Case 7: Multiple Fracture Interaction

ExtraDemo: Multiple Wells, Short Perf Cluster Spacing, Limited Entry, Perf Erosion, Multi-Layered Reservoirs

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Features and Equations

Fracture
Fluid Flow
Fluid Loss
Proppant Transport
Proppant Retardation
Proppant Settlement
Proppant Bridging
Heat Transfer
Fluid Rheology
Slurry Rheology
Wellbore Mechanics
Wellbore Friction

Boundary integral method
Reynolds equation
Carter leakoff model
Transport equation
Equivalent flow width model
Chien’s settling formula
Gruesbeck & Collins model
Boit thermal model
Tabulated crosslinker, breaker n, K
Landel model
Bernoulli equation and erosion model
Szilas-Bobok-Navratil formula

Comprehensive service features for practical applications
Major Numerical Methods

3D displacement discontinuity method (Fracture)
Finite volume method (Fluid)

“Multi-step method” (Transient analysis)
“Successive matrix method” (Multilayer)
Semi-analytical method (Heat coupling)

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Stable + Accurate + Efficient
Case 1: Frac Radius versus Dontsov KGD Approximate Solution

Dontsov KGD approximate solution is most accurate for the limiting cases.

Dontsov 2016 An approximate solution for a penny-shaped hydraulic fracture that accounts for fracture toughness, fluid viscosity and leak-off, Royal Society Open Science 3: 160737
Case 1: Frac Net Pressure versus Dontsov KGD Approximate Solution

For large viscosity and leakoff, FrackOptima solution appears to be more consistent among the length and width. Dontsov KGD approximate solution for net pressure may not be accurate. Need discussion since it is only stated in the paper that the solution is not accurate at the tip.
Case 1: Formation Min Stress Perturbation by the KGD Fracture (d)

Can be readily compared with the existing analytical solution
Case 7

Five stages

Three fracs per stage
Perf spacing 40, 75, 150 ft
Horizontal stress difference 100, 300, 1000 psi

Nine sets of data
15 curves for each set

Only interesting points are made for the limiting situations
Case 7: 1 Stage 3 Fractures: Perf Spacing 40ft & H stress diff 100psi
Case 7: Short Perf Cluster Spacing 40ft: 5FS-15F-100SD

Strong stress interaction
Could break stress barrier
Fracture intersection

Could be beneficial if it is practiced in reservoirs with multiple layered pay zones. Can be ineffective and wasteful for many other situations.
Case 7: Large H Stress Difference 1000psi on Short Perf Spacing 40ft

Strong stress interaction
Could break stress barrier
Straight fracture but could be nonuniform
Best for limited entry practice but be cautious about perf erosion for large operations.
Case 7: Large Perf Spacing 150ft

Weak stress interaction after fracture spacing is greater than 30m
100 psi H stress difference can maintain straight fractures for large perf cluster spacing
Relatively easy to generate uniform straight long fractures for long term production?
Drill long wells with more fractures to compensate the drop of IP rate?
Beneficial for the secondary fracture?
Case 7: Downhole Pressure Perf Spacing 150ft vs 40ft

Higher downhole pressure is required for shorter perf spacing as expected. Stress interaction drops quadratically as distance increases. The stage is majorly influenced by its adjacent stages. Stage time interval is an interesting factor too. Alternative fracturing between multiple wells could be exploited.
Case 7: Injection Volume at Each Perf Cluster

Shall we perf non-uniformly for each stage?
Case 7: Net Pressure Variation at Each Perf Cluster

Can tell when one frac hits another frac...
From Einhorn’s “Mother Fracker”: Is this really the solution?
Optimize frac treatment in multiple shale layer: Narrow Spacing: Limited Entry: Erosion: ...
Short Perf Cluster Spacing 16 ft & Limited Entry

10 perf clusters, 16ft spacing
Tapered design toe to heel 3, 4, 4, 4, 5, 5, 5, 6, 6, 8 60 degree phasing

Are fractures uniform? Is erosion an issue? Shall we try 10ft? ...
Points to make:

Fluid distribution could be quite non-uniform due to inaccurate perf design.

Both fracture length and height can be quite non-uniform due to strong stress interaction and inaccurate perf design.

The effectiveness of the design largely depends on the formation characteristics.

There appears to be quite a large room for improving fracture design.

Short term economics appears to matter most at present!