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Project Title: 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 on how induced hydraulic fractures interact with preexisting natural fractures under different stress and rock conditions. To this end, a multiscale (micro and meso) hybrid finite element-neural net (FENN) approach is adopted to investigate the interaction of hydraulic fractures with pre-existing fractures. The approach uses Comsol Multiphysics and MATLAB, which require CT scans of laboratory rock specimens. In the previous report for Year 2017 – 2018, 2D scans of rock specimens were imported and modelled in Comsol Multiphysics and MATLAB as reported. Challenges were then encountered when acquiring 3D images of rock specimens to construct 3D model geometries. We have finally overcome this challenge by utilizing appropriate software to act as an interface between the 3D scans of rock specimens and Comsol Multiphysics.

The importation of STL files into COMSOL consists of three steps: acquisition of the surface mesh from the STL file, generation of a surface geometry from the imported mesh, and the creation of a solid object. The default Automatic boundary partitioning is best suited for cases where the imported mesh has a neutral face partitioning. The Detect faces option is most useful when a mesh comes from a 3D scan, and has one or more planar faces. After modifying the mesh using Mesh toolbar tools, the mesh can be converted into a geometrical format.

In the geometrical format, there are about 16000 boundaries assigned to the model. To simplify the model, the boundaries were manually adjusted to decrease the total number of boundaries to 350 (Figure 1).

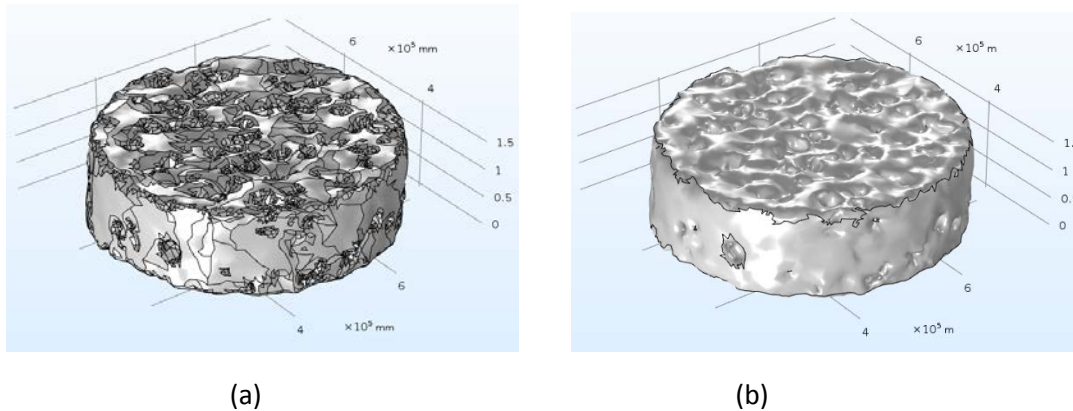(a)   (b)

Figure 1. Simplifying the geometry: (a) – 16000 boundaries, (b) – 350 boundaries

After identifying and fixing minor defects in the imported STL mesh, and simplifying the geometry of the model, the object was partitioned set up for simulations. A transparent boundary was placed around the sandstone core (Figure 2) and a mesh volume was generated.
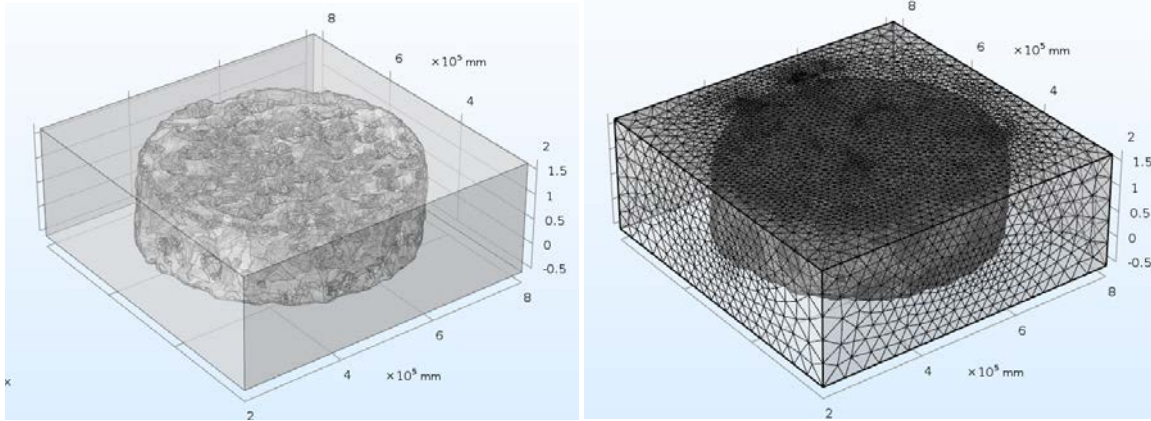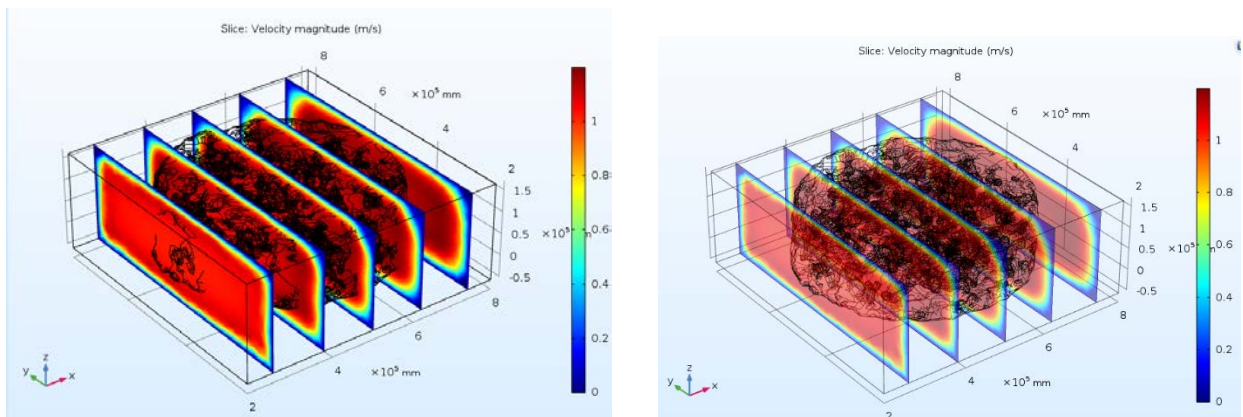
Figure 2. (a) Sandstone surrounded with transparent solid (b) meshed volume

To test the setup, a preliminary simulation was run by assigning laminar flow physics and inlet and outlet boundaries, with Inlet fluid velocity 1 m/s (Figure 4).

(a) – default XYZ view, (b) – Transparance XYZ view

Figure 4. Example of laminar flow simulation through the model using Birmingham Equation, with pressure differences of 0.7, 1 and 2 Pa.

In summary, during the first year of the project 2018 - 2019, this project has provided valuable training and professional development for the PI and two PhD graduate students: Lois Kamga-Ngameni and Medet Madalimov. The supported work will help foster valuable laboratory research experience, finite element numerical modeling and working with MATLAB and artificial neural networks for graduate students. The PI was also able to make a presentation on the research at an Energy workshop.