To Predict ▶ To Design ▶ To Perform

College of Engineering
Department of Mechanical & Industrial Engineering

ME, ECE, IE Capstone Design Programs

envisionTEC

Team #26: Particle Mobility Studies in Porous Media

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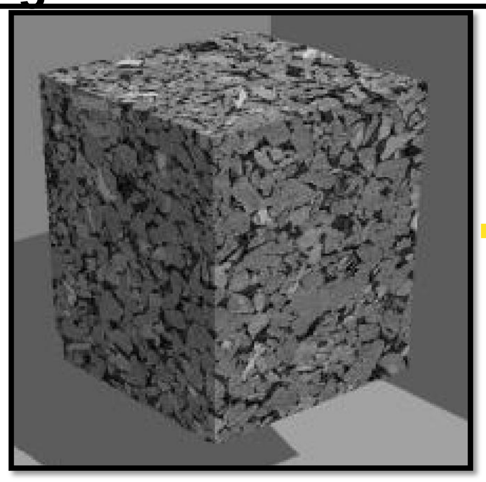
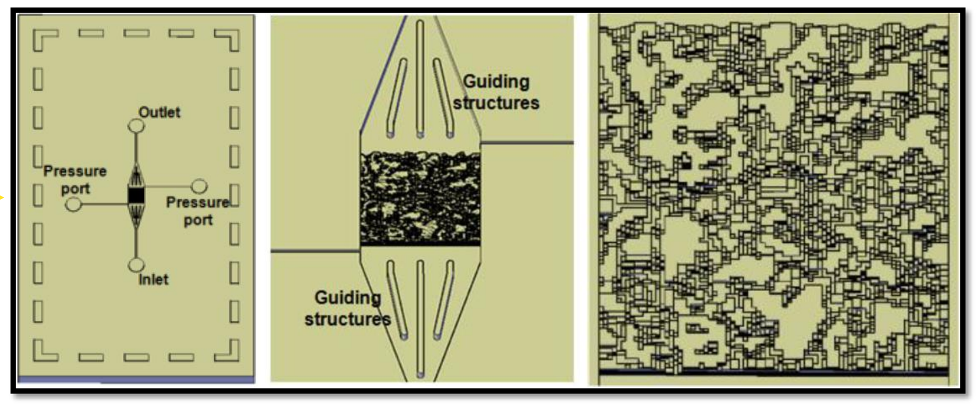
AEC Advanced Energy Consortium

Background Information [1]

Original Sandstone CT Scan | **Simplified 2.5D Geometry**





- Sandstone sample simplified for manufacturing by depth averaging; manufactured by hot embossing with brass mold
- Test cell resulted in moderate out of plane velocities, a feat previously unachieved in microfluidic devices
- 3D Test Cell and Micromodel project initiated for a better understanding of 3-dimensional flow behavior in porous media

Applications

- Particle Mobility Studies
- Reservoir Rock Characterization
- Enhanced Oil Recovery (EOR)
- CO_2 Sequestration
- Separation
- Lab-on-a-chip Technology
- Filtration

Engineering Specifications

Category	Specification	Target	Thin Model	Thick Model
General Requirements	Supports Multi-Phase Flow		✓	✓
	Reynolds Number < 0.1		✓	✓
	Velocity Measurement - x,y		✓	✓
Geometric Similarity	% Overlap	> 80%	75-85%	65-75%
	Smallest Feature Printed*	15 µm	30 µm	35 µm
Flow Similarity	Velocity Error - x,y direction	< 0.1 SSE	< 0.3	N/A
	Permeability - % error	< 10%	61%	N/A

*Actual value possibly lower; limited by CT scan resolution

References:
1. E. Park, Daniel S., Saade Bou-Mikael, Sean King, Karsten E. Thompson, Clinton S. Willson, and Dimitris Nikitopoulos. "Design and Fabrication of Rock-Based Micromodel." *Volume 9: Micro- and Nano-Systems Engineering and Packaging, Parts A and B* (2012)

Objective Statement

Create a transparent 3-D printed micromodel of a reservoir rock that:

1. Exhibits both flow and geometric similarity to Berea Sandstone
2. Supports multi-phase flow
3. Measures particle and fluid velocities with existing LSU system
4. Measures pressure drop across device

Final Embodiment – 15:1 Scale Rock

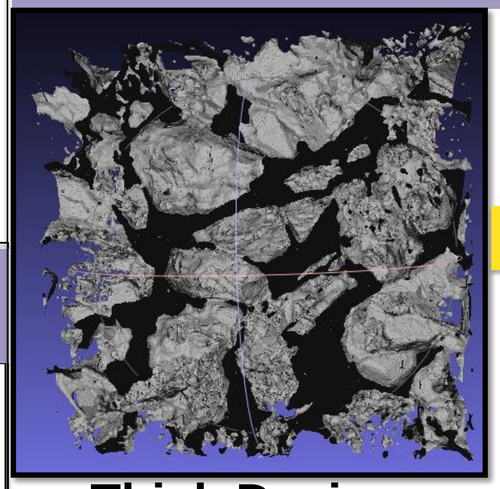
Thin Model

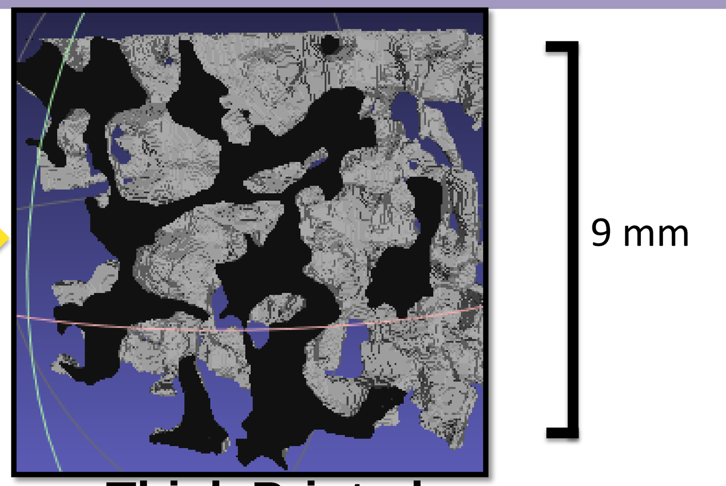
- Models printed on P4 Mini SLA printer
- First Iteration: used for testing and validation
- Representative of 0.25mm of reservoir rock

Thick Model

- Final Iteration
- Representative of 0.625mm of reservoir rock
- 1.25mm total is needed for REV

Geometric Validation


Thick Design

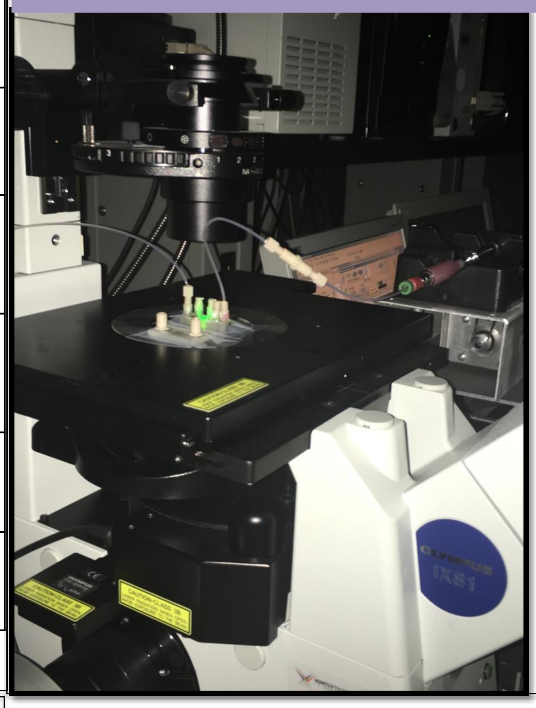


Thick Printed

Methods:

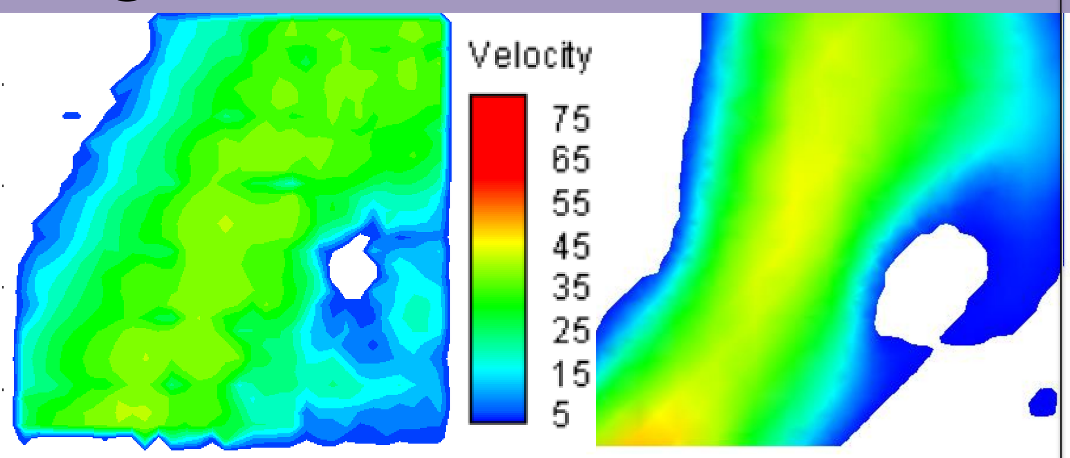
- CT scans performed by LSU Vet School by Dr. Michelle Osborn
- Geometries reconstructed using MATLAB and MeshLab
- % Overlap Comparison performed using custom MATLAB script

Fluid Testing



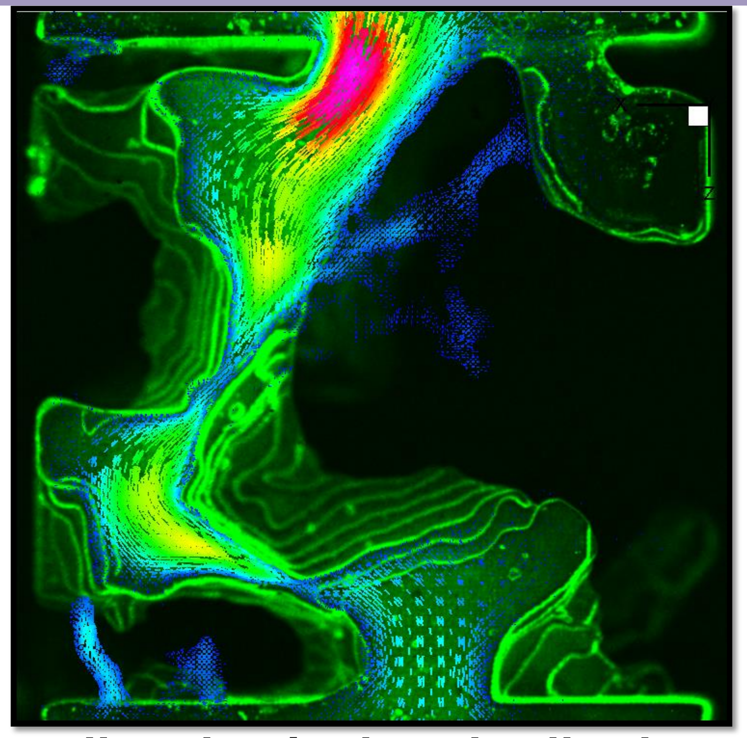
Micro Particle Image Velocimetry (microPIV)

- Inject micro-particles into model
- Capture rapid, successive images of particle motion at specified locations
- Calculate particle speed based on timing between images and change in locations



Experimental Velocity at Depth = 60 µm | **CFD Velocity at Equivalent Depth**

Results and Analysis



Predicted Velocity Distribution Overlaid on Manufactured Model at 165 µm depth

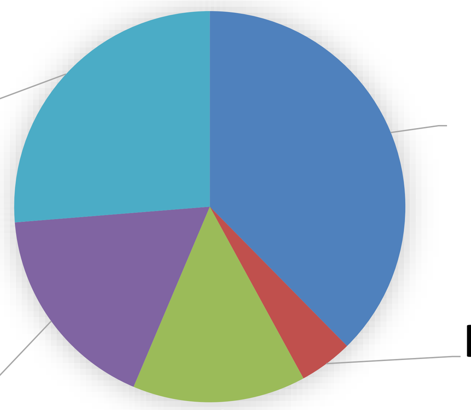
Conclusions: 3D printing porous media provides reasonable accuracy to desired data; however, SLA printers cannot currently produce the physical scale of reservoir rock. The measurable depth for microPIV prevents attaining a representative elementary volume.

Safety

- Standard lab safety procedures
- Eye protection from laser

Budget Breakdown

Actual Value of Items : $3044.95



Total Amount Paid By Team: $275.38

Legend: Design | Manufacturing | Testing | Analysis

Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
	Defined Engineering Specifications	Received CT Scan From Sponsors; Defined Area of Interest	Finalized Flow Cell Design	Begin 3D Printing	1st Round Print Evaluation; CT Scan Prints	2nd Round Model Prints	CT Scan Prints; 3rd Round Model Prints	Fluid Testing	Compare Empirical Data with CFD

Sponsors: Dr. Karsten Thompson and Dr. Dimitris Nikitopoulos

Advisors: Dr. Daniel Park and Jagannath Upadhyay