Propagation of Hydraulic Fracture Driven by Non-Newtonian Fluid in Permeable Rock: Numerical Solution

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This paper studies the general solution of a fracture driven by an incompressible, viscous non-Newtonian fluid (with power-law rheology) propagating in an elastic, permeable rock with finite toughness under plane strain conditions. Based on the scaling considerations [1], fracture evolution is characterized by two dimensionless time-dependent parameters with the meaning of, for example, toughness and leak-off, respectively. It is shown that for shear-thinning fluids, the fracture propagation regime evolves in time from the toughness/storage- to the viscosity/leak-off-dominated regime. The former is the regime when (i) the viscous dissipation in the fluid flow along the crack channel is negligible compared to the energy expended in fracturing the rock at the crack tip and (ii) the rate of fluid flow outflow from the crack into surrounding rock (leak-off) is negligible compared to the rate of flow along the crack. The opposite is true for the viscosity/leak-off-dominated regime when the viscous dissipation and the fluid leak-off processes dominate. The method-of-lines approach is used to compute numerically the transient solution which describes evolution of the crack length, the fracture opening, and the net pressure between these two asymptotic regimes. Zero-leak-off (variable toughness) solution [2] and zero-toughness (variable leak-off) solution are used for the purpose of comparison and testing of convergence of the general numerical solution. The general solution and its asymptotic cases are used to estimate the practical ranges of parameters pertaining to different propagation regimes.

References

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