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Modeling Matrix-Fracture Fluid Leakage in Fractured Rocks Using Multi-Scale Darcy-Brinkman-Stokes Approach

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Objectives/Scope
Understanding the fundamental mechanisms of fracture-matrix fluid exchange is crucial for the modeling of fractured reservoirs. Traditionally, high-resolution simulations for flow in fractures often neglect the effect of matrix contribution on the fracture hydraulic behavior. In this study, we develop a multi-scale approach to capture the matrix-fracture leakage interaction and its impact on the hydraulic properties of roughed fractures.

Methods, Procedures, Process
Because of the multiscale nature of the fracture and matrix rocks, full physics Navier-Stokes (NS) simulation in both matrix and fracture media is not feasible. For such multiscale phenomena, we use NS equations to describe the flow in the fracture, and Darcy's law to model the flow in the surrounding porous rocks. The hybrid modeling is achieved using the extended Darcy-Brinkman-Stokes (DBS) equation. With this approach, a unified conservation equation for flow in both media is applied. We use an accurate Mixed Finite Element approach to solve the extended DBS equation. Analytical solutions were used to verify the numerical method.

Results, Observations, Conclusions
Various sensitivity analyses were conducted to explore the leakage effects on the hydraulic aperture of rock fractures by varying the permeability of the surrounding medium, fracture roughness, and Reynolds number (Re). A series of pore-scale simulations for flow through roughed fractures were performed, and the results were used to develop a relationship between the flow rate and pressure loss. Streamline profiles show the presence of back-flow phenomena, where in- and out-flow are possible between the matrix and the fractures. Further, zones of stagnant (eddy) flow are observed within locations of large asperities of sharp roughness within the fracture and high Re. This implies the presence of dynamic trapping mechanisms that may impact the relative permeabilities and residual saturations within the fractures. Numerical results show the side-leakage effect can create non-uniform flow distribution in the fracture that deviates significantly from the flow with impermeable wall conditions. The proposed friction factor has the potential to be used as an upscaling tool to estimate the hydraulic properties of roughed fractures within permeable rocks in fractured reservoir simulations.

Novel/Additive Information
We develop a high-resolution approach to investigate the flow exchange behavior between the fracture and rock matrix. We investigate static and dynamic effects, including variable Reynold numbers, mimicking flow near and away from the wellbore. We show that local fracture characteristics such as roughness and tortuosity may impact the flow, which is often not accounted for in dual-porosity simulations. We propose a new upscaling friction factor to account for these mechanisms in field-scale reservoir simulations.

Participation

In-Person

References

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