3-D Modeling of Multi-Stage Hydraulic Fracturing from a Borehole within a GFEM Framework

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Hydraulic Fracturing is the process in which a fracture propagates through the injection of pressurized fluid in its cavity. This process is widely used in the oil and gas industry to increase reservoir permeability which leads to high rates of both injection and production. In order to reduce operational costs, hydraulic fractures are usually created in stages where multiple fractures are propagated at the same time [1]. Interactions among fractures and their realignment with the preferential propagation direction often lead to complex fracture geometries. The fracture shape, and consequently pressure drop, varies significantly between fractures which can impact their productivity. Miller et al. [2] studied more than 100 horizontal shale wells in multiple basins and concluded that an average of 29.6% of the hydraulic fracture clusters do not produce. Computational methods able to predict the near-wellbore tortuosity and pressure drop can play a key role in improving the performance of multistage fracturing.

This presentation reports on recent advances of an adaptive Generalized Finite Element Method (GFEM) for the simulation of multiple 3-D non-planar hydraulic fracture propagation near a wellbore [3]. This method is particularly appealing for the discretization of the fractures since it does not require the finite element mesh to fit fracture faces. Additionally, analytical asymptotic solutions are used to enrich the fracture fronts, which increases the accuracy of the approximation. The governing equation of the rock is discretized in space with a quadratic GFEM and the equation for the flow in the fractures is discretized in space with a quadratic FEM. The injected fluid partitioning among fractures is automatically computed by modeling the wellbore, where the flow is assumed to be governed by the Hagen–Poiseuille relation. The pressure losses between wellbore and hydraulic fractures are modeled with the sharp-edged orifice equation and with the use of 1-D connecting elements. A linear FEM is adopted for the spatial discretization of the equation governing the flow in the wellbore and the connection between wellbore and hydraulic fracture. A propagation criterion based on a regularization of Irwin's criterion is adopted and a methodology to automatically estimate the time step that leads to the propagation of fractures based on linear interpolation/extrapolation is presented.

Several wellbore and fracture configurations are investigated to demonstrate the non-intuitive propagation behavior in these near-wellbore conditions and the robustness of the proposed GFEM methodology. They show that even a fairly small misalignment between the wellbore and the minimum in-situ stress leads to fracture geometries that are vastly different from those predicted by simulations that assume fracture planarity – a simplification often adopted in the simulation of hydraulic fractures propagation.

References

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