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Homogenization of a Stokes-Biot system modeling deformable fractured and vuggy porous media

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Vugs and fractures have significant impacts on the fluid flow paths through fractured and vuggy porous media. On the other hand, the presence of vugs and fractures also can significantly affect the geo-mechanical behavior of the porous media. How to quantify and analysis the accurate effects of the vugs and fractures on the hydro-mechanical behavior of the media is still an opening and challenging problem. To this end, we systematically derive a macroscopic poroelastic model for a single-phase, incompressible, viscous fluid flow in a deformable fractured and vuggy porous medium. Herein, we assume that a fractured and vuggy porous medium is divided into two parts, i.e., the porous matrix and fractures/vugs, on a mesoscopic scale (e.g. lab core scale). In the porous matrix, the classical Biot's equations are used to model the poroelastic process. In fractures and vugs, the Stokes equations are applied to model the free fluid flow, which couple with Biot's equations through the extended Beavers-Joseph-Saffman (BJS) boundary condition on the porous-fluid interface. Through a two-scale homogenization limit as the period tends to zero, we obtain a macroscopic Biot's equations governing the fractured and vuggy medium on macroscopic scale. The homogenization approach determines the form of the macroscopic constitutive relationships between variables, and shows how to compute the poroelastic coefficients in these relationships. It should be noted that the calculations of the macroscopic properties only depend on the decoupling three base cell problems, i.e., two Navier equations for elastic problem and one Darcy-Stokes flow problem with BJS conditions. It is shown that our homogenized results provide a natural way of modeling deformable realistic fractured and vuggy porous media.

References

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Primary authors: Prof. YAO, Jun (Research Centre of Multiphase Flow in Porous Media , China University of Petroleum (East China), Qingdao, China); HUANG, Zhaoqin (China University of Petroleum (East China))

Presenter: HUANG, Zhaoqin (China University of Petroleum (East China))

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