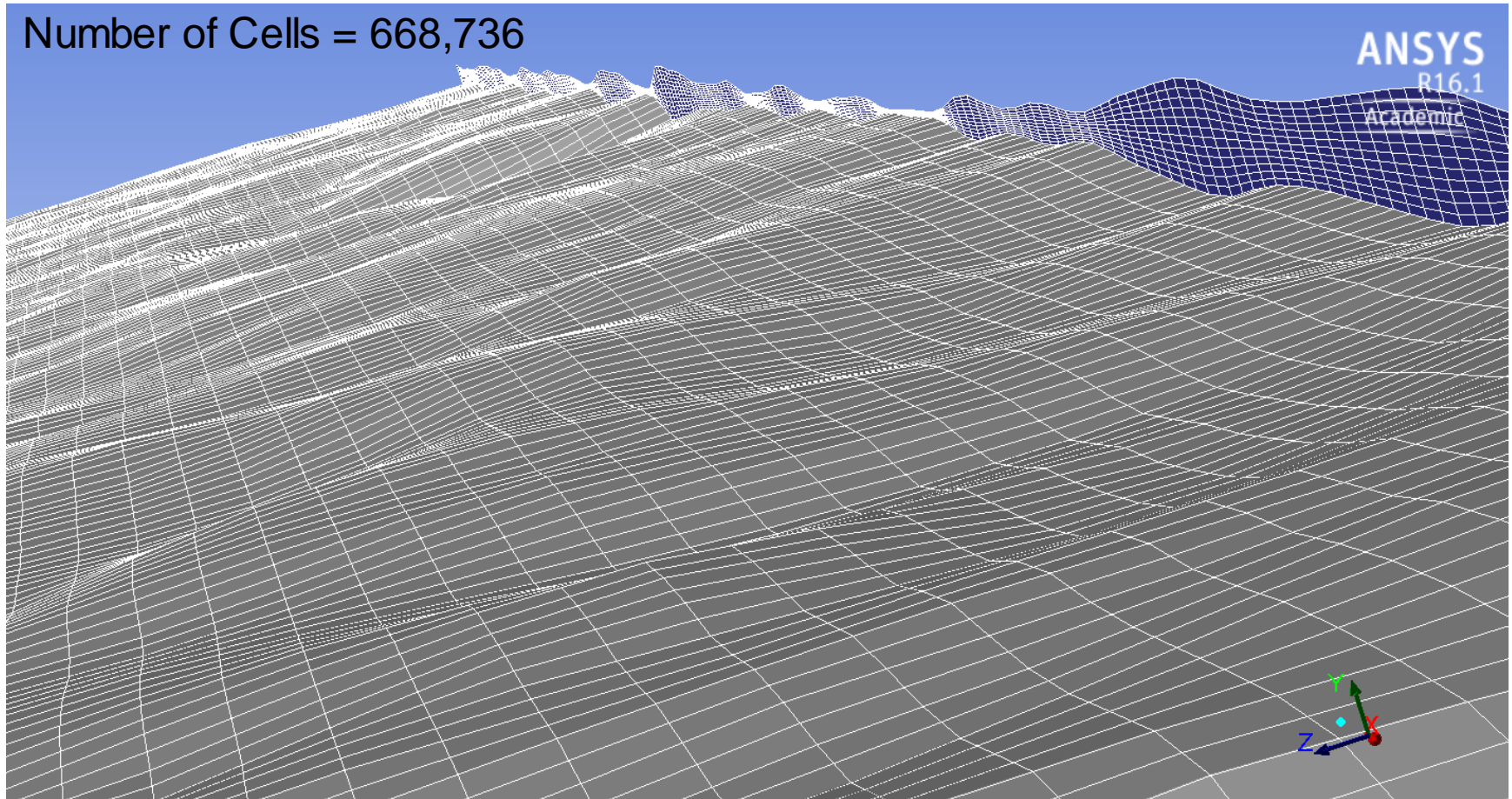


Grid Study of IS-6_0

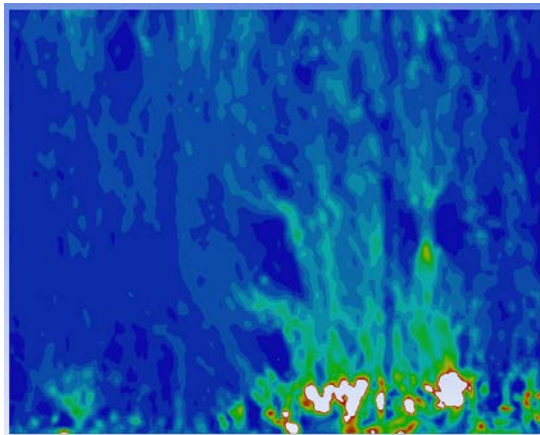


Grid (2,12,2) for IS-6_1

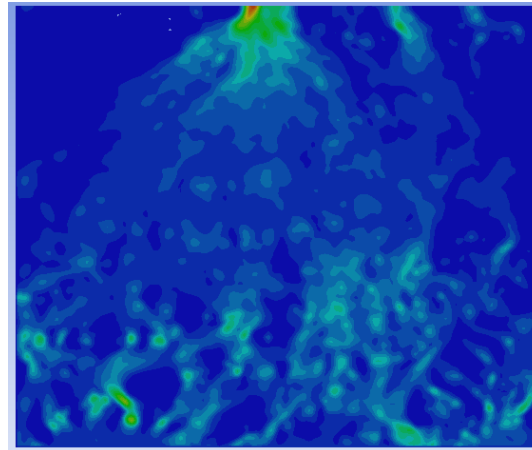
Number of Cells = 668,736



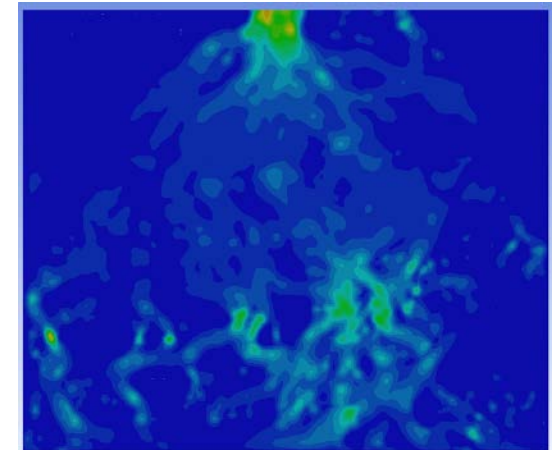
Velocity Magnitude (m/s)



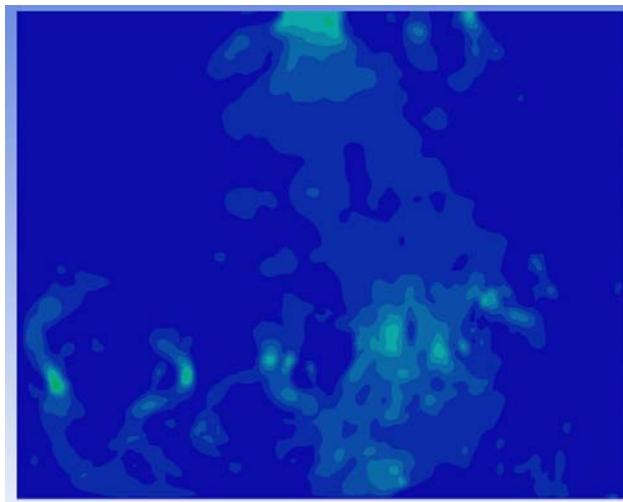
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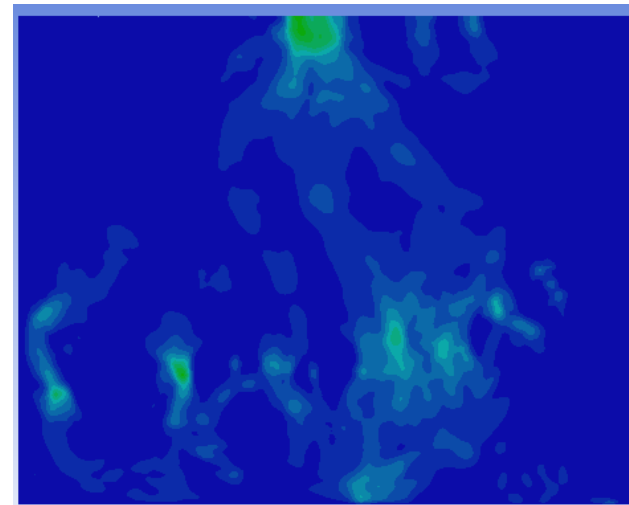
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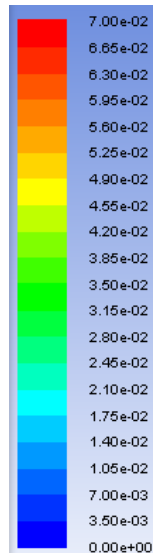
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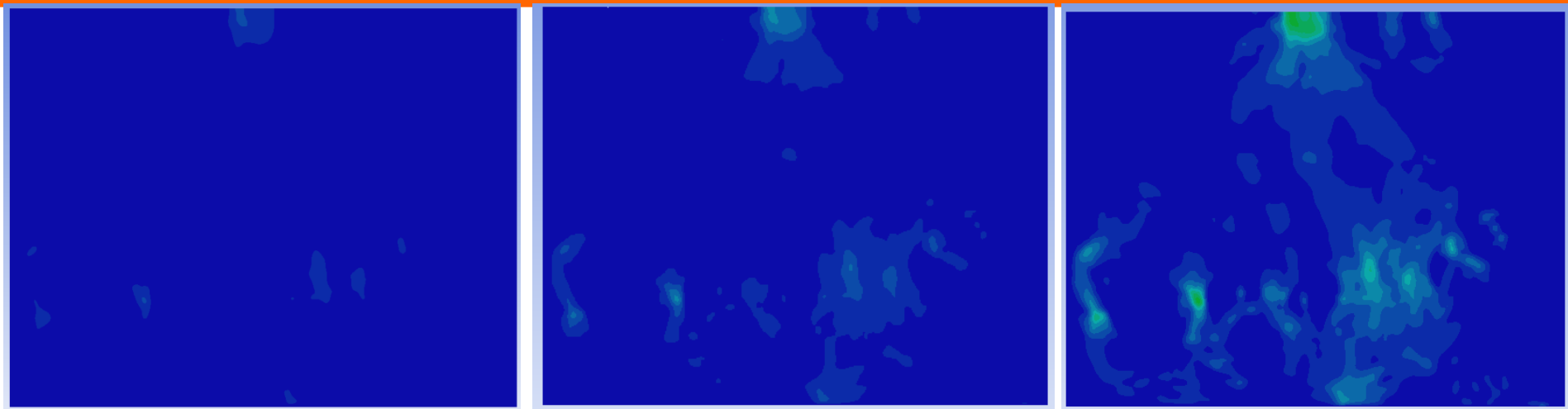


IS-6_4_ApertureMapRB-10AVG



Flow Rate = 1 mL/min

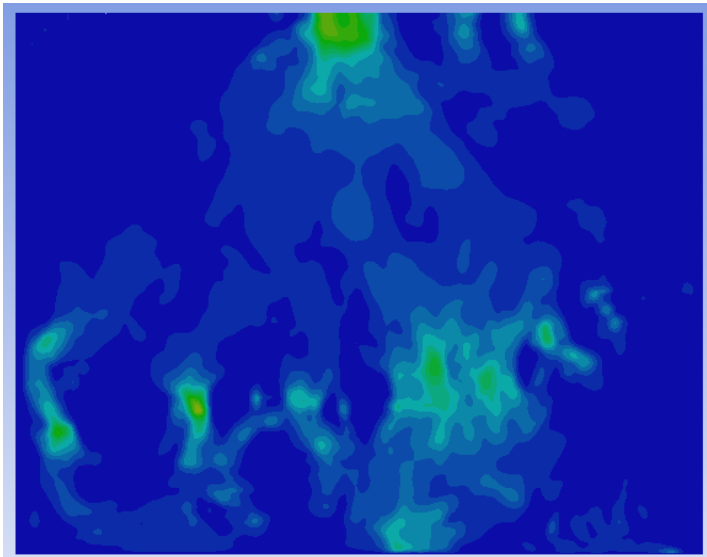
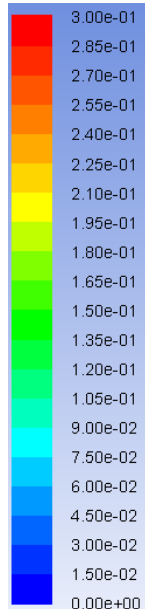
Velocity Magnitude (m/s)



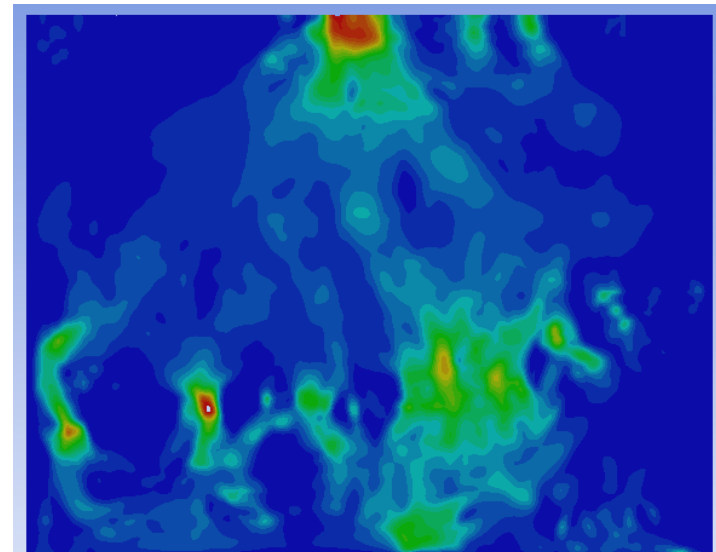
Flow Rate = 1 mL/min

Flow Rate = 2 mL/min

Flow Rate = 4 mL/min

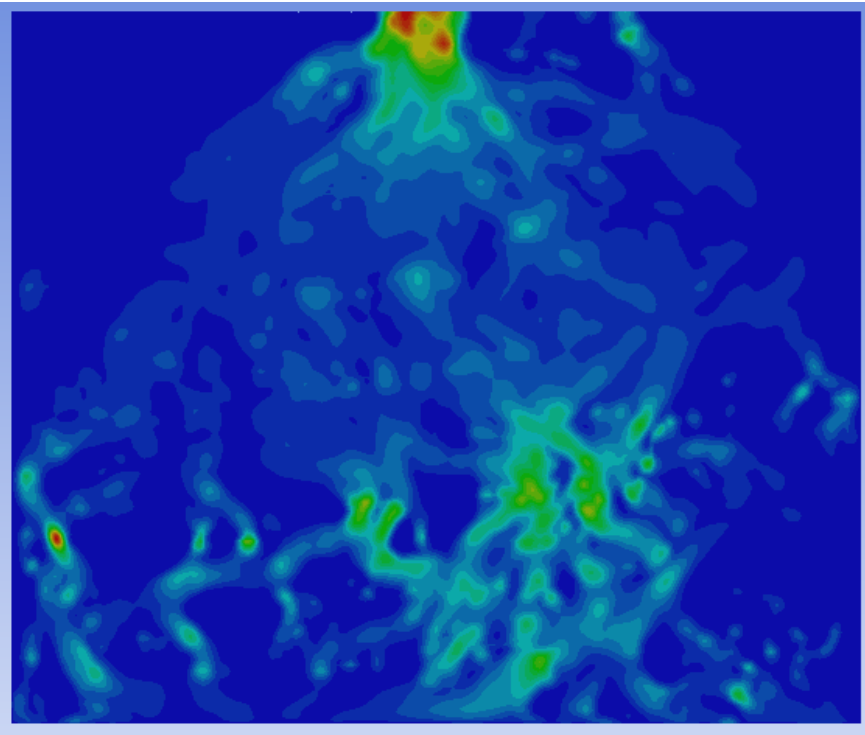
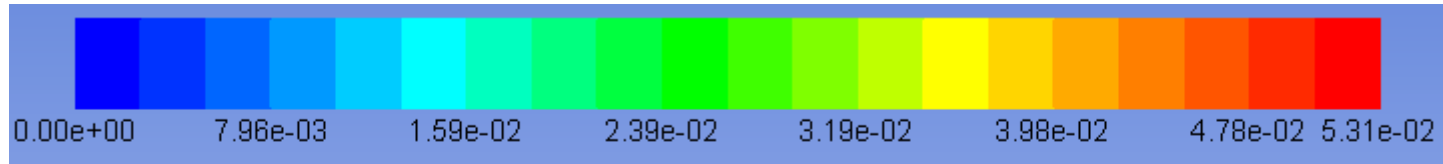


Flow Rate = 6 mL/min

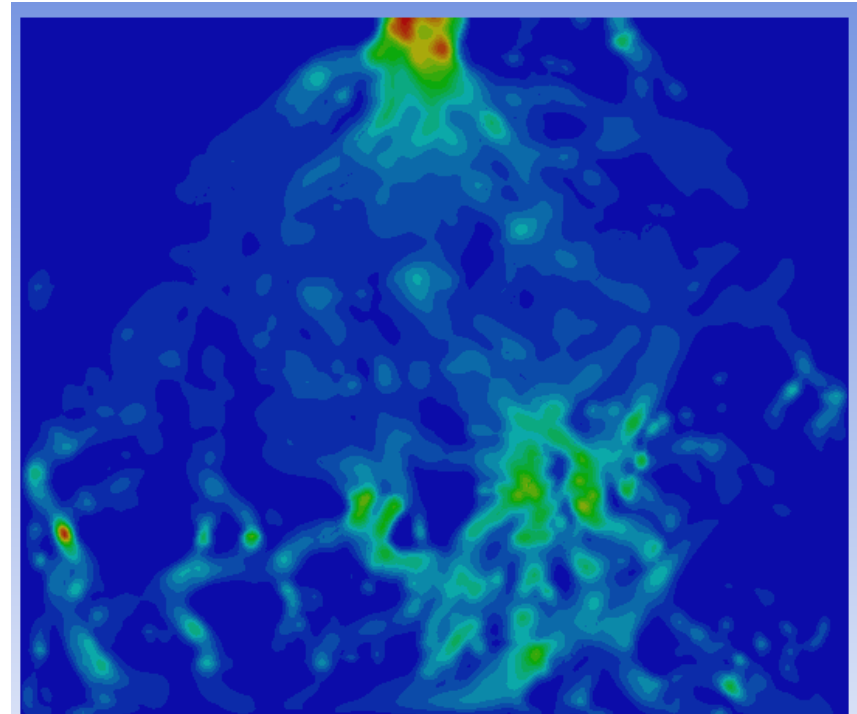


Flow Rate = 10 mL/min

Comparison of Fluent and OpenFOAM



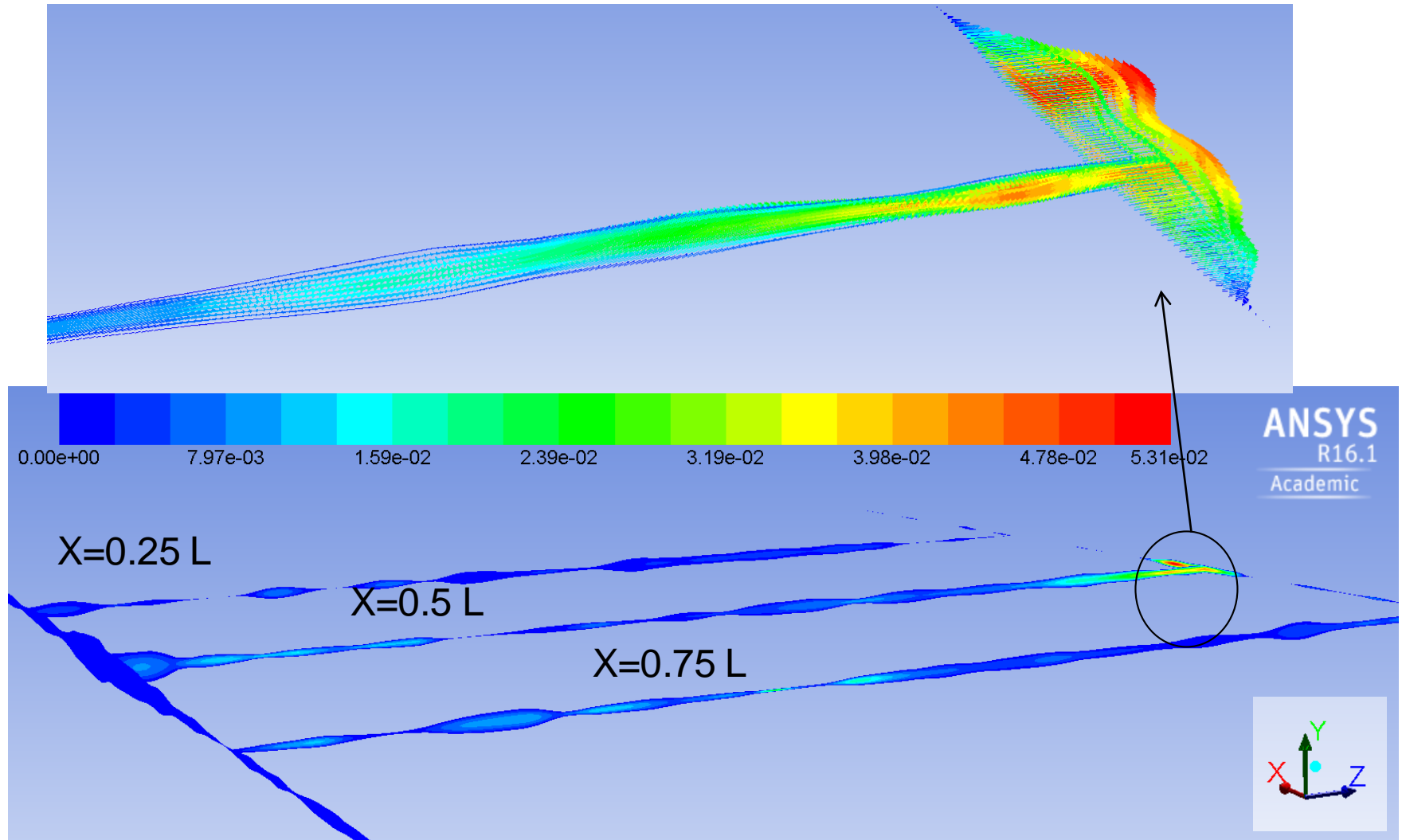
Fluent



OpenFOAM

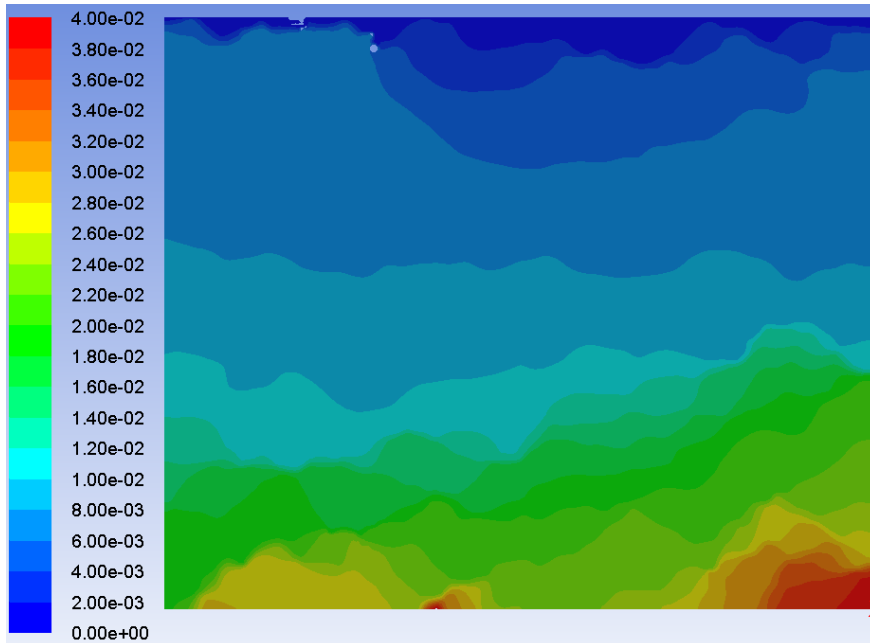
Contour of Velocity Magnitude (m/s) of IS-6_2 for Flow Rate = 1 mL/min

Velocity Magnitude at $X=0.5L$

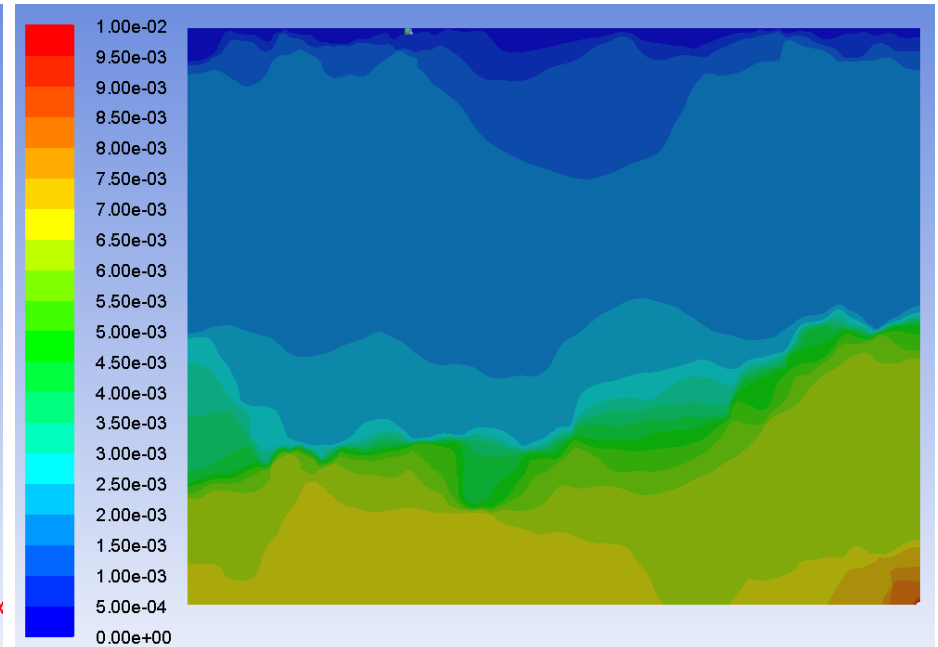


IS-6_2 Flow Rate = 1 mL/min

Static Pressure (psi)



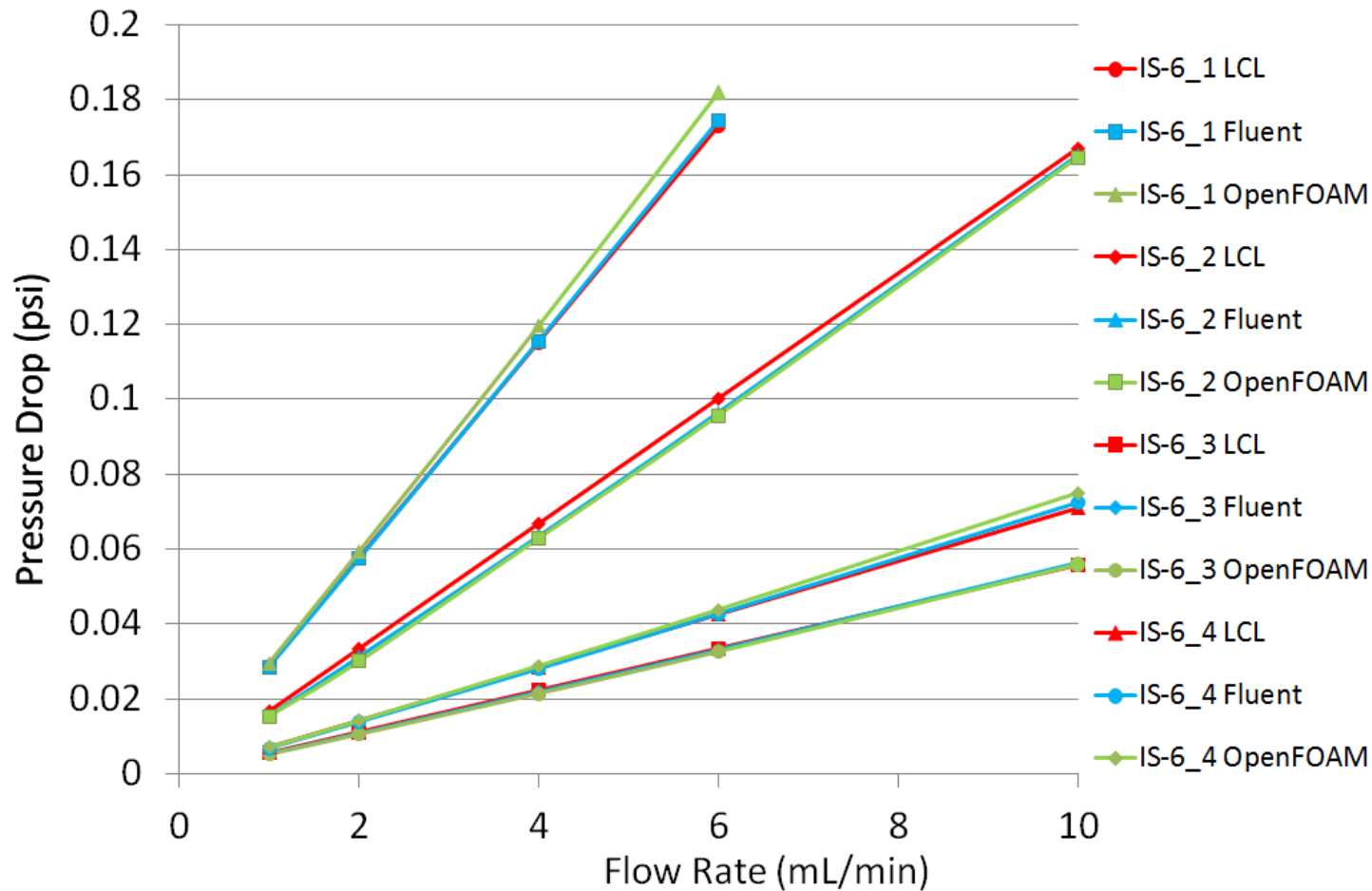
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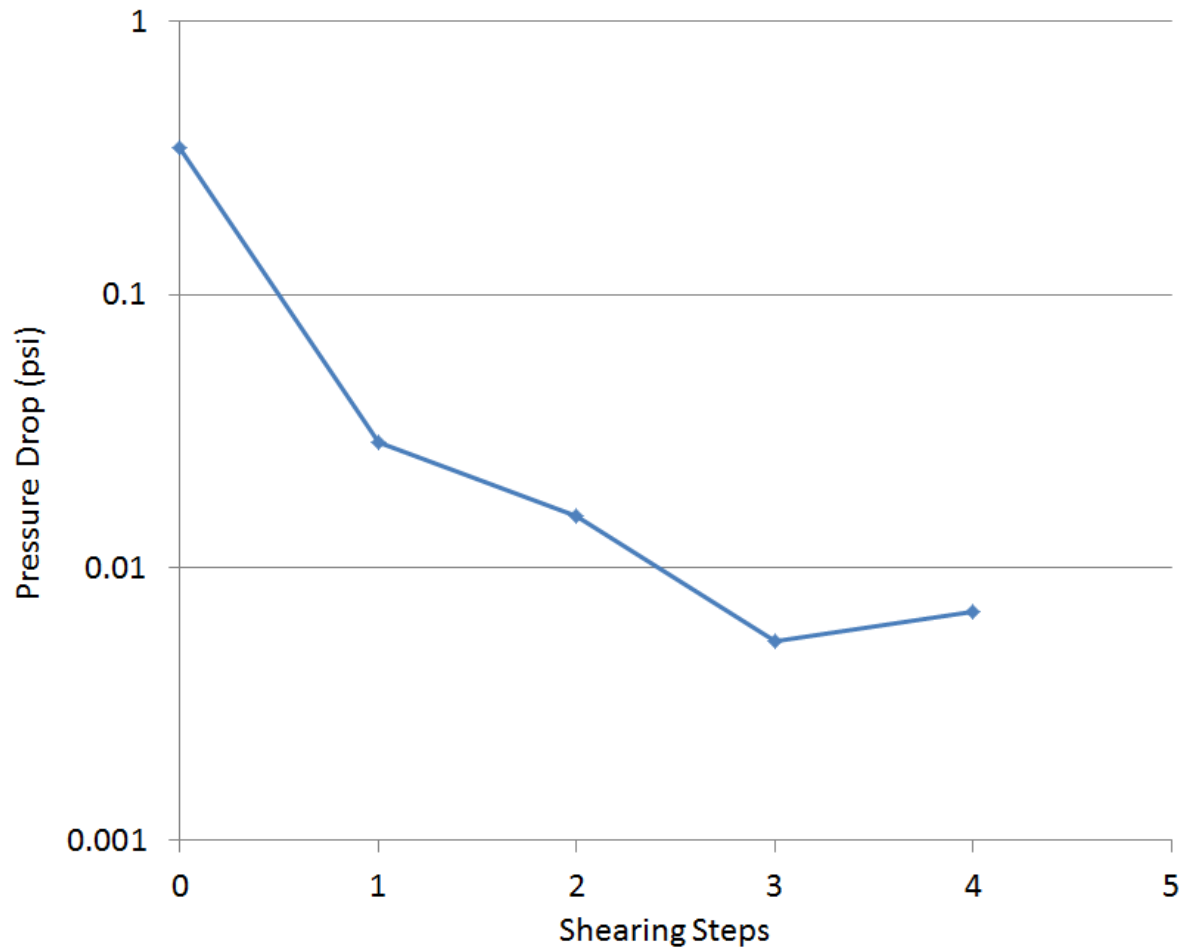
IS-6_4_ApertureMapRB-10AVG

Flow Rate = 1 mL/min

Pressure Drop versus Flow Rate



Pressure Drop of Shearing Steps



Flow Rate = 1 mL/min

Conclusions

- **Generate the geometries and grid from CT scan files.**
- **Numerical simulation by LCL model, Fluent and OpenFOAM software.**
- **Agreement between results of LCL model, Fluent, and OpenFOAM results.**

Aperture Map

