**Reports: DNI58135-DNI9: Hybrid Numerical Simulations of Microstructure Effects and Stress State during Hydraulic Fracture Propagation**

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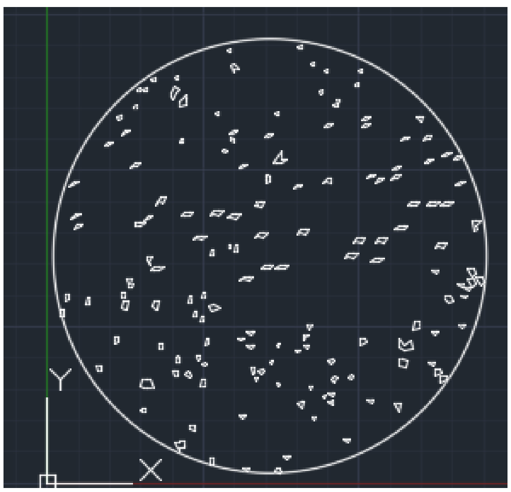
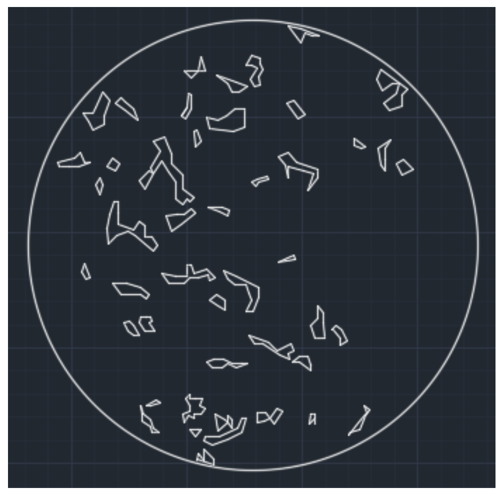
The efficient implementation of hydraulic fracturing is important for oil and gas recovery. The goal of this project is to improve current understanding pertaining to how induced hydraulic fractures interact with preexisting natural fractures, relationships between induced stresses and insitu local stresses, and in particular, the effects of microstructure heterogeneity on induced fracture properties. This is achieved by conducting microscopic, hybrid finite element-neural network (FENN) modeling.

Micro CT scans of Brazilian oil shale and Barre granite were input and digitized in AutoCAD, and preexisting cracks were traced as shown in Figure 1. In AutoCAD, preexisting cracks were segregated from the rock matrix as intragranular white patching and grain boundary white patching.

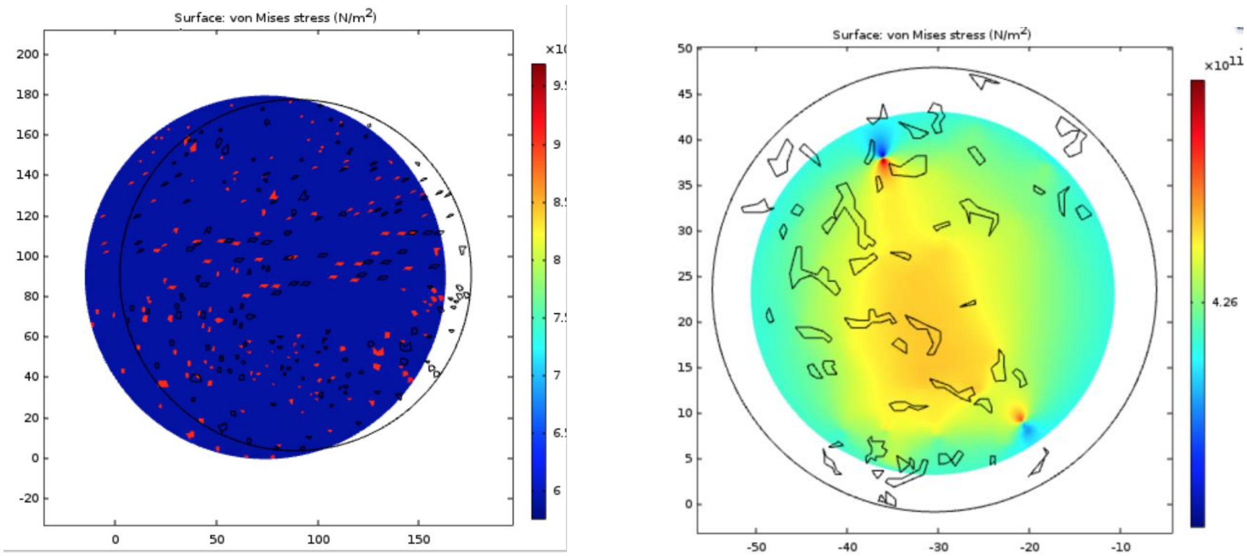


(A) Brazilian oil shale (1 micron resolution) (B) Barre granite (18 micron resolution)

Figure 1. Micro CT scans of (A) Brazilian oil shale (B) Barre granite exported to AutoCAD

The digitized images of the CT scans were then exported from AutoCAD to COMSOL Multiphysics software as dxf files. The first goal was to simulate a hydraulic fracture that would intersect the natural fractures propagated in the rock specimen, with the view to seeing where and how the natural fractures evolved and interacted with the hydraulic fractures. To achieve this first step, it was important to assign material and fluid properties representative of expected actual conditions. Preliminary mechanical and fluid properties were obtained from an extensive literature study to be used as inputs to the models. Given that crack propagation was not explicitly modeled during the first stage, the evolution of tensile stresses around the cracks was monitored to indicate regions of high stress concentrations. Four different phenomena were simulated in COMSOL: solid mechanics for the structural and stress analysis for the rock specimen, Darcy's law to simulate fluid flow, fluid-structure interaction to simulate coupling between fluid and rock, and fracture flow to simulate flow within the fractures. Several trial runs were simulated in COMSOL, each time adjusting fluid parameters and material properties to monitor the progression of the tensile stresses. Figure 2 shows an example of the results observed for a Brazilian oil shale and Barre granite specimen after one of the test runs.




(A) Brazilian oil shale specimen

(B) Barre granite specimen

Figure 2. Preliminary stress distributions around preexisting cracks during simulations of hydraulic fracturing

Given the limitations of using COMSOL to simulate more realistic hydraulic fracturing, a computer code was developed in MATLAB to enhance deficiencies and capabilities. The algorithm can import geometries, boundary conditions including material properties and allows for the incorporation of additional physics to solve. The next step is to expand the code in MATLAB to interface between COMSOL and an artificial neural network model creating a hybrid. Mesoscopic variables and boundary conditions at each finite element node of the created mesh will be computed and passed to the local (micro) scale. The passed information from the mesoscale finite element analysis will be added to a trained neural net for rapid computation of microcrack density and lengths based on microstructure morphology and stress state. The neural net inputs will include geometry, elastic modulus, microporosity, mineraology, stress state, injection pressure and load cycle. The microscale information will be passed back in a feedback loop to the mesoscopic scale for finite element simulation. The changes in the material distribution of the continuum model will have impacts on the stress field, and thus the mechanical state of the model. Although the preliminary analyses to date have focused on shale and granite, the ultimate goal is to compare and observe the response in shale granite, and sandstone.

In summary, during the first year of the project 2017 - 2018, this project has provided valuable training and professional development for the PI and PhD student Lois Kamga-Ngameni. The supported work has fostered valuable laboratory research experience, finite element numerical modeling and working with MATLAB and artificial neural networks.