Using Plunger Surface Velocity to Increase Safety and Production

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SURFACE VELOCITY TRACKING
An Essential Monitoring and Troubleshooting Tool
Adopting Surface Velocity

• Tracking surface velocity is the first step
  – More visibility into the plunger behavior
  – Identify issues that may have been missed

• Safety
  – Watch for increasing speeds
  – Correct before a potential well head failure

• Maintenance
  – Avoid increased wear on equipment
  – Catch unexpected additional arrivals

• Production
  – Prevent downtime
  – Opportunity to run plungers faster
Surface Velocity when Venting

Problem
- Surface velocity (over 2000 ft/min) was much higher than average velocity (400 ft/min)

Solution
- Keep track of magnitude and frequency to properly align maintenance
- Possibly adjust optimization type or other operational parameters
- Move away from venting
Higher Surface Velocity

• Problem
  – Surface velocity (1200 ft/min) was consistently more than 50% higher than average velocity (750 ft/min)

• Solution
  – Lower average velocity target to reduce equipment wear and possible failure
  – Possibly move away from average velocity optimization on this well
Broken Plunger Investigation

• Problem
  – Some arrivals over 1700 m/min (5500 ft/min)

• Solution
  – Close time was increased to ensure plunger came to surface on first attempt
  – Operator was able to catch issues earlier
  – More timely maintenance
  – Stopped breaking plungers and springs
SAFETY AND PREDICTIVE MAINTENANCE AUTOMATION

Application of Surface Velocity
Impact of Surface Velocity

- Impact at surface is critically important
- Spring and lubricator together absorb the energy
- Repetitive fast plunger arrivals lead to broken plungers and springs
- If spring is compromised, energy is transferred to lubricator
Kinetic Energy

- Velocity is the most important factor in the energy of a moving plunger.
- Plunger mass cannot be ignored as a plunger with double the mass will double the energy.
- Energy of a moving plunger absorbed by the spring at surface.
- Calculate the kinetic energy each arrival:
  - \[ E = \frac{1}{2} mv^2 \]
- Move lubricator standards to kinetic energy.
- Controller compares arrival kinetic energy to manufacturer’s specifications.
Predictive Maintenance

- Lubricator springs break down over time
- Related to the cumulative impacts taken
- Create lifetime spring wear parameters based on kinetic energy
- Controller sums kinetic energy to predict spring wear
- Move away from time based replacement of springs
  - i.e. Replace springs every 6 months
Stopping Fast Plungers

• Prefer to be proactive and prevent fast plungers
• Is it possible to react to fast plungers?
• Velocity sensor has to be installed sufficiently far away from spring
• Distance set based on maximum velocity and latency in the overall system
  – Simple calculation \( d = vt \)
Stopping Fast Plungers

• Maximum velocity should be over estimated.
• All latencies need to be factored in
  – Sensor reaction time
  – Controller latency time
  – Communication time
  – Time to actuate valve
• Sasquatch currently has latency of 750 ms

<table>
<thead>
<tr>
<th>Latency</th>
<th>2000 fpm</th>
<th>3000 fpm</th>
<th>5000 fpm</th>
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<tbody>
<tr>
<td>1000 ms</td>
<td>34 ft</td>
<td>50 ft</td>
<td>84 ft</td>
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<tr>
<td>500 ms</td>
<td>17 ft</td>
<td>25 ft</td>
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<tr>
<td>250 ms</td>
<td>9 ft</td>
<td>12.5 ft</td>
<td>21 ft</td>
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PRODUCTION OPTIMIZATION USING SURFACE VELOCITY

Using velocity to increase revenue
Surface Velocity Optimization

• **Goal**
  
  – Modify system parameters to influence the plunger to arrive at a given velocity.
  
  – Velocity must be slow enough to be safe, but fast enough to lift fluid.

• **Overview**
  
  – Each fast or slow plunger arrival causes a proportional adjustment to either the afterflow or close time.
  
  – Based on patented Arrival Time Optimization.

• **Assumption**
  
  – Velocity of plunger is dependent on the amount of fluid being brought to surface
Arrival Time Optimization - Afterflow

Algorithm:

$$\Delta \text{Afterflow} = \frac{\text{Rise}_{\text{Target}} - \text{Rise}_{\text{Actual}}}{\text{Rise}_{\text{Target}}} \cdot S \cdot \text{Afterflow}$$

Afterflow = Afterflow Time
Rise = Rise Time
S = Scale Factor

- Fast plunger adds to Afterflow Time
- Slow plunger subtracts from Afterflow Time
- Changes proportional to:
  - magnitude of the target miss
  - Amount of current Afterflow time
- Scale Factor used to dampen the response
Arrival Time Optimization - Close

Algorithm:

$$\Delta \text{Close} = \frac{\text{Rise}_{\text{Actual}} - \text{Rise}_{\text{Target}}}{\text{Rise}_{\text{Target}}} \cdot S \cdot \text{Close}$$

- \text{Close} = \text{Close Time}
- \text{Rise} = \text{Rise Time}
- S = \text{Scale Factor}

- Fast plunger subtracts from Close Time
- Slow plunger adds to Close Time
- Changes proportional to:
  - magnitude of the target miss
  - Amount of current Close time
- Scale Factor used to dampen the response
Close Then Afterflow

- Close Time is minimized as well is unloaded and plunger arrives faster than the target.
- Then Afterflow Time is maximized to increase production while plunger is still arriving faster than target.
- Slow plunger reduces Afterflow Time. If Afterflow Time at minimum, Close Time is increased.
- Fast plunger reduces close once again. If close is at the minimum, Afterflow Time is increased.
- This is a dynamic system that responds to changing conditions and does not require operator intervention.
Optimization Algorithm Results
Velocity Optimization

Algorithm:

\[ \Delta AF_{Time} = \frac{V_{Actual} - V_{Target}}{V_{Target}} \cdot S \cdot AF_{Time} \]

AF = Afterflow
V = Velocity
S = Scale Factor

- Based on arrival time optimization
- Safety factor can be reduced to increase production
- Proportionally adjust afterflow and close times based on instantaneous surface velocity
- Makes small corrections on each run instead of trying to stop a dangerously fast plunger
Future Work

• Currently running pilot projects
  – Find ideal velocities for different plunger types to maximize production
  – Adapt algorithms to account for pressure fluctuations

• Adaptation of Sasquatch
  – Continually improve detection and accuracy
  – Add in continual kinetic energy calculation

• Algorithm Building
  – This is just the start
  – Many more ideas expected to spring up
Conclusions

- Surface velocity is key to safe operation
- Opportunity to incorporate predictive maintenance
- Production gains are certainly available
- Surface velocity adoption opens up many more possibilities
- Surface velocity is the future of all plunger lift well operations
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