SLAP-41 - SPE-163549

Perforating Gunshock Loads
Prediction and Mitigation

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Outline

• Wellbore hydrodynamics - Pressure wave propagation animation
• Wellbore hydrodynamics and structural dynamics / gunshock animation
• Corkscrewed tubing joints analysis - TCP job with 7-in guns and 2-7/8-in tubing
  • Analysis of transient wellbore dynamics and gunshock loads
• Reduction of Dynamic Loads - TCP job with Automatic Gun Release System
  • Initial vs. Optimal gun-loading to minimize gunshock loads
• Wireline perforating - Prediction and verification of wellbore pressure and dynamic loads on the weak point
• Conclusions
Wellbore Hydrodynamics – After Creation of Perforation Tunnels

Detonator cord
Case
Liner
Primer charge
Explosive

Detonation front (30 GPa)
Tip (7,000 m/s)
Tail (500 m/s)

Jet tip ($15 \times 10^6$ psi)
Wellbore Dynamics - Fundamentals

- Dynamic Underbalance: Detonation Pressure < Wellbore Pressure immediately after firing guns become a pressure sink

- Dynamic Overbalance: Detonation Pressure > Wellbore Pressure immediately after firing guns become a pressure source
Wellbore Hydrodynamics and Structural Dynamics - Fundamentals

- Pressure waves propagate / reflect inside the wellbore
- Gunstring / Tools cross sectional area changes produce gunshock loads
Wellbore Dynamics – Axial Force applied on Gunstring - Animation

Wellbore Pressure Transient - Time: 0.0000 s

Axial Force on Gunstring

Depth from Wellhead [ft]

Pressure [psi]

Force [k lbs (tension > 0)]

Time [sec]
Instant when the Maximum Uphole Force on the Gunstring Occurs

Wellbore Pressure Transient - Time: 0.1129 s

Axial Force on Gunstring

Depth from Wellhead [ft]

Pressure [psi]

Time [sec]

Force [k lbs] (tension > 0)
Coupled wellbore dynamics (fluids) & structural dynamics simulation

Prediction of transient pressure around the guns / sand-face

Gun Shock is typically a problem with large guns

Prediction of guns movement, velocity, acceleration, tubing and packer loads, cable tension, peak load on the weak point

Software verified with a large database of perforating jobs (thousands)
TCP job with 7-in guns
Bent 2-7/8" tubing joints

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Wellbore Pressure and Dynamic Tubing Load – Up to 80 ms

Wellbore Pressure

Tubing axial load w/o shock abs.

Measured Depth [ft]

Pressure [psi]

Force [k lbs] (tension > 0)

Time [sec]

Top of Gunstring

Bottom of Gunstring

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Wellbore Pressure and Dynamic Tubing Load – 308 ms

Wellbore Pressure Transient - Time: 0.3082 s

Force above guns w/o shock abs.

Helical buckling
Plastic Deformat.

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Applied Force on Guns and Dynamic Tubing Load – Up to 720 ms

![Graph showing axial force over time](image-url)

- **Dynamic Force - No SXVAs**
- **Applied Force on Guns**

- **Axes:**
  - Y-axis: Axial Force [kN], (0 tension)
  - X-axis: Time [sec]

- **Annotations:**
  - Helical buckling
  - Plastic deformation

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Reduction of Dynamic Loads

TCP job with 7.0-in guns and Automatic Gun Release SXAR

- 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 SXAR

No-go
Bar hydrostatic firing head
Pull tube
Tubing connection
Release housing
Release fingers
Muleshoe
Break plug

Before firing
After firing

Release Housing
Release Pin
Support Sleeve
Release Mandrel
Release Piston
Break Plug

As Assembled

Detonating Cord Initiated, Gun Shots
Drop Off
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Initial Gun-Loading

Movement and Tubing Axial Load at AGR up to 0.1 sec
Initial Gun-Loading

Optimized Gun-Loading

to Minimize Gunshock Load

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Optimized gun-loading to minimize gunshock load

Movement and Tubing Axial Load / AGR up to 0.1 sec
Wellbore Pressure - Time: 0.000 sec

- Top of Gunstring
- Bottom of Gunstring

Guns movement w/o shock abs.

Displacement [inch] (downhole ≥ 0)

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Initial vs. Optimized Gun-Loading to Minimize Gunshock Loads

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Initial vs. Optimized
Gun-Loading to Minimize Gunshock Loads

Graph showing wellbore pressure and time at 0.000 sec. The graph compares the top and bottom of the gunstring with measurements in psi and ft. Another graph shows the force in klbs (downhole > 0) over time in seconds.
**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
Perforating on Wireline – Four 4-1/2-in DUB guns – DP 4512 charges
Cable – Surface Tension – Predicted vs. Measured

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Cable — Weak Point Peak Tension — Predicted vs. Measured

Axial Force [klbf] (>0 tension)

Time [sec]

~ 4 klbf

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Reliable prediction gunshock loads - TCP and WL

Effect of all components / variables can be analyzed:

• Position of packers
• Size and length of conveyance
• Type and number of shock absorbers
• Types and sizes of guns and shaped charges
• Guns loading strategies
• Reservoir pressure and properties
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• Reliable software predicts wellbore hydrodynamics and structural dynamics

• Prediction of transient wellbore pressure is crucial for
  • Cleanup – Productivity $+
  • Gunshock loads (whenever important) prevent $-

• Good prediction of gunshock loads allows risk evaluation & mitigation

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

THANK YOU! – Questions?