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Fully Integrating a Hydraulic Fracturing, Reservoir, and Wellbore Simulator into a Practical Engineering Tool

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In this talk, I give an overview of our software ResFrac, which fully integrates a 'true' hydraulic fracturing simulator and a multiphase reservoir simulator (McClure et al., 2020a). Conventionally, these processes have been described with separate codes, using separate meshes, and with different physics. Integrating these two categories of software is advantageous because it enables seamless description of the entire lifecycle of a well. It is possible to seamlessly integrate wells with complex histories such as frac hits from offset wells, refracs, and huff and puff EOR injection.

ResFrac has been applied on 25+ studies for operators optimizing development of oil and gas resources in shale and has been commercially licensed by 15+ companies (https://www.resfrac.com/case-studies; https://www.resfrac.com/publications; https://www.resfrac.com/about-us/our-team). The simulator has a modern user-interface with embedded help-documentation, wizards to help set up simulations, automated validators to identify issues with the setup prior to submitting, and plotting capabilities to preview 3D and tabular inputs. Simulations are run on the cloud and results are continuously downloaded to the user's computer. This allows a user to easily run a large number of simultaneous simulations from their personal computer. The user-interface includes a custom-built and fully-featured visualization tool for 3D visualization and 2D plotting.

Hydraulic fracturing simulators must handle a diverse set of coupled physics: mechanics of crack propagation and stress shadowing, fluid flow in the fractures, leakoff, transport of fluid additives that impart non-Newtonian flow characteristics, and proppant transport. Proppant transport is particularly complex because proppant settles out into an immobile bed and may screen out at the tip. Many fracturing simulators approximate wellbore flow effects. However, because these effects are closely coupled to fracturing processes (especially in horizontal wells that have multiple simultaneously propagating fractures), we include a fully meshed, detailed wellbore model in the code, along with treatment of perforation pressure drop and near-wellbore tortuosity.

In the literature, separate constitutive relations are available to describe transport in open cracks, closed unpropped cracks, and closed propped cracks. However, there were not relations in the literature designed to describe transport under conditions transitional between these end-member states. A general numerical simulator must be able to describe all conditions (and avoid discontinuous changes between equations). To address this limitation, we developed a new set of constitutive equations that can smoothly transition between these end-member states – smoothly

handling any general combination of aperture, effective normal stress, saturation, proppant volume fraction, and non-Newtonian fluid rheology (McClure et al., 2020).

The code solves all equations in a fully coupled way, using an adaptive implicit method. The fully coupled approach is chosen because of the tight coupling between many of the key physical processes. Iterative coupling converges very slowly and/or forces excessively small timesteps when tightly coupled processes are handled with iterative or explicit coupling.

McClure, Kang, Hewson, and Medam. 2020. ResFrac Technical Writeup (v5). arXiv.