Modeling and Testing of Sand Jet Perforation as a Safer Alternative to Conventional Tubing-conveyed or E-line Explosives Techniques (IPS-12-19)

Presenting Author: Michael W. Mitchell
Co-Authors: G. Ingram, M. Haq, S. Fagley, J. Bramwell
Sand Jet Perforator System

- Introduction
- Product Development
- Prototype Perforator
- Laboratory Testing
- Advantages
- Applications
- Conclusion
- Questions
Introduction to Sand Jet Perforators (SJPs)

- SJPs are down hole tools that utilize:
  - High pressure abrasive laden fluids
  - Perforate casing, cement, and extend cavity into reservoir
- SJPs are safer
  - Tubing conveyed perforating
  - E-line perforating
- SJPs run on jointed tubing or coiled tubing
  - Depth
  - Temperature
- SJPs can be customized for specific phasing
  - Jet nozzle quantity
  - Orifice diameter
Product Development

Sand Jet Perforator CFD Erosion Modeling

- CFD fluid simulation
  - Sand particle motion analysis
  - Erosion modeling with dynamic mesh
- Erosion is dependent on
  - Fluid conditions
  - Sand particle, casing & cement properties
- No structural analysis is required
Product Development

CFD Erosion Modeling Configuration

Geometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle Diameter ($D_n$)</td>
<td>0.125in &amp; 0.188 in.</td>
</tr>
<tr>
<td>Nozzle length ($L_n$)</td>
<td>1.25in</td>
</tr>
<tr>
<td>Standoff distance from nozzle to casing ($S_d$)</td>
<td>0.08-0.35in</td>
</tr>
<tr>
<td>Casing OD/ID</td>
<td>4.5/3.5in</td>
</tr>
</tbody>
</table>

Flow Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>26 - 43gpm</td>
</tr>
<tr>
<td>Perforation pressure</td>
<td>2500psi</td>
</tr>
<tr>
<td>Reference conditions</td>
<td>75degF &amp; 14.5psi</td>
</tr>
</tbody>
</table>

Concrete Property

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>7500psi</td>
</tr>
</tbody>
</table>

Sand Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>1ppg</td>
</tr>
<tr>
<td>Size</td>
<td>20/40 Ottawa</td>
</tr>
</tbody>
</table>

Casing Material Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>2.87lbm/in³</td>
</tr>
<tr>
<td>Young's modulus</td>
<td>30M psi</td>
</tr>
<tr>
<td>Poisson's ratio</td>
<td>0.3</td>
</tr>
<tr>
<td>Yield stress</td>
<td>110ksi</td>
</tr>
</tbody>
</table>

Schematic of the SJP model
Product Development

CFD Erosion Modeling

1st Cut Through Casing

2nd Cut Through Cement
Prototype Perforator

- Contains a flow actuated valve
  - Allows function of hydraulic tools below when open
  - Allows high pressure abrasive perforating when closed
  - Switch flow is adjustable from 40–185gpm (1–4.5 bpm)

- Enables multiple operations during a single trip
  - Operates a motor for milling operations then perforates
  - Reactivates motor for well cleanout
  - Sets a plug then perforates
Laboratory Testing

- Cutting fluid of density 9 lbs./gal
  - Gel, water and 20/40 sand at 1ppg concentration
- Minimum cutting pressure (2500 psi)
- Cutting time ranges from 15 to 30 min
- Two and Four nozzle patterns per respective orifice diameter
  - 0.125” (3.175 mm)
  - 0.188” (4.763 mm)
- Jet stand-off 3 times orifice diameter
- 4.5 in. OD casing of P110 material (0.50” thickness)
Laboratory Testing Results

<table>
<thead>
<tr>
<th>OUTPUT DATA 4-1/2” OD WITH 1/8” NOZZLES</th>
<th>CUT # 1</th>
<th>CUT # 2</th>
<th>CUT # 3</th>
<th>CUT # 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting Time ( min)</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Avg. Flow Rate (gpm)</td>
<td>84</td>
<td>84</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>Avg. Perf. Pressure (psi)</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>Avg. Perf. depth (inches)</td>
<td>2.63</td>
<td>2.90</td>
<td>3.23</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Laboratory Testing Results

<table>
<thead>
<tr>
<th>OUTPUT DATA 4-1/2&quot; OD WITH 3/16&quot; NOZZLES</th>
<th>CUT # 1</th>
<th>CUT # 2</th>
<th>CUT # 3</th>
<th>CUT # 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cutting Time ( min)</strong></td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td><strong>Avg. Flow Rate (gpm)</strong></td>
<td>84</td>
<td>84</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td><strong>Avg. Perf. Pressure (psi)</strong></td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td><strong>Avg. Perf. depth (inches)</strong></td>
<td>3.5</td>
<td>3.75</td>
<td>4.25</td>
<td>6.25</td>
</tr>
</tbody>
</table>
Comparison of CFD & Test Results

[Diagram showing comparison of cutting depth vs. time for different nozzle sizes (1/8" and 3/16") in terms of both test results and CFD simulations.]

Cut through Steel
# Job Modeling Capabilities

![Job Modeling Capabilities](image)

## Calculation Table

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Surface</th>
<th>Downhole</th>
<th>Power Curve</th>
<th>Impact Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Flow</td>
<td>Gas</td>
<td>Output Torque</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
<tr>
<td>Liquid Flow</td>
<td>% Gas</td>
<td>Annulus Pressure at Motor</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
<tr>
<td>Choke</td>
<td>% Gas</td>
<td>Pressure Loss in String</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
<tr>
<td>Loss Calibr</td>
<td>Pump Pressure</td>
<td>Torque Over Motor</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
<tr>
<td></td>
<td>% Gas</td>
<td>Total Flow into Motor</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Gas into Motor</td>
<td>No. of Holes</td>
<td>No. of Holes</td>
</tr>
</tbody>
</table>

## Parameters

- **Motor & BHA**: Sand Jet
- **Depth**: 0 ft
- **Sand Conc**: 0.25 in
- **Formation Strength**: 5000 psi
- **Sand Mesh Size**: 40
- **Nozzle Count**: 12.5
- **SJP OD**: 0.125 in
- **Nozzle Diameter**: 0.125 in
- **Formation Strength**: 5000 psi
- **Sand Conc**: 1
- **Nozzle Velocity**: 437 ft/s
- **Nozzle Losses**: 2538 psi
- **Wall Perf Time**: 53 seconds
- **Total Perf Time**: 11 minutes

## Pressure Curves

- **Perforation Depth (inches)**: 0.437
- **Impact Pressures**: At Steel 2542 psi, At Depth 1749 psi

## Additional Data

- **String Section**
  - Length: 6000 ft
  - Thickness: 0.151 in
- **Volume**: 1086.3 gallons
- **Hydrostatic Pressure in String**: 5389 psi
- **Charge Time**: 22 minutes

## Completion/Logging

- **Surface Temp**: 14320.0 F
- **Core**: 50 ft
- **Current Measured Depth**: 14320.0 ft
- **Current V. Depth**: 13115 ft
- **Total Length**: 14320.0 ft
Abrasive Perforating Advantages

- Reduces near wellbore friction effects → Better Frac
- Does not require explosives → Safer operations
- Does not induce formation damage → Lower breakdown pressures & increased permeability
Applications

- Perforating new vertical and horizontal completions
- Re-perforating trouble zones
  - Substantial formation damage
  - Production reduced due to the sediment build-up
- Perforation and treatment of coal bed methane wells
- Integrated one-trip applications that utilize
  - Bridge plugs for zonal isolation
  - Motors for well cleanout prior to perforating
- Cut tubing or slotting
Conclusions

- **CFD Erosion Modeling**
  - Pure CFD erosion modeling
  - P110 material and 7500 psi C.S.

- **Laboratory Testing**
  - CFD results correlates well with test results
  - Perforation depth of up to 6.25”
  - ½” thick P110 material and 7,500 psi C S. Concrete

- **Perforator Versatility**
  - Bridge plugs for zonal isolation
  - Motors for well cleanout prior to perforating

- **Safer because no explosives is required**
  - Eliminate concerns of misfiring or unexploded ordnance returning to surface
  - Reduce transportation cost
  - Eliminate military escort for international locations
Questions?

Contact Info:

Michael.Mitchell3@weatherford.com

1-713-983-5000