Simulating Hydraulic Fracturing and Contaminant Transport with MATLAB® and COMSOL Multiphysics® Software

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Abstract

Hydraulic fracturing, or fracking, is a technique used to extract oil and gas in shale rock. A mixture of water, sand, and chemicals are pumped into the well at high pressures to keep the fissures open, which allows the gas to flow. Although intermediate casings are inserted into the well to prevent the fracturing fluid or oil or gas from entering the water supply at the ground water layer (between 1000 and 4000 feet), formed cracks can permit the fracturing fluids and gas to spread into aquifers due to the increased permeability from fracturing. In this study, a MATLAB® code is linked with the COMSOL Multiphysics® software to trace the fracture propagation and examine the extent of contamination associated with the fracking process.

The simulation domain for the hydraulic fracturing is 100m × 2000m. The pumping source is at the bottom center element of the domain. Figure 1 shows the mesh refinement as the pressure increases. The crack propagation evolves from using the mix mode stress criteria to determine the propagation direction (MATLAB®). The crack opening is calculated directly from the displacement field of the opposite nodes on the cracked element. If water continues to be pumped for 24 hours, the fractured bond keeps increasing (COMSOL®). This fracture can reach up to at least 1000 meters just within 24 hours, which can just begin to reach the aquifer.

Once the crack reaches the groundwater layer, the time for the contamination to reach the shallow groundwater layer is then calculated. The permeability is chosen to be 〖10〗^3 md and porosity is 0.35 for the groundwater layer. The simulation domain is 400m ×150m, and the contamination source is the rectangular element shown in Fig. 2, along with subsequent dispersion results. The primary flow of the contamination is seen to be dispersing into the shallow layer. It takes approximately 800 days to contaminate the entire groundwater layer with the flowing gas or proppant used for the hydraulic fracturing.

MATLAB® and COMSOL® are used to simulate hydraulic fracturing and contaminant transport. The fracture volume is treated as porosity and permeability to be used in the pressure equations, therefore no discontinuity is considered (MATLAB®). Results from this preliminary study illustrate the implementation of COMSOL®, when linked with MATLAB®,

to accurately simulate hydraulic fracturing.

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Figures used in the abstract

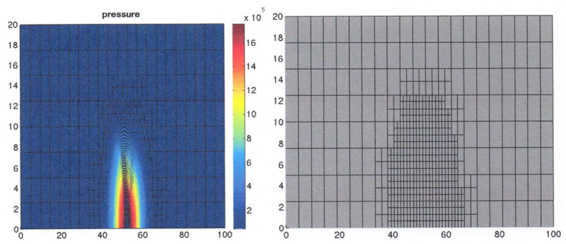

Figure 1: Mesh refinement.

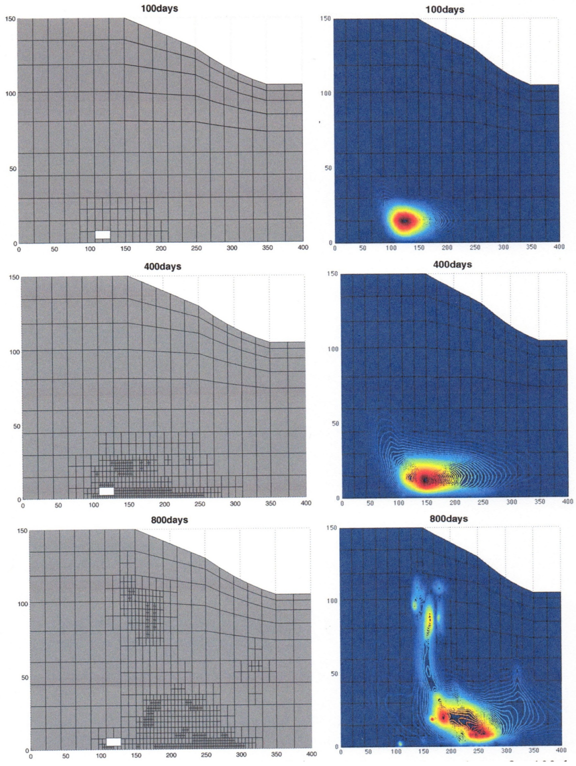

Figure 2: Contaminant transport and refinement after 100, 400, and 800 days.