The Effects of Fluid “Shock” on the Efficiencies of Milling Composite Bridge Plugs

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Composite Plug Milling

• Most common CT operation in USA
  – Approximately 140,000 plugs installed in 2010
  – Over 9,000 associated CT jobs

• Typically 2” CT Unit
  – 2 7/8” or 3 3/8” PDM
  – Mill or Bit

• Typical completions
  – 4 1/2”, 5” or 5 1/2”
  – Lateral reach ~ mostly 4,000 to 5,000 ft (1,200 to 1,500 m)

• Operational efficiencies reduce with reach
  – Lower weight on bit
Milling Efficiencies in Extended Reach

- Reaching the limits of CT’s work ability
  - Approaching CT helical buckling limits
  - Stick/Slip
  - Significantly reduced milling efficiency due to poor weight on bit control
  - Planning on ~1,200 lbf/500 daN weight on bit
Extending Reach Options

• Coiled Tubing Size
  – Larger the pipe, the further we can go before onset of buckling

• 2 3/8” OD Coiled Tubing
  – Reduced fatigue life, logistical challenges

• Reduced Drag/Friction
  – Metal-to-Metal Lubricants
  – Beads

• Lubricants
  – Significant volumes to reduce friction by 15-20%
  – Limited benefits observed when debris present
Extended Reach Options

• **Tractors**
  – Provide tensile force at BHA
  – Increased BHA length, reduced RIH speed
  – Smooth control of weight on bit?

• **Vibration/Water Hammer**
  – Provide tensile load along the CT
  – For several years, most commonly used assistance method in US
Functionality of Water Hammer Tool

• Tool that temporarily restricts fluid flow to the lower BHA
  – Repeated multiple times per second

• This creates a pressure build up then release

• Resulting in a shock/pulse that is transmitted back up the coiled tubing
  – Pressure pulse negatively impacted with two phase flow
Physical Results of Water Hammer Tools

- Extended reach
- Improved milling efficiency on plugs set deeper in the well
Objectives for Field Study

• Analysis from three different water hammer tools used in 11 wells
  – Results compared to 9 well operations conducted without a hammer tool
• Calculate friction and net tensile benefit
• Calculate milling efficiency
• Other pertinent variables
  – Number of plugs milled per wiper (short) trip
  – Wiper trip speed
Data Set

• Common to Study
  – CT Supplier
  – CT data acquisition
  – Force analysis software
  – Personnel reviewing the results

• Variables in Study
  – BHA supplier
  – Type of mill or bit
  – Composite plug type
  – Client and location
  – Completion size
  – Personnel
    • CT operator
    • Company rep
    • Motor hand
Method of Analysis

• Force Analysis
  – Perform force matching to determine coefficient of friction and
  – Calculate the associated tensile load created by each water hammer tool

• Milling Efficiency
  – Review milling time for each plug
  – Confirm efficiency by removing any NPT from motor stalls, resetting the tool etc
Tensile Benefits

2" Actual Comparison

- Depth (ft)
- Weight (lbs)

- Weight No Tool
- Weight W/ Tool
Sample Of Milling Efficiency

Sample Plug Milling Efficiency Chart

- Wiper Trip After Plug
- Stalls/Pickups
- Active Milling

Time (min)

Plug
Results – No Hammer Tool
9 Wells in 3 States

• Force Analysis
  – 6 wells 0.24 coefficient of friction, 3 wells 0.19 – 0.22, lubricants used in 8 of 9 wells
  – No tensile benefits observed (no hammer tools)

• Plug Milling Efficiency
  – 93 plugs milled
  – Average milling time 37.95 mins
  – Average active milling time 30.78 mins
  – Efficiency 81.1%

• Other Data
  – Wiper trips ever 2.2 plugs at speeds of 35-45 ft/min/10-14 m/min
  – Some speeds in excess of 60 ft/min / 18 m/min
  – Lateral lengths 3,500 ft to 5,500 ft/1,000 m to 1,400 m
Results – Hammer Tool A
5 Wells in 2 States

• Force Analysis
  – 4 wells 0.24 coefficient of friction, 1 wells 0.16 lubricants used in 2 of 5 wells
  – No tensile benefits observed

• Plug Milling Efficiency
  – 33 plugs milled
  – Average milling time 41.27 mins
  – Average active milling time 32.97 mins
  – Efficiency 79.9%

• Other Data
  – Wiper trips ever 2.2 plugs at speeds of 45-75 ft/min / 14-23 m/min
    • Stuck in hole issues
  – Circulation rate too low for effective use ?
Results – Hammer Tool B
3 Wells in 1 States

- **Force Analysis**
  - 3 wells 0.24 coefficient of friction, lubricants
  - No tensile benefits observed – significant debris in well working against reach

- **Plug Milling Efficiency**
  - 20 plugs milled
  - Average milling time 91.45 mins
  - Average active milling time 80.4 mins
  - Efficiency 87.9%

- **Other Data**
  - Wiper trips ever 2.3 plugs at speeds of 35-45 ft/min/10-14 m/min
  - One well exhibited very poor milling times from plug one, resulting in extreme milling times
  - Lateral lengths approx 4,000 ft/1,200 m
Results – Hammer Tool C
3 Wells in 1 States

• Force Analysis
  – 3 wells 0.24 coefficient of friction, no lubricants
  – 1,200 to 1,400 lbs tensile benefit observed

• Plug Milling Efficiency
  – 18 plugs milled
  – Average milling time 25 mins
  – Average active milling time 22.2 mins
  – Efficiency 88.9%

• Other Data
  – Wiper trips ever 2.3 plugs at speeds of 35-45 ft/min / 10-14 m/min
  – Most positive tensile benefits seen
  – Lateral length 4,700 to 5,800 ft / 1,400 to 1,750 m
Results Comparison Well

<table>
<thead>
<tr>
<th>Plugs</th>
<th>Avg Milling Time (mins)</th>
</tr>
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<tbody>
<tr>
<td>1 – 9</td>
<td>47</td>
</tr>
<tr>
<td>10 – 13</td>
<td>99</td>
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<tr>
<td>14 - 17</td>
<td>16</td>
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Use of Water Hammer Tools

Conclusions

• On correctly planned and executed operations, water hammers have reduced average plug milling times

• On incorrectly planned and executed operations no hammer tool benefits were observed

• Achievable lateral depths for efficient plug milling can be increased

• Recording and calculating milling times and force analysis promotes an engineered approach to operational planning
Reference

• SPE 147158 ‘The Effects of Fluid Hammer Tools on the Efficiencies of Coiled Tubing Plug Milling – A Comparative Best Practices Study’

• SPE ATC Denver 2011
Questions?

Thank you to ICoTA Canada for the opportunity to present today