Topics in low Re flow: From microfluidic fluid--structure interactions to multiphase flow in hydraulic fractures discrete-continuum method for geological materials in extreme environments

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Abstract: In this talk, I will summarize some recent results from and new research directions for my research group, the Transport: Modeling, Numerics & Theory laboratory [http://tmnt-lab.org] at Purdue. The first topic is from the field of microfluidics, in which rectangular channels with deformable walls are used as one of the simplest models for lab-on-a-chip devices. Experimentally, these devices are found to deform into a non-rectangular cross-section due to fluid--structure interactions, leading to a non-linear relationship between the volumetric flow rate and the pressure drop. We predict this relation via perturbative calculations involving a coupled system of Stokes (Re=0) flow in a 3D rectangular channel with a top wall that is a linearly elastic Kirchhoff--Love plate. We have benchmarked and verified the theoretical predictions by 3D numerical simulations, calibrated with experimental pressure drop--flow rate data, using the commercial software suite ANSYS. The second topic addresses some new ideas about multiphase flows in the subsurface. Oil and water are a classic example of an immiscible two-phase flow, while supercritical carbon dioxide and brine are a miscible one. Interfacial instabilities have been shown to be affected by the passage geometry and its compliance, some example of which I will discuss. Fracking, on the other hand, involves the use of not just clear fluids but also fluids bearing proppants, which are particulate materials meant to settle into cracks to prop them open, prevent crack localization instabilities and increase fracture conductivity. There still remain fundamental aspects to particle migration in flows that are not fully understood, specifically related to formulating the two-phase transport problem for proppants and understanding how nonuniform conduit shapes and nonuniform hydrodynamic forcing could be exploited to preferentially control particle migration.

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