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Effects of Pore Pressure Depletion on Horizontal Stresses and Propagation of Hydraulic Fractures during Refracturing

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Summary

Refracturing of a horizontal well is a method to restore the productivity of the well in unconventional reservoirs after the expected production decline. Placement of new fractures in a system that has been already depleted poses new challenges for operators. These challenges are due to the altered stress zones resulting from the expected pore volume depletion and corresponding pressure decline. In this study, effect of pore pressure depletion on horizontal stresses, and refracture propagation issues in a horizontal well are studied using a numerical method called displacement discontinuity method.

Introduction

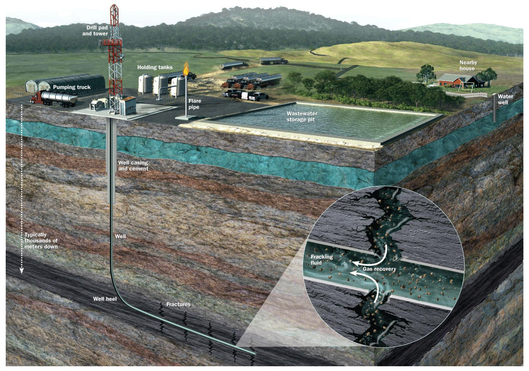

Figure 1. A schematic of the horizontal drilling and hydraulic fracturing process

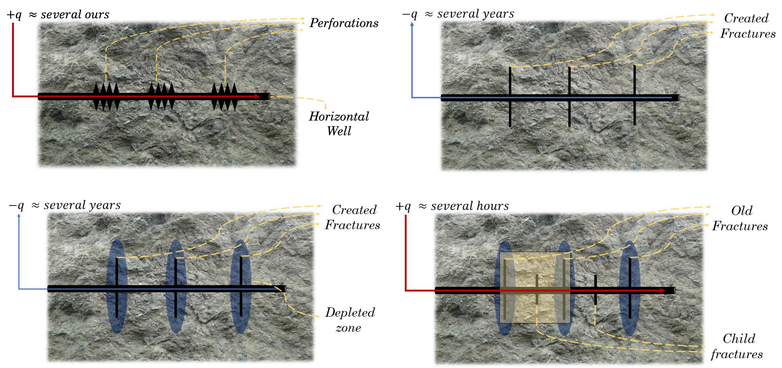

Figure2. Schematic of the problem: a) horizontal well is perforated, b) fractures at their final lengths, c) depleted area around fractures after production, d) areas of Interest

Method

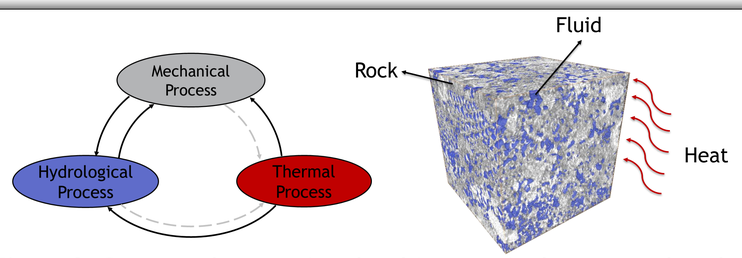

Figure3. Process that are involved in a typical saturated rock problem

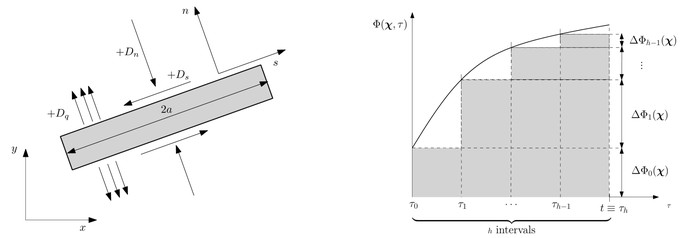

Figure4. Displacement discontinuity method: a) a constant DDM element, b) time marching process

$$\sum_{\lambda=1}^{N} A_{xx}^{\beta\lambda} D_s^{\lambda,h} + \sum_{\lambda=1}^{N} A_{xy}^{\beta\lambda} D_n^{\lambda,h} + \sum_{\lambda=1}^{N} A_{xq}^{\beta\lambda} D_q^{\lambda,h} = \sigma_s^h(x^\beta, t) - \sum_{\eta=0}^{h-1} \sum_{\lambda=1}^{N} \left(A_{xx}^{\beta\lambda,\eta} D_s^{\lambda,\eta} + A_{xy}^{\beta\lambda,\eta} D_n^{\lambda,\eta} + A_{xq}^{\beta\lambda,\eta} D_q^{\lambda,\eta} \right)$$

$$\sum_{\lambda=1}^{N} A_{yx}^{\beta\lambda} D_s^{\lambda,h} + \sum_{\lambda=1}^{N} A_{yy}^{\beta\lambda} D_n^{\lambda,h} + \sum_{\lambda=1}^{N} A_{yq}^{\beta\lambda} D_q^{\lambda,h} = \sigma_n^h(x^\beta, t) - \sum_{\eta=0}^{h-1} \sum_{\lambda=1}^{N} \left(A_{yx}^{\beta\lambda,\eta} D_s^{\lambda,\eta} + A_{yy}^{\beta\lambda,\eta} D_n^{\lambda,\eta} + A_{yq}^{\beta\lambda,\eta} D_q^{\lambda,\eta} \right)$$

$$\sum_{\lambda=1}^{N} A_{px}^{\beta\lambda} D_s^{\lambda,h} + \sum_{\lambda=1}^{N} A_{py}^{\beta\lambda} D_n^{\lambda,h} + \sum_{\lambda=1}^{N} A_{pq}^{\beta\lambda} D_q^{\lambda,h} = p_p^h(x^\beta, t) - \sum_{\eta=0}^{h-1} \sum_{\lambda=1}^{N} \left(A_{px}^{\beta\lambda,\eta} D_s^{\lambda,\eta} + A_{py}^{\beta\lambda,\eta} D_n^{\lambda,\eta} + A_{pq}^{\beta\lambda,\eta} D_q^{\lambda,\eta} \right)$$

Figure 5. Three linear DDM equations that must be solved

Results

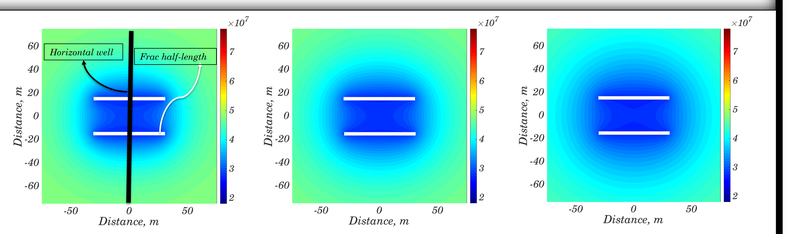

Figure6. Pore pressure depletion: a) 6 months, b) 1 year, c) 3 years

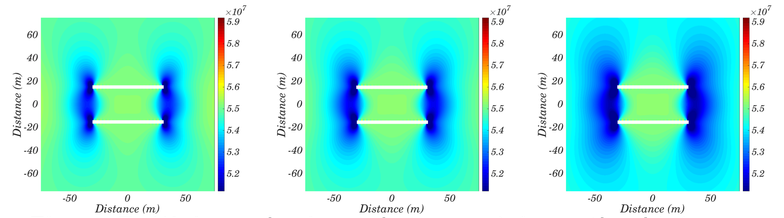

Figure 7. Minimum horizontal stress: a) 6 months, b) 1 year, c) 3 years

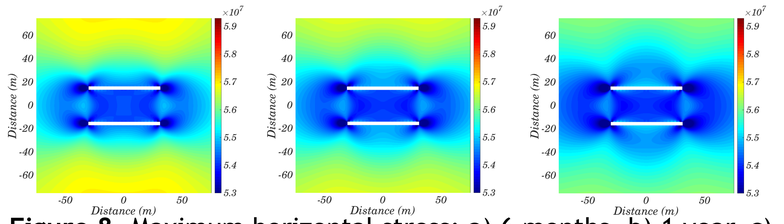

Figure 8. Maximum horizontal stress: a) 6 months, b) 1 year, c) 3 years

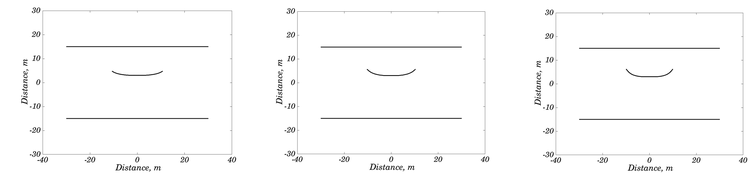

Figure9. Child fracture propagation after: a) 6 months, b) 1 year, c) 3 years, as the result of pore pressure depletion

Conclusion

1. Pore pressure depletion does not reduce the amount of stresses evenly.
2. It is shown that a secondary fracture tends to propagate toward a primary fracture and this tendency becomes more severe as time progresses.
3. One should consider a proper time window for a specific set of rock and problem variables to guarantee success in refracturing.

References

1. Crouch S, Starfield AM. Boundary Element Methods in Solid Mechanics. George Allen & Unwin, 1983.
2. Carvalho JL. Poroelastic effects and influence of material interfaces on hydraulic fracture behavior. Ph.D. thesis; University of Toronto; 1991.