Temple University Mathematics Colloquium

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will speak on

Low Reynolds number flows through shaped and deformable conduits

ABSTRACT: Unconventional fossil energy resources are revolutionizing the US energy market. While the techniques developed over the last 50 years lead to viable and profitable extraction of, e.g., trapped gas and hydrocarbons from almost-impermeable rock formations via hydraulic fracturing, the abysmal extraction rates (typically 15%) suggest the fluid mechanics of these processes is not well understood. In this talk, I will describe three basic theoretical fluid mechanics problems inspired by unconventional fossil fuel extraction. The first problem is flow in a deformable microchannel. Fluid-structure interaction couples the shape of the conduit to the flow through it, drastically altering the flow rate–pressure drop relation. Using perturbation methods, we show that the flow rate is a quartic polynomial of pressure drop for shallow channels, in contrast to the linear relation for rigid conduits. The second problem involves two-phase (gas-liquid) displacement in a horizontal Hele-Shaw cell with an elastic membrane as the top boundary. This problem arises at the pore-scale in enhanced oil recovery for large injection pressures. Once again, fluid-structure interaction alters the problem, leading to stabilization of the Saffman–Taylor (viscous fingering) instability below a critical flow rate. Using lubrication theory, we derive the stability threshold and show that it agrees well with recent experiments. The third problem involves the spread of a viscous liquid in a vertical Hele-Shaw cell with a variable thickness in the flow-wise direction, as a model for the spread of a plume of supercritical carbon dioxide through the non-uniform passages created by hydraulic fracturing. We show that the propagation regimes in such a shaped conduit are set by the direction of propagation. While the rate of spread in the direction of increasing gap thickness (and, hence, permeability) can be obtained by standard scaling techniques, the reverse scenario requires the construction of a so-called second-kind self-similar solution, leading to nontrivial exponents in the rate of spread.

Thursday, January 22, 2015
Lecture at 3:00 pm
Coffee, tea, and refreshments from 2:45 pm
Room 617, Wachman Hall
Department of Mathematics