Optimizing Horizontal Wellbore Design to Extend Reach with Coiled Tubing

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Introduction

• What?
  • How can wellbore designs be altered to maximize coil tubing reach capacity?
  • Concentrate on key wellbore variables that effect coil tubing lockup depths
  • Maintain a set of control variables
  • Compare field data to model results
  • Provide a set of recommendations for drilling of wells

• Why?
  • Allow for wellbore cleanouts post frac
  • Allow all frac stages to be stimulated
  • Prevent sterilizing production and reserves due to inability to reach TD
Background

- **Area of interest:**
  - Western Canada, Montney Formation

- **Investigation drivers:**
  - CT annular frac design
  - Wellbore interventions

- **General:**
  - Wellbore lengths
  - # of stimulations
  - Trends

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**Western Canada - Horizontal Well Statistics**

1. Canadian Discovery, Western Canadian Frac Database

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Horizontal Wellbore Design Factors

- **Build Rate**
  - Expected to have largest impact

- **Turn Rate**
  - Multi-well pad applications

- **Casing Size**
  - Cost
  - Artificial Lift
Limiting Factors

- Directional tools
- Geology
- Surface access
- Stimulation System
- Economics

Fox Creek, Alberta
Coil Tubing Model Design

Manipulated Variables

- **Build Rate**
  - 0 – 20 ° / 30 m

- **Turn Rate**
  - 0 – 6 ° / 30 m
  - ‘Build and turn’

- **Casing Size**
  - 114 mm
  - 139 mm
  - 139 mm w/ 114 mm lateral
## Coil Tubing Model Assumptions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Assumed Value</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coil tubing OD</td>
<td>50.8 mm</td>
<td>2”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Match field data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Common size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annular velocity limits</td>
</tr>
<tr>
<td>TVD</td>
<td>2000 m</td>
<td>6561 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Match field data</td>
</tr>
<tr>
<td>Friction Coefficient</td>
<td>0.3</td>
<td>Conservative value used</td>
</tr>
<tr>
<td>Lateral</td>
<td>Smooth / Flat</td>
<td>Impractical to model random variations</td>
</tr>
<tr>
<td>Fluid</td>
<td>Fresh Water</td>
<td>Match field data</td>
</tr>
<tr>
<td>Reference Point</td>
<td>8 degrees / 30 m</td>
<td>Match field data</td>
</tr>
</tbody>
</table>
Results - Build Angle

Percent Change in Lateral Length vs Build Angles in 114 mm Casing

Note: Y-axis depicts percentage change in lateral length relative to an 8° /30m build rate

Build Effect = 5.6%/deg

Build Effect = -1.25%/deg
Results – Turn Angle

Lateral Section vs Build Angles (114 mm casing)

- 0 degree turn
- 2 degree turn
- 4 degree turn
- 6 degree turn

Turn Effect (239m)
Turn Effect (167m)
Results – Casing Size

Change in Percent Lateral (%) vs Build Angles (114 mm casing)

- Change in percentage (%)
- Build Angles (Degree)
- Δ = 7.2%
- Δ = 4.8%

Change in Percent Lateral (%) vs Build Angles (139 mm casing)

- Change in percentage (%)
- Build Angles (Degree)
- Δ = 5.2%
- Δ = 1.8%
Results – Sinusoidal and Helical Buckling

Sinusoidal Bucking and Helical Buckling (114 mm casing)

- 0 degree turn (Sin)
- 2 degree turn (sin)
- 4 degree turn (sin)
- 6 degree turn (sin)
- Turn (sin)

Coil Depth (m) vs. Build Angles (Degree)
# Matching Field Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubrication Additives</td>
<td>Friction Coef.</td>
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<tr>
<td>Wellbore DLS</td>
<td>Wellbore comparison</td>
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<tr>
<td></td>
<td>Coil behavior</td>
</tr>
<tr>
<td>Fluid Types</td>
<td>Friction coef.</td>
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<td>Buoyancy</td>
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<tr>
<td>Wellbore Pressures</td>
<td>Coil behavior</td>
</tr>
<tr>
<td>Debris</td>
<td>Coil behavior</td>
</tr>
<tr>
<td></td>
<td>Drag</td>
</tr>
</tbody>
</table>

Match model to field data.

Debris sample, stage tool millout.
Quantifying Model to Field Data

- 30 well data set
- Compare matched friction coefficient
- Large variety of well types
- Casing size ignored (proven to be lower impact variable)
- Build to 45 – turn @ 4°/30m shown to be lowest average friction coefficient

<table>
<thead>
<tr>
<th>Average build (degrees / 30m)</th>
<th>Build-Land</th>
<th>Build-land-turn</th>
<th>Build to 45 deg - start turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>0.150</td>
</tr>
<tr>
<td>5</td>
<td>0.300</td>
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<td>0.247</td>
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<tr>
<td>6</td>
<td>0.300</td>
<td>0.270</td>
<td>0.263</td>
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<td>7</td>
<td>0.300</td>
<td>0.213</td>
<td>0.260</td>
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<tr>
<td>8</td>
<td>0.300</td>
<td>-</td>
<td>0.225</td>
</tr>
</tbody>
</table>
Conclusions

**Build Angle**
- Directly related to the maximum coil reach, as well as friction coefficient.
- Relative effect of decreasing the build angle (relative to 8 degrees/30m) drastically increases reach (up to 20%); while the loss is not as drastic for the same change (-5%).
- Increasing build angle above 12 degrees / 30 m shows a diminishing losses.
- Decreasing build angle below 4 degrees / 30 m shows diminishing gains.

**Turn Angle**
- Lower turn rates are directly related to coil reach, as well as friction coefficient.
- A build and turn profile provides an extended reach and lower friction coefficient relative to when a turn is completed in the lateral section of the well.

**Casing Size**
- 114 mm casing allows for extended reach versus 139 mm casing.
- 114 mm casing is more sensitive to changes in turn rates than 139 mm casing.
- Casing size effect is dominated by the size of casing from surface to the heel of the well.

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**Build rates of 4 ° /30m**

**Turn rates of 2-3 ° /30m**
‘Build and turn’

**114 mm monobore design**
Thank You / Questions

Acknowledgements

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4. Jeff Liu, Trican Well Services