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The Transient Phase of Planar, Three-Dimensional Buoyant Hydraulic Fractures Emerging from a Point Source

A. Möri[1*], C. Peruzzo[1] and B. Lecampion[1]

[1] Geo-Energy Lab - Gaznat chair on Geo-Energy EPFL, EPFL-ENAC-IIC-GEL Station 18 CH-1015 Lausanne, andreas.mori@epfl.ch, https://www.epfl.ch/labs/gel/

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Hydraulic fractures (HF) are propagating Mode I (tensile) fractures emerging from a pressurized fluid source. They appear in industrial applications to enhance the permeability of rock masses and naturally as a mechanism of magma transport in the crust. The buoyancy of the fluid (density contrast between the host rock and the fluid) gives rise to self-sustained buoyancy-driven fractures. Recently, the transition and final shapes of such buoyancy-driven fractures have been investigated in detail [1]. The transition strongly depends on a dimensionless parameter relating the energy dissipation by viscous flow to the dissipation by surface creation. This balance strongly depends on a material parameter called the fracture toughness K_{Ic}. Laboratory experiments of this parameter seem not to match data from field evaluations, a conclusion that is challenged by the emergence of a transient phase [1].

This transient phase appears when the energy dissipation by surface creation dominates the buoyant stage. To validate the late time solution, where initial conditions can be neglected, modeling of a large domain and several orders in time is necessary. Those requirements forced us to significantly increase computational efficiency of our open-source solver PyFrac [2]. We notably implemented a heap structured fast marching method to solve for the fracture front position and solve the non-linear elastohydrodynamic system using an Anderson acceleration of fixed-point iterations. The linear system is solved using a preconditioned BiCGSTAB solver. This scheme allows us to significantly speed up the calculation for large domain sizes without compromising numerical accuracy.

These significant gains in computational efficiency have allowed us to investigate the transition towards an established buoyant hydraulic fracture over more than ten orders of time and spatial scales.

REFERENCES

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