MENAPS-11-14
Reliable Prediction of Perforating Wellbore Pressure and Gun Shock Loads

Andy Martin, Alan Salsman, Carlos Baumann, and Harvey Williams
Prediction of Wellbore Pressure and Gun Shock Loads

- Model Overview
- Example of Wellbore Dynamics
- Wireline Perforating Example
- Scale Cleanup in Libya Example
- Completion Perforating Example
- HP Well Study
Wellbore Hydrodynamics - Timeline

Jet Formation

Pressure inside the gun varies widely, in both time and space (shocks subsiding, gun internal pressure decaying and reaching spatial equilibrium)

Perforation tunnel (& crushed zone) created

Charge detonation

Perforation cleanup

Wellbore dynamics

Is $P_{\text{gun}} > P_{\text{wellbore}}$ or is $P_{\text{gun}} < P_{\text{wellbore}}$?

This dictates wellbore dynamics and perforation cleanup

gun internal has reached spatial equilibrium, begins to “see” and interact with wellbore;
Now we can discuss “gun pressure”
Model Overview

- Guns and spacers act as a pressure sink generating pressure waves in the wellbore.
- Pressure waves acting on cross-sectional area changes produce gun shock loads.
- Model predicts interaction between guns and wellbore, and wellbore and reservoir.
- Discontinuous finite element method used to solve governing equations in both space and time.
Model Overview

- Prediction of transient pressure around guns and sandface for perforation clean up (DUB)
- Prediction of gun movement, tubing and packer loads, cable tension and weak point load
- Gun shock is typically an issue in very high pressure wells and/or with large OD guns
- Typically not an issue for most perforating jobs
- Software verified using our extensive database of jobs
Wellbore Dynamics Animation - Pressure

Wellbore Pressure Transient - Time: 0.0000 s

Depth from Wellhead [ft]

Top of Gunstring

Bottom of Gunstring

Pressure [psi]

Gauge Pressure

Pressure [psi]

Time [sec]
Wellbore Dynamics Animation - Force

Wellbore Pressure Transient - Time: 0.0000 s

Axial Force on Gunstring

Depth from Wellhead [ft]

Pressure [psi]

Force [k lbs (tension > 0)]

Time [sec]
Wellbore Dynamics Animation – Instant of Max Force

Wellbore Pressure Transient - Time: 0.1129 s

Axial Force on Gunstring

Depth from Wellhead [ft]

Pressure [psi]

Force [k lbs] (tension > 0)

Time [sec]
Example 4 ½” Wireline guns – IBP 3359
Example DUB Job – IPTC 14300

Wellbore Pressure - Time: 0.0000 sec

Bottom Gauge Pressure

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Example DUB Job – IPTC 14300

Gunsring Bottom Movement

Cable Load above Guns

Axial Force/Ball [mPa*sec]


Time [sec]

Darcy Skin

Total Skin

Perforation Skin

Exploration Well
Development Well 1
MAXR / K > 100 md

Development Well 2
Wireline / K < 10 md

-0.5
1.6

-0.6
-0.6
Example Implosion Scale Removal – SPE 144080
Example Reducing Dynamic Loads on Completions

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

Before firing

After firing

Packer
Debris Sub
Automatic Explosive Release

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String Movement – Original vs Modified

Wellbore Pressure - Time: 0.0000 sec

- Top of Gunstring
- Bottom of Gunstring

Guns movement w/o shock abs.

- Displacement [inch] (downhole 0)
- Time [sec]

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Axial Force Reduced on Tubing

Wellbore Pressure - Time: 0.0000 sec

Measured Depth [ft]

Pressure [psi]

Top of Gunstring

Bottom of Gunstring

Tubing axial load w/o shock abs.

Force [k lbs] (tension > 0)

Time [sec]

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Loads Reduced on Packer

Wellbore Pressure - Time: 0.0000 sec

Max pressure: 13600 psi

PKR annulus+tubing load w/o shock at:

Tower of Gasstring

Bottom of Gasstring
Simulation of original design shows axial forces on explosive gun release of 70 klbs and 160 klbs on packer.

Adding spacer at bottom of gun reduced load on packer to 100 klbs and force on explosive gun release to 3 klbs. String movement downwards.

Modified design was used on jobs and executed successfully.
Gun Shock Study in HP Wells – SPE 146809

19 3 1/2" IF 13.3#/ft Cut Joint
20 3 1/2" IF 13.3#/ft
21 Long Stroke Retrievable Packer
22 Cross Over
23 3 1/2" Joint
24 Centralizer
25 R.H. Release Safety Joint
26 Safet Joint
27 3 1/2" Joints
28 Long Slot Debris Sub
29 Pup Joint
30 3 1/2" IF
31 Electronic Firing Head
32 Shock Absorber
33 Shock Absorber
34 7.00" Safety Spacer
35 Slick Top
36 7.00" HP HSD
37 Centralized at 8.25
38 7.00" HP Blank
39 Centralized at 8.25
40 7.00" HP HSD
41 Centralized at 8.25
42 7.00" HP HSD
43 Centralized at 8.25
44 Threaded Bull Nose
45 77/8 EUE
46 Centralized at 8.25

Gun connector
Detonating cord
Shock element
Floating piston
Operating piston
Pore
Trigger section
Gun connection
Some tubing damage on one well. If simulation run before the job, helical buckling with plastic deformation would have been predicted.
- Recovered crushable elements from explosive activated shock absorbers are evidence of loads. Model can be used to predict shock loading with or without shock absorbers.
Summary

- Wellbore dynamics are accurately predicted for DUB and DOB modeling
- Forces on completions are accurately predicted
- Loads on wireline strings are accurately predicted
- Solutions to reduce gun shock can be quickly analyzed
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Questions?