Core-scale pulse-decay experiment based on Embedded Discrete Fracture Model (EDFM)

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Summary

Pulse-decay experiment is an unsteady state method of measuring ultra-low permeability in tight rocks (Brace et al., 1968; Hsieh et al., 1981; Cui et al., 2009). Previous attempts have shown that this kind of experiment is also able to measure the permeability of fracture and matrix simultaneously for fractured cores (Ning 1992; Alnoaimi 2016). However, the fractures were mostly assumed to be planar, and fracture roughness was generally ignored. We aimed to fill the gaps using the approach of Embedded Discrete Fracture Model (EDFM) in this work (Xu et al., 2016).

Theory / Method / Workflow

A fractured Wolfcamp shale core was applied in this study. An in-house pulse-decay experimental set-up comprised of an upstream reservoir, core-holder, and downstream reservoir was manufactured. During the experiment, pressure at upstream monotonically decreased with time; pressure at the downstream first increased to the point of converging with the upstream pressure, then decreased slowly to the equilibrium pressure. The upstream and downstream pressure curves were used as the main source for history matching permeability and porosity. A 3D scanner was applied to depict the roughness of the fracture surface, which was imported in the discrete fracture network (Figure 1). Grid refinement was used for the core to capture the flow movement inside the core. Subsequent simulation efforts were carried out to investigate fracture aperture and volume, core heterogeneity, and flow direction on pressure responses.

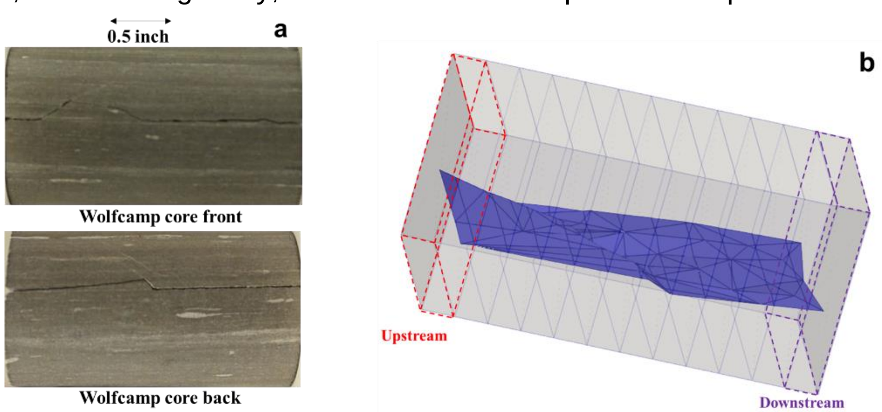

Figure 1. (a) Fractured Wolfcamp core used in this study and (b) Embedded Discrete Fracture Model (EDFM) based on the scanned fracture surface roughness.

Results, Observations, Conclusions

During the course of fluid flow in the fractured core, the upstream and downstream were first connected through the fracture, and then the fluid slowly permeated into the matrix. 3D discrete fracture network model effectively simulated the pulse-decay experiment with the fractured shale core plug. History matching was successfully implemented to match the pressure curves with low average absolute deviation. Fracture permeability is 4 orders' magnitude larger than the tight matrix permeability. Fracture permeability and matrix permeability dominated the early pressure response and late pressure response, respectively. The sensitivity analysis revealed that fracture volume was the dominating factor affecting the dual-porosity region of the pressure curves; the matrix heterogeneity hampered gas flow in the porous media mainly in the late flow period.

Novel/Additive Information

To the best of our knowledge, this work is the first to perform a 3D discrete fracture network model to simulate the pulse-decay experiment with the aid of a detailed roughness scan on fracture surface roughness. Using the workflow proposed in this study, more realistic and precise petrophysical properties for fractured shales could be obtained in the laboratory.

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References

Brace, W. F.; Walsh, J. B.; Frangos, W. T., Permeability of granite under high pressure. Journal of Geophysical Research 1968, 73 (6), 2225-2236.

Cui, X.; Bustin, A. M. M.; Bustin, R. M., Measurements of gas permeability and diffusivity of tight reservoir rocks: different approaches and their applications. Geofluids 2009, 9 (3), 208-223.

Hsieh, P. A.; Tracy, J. V.; Neuzil, C. E.; Bredehoeft, J. D.; Silliman, S. E., A transient laboratory method for determining the hydraulic properties of 'tight' rocks—I. theory. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts 1981, 18 (3), 245-252.

Xu, Y.; Cavalcante Filho, J. S. ; Yu, W.; K. Sepehrnoori., Discrete-fracture modeling of complex hydraulic-fracture geometries in reservoir simulators. SPE Reservoir Evaluation & Engineering 2017, 20, 403–422.