Perforating Requirements for Fracture Stimulation

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Agenda

- Perforating objectives for fracture stimulation
- Effect of perforating parameters
- Horizontal wells
- Conclusions
Perforating Objectives for Fracturing

• Make frac jobs more effective
  – Lower breakdown pressures
  – Lower treatment pressures with better treatment rates
  – Controlled frac placement

• All of this leads to better production
• Also helps avoid disasters like aborted jobs
Perforating Objectives

- Perforations should minimize:
  - Near wellbore pressure drop
  - Perforation friction
  - Tortuosity
  - Micro-annulus pinch points
  - Multiple competing fractures
What can we control?

- Size and type of gun
- Penetration (type of charge)
- Casing entrance hole
- Shot density
- Shot phasing
- Interval length
- Gun orientation
Casing Entrance Hole

- EH size about 8 to 10 times proppant diameter to prevent bridging
- Consistent EH for accurate limited entry designs
- 40% variation in EH results in 120% increase in pressure drop

\[ \Delta p = \frac{0.239 \rho}{D_p^4 C^2} \left( \frac{q}{n_p} \right)^2 \]

(from SPE 83590)
Minimizing Casing Entrance Hole Variation

- Use largest gun possible to reduce water clearance
- Centralize gun
- Design shaped charge for minimum variation even across large water clearances
Is Penetration Important?

- Sometimes ignored (we just need some holes in the casing)
- What about near wellbore conditions?
  - breakouts
  - formation damage?
  - near wellbore stress?
- Frac experts starting to realize that penetration is a benefit (>1 BH)
- Connection to the far field helps avoid near-wellbore tortuosity effects

Up to 5-inch damage (SPE 112862)
What about Clean Perforations?

- Enable injection to start deeper in formation, avoids near wellbore damaged zone
- Fractures may not initiate from plugged perforations (see “big block” tests left)
- Clean perforations allow fluid leak-off, increasing near-wellbore pressure prior to fracture initiation

Plugged perforations NO fracture

Clean Perforations with fracture passing through perforations (from SPE 20661)

Non-DUB tunnel; flow predominantly into first couple inches

DUB tunnel; flow more uniformly distributed along length (from SPE 143997)
Plugged perfs $\rightarrow$ NO fracture

(from SPE 20661)
Clean Perfs → Fracture

(from SPE 20661)
Gun Phasing and Direction

Near-vertical wells

- Fractures initiate from perforations aligned with maximum stress direction
- Best gun phasing is 0° – 180° in max stress direction

Perforations aligned with maximum horizontal stress

(from SPE 20661)
Perforations aligned with maximum horizontal stress
Gun Phasing and Direction
Near-vertical wells

- Fractures initiate from sand-face when perforations are misaligned
- Other gun phasings: 120° (at 1 ½ times spf); 60° (at 3 times spf)

Perforations misaligned with maximum horizontal stress

(from SPE 20661)
Perforations not aligned with maximum horizontal stress

No frac between perfs

(from SPE 20661)
Well Direction and Gun Phasing

Gun phasing and interval perforated should be based on well direction compared to the preferred fracture plane
Hydraulic Fractures in Horizontal Wells

The goal is to create surface area

Longitudinal fracs

Transverse fracs

What we want
What We Get with 60° Phasing

Longitudinal fractures initiate first
Terminate about 2 wellbore diameters in vertical direction
  – Extend along wellbore
  – Initial pumped volumes dominated by longitudinal fracs

Transverse fractures initiate after
  – Perpendicular to longitudinal
  – Do not rotate from longitudinal
What we get with 60° Phasing
Can We Do Better?

- Several experiments done in large blocks in a tri-axial stress frame to simulate horizontal well
- Both DP and BH charges used
- Directional perforations aimed at the same transverse plane

Result: Transverse fractures created
Directional perforations in the same transverse plane → transverse fractures are created
Perforation Gun Length-Horizontal Wells

- In horizontal wells perforation length should be limited to about 2 to 4 times the wellbore diameter (ref SPE 19720)
  - Minimizes multiple competing fractures
- Typical gun contains 6 to 10 shots (60° phased)
- 2 to 4 guns are shot for each frac stage
- Guns run with addressable switches in pumpdown plug-n-perf mode
How Many Clusters per Stage?

• Closely spaced clusters increases flow rate in gas shales
  • Trade off is cost (number of fractures vs production)
  • SPE 144326 shows study on production vs clusters for major shale plays

• Reducing the number of clusters increases odds of all clusters being stimulated
  • 48% of perf clusters aren’t contributing in wells having 6 or more perf clusters / frac stage

• Cluster placement should be matched to reservoir quality
  – Requires detailed modeling
  – SPE 146872 and SPE 146876 detail modeling work flow
Horizontal shale well production log analysis

Non-Producing Perforation Clusters vs Perforation Cluster Density (clusters per stage)

Increasing clusters per stage improves operational efficiency, but compromises well productivity.

SPE144326
Conclusion
Well planned perforating will make frac jobs more effective

- Careful choice of shaped charges, gun phasing and orientation will help initiate fractures and minimize tortuosity

- In horizontal wells selection of number of shots, position of clusters impacts well productivity
Questions?