Prediction of Perforating Wellbore Dynamics and Shock Loads
Improves Service Quality and Reduces Non Productive Time

MENAPS 13-03

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Outline

– Wellbore hydrodynamics and structural dynamics / gun shock animation

Cases

– High-pressure TCP job with 4.72-in guns
  • Pressure comparison: simulated vs. actual fast-gauge data
  • Reduce tubing load
– Unexpected Pull-Off when Perforating on Wireline
– Reduction of Dynamic Loads - TCP job with Automatic Gun Release
  • minimize gun shock loads

– Conclusions
Wellbore Hydrodynamics > 1 ms – After Creation of Perforation Tunnels

Detonator cord
Case
Liner
Primer charge
Explosive

Detonation front (30 GPa)
Tfp (7,000 m/s)
Tall (500 m/s)

Jet tip (15 × 10^9 psi)

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Wellbore Dynamics

- **Dynamic Underbalance:**
  - Deto Pressure < Wellbore Pressure
  - Immediately after firing, guns become a pressure sink

- **Dynamic Overbalance:**
  - Deto Pressure > Wellbore Pressure
  - Immediately after firing, guns become a pressure source

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Wellbore Dynamics – Net Load on the Gunstring - Animation

Wellbore Pressure - Time: 0.0000 sec

Axial Force on Gunstring

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Gunshock Software - Capabilities

- Coupled wellbore dynamics (fluids) & structural dynamics simulation
- Prediction of transient pressure around the guns / sand face
- DUB at the sand face (magnitude and duration) used to predict cleanup, skin, expected productivity / injectivity, sand production, etc
- Prediction of guns movement, velocity, acceleration, tubing and packer loads, cable tension, peak load on the weak point
- Gunshock is typically an issue with high pressure wells and/or large guns
- Software verified with an extensive database of perforating jobs (thousands)
Reliability of Predictions – Case 1

TCP job with 4.72-in high density guns – Fast pressure gauges: 2

Net perforation interval 200 ft
29-gram HMX big-hole charges at 20 spf
Top of safety spacer to packer 360 ft
   initially planned 180’
Bull-nose to sump packer 10 ft
Bull-nose to PBTD 267 ft
Initial wellbore pressure at depth 19,320 psi
14.8 ppg brine
Fast-Gauge Data

Actual vs. Simulated

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Tubing Axial Load Sensitivity to Tubing Length: 180-ft vs. 360-ft (as run)

Wellbore Pressure - Time: 0.000 sec

Pressure [psi]

Force [klbs (tension > 0)]

Time [sec]

Top of Gunstring
Bottom of Gunstring
Sump Packer

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Planner results:

2 7/8” Tubing Length cases: 180-ft vs. 360-ft (as run)

Tubing Compression reduced from -65 klbf to -10 klbf

Tubing Tension load reduced from 100 klbf to 30 klbf

Job was successfully executed

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Case #2 - Wireline Perforating with 7.0-in Guns - Unintentional Pull-Off (UPO)

- Gun System: 7" high density - 4505 DP String: WL head, CCL - 2 x 6m carriers Distance to TD: 25m Cable: 0.46” OD 7 conductor
- Green Weak Point strength: min 5450 lbf - max 6900 lbf
- After shooting, surface tension peaked at 9500 lbf - UPO!
- Customer requires an explanation of the incident and a technical justification demonstrating that the next runs will not have the same problem!
Unexpected Pull-Off Explanation - As Run - Two 7.0-in Guns (net 11m)

Spider Weak Point: Min 5450 lbf - Max 6900 lbf
Peak Load at the Weak Point 5900 lbf > 5450 lbf
As Run-2 Guns – UPO - Dynamic Force at the Weak Point up to 0.3 sec
Peak Load at the Weak Point 5900 lbf > 5450 lbf (Min WP Rating)

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Proposed – 1 Gun/Run - Dynamic Force at the Weak Point – Animation

Peak Load 3600 lbf < 5450 lbf (Min WP Rating)
Proposed – 1 Gun/Run - Dynamic Force at the Weak Point up to 0.3 sec
Peak Load 3600 lbf < 5450 lbf (Min WP Rating)
Wireline Perforating with 7.0-in Guns

UPO Understanding

- 2 gun simulation shows peak WP load of ~ 5900 lbf
- Above the min strength of the Spider WP: 5450 lbf
  - This explains the UPO
- 1 gun/run to reduce WP load to ~ 3600 lbf
  - \( \frac{3600}{5450} \times 100 = 66 \% \) of the minimum WP strength
- The job completed with multiple 1-gun runs w/o any problems
- Gunshock simulation provided an explanation for the UPO, and helped plan the way forward using available equipment on site
Case #3

Reduction of Dynamic Loads

TCP job with 7.0-in guns and Automatic Gun Release

Net perforation interval 50m.
39-gram HMX DP charges 12 spf
Top of safety spacer to packer 115 ft.
Bull-nose to PBTD 596 ft.
Wellbore pressure at depth 5,500 psi, 9.2 ppg
Reservoir pressure at depth 6,500 psi.
Automatic Gun Release

- Auto release run on top of gun string
  - Integrated with firing head
- Ballistic switch
  - Detonation triggers drop
- Guns drop immediately after firing
Initial Gun-Loading

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Initial Gun-Loading Simulation

Movement and Tubing Axial Load at the Auto Release up to 0.1 sec

- Wellbore Pressure
- Guns movement w/o shock abs.
- Tubing axial load w/o shock abs.

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Initial Gun-Loading

Optimized Gun-Loading to Minimize Gunshock Load

MENAPS13-03 Prediction of Perforating Wellbore Dynamics and Shock Loads
Optimized gun-loading to minimize gunshock load

Movement and Tubing Axial Load at the Auto Release up to 0.1 sec

Wellbore Pressure

Guns movement w/o shock abs.

Tubing axial load w/o shock abs.

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Initial vs. Optimized Gun-Loading to Minimize Gunshock Loads

Wellbore Pressure - Time: 0.000 sec

Tubing axial load w/o shock abs.

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**Initial vs. Optimized** Gun-Loading to Minimize Gunshock Loads

- Peak load on the Auto. Gun Release system: \(-58\) klbf vs. \(-1\) klbf
- Peak up-hole force on the packer: \(-47\) klbf vs. \(-3\) klbf
- Peak down-hole force on the packer: \(155\) klbf vs. \(75\) klbf
- Conclusion: Software optimization is crucial to prevent gunshock damage and non-productive time / $ loss
Reliable Shock Prediction

- Many variables to be considered:
  - Position of packers
  - Distance from PBTD
  - Size and length of conveyance tubulars
  - Type and number of shock absorbers
  - Types and sizes of guns and shaped charges
  - Guns loading strategies
  - Reservoir pressure and properties
  - Well Pressure and fluids
Prediction of Perforating Wellbore Dynamics and Shock Loads

Improves Service Quality and Reduces Non Productive Time

• Gunshock loads are very difficult to predict without reliable model

• Reliable and efficient model allows gunshock load reduction/optimization

• Reduction of gunshock loads reduces risks & improves Service Quality

• Crucial to prevent / minimize non-productive time / losses

Thank You