New Method to Reduce Pump Slippage

Bill Elmer, P.E.
Enclave Artificial Lift Technologies LLC
Think Out of the Box

• This stale phrase is appropriate for this presentation

• Our history of running pumping units at fixed speeds, even while on VFD, put blinders on our industry
  – This kept us from seeing a simple way to reduce slippage

• Today, you will leave thinking differently than when you walked in
Referencing previous ALRDC Presentation

• “Use of the Pump Slippage Equation to Design Pump Clearances”
  – Lynn Rowlan, James N. McCoy, and James F. Lea
  – Presented at 8th Annual Sucker Rod Pumping Workshop in Oklahoma City September 25-28, 2012

• This presentation represents the industry’s current thinking on pump slippage.
  – No dispute, in fact it is very helpful in making this presentation.
  – 5 slides come from this presentation, some twice
Pump Slippage

1) Fluid that leaks back into pump between the Plunger OD and the Barrel ID
2) Leaks into the pump chamber between the standing valve and traveling valve
3) When traveling ball is on Seat.

Pump Efficiency = BPD Tank / BPD Pump

Slippage % = Slippage BPD / BPD Pump
VSD Slows SPM Until Slippage = Displacement

2” Plunger, 1” Rod String, 0.009” Clearance, 12” Sheave

Wrf + Fo Max

0.6 HP

0.6 SPM, Input 4.8 HP, 0% System Efficiency

0 BPD in Tank, 29.0 BPD @ 104” Pump Stroke

100 Sec/Stroke

0.7 HP

0.7 SPM, Input 5 HP, 2.4% System Efficiency

4.7 BPD in Tank, 34.4 BPD @ 105” Pump Stroke

85.53 Sec/Stroke
New Method to Reduce Pump Slippage

• Note that in the testing, when the SPM is listed as 0.6 SPM, or 0.7 SPM, this means that the VFD was operating at a fixed frequency. In the case of the previous slide, perhaps 3 or 4 Hertz.

• The next slide makes this same assumption, that the VFD was operated at a fixed frequency.
Pump Speed vs Pump Efficiency

\[ \text{Pump Efficiency} \% = \frac{\text{Surface Rate}}{\text{Pump Displacement}} \times 100 \]

As the SPM increases the Pump Efficiency Increases: Slippage Volume is a Smaller % of Pump Displacement
Patterson Slippage Equation

\[ 453 \cdot \left[ (0.14 \cdot SPM) + 1 \right] \frac{DPC^{1.52}}{L\mu} \]

Patterson Equation modified ARCO-HF equation to include the effect of SPM on slippage

Available:
QRod Tool - “Pump Slippage Calculator”
1) **Point A to B** pressure acting on closed SV gradually transferred from tubing at point A to be fully carried by the Closed TV at point B.

2. **Point B to C**, plunger carries full differential pressure across Closed TV

3) **Point C to D** pressure across closed TV gradually transferred from rods to be fully carried by the Closed SV at point D.

4) **Point D to A**, TV open as fluid in the pump is displaced through the traveling valve on the down stroke

---

Sept. 25 - 28, 2012

Sept. 15 - 16, 2015
There is no deleterious slippage during the downstroke.

VSD Slows SPM Until Slippage=Displacement

2” Plunger, 1” Rod String, 0.009” Clearance, 12” Sheave

0.6 HP
0.6 SPM, Input 4.8 HP, 0% System Efficiency
100 Sec/Stroke
0 BPD in Tank, 29.0 BPD @ 104” Pump Stroke

0.7 HP
0.7 SPM, Input 5 HP, 2.4% System Efficiency
85.53 Sec/Stroke
4.7 BPD in Tank, 34.4 BPD @ 105” Pump Stroke
Observations about Pump Slippage

• Pump Slippage during the Upstroke reduces system efficiency
  – Since standing valve is open, slippage replaces fluid that would normally be entering pump
  – Results in less fluid entering the pump each upstroke

• Pump slippage during the Downstroke does not impact system efficiency
  – Due to a closed standing valve, downstroke slippage does not result in less fluid entering the pump. (None enters during downstroke anyway.)
New Method to Reduce Pump Slippage

- Pump Slippage during the Downstroke is desirable
  - With closed standing valve and travelling valve, slippage increases the pressure between the two valves
  - Causes the travelling valve to open sooner
  - Opening sooner generally better for pumping unit loading
New Method to Reduce Pump Slippage

• So, upstroke slippage is undesirable, and downstroke slippage is desirable. How can we take advantage of that?

• Spend less time on the upstroke, and more time on the downstroke
  – Conventional pumping units spend about 50% of their stroke duration on the upstroke
  – Reverse geometry pumping units spend about 55% of their stroke duration on the upstroke. For same SPM, they will have about 10% more slippage than conventional
Example: Conventional unit setup to run 10 SPM, but only needs to run at 3 SPM

- On VFD, 3 SPM would be 30% of 60 Hz, or 18 Hz
  - Total stroke duration is 20 seconds
  - Upstroke duration is 10 seconds (50% upstroke duration)
- By increasing the upstroke speed in relation to the downstroke speed, less of the stroke duration is spent on upstroke.
  - 6 SPM (36 Hz) on upstroke, a 5 second duration
  - 2 SPM (12 Hz) on downstroke, a 15 second duration
  - Total stroke duration is still 20 seconds with 3 SPM but the upstroke duration is now only 25% of each cycle, not 50%. (5/20 instead of 10/20)
New Method to Reduce Pump Slippage

Less time on upstroke
  =
Less time slipping
  =
Less slippage
  =
Higher System Efficiency
  =
Less Strokes per day for same fluid volume
Example of modified Patterson slippage formula accounting for % upstroke duration

Pump Efficiency Using Arco-HF-COP
Base, Reverse Mark, U/D Speed Control
1.5” Pump at 10000 Feet with .006 clearance, 0.7 vis
350 psi PIP, 6 foot plunger, 0.8 gravity fluid
4 SPM Max SPM Differential, 4 sec Accel/Decel

![Pump Efficiency Graph](image-url)
What does this look like at the well?

<table>
<thead>
<tr>
<th>Desired SPM</th>
<th>Upstroke SPM</th>
<th>Downstroke SPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td>7.2</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>6.2</td>
</tr>
<tr>
<td>7</td>
<td>9.2</td>
<td>5.2</td>
</tr>
<tr>
<td>6</td>
<td>8.2</td>
<td>4.4</td>
</tr>
<tr>
<td>5</td>
<td>7.4</td>
<td>3.4</td>
</tr>
<tr>
<td>4</td>
<td>6.4</td>
<td>2.6</td>
</tr>
<tr>
<td>3</td>
<td>5.6</td>
<td>1.8</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>4.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Potential Implications

Worn pumps can stay in the well longer with minor average SPM increase

Pumps with higher clearance (solids, etc) are possible for lower fluid volume wells

Less strokes per day for the same production

By virtue of less strokes for the same production, less wear for the same production
Potential Implications to Current Art

• Best practice will be pumping units equipped with VFD’s and RPC’s that allow slower downstroke operation

• Pumping unit motors no longer will be Nema D high slip, but Nema B Inverter Duty rated motors with high efficiency

• Current industry rod pumping modeling programs will need to be re-written.
Copyright

Rights to this presentation are owned by the company(ies) and/or author(s) listed on the title page. By submitting this presentation to the Sucker Rod Pumping Workshop, they grant to the Workshop, the Artificial Lift Research and Development Council (ALRDC), and the Southwestern Petroleum Short Course (SWPSC), rights to:

- Display the presentation at the Workshop.
- Place it on the www.alrdc.com web site, with access to the site to be as directed by the Workshop Steering Committee.
- Place it on a CD for distribution and/or sale as directed by the Workshop Steering Committee.

Other use of this presentation is prohibited without the expressed written permission of the author(s). The owner company(ies) and/or author(s) may publish this material in other journals or magazines if they refer to the Sucker Rod Pumping Workshop where it was first presented.
Disclaimer

The Artificial Lift Research and Development Council and its officers and trustees, and the Sucker Rod Pumping Workshop Steering Committee members, and their supporting organizations and companies (here-in-after referred to as the Sponsoring Organizations), and the author(s) of this Technical Presentation or Continuing Education Training Course and their company(ies), provide this presentation and/or training material at the Sucker Rod Pumping Workshop "as is" without any warranty of any kind, express or implied, as to the accuracy of the information or the products or services referred to by any presenter (in so far as such warranties may be excluded under any relevant law) and these members and their companies will not be liable for unlawful actions and any losses or damage that may result from use of any presentation as a consequence of any inaccuracies in, or any omission from, the information which therein may be contained.

The views, opinions, and conclusions expressed in these presentations and/or training materials are those of the author and not necessarily those of the Sponsoring Organizations. The author is solely responsible for the content of the materials.

The Sponsoring Organizations cannot and do not warrant the accuracy of these documents beyond the source documents, although we do make every attempt to work from authoritative sources. The Sponsoring Organizations provide these presentations and/or training materials as a service. The Sponsoring Organizations make no representations or warranties, express or implied, with respect to the presentations and/or training materials, or any part thereof, including any warranties of title, non-infringement of copyright or patent rights of others, merchantability, or fitness or suitability for any purpose.