Technological Enhancement of PC Pumps for Heavy Oil Production

Courtney Ward P.Eng.

April 28, 2008
Development and Test Area

* Lloydminster
History

• Initial PC Pump Installations
  – Initial install occurred 1979; first pumps with any success were ran in Feb 1983
  – These were wells near Elk Point Alberta (120km NE of Lloydminster)
  – Amoco Canada Petroleum Company Ltd.
  – Pumps were 28-9 (28 ml/rev and 9 stages)
    • Corresponds to a 4-600 with current nomenclature (4 m3/d/100rpm and 600 m lift)
  – None of the first 3 pumps installed ran 120 days
  – Reasons for failure
    • Over pressured (pump could not generate enough pressure to overcome the hydrostatic pressure required to lift the heavy viscous sandy oil)
    • Sanded suction so pump ran dry
History Continued

• By the end of 1985
  – The major problems were corrected
  – 110 wells in the Elk Point Area were operated by a pc pump

• By the late 1990’s
  – Well operators suspected that 1 of the reasons for poor pump efficiency was the oil was so viscous it could not enter the pump fast enough with low fluid levels

• Today
  – There are approximately 10,000 heavy oil wells in the Lloydminster Area (defined as a 200 km radius of Lloydminster)
  – 5,000 are active or producing
Recovery Efficiency

- Before 1990
- CHOPS
- CSS
- SAGD (cold + steam)

Source: ARC

© 2007 Weatherford. All rights reserved.
Typical Lloydminster Area Heavy Oil Reservoirs Are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>26,000 sq km</td>
</tr>
<tr>
<td>Depth</td>
<td>400-600 m</td>
</tr>
<tr>
<td>Depositional Environment</td>
<td>Cretaceous Deltaic Sand (unconsolidated)</td>
</tr>
<tr>
<td>Oil Density @ 20C</td>
<td>960-990 kg/m³</td>
</tr>
<tr>
<td>Dynamic Oil Viscosity @ 20C</td>
<td>Up to 131,000 mPa.s</td>
</tr>
<tr>
<td>Reservoir Porosity</td>
<td>25 - 35%</td>
</tr>
<tr>
<td>Reservoir Permeability</td>
<td>0.5 – 8.0 darcies</td>
</tr>
<tr>
<td>Reservoir Temperature</td>
<td>20°C</td>
</tr>
<tr>
<td>Virgin Reservoir Pressure</td>
<td>3500 kPa</td>
</tr>
<tr>
<td>Original GOR</td>
<td>20-30 m³/m³</td>
</tr>
<tr>
<td>Original Sw</td>
<td>15%</td>
</tr>
<tr>
<td>Reservoir Sorting</td>
<td>Moderate to well</td>
</tr>
</tbody>
</table>
# Lloydminster Area Production Operating Ranges

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC Pump Operating Speed</strong></td>
<td><strong>50-250 rpm</strong></td>
</tr>
<tr>
<td><strong>Oil Production</strong></td>
<td><strong>1-100 m³pd</strong></td>
</tr>
<tr>
<td><strong>Water Production</strong></td>
<td><strong>1-300 m³pd</strong></td>
</tr>
<tr>
<td><strong>Sand Production</strong></td>
<td><strong>Trace to 80%</strong></td>
</tr>
</tbody>
</table>
Lloydminster Operating Philosophy

• CHOPS (Cold Heavy Oil Production with Sand)
  – Alternate Names
    • Cold Flow
    • Cold Heavy Oil Production (CHOP)
    • Cold Production
  – Working Definition
    • Aggressive production of sand along with heavy oil under primary production process
Cold production theory states that continuous sand production is required to maintain and/or maximize oil production.

Initial sand production rates can be in excess of 80% by volume—this decreases over time and settles at about 1% by volume on a cold production well.
CHOPS - How is it accomplished?

- Perforations are maximum diameter and density
  - 26 shots per meter and 2.54cm diameter with Extra Big Hole Charges (19.8cm API Standard Penetration Test)
- Start well up at maximum production rate; i.e. maximum drawdown on formation
- Maintain continuous sand (and oil) production for as long as possible
Sand Production

• Reservoir Impact
  – long wormholes in preferred, high permeability layers
  – short lateral drainage distances to high permeability channels
  – Provide paths for CHOPS products to flow

Photo courtesy Dr. Ron Sawatzky- ARC
Sand Production Problems

- Forms bridges in casing/tubing annulus restricting flow to pump intake
- Settles in sump restricting flow to pump
- Slugs can fill pc pump cavities resulting in excessive torque
- Settles out in tubing causing sand bridges resulting in excessive pump discharge pressures
- Settles out in the flow line

**NOTE:** Sand production problems are significantly compounded with the production of free water
Sand Production Solutions

• Keep the sand moving

• The heavier more viscous the oil; the more sand it will carry

• If water cut results in sand falling out – load well with oil to:
  – Increase oil cut and ability to carry sand
  – Increase intake velocity
  – Increase velocity through tubing and flow line
  – Reduce overall % of sand in the system
How To “Keep Sand Moving”

• “Control” oil volume in order to carry sand-load with oil if required

• Utilize a pump that will operate at high efficiency and maintain required fluid velocities to move sand

• Use a pump capable of handling high percentages or slugs of sand; i.e. use a pump:
  – At low rpm
  – With soft elastomer
  – With a “looser” fit
  – With increased lift
  – With a short/broad cavity

• Monitor production to ensure sump or pump intake does not plug and be prepared to do “flush byes” or circulate sand out of the sump if production declines
PC Pumps With Heavy Oil Geometry (designed to operate at high efficiencies with heavy viscous oil and produce large volumes of sand)

NOTE: all pump volumes are m³ per 100 rpm
Comparison-Heavy Oil Pumps versus “Conventional”

NOTE: all pump volumes are m³ per 100 rpm
# Pump Cavity Cross-Sectional Area Comparisons

<table>
<thead>
<tr>
<th>Pump Volume (m³ per 100 rpm)</th>
<th>Stator Tube OD</th>
<th>Cavity Opening Cross-Sectional Area</th>
<th>Cross Sectional View*</th>
<th>Rotor Pitch View*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>sq mm</td>
<td>% Increase</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>75.0</td>
<td>477</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>88.9</td>
<td>871</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>101.6</td>
<td>1103</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>90.0</td>
<td>819</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>88.9</td>
<td>1006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>108.0</td>
<td>1452</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>88.9</td>
<td>987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>114.3</td>
<td>1767</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>114.3</td>
<td>1839</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>100.0</td>
<td>1187</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*diagrams are to scale
Heavy Oil Line of Pumps Features and Benefits

• Features
  – Increased pump cavity cross-sectional area
  – More aggressive rotor pitch angle
  – Decreased pitch length

• Benefits
  – Requires less pressure (head) to fill the pump cavity resulting in increased cavity fill up
  – Improved movement of heavy oil and sand
  – Shorter pump length
  – Improved ability to pump large particles like pyrite or perf debris
# Installations For "Heavy Oil Line of PC Pumps"

<table>
<thead>
<tr>
<th>Pump Volume (m³ per 100 rpm)</th>
<th>Date of Initial Installation</th>
<th>Number of Pumps Installed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Feb-08</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>May-02</td>
<td>1217</td>
</tr>
<tr>
<td>23</td>
<td>Feb-08</td>
<td>1</td>
</tr>
<tr>
<td>35</td>
<td>Feb-07</td>
<td>18</td>
</tr>
<tr>
<td>52</td>
<td>Mar-07</td>
<td>30</td>
</tr>
</tbody>
</table>

*Data as of Feb 29, 2008
Performance Example

5-1 PC Pump Model 13 Performance

LOADEFLUSH FREQUENCY
PRIOR PUMP: 14 loads in 319 days or 16 loads/yr
13-1500: 0 loads in 92 days or 0 loads/yr

© 2007 Weatherford. All rights reserved.
Performance Example

13-35 PC Pump Model 35 Performance

- Efficiency (%)
- Gas Pressure (kPa)
- rpm
- Produced Fluid m³/day
- Torque (ft-lbs)

LOAD/FLUSH FREQUENCY

PRIOR PUMP: 5 loads in 127 days or 23 loads/yr
35-1500: 6 loads in 233 days or 7 loads/yr

© 2007 Weatherford. All rights reserved.
Performance Example

8-23 PC Pump Model 35 Performance

- Efficiency (%)
- Gas Pressure (kPa)
- rpm
- Produced Fluid m³/day
- Torque (ft-lbs)

LOAD/FLUSH FREQUENCY

Prior PUMP: 5 loads in 53 days of 34/yr

35-1590: 14 loads in 353 days of 14/yr

© 2007 Weatherford. All rights reserved.
Performance Example

12-35 PC Pump Model 35 Performance

- Efficiency (%)
- Gas Pressure (kPa)
- rpm
- Produced Fluid m³/day
- Torque (ft-lbs)

LOAD/FLUSH FREQUENCY

Prior Pump: 23 loads in 371 days or 23/yr

35-1560: 1 load in 42 days or 9/yr

Dec
Jan
Feb

100% Efficiency Line

© 2007 Weatherford. All rights reserved.
Performance Example
Performance Example

3-13 PC Pump Model 35 Performance

- Efficiency (%)
- Gas Pressure (kPa)
- rpm
- Produced Fluid m³/day
- Torque (ft-lbs)

LOAD/FLUSH FREQUENCY
PRIOR PUMP: 16 loads in 123 days or 49/yr
36-1560: 21 loads in 262 days or 25/yr

© 2007 Weatherford. All rights reserved.
Performance Example
Performance Example

13-27 PC Pump Model 52 Performance

LOAD/FRESH FREQUENCY
PRIOR PUMP: 4 loads in 35 days or 42yr
52-1500: 5 loads in 346 days or 5yr

© 2007 Weatherford. All rights reserved.
Conclusions

• PC Pumps producing heavy sandy viscous oil with a cavity that is shorter and has a larger cross-sectional area:
  – Do produce at higher pump efficiencies
  – Do reduce the number of load/flushes required to keep the well producing

• Just like elastomers are chosen for specific applications; pump geometry should be a consideration as well
Questions