

USING MFEM FOR WELLBORE STABILITY ANALYSIS

OpenSim Technology, LLC

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Nathalie Nieto

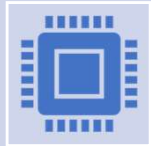
Office of Advanced Scientific Computing Research

SBIR Phase I

Award #: DE-SC0022500

Development of a Cloud-based Web-App for Wellbore Stability Analysis

Our Company



OpenSim Technology, LLC is a Houston based company founded in 2016 with the objective of developing advanced multi-physics reservoir simulation software.



Our team combines more than 40 years of experience in scientific software applied to the Oil & Gas Industry.



We are specifically targeting coupled flow-geomechanics applications.

Team



Adolfo Rodriguez, Co-Founder
PhD Physics
20 years experience in Geomechanics
Past work: ConocoPhillips, UT-Austin, PDVSA

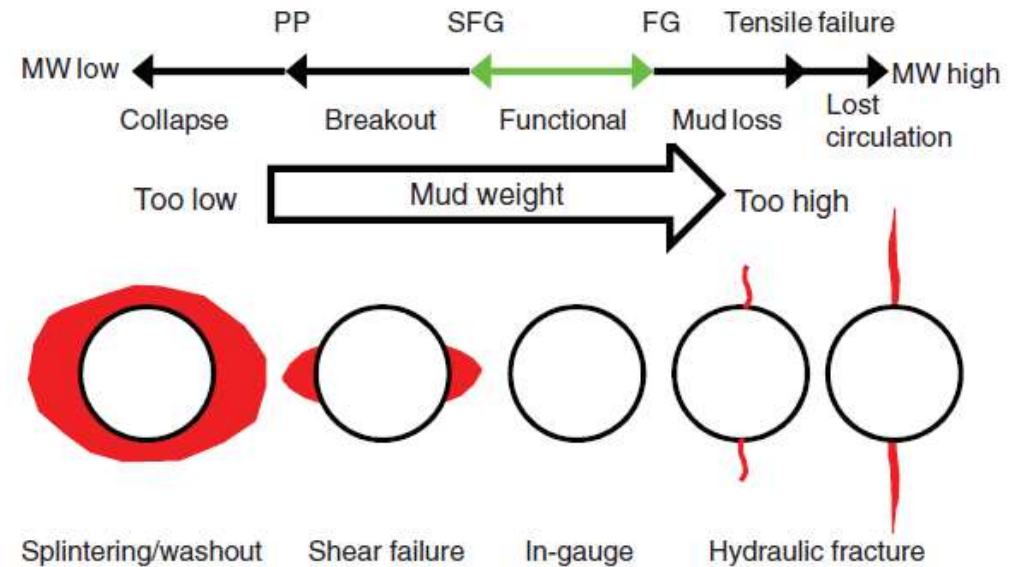
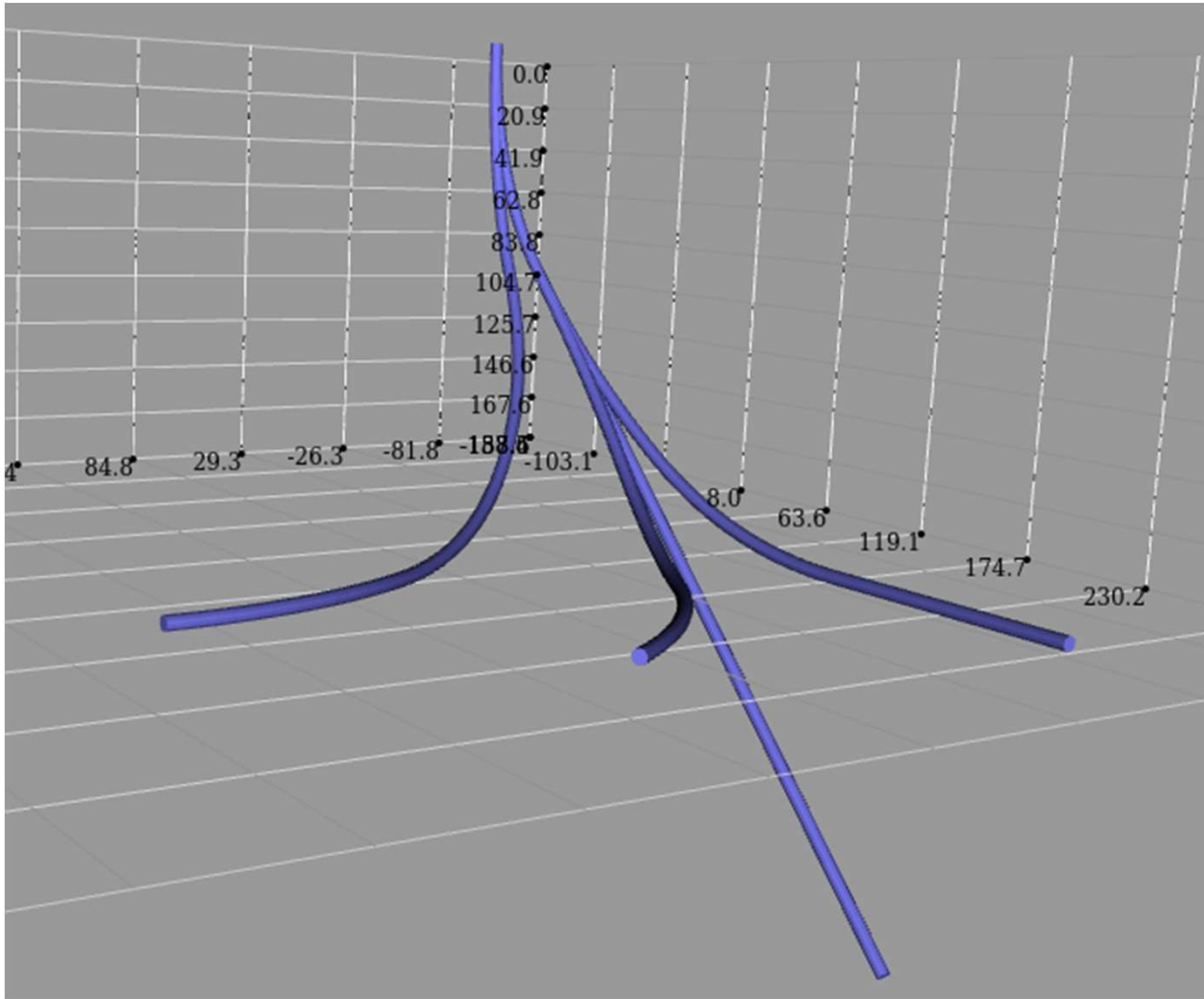


Jorge Monteagudo, Co-Founder
MSc, PhD Chem. Eng.
20 years experience in Reservoir Simulation
Past work: ConocoPhillips, Reservoir Engineering Research Institute, PetroPeru



Nathalie Nieto, IT Support
BSc Computer Science
8 years experience as Java consultant
Past work: TCS Consulting Solutions, Mobile-Globe (France)

The Problem: Wellbore Stability



The Equations and BC

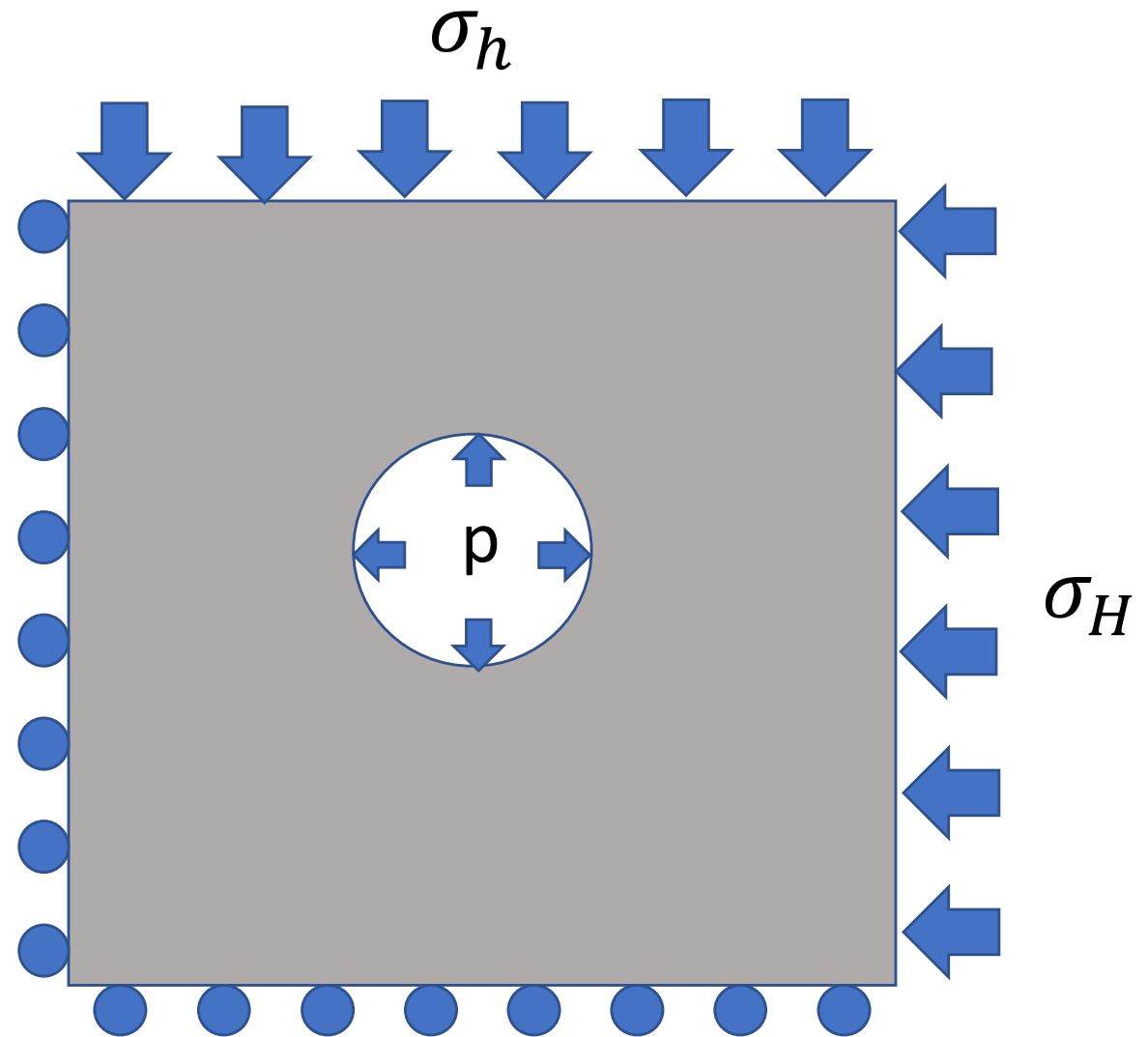
Mechanical equilibrium
Linear elasticity

$$\sigma_{ij,j} - f_i = 0$$

$$\sigma_{ij} = \lambda \delta_{ij} \varepsilon_{kk} + 2\mu \varepsilon_{ij}$$

$$\varepsilon_{ij} = \frac{1}{2} (u_{i,j} + u_{j,i})$$

We used PYMFEM to
implement the
solution



Creating a Synthetic Well

Synthetic Well Trajectory

WellHead Coordinates

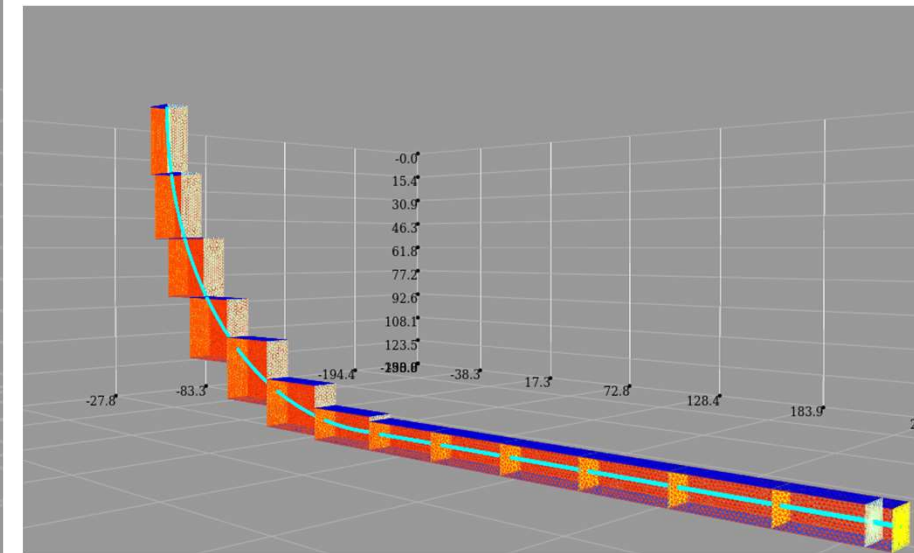
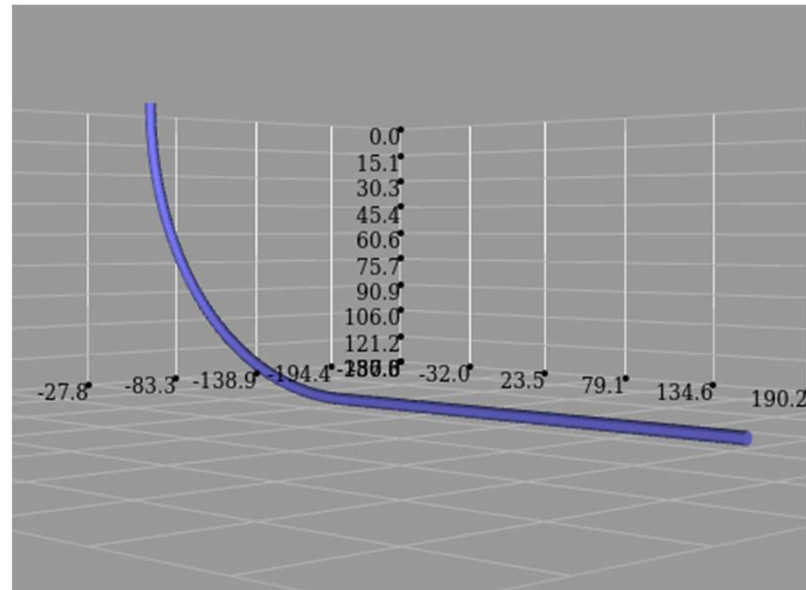
Xc: Yc: Zc:

Well Drilling Design

Number of Drilling Stations: Survey intervals (md): Wellbore intervals (md):

Input per station:

index	md (m)	inc (deg)	azi (deg)	radius (m)
1	0	0	0	0.5
2	100	45	0	0.5
3	200	90	0	0.5
4	300	90	0	0.5
5	400	90	0	0.5



Meshing options

Matrix Representation: box cylinder

Mesh type: tetra hexa

TopSide/Rwb:

Discretization Input:

Tetrahedral discretization parameters:

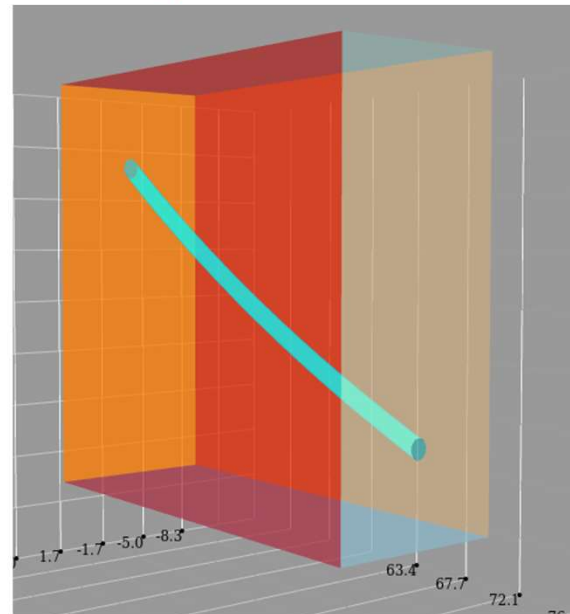
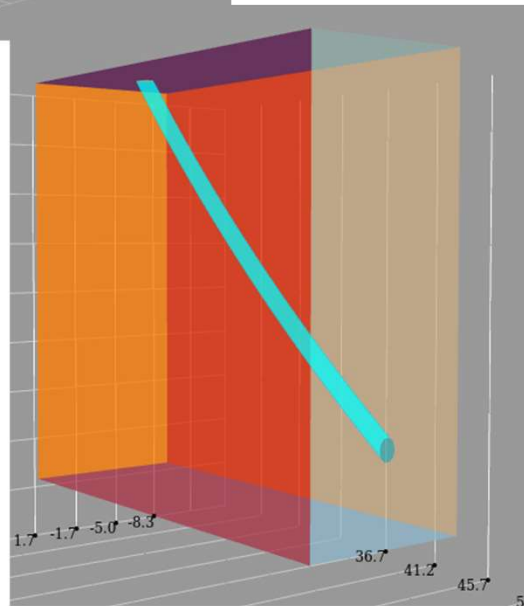
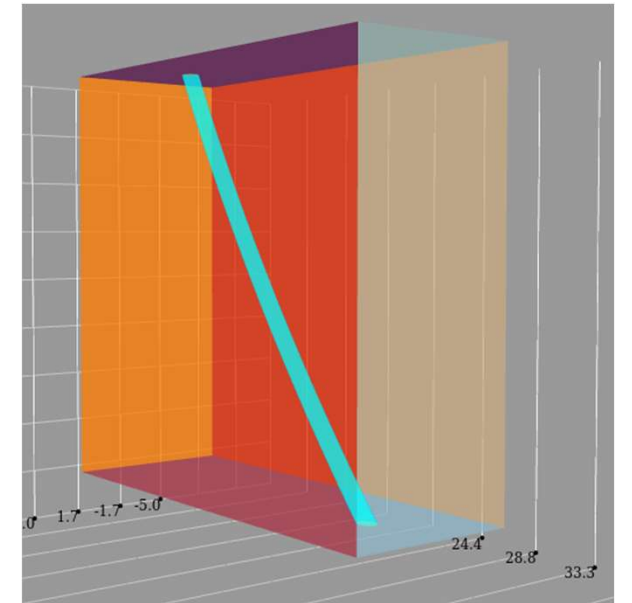
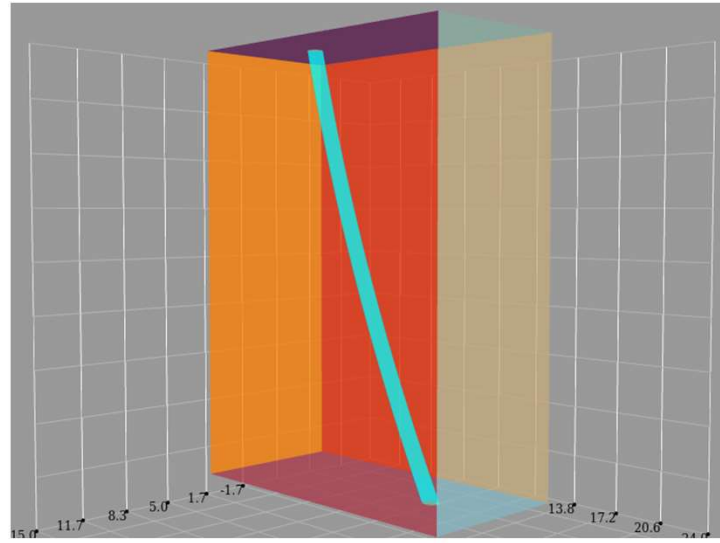
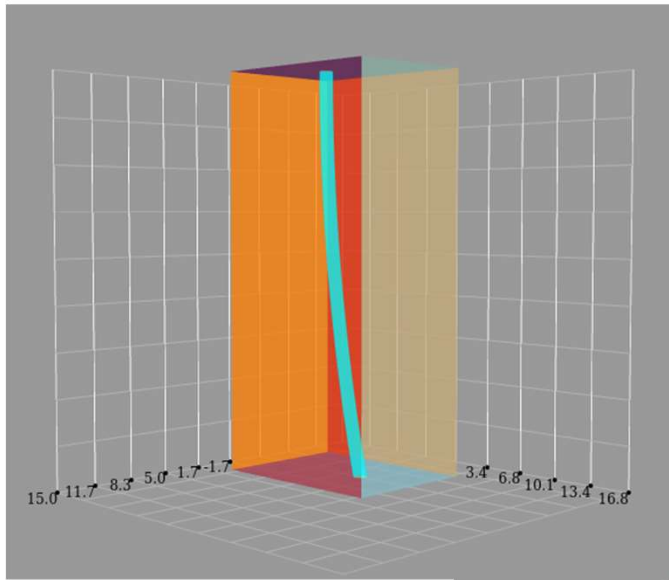
Borehole perimeter partition:

Tets max_size/min_size:

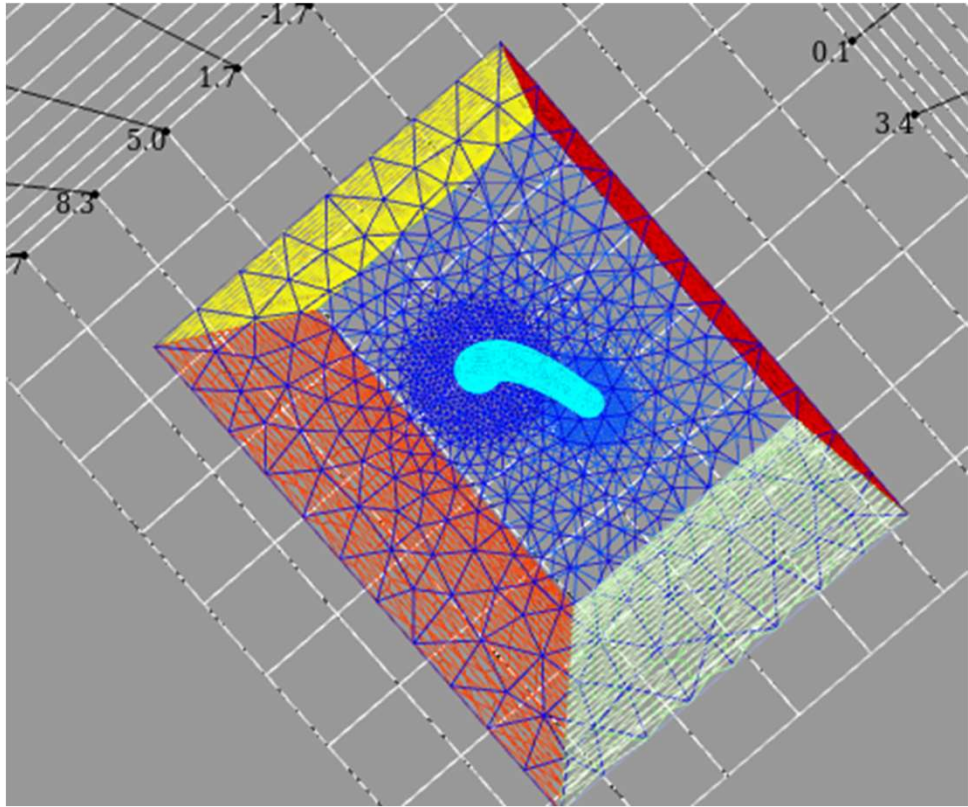
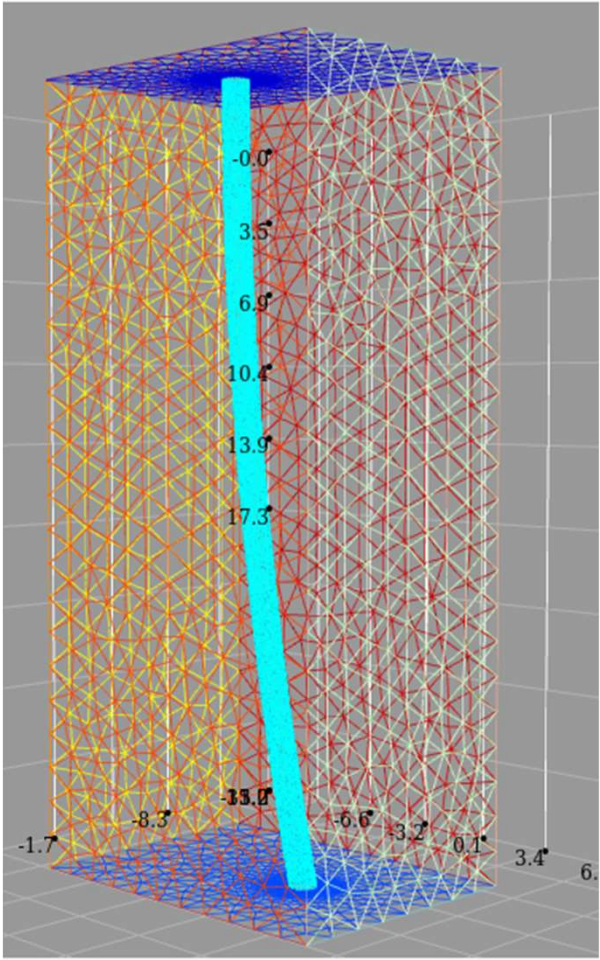
Min radius multiplier:

Max radius multiplier:

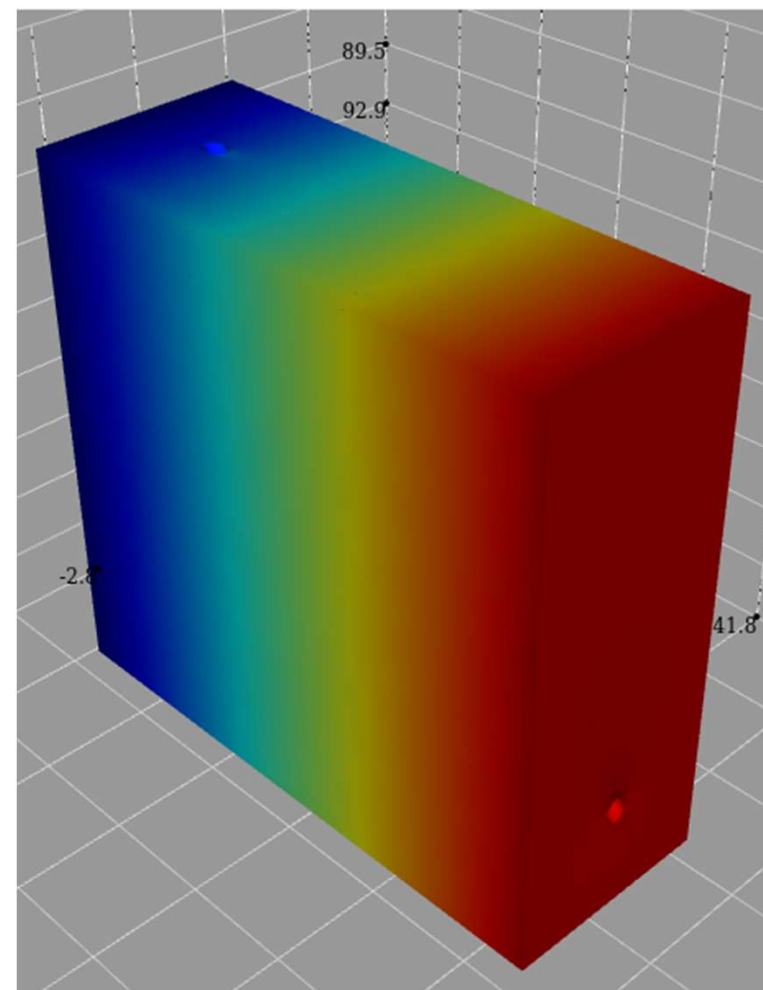
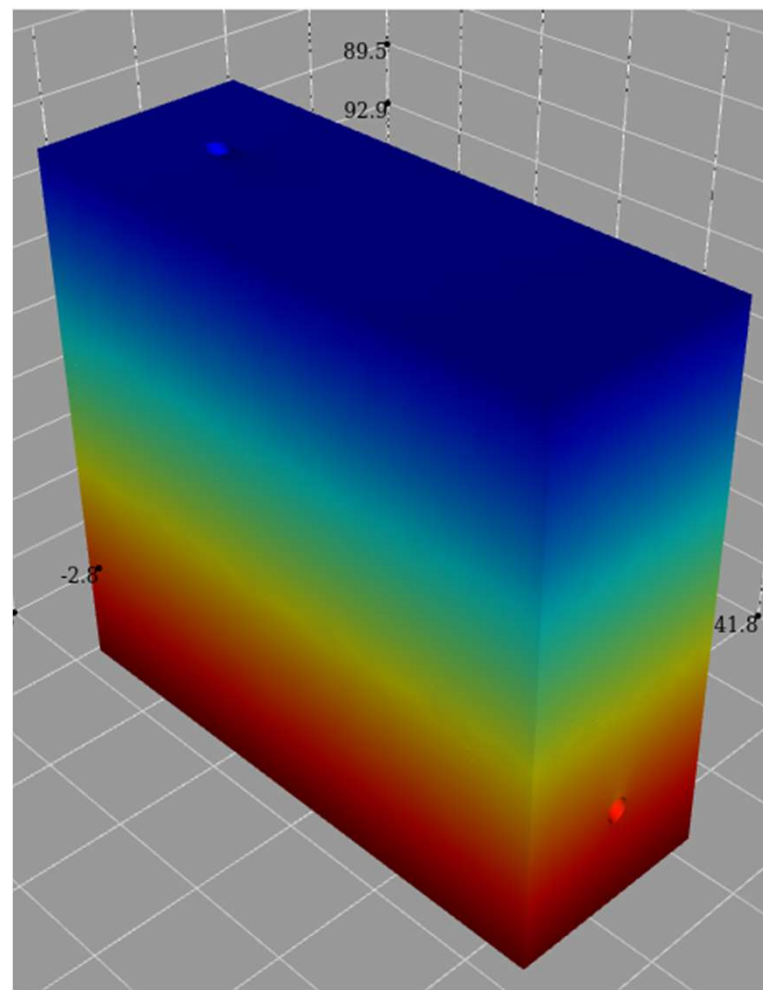
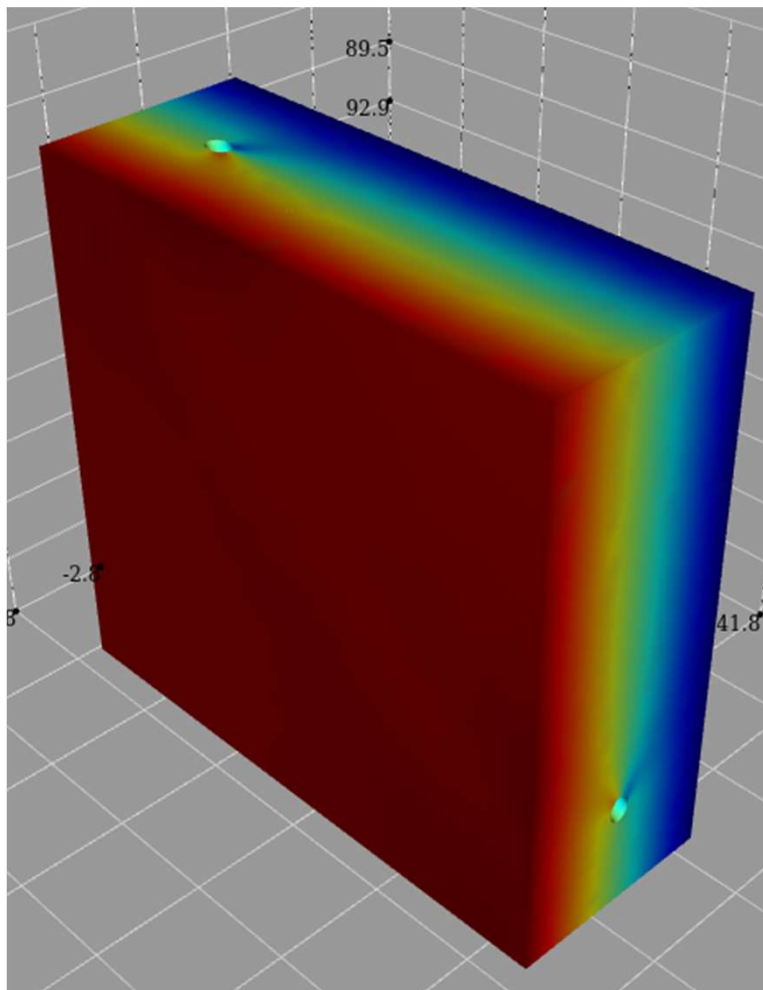
Wellbore Segments



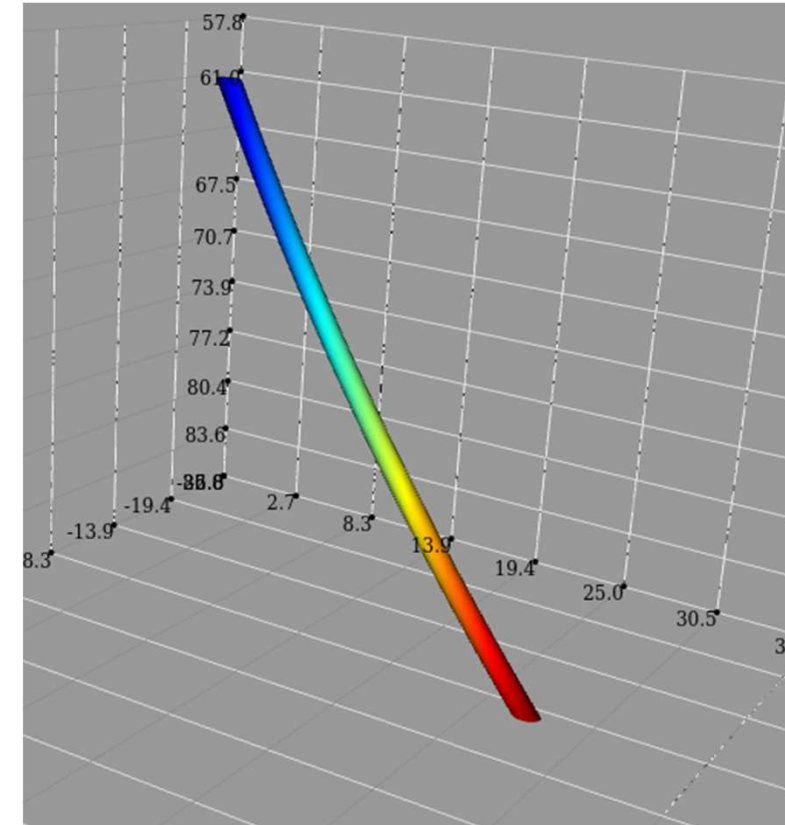
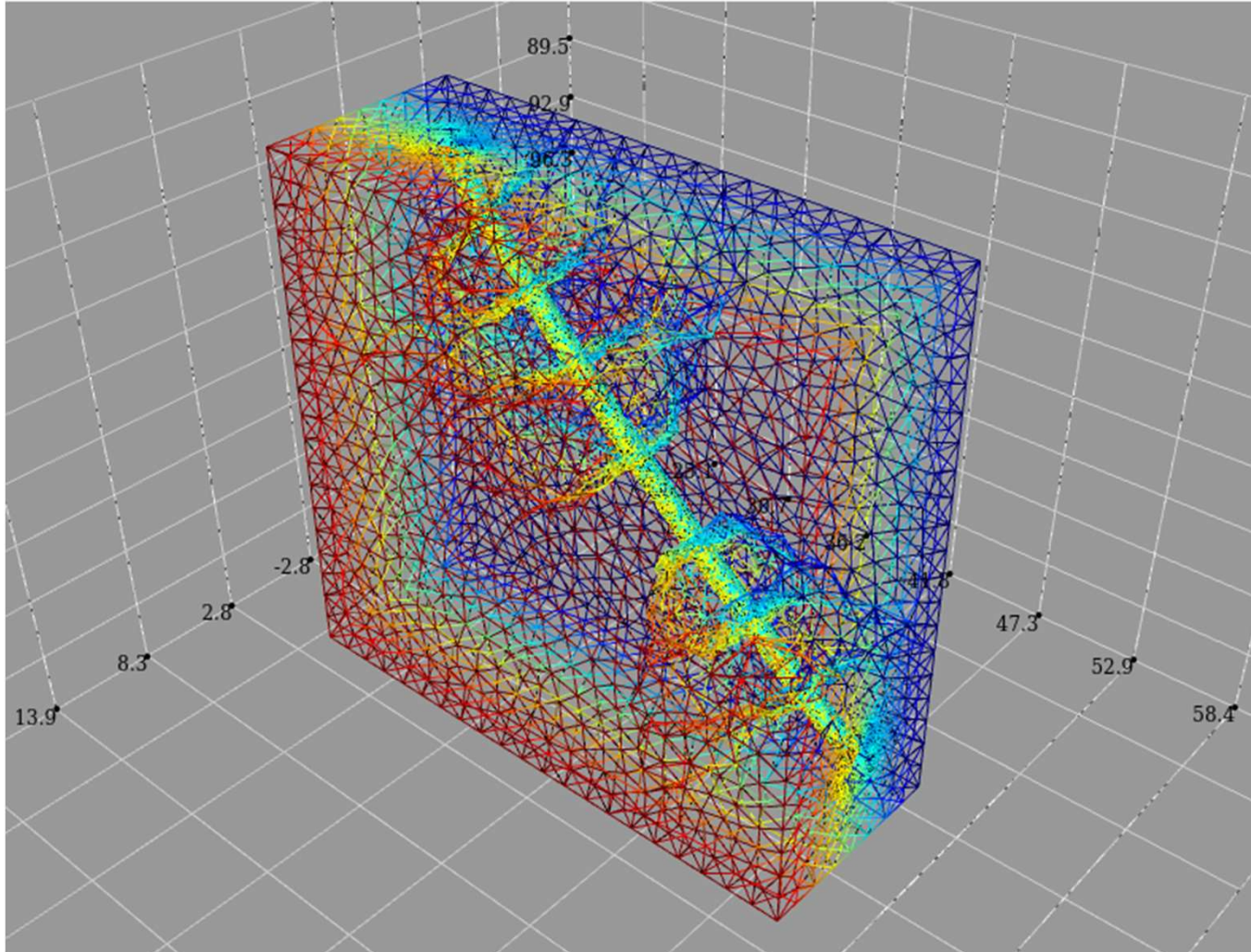
A Gridded Segment



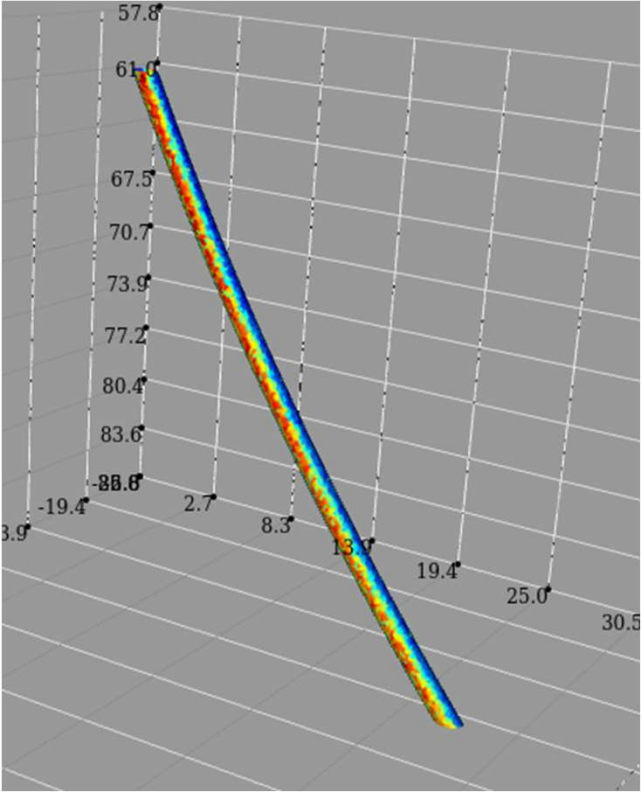
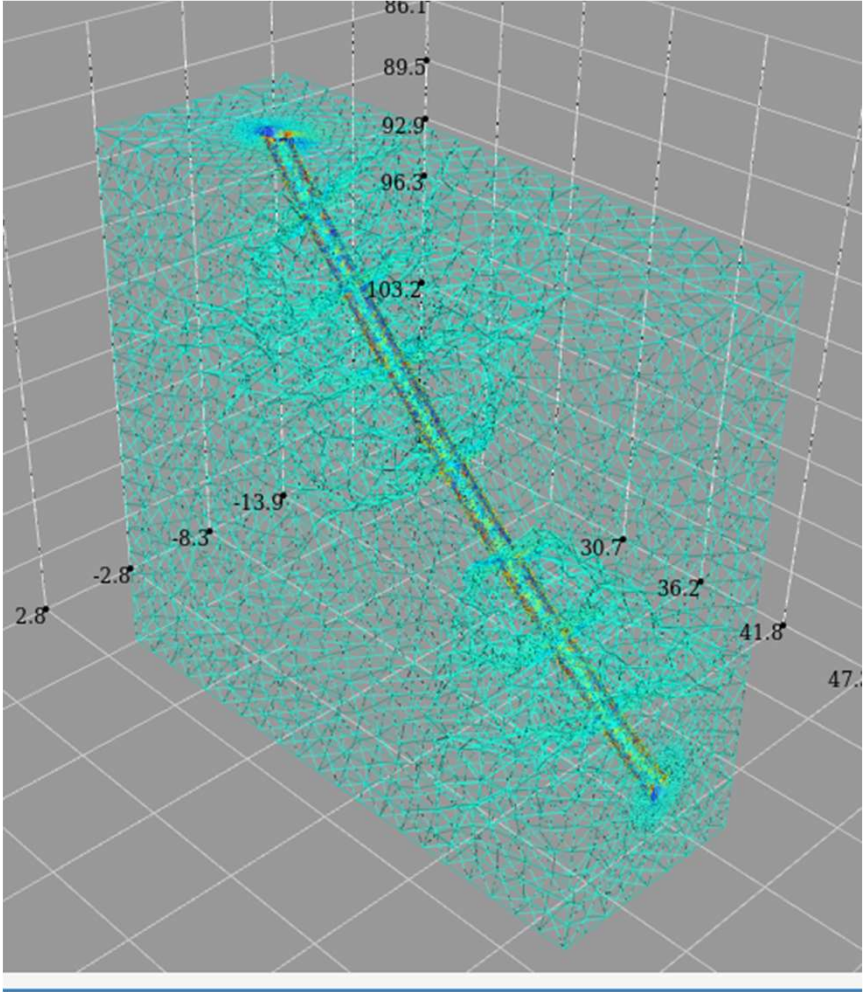
The solution: Displacements



Displacement in the x-direction, wireframe



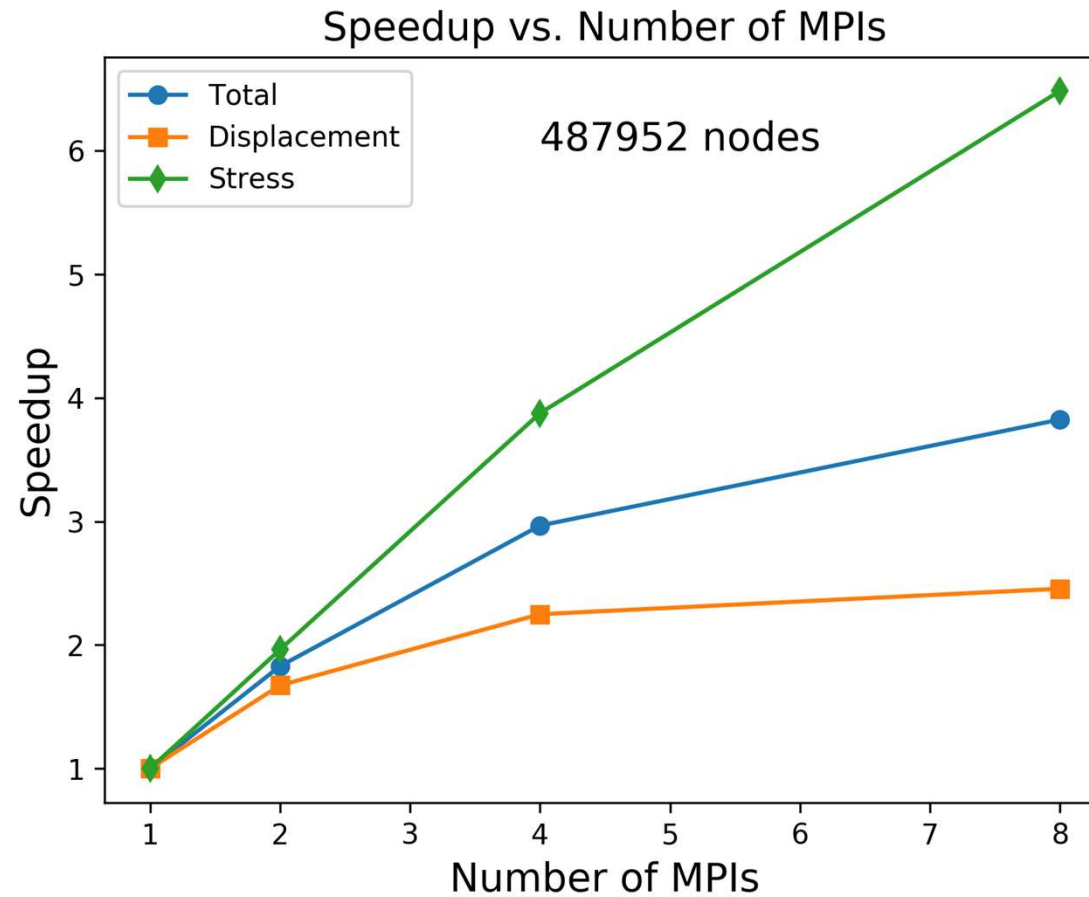
The Stress Field Calculation



Performance and Scalability

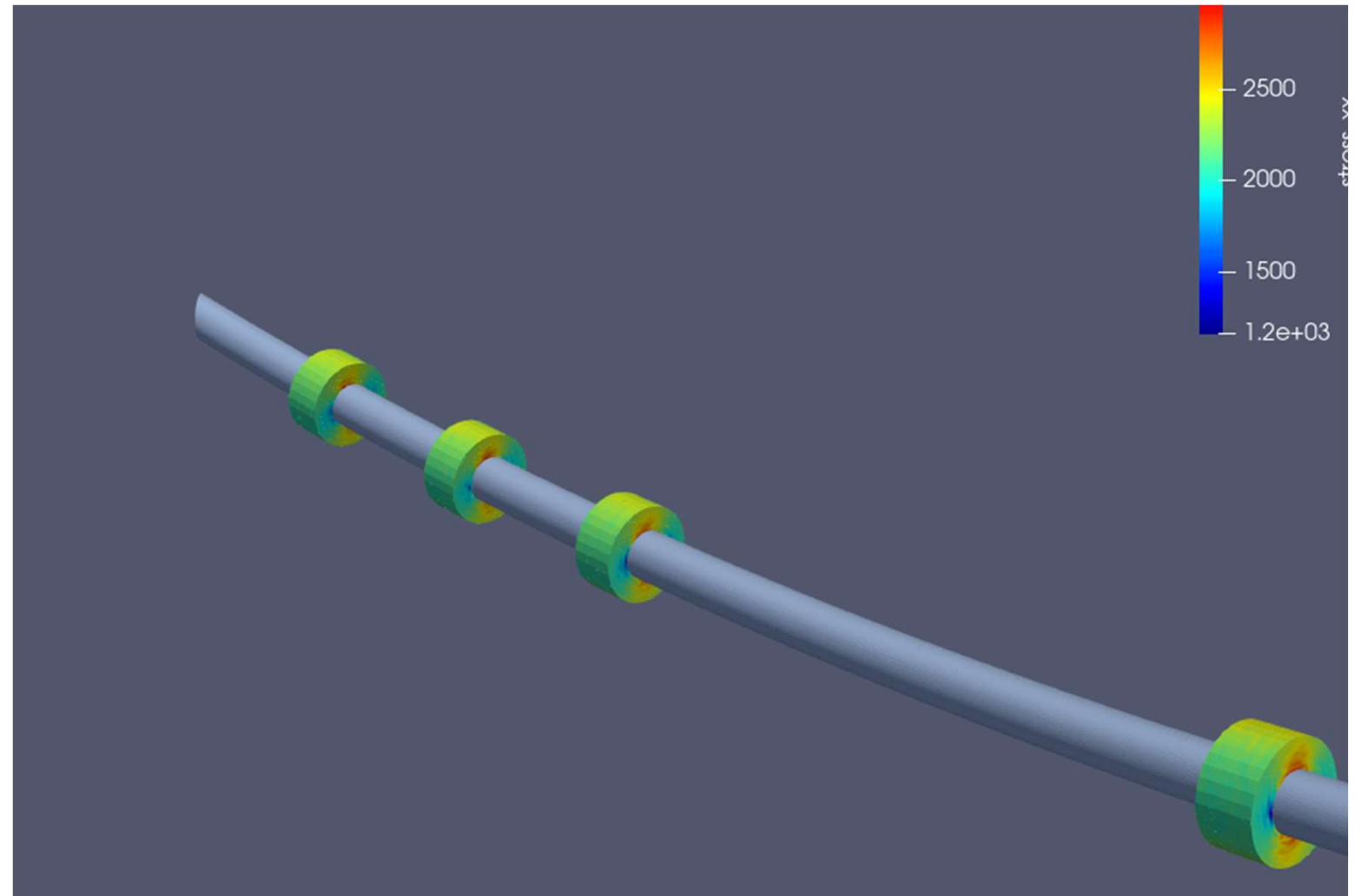
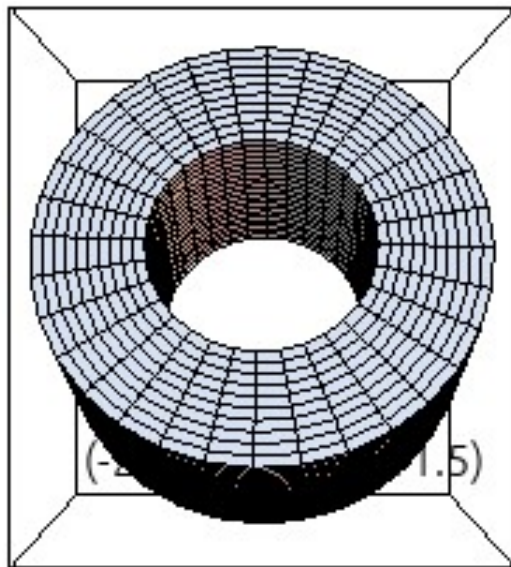
AMD Ryzen 9 4900H
8 Cores
32 GB

MPis	U+Stress	U	Stress
1	906.439	384.114	522.325
2	495.697	229.528	266.169
4	305.521	170.779	134.742
8	236.9	156.42	80.48

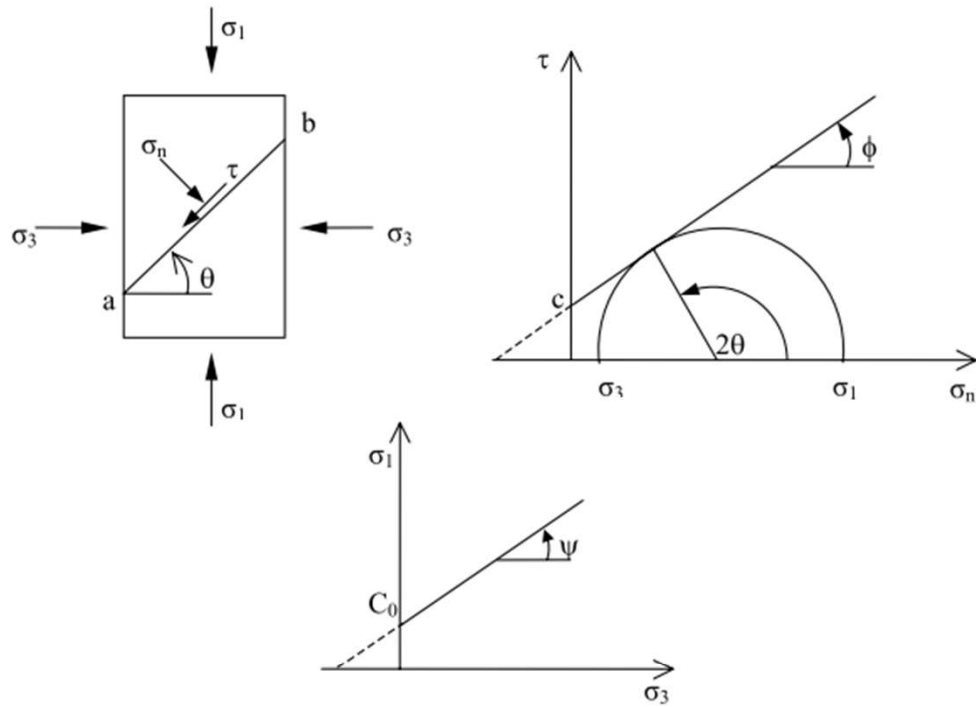


The Rings

The solution is projected on a second grid which is a cylindrical grid concentric with the well at a given position

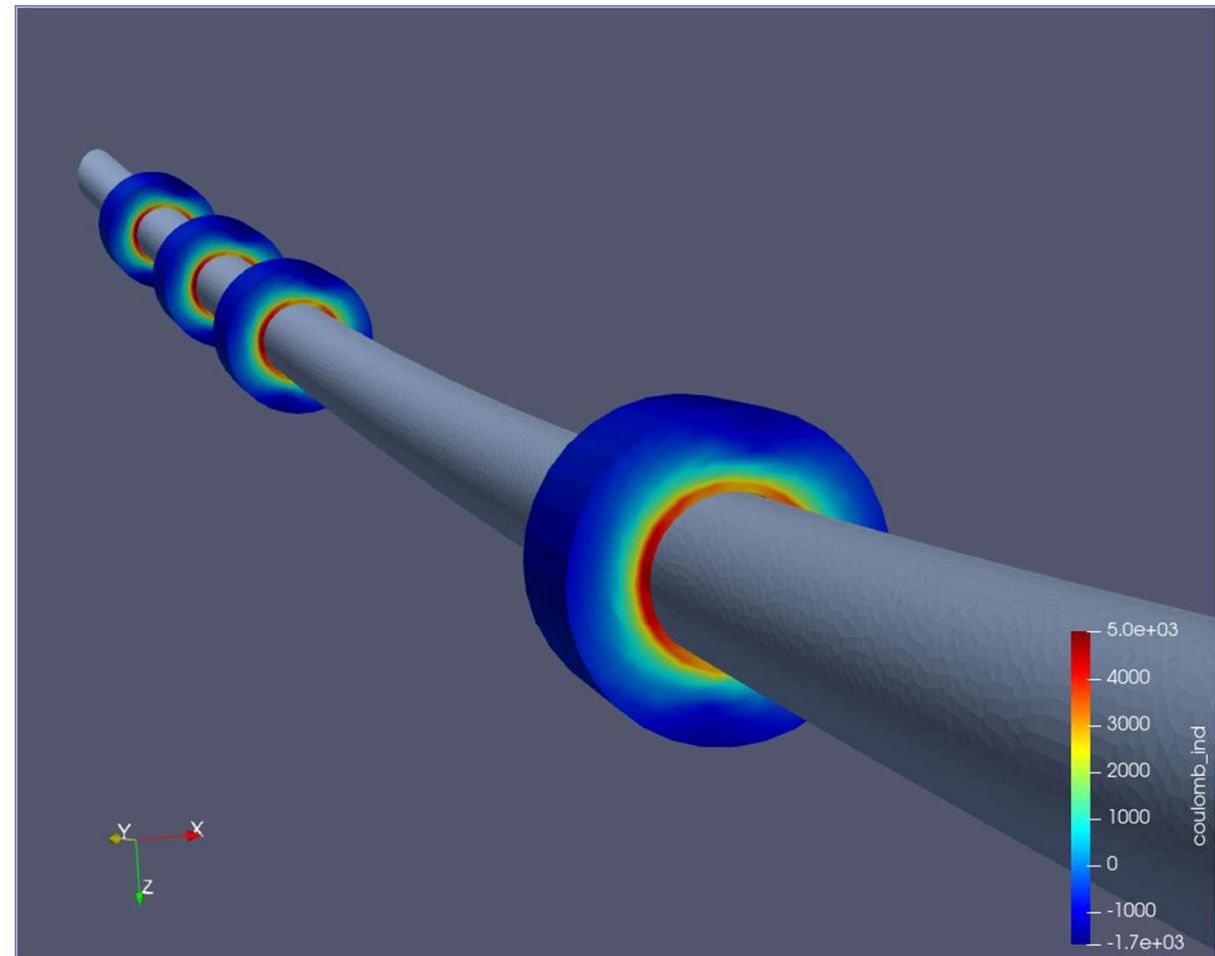


Failure Criteria: Coulomb

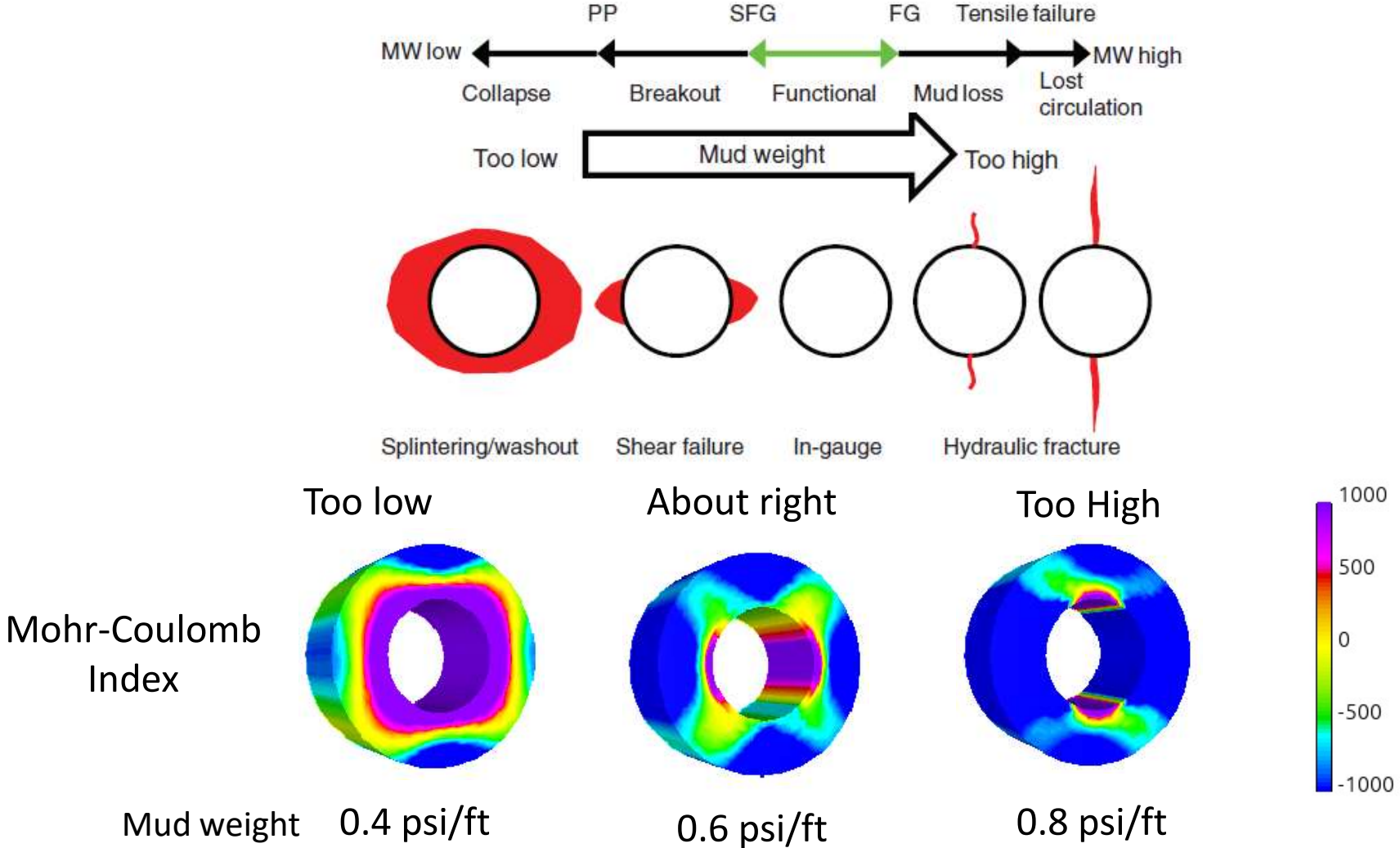


$$\sigma_1 = C_0 + q\sigma_3$$

$$s = C_0 + q\sigma_3 - \sigma_1 < 0$$



Coulomb index for different values of the mud-weight



Webapp and Cloud Deployment



The image displays the 'Wellbore Stability Analysis' web application interface, which is a web-based tool for simulating wellbore stability. The interface is divided into several sections:

- Left Panel:** Contains a 'Wellbore Stability Analysis' header, a brief description of the application, and a 'Set Project Folder and Name' section with input fields for 'Root Folder' and 'Project Name', and a 'Set Project Folder' button.
- Units Section:** Allows users to select 'Length units' (meter or feet) and 'Angle units' (degrees or radians).
- Synthetic Well Trajectory:** Includes 'Wellhead Coordinates' (Xc, Yc, Zc) and 'Well Drilling Design' parameters such as 'Number of Drilling Stations', 'Survey intervals (md)', and 'Wellbore intervals (md)'. It also features an 'Input per station' table with columns for index, md (m), inc (deg), azl (deg), and radius (m).
- 3D Visualization:** A central 3D plot showing a wellbore trajectory in a coordinate system. The trajectory is a blue line that curves downwards and then horizontally.
- MFEM Analysis Section:** Includes a 'Case Name' field, 'Number of Processors', and a table of material properties (Young's modulus, Poisson's ratio, etc.) for different indices.
- MFEM Analysis View Controls:** Provides options to 'Run MFEM Simulation' and 'View 3D'.
- Matrix Representation and Mesh type:** Allows selection of 'Matrix Representation' (box or cylinder) and 'Mesh type' (tetra or hexa).
- Tetrahedral discretization parameters:** Includes 'Borehole perimeter partition', 'Tets max_size/min_size', 'Min radius multiplier', and 'Max radius multiplier'.
- Well Trajectory Full Mesh Control Panel:** Features a 'Generate Mesh Along Well Trajectory' button and a 'Wellbore View Only' checkbox.
- Section View Controls:** Includes a 'Section To Plot' dropdown, 'Arrays' and 'Representation' dropdowns, and an 'Opacity' slider.
- MFEM Parameters Table:** A table with columns for 'index', 'Young', 'Poisson', 'SigmaH', 'SigmaH', 'hmin_grad', 'hmax_grad', 'L_grad', 'mud_grad', 'CD', and 'mul'. The first row shows values for index 1.

A central image shows a hand holding a tablet displaying the application interface, overlaid on the main screenshot. The browser's address bar shows 'localhost:3006/wsa_synthetic_well'.

Acknowledgment

- Thanks to the MFEM team
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