VFD CONTROLLER AND SUCKER-ROD PUMP OPTIMIZATION

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Abstract:

Sucker-rod pumps (SRP) are one of the most commonly used types of artificial lift in the oil and gas industry. SRP performance can be dependent upon reservoir behavior, field development, well design, and production. These factors can cause SRPs to experience issues, including fluid pound and gas interference that lead to mechanical failures (rod string, pump) and energy losses (pump cycling), ultimately affecting the unit's efficiency and the cost of operations. Variable frequency drive (VFD) offers a solution by adjusting the speed of the motor that drives the pump. VFDs allow SRPs to run longer without shutting off, the ability to adapt to changing reservoir conditions, minimize loads on rod string, increase pump efficiency, and increase production among other benefits.

Introduction:

SRPs are a type of artificial lift used for low-pressure reservoirs to continue the drawdown of the reservoir to maximize the inflow of hydrocarbons. The SRP can run into operational issues as the reservoir depletes, these issues are recognized as gas interference and fluid pound. Gas interference occurs when gas enters the pump chamber along with the liquids that are being produced and occupies volume within the chamber, reducing pump fillage. Moreover, having gas in the pump chamber requires the SRP to waste part of its stroke in compressing the gas to a high enough pressure to unseat the traveling valve, contributing to its inefficiency. The other potential issue that arises is fluid pounding. As the reservoir depletes, the fluid inflow will not be able to keep up with the displacement of the SRP, and there will not be enough fluid to fill the barrel of the pump on the stroke; this is recognized as being pumped off. Fluid pound occurs in a similar way to gas interference; the gas inside the pump must be pressurized up to a point where it can exceed the discharge pressure and unseat the traveling valve. In this case, you get a surge of liquid that the pump draws in, creating a pressure spike and leading to buckling/wear in your rod string and tubing, and just as with gas interference, the operator is leaving some production on the table due to poor pump fillage and efficiency.

VFDs allow SRPs to adjust to these conditions and optimize their performance by reducing pump cycling/shutoff, minimizing loads on rod string, increasing pump efficiency (fillage), allowing for continuous monitoring, reduction in failure rates, and adjustments to the BHA. Despite the improvements, operators need to determine which wells may require the implementation of VFD systems by considering reservoir types (conventional unconventional), field development (injection and fluid type), and well economics (VFD cost, electricity, algorithms for VFD, etc.)

Overview of Parameters:

Although implementing a VFD system to an SRP can be beneficial, operators must first consider some preliminary factors that make a well a candidate for the implementation of the VFD system:

- Reservoir type and behavior (conventional or unconventional, fluid inflow, and GOR/GLR, age)
- Well Design (Vertical or horizontal, TVD, DLS)
- Field Development (is there injection and fluid type)
- Well economics (electricity cost, cost of VFD and controller packages, algorithms, repairs, hardware/software updates)

Once the operator determines if the VFD system will be implemented, they can focus on the following parameters to optimize the performance of the SRP.

- Set points for the VFD (pump fillage, min, and max speeds)
- Monitoring (SCADA implementation and remote monitoring)
- Pump performance (continuous pumping, fillage, solids)
- Failure Reduction
- Rod loads (buckling)
- BHA and sizing

Discussion of Parameters:

Reservoir behavior: The focus of this point is the type of reservoir being produced. When considering conventional and unconventional reservoirs, the unconventional reservoir is known for producing more gas due to the properties of the tight rock as well as other geological parameters such as shale being its source and seal. Taking this into account, what does gas production look like for the well, and how will fluid inflow from the reservoir look as the well declines and GOR/GLR continues to change?

Well design: With the wellbore being vertical or horizontal, at what depth or part of the wellbore is the pump for the SRP being placed? If there is too much DLS this could cause more wear in the system due to friction and require the operator to change the speed of the pump. Depending on if the tubing is anchored or unanchored, the pumping efficiency can be affected due to “breathing” which can affect the strokes of the pump.

Field developments: As fluid production declines and fluid infill becomes less, operators can look to secondary and tertiary recovery methods (water and gas injection) to produce more hydrocarbons. Water-alternating-gas flooding can create issues with pump cycling when injecting CO_2 into the reservoir. Another issue that may arise is when injecting water, fluid rates could increase and for the SRP to move such rates may lead to more power consumption of the system, the VFD could control the motor of the unit based on the fluid infill coming from the reservoir and use the required power when necessary.

Well economics: VFD offers many solutions, however, not every well requires the implementation of VFD and a cost analysis must be considered to determine if VFD is useful in certain applications. Certain VFD and controller packages could allow operator insight into more parameters and different algorithms that can monitor each stroke and adjust on the fly at a higher cost. Other expenses could fall back on maintenance of the system regarding repairs and any updates to the hardware/software.

Set Points: Setting the VFD to a specific pump fillage percentage will allow the SRP to continuously run and prolong the time between shut-offs or failures since the VFD can adapt to the inflow from the reservoir and it will speed up or slow the unit. In cases where infill and pump fillage are high, the unit can increase speed (SPM) and get the most production, and as the fluid level reduces the unit can slow down to avoid pumping itself off (I. Nickell, 2023). Gas interference and fluid pound can also be avoided by slowing down the SRP using the VFD on downstrokes and increasing the upstroke speed to maintain the overall SPM of the unit (Westerkamp and Calder, 2024).

Monitoring: Using the VFD system with supervisory control and data acquisition (SCADA) the operator can monitor wells remotely, allowing them to respond promptly to any failures or if they see any indications of a potential failure based on dynamometer cards or other data received from the system and prioritize well visits and allows them to monitor pump changes (Gardner 2014).

Pump Performance: pump-offs could lead to having POCs shut down equipment to allow the fluid level to rise again, reducing the efficiency of the system since it is turning on and off which could also damage the equipment and lead to energy losses from drawing power to start the equipment back up. Having SRPs shut off constantly could also lead to solids and particles falling back onto the valves of the pump potentially causing them to stick. The presence of gas in the pump could lead to issues with fillage and waste a certain portion of strokes from the unit to compress the gas in the pump chamber leading to losses in production. As the VFD controls the speed of the motor, the pump can adapt to the fluid inflow from the reservoir and has continuous pumping where the operator can avoid issues with pump cycling and power consumption as well as the settling of solids on the pump. Adjusting the fillage setpoint could also allow the pump to adjust the SPM leading to higher produced volumes.

Failure reduction: Using the VFD allows continuous pumping operation as well as varying SPM, this continuous pumping can be useful in scenarios such as solid production and preventing solids from falling on the plunger, wells dealing with incomplete fillage, water-alternating-gas environments, and rod-buckling due to pump off (Lee and Gault). In a study conducted of 64 wells with VFD, a 56% reduction in failures was noticed at the expense of a slightly higher increase in maintenance cost (Lee and Gault)

Rod loads: Having issues with fluid pound could lead to buckling due to the sudden slug of fluids the plunger sees on the downstroke causing rods to compress and wear as well as other downhole equipment such as tubing. Using a VFD can allow for a slower downstroke minimizing the compression forces on the rods and prolonging their lifespan depending upon the material of the rod string. Other studies have shown that using two-speed modes on the VFD also reduces the wear on rods and tubing, but also may mitigate tagging (H. Janjua, et al. 2024)

BHA and sizing: This parameter considers the other tools that we use with the SRP downhole such as the gas separators that are used to create artificial sumps to break out as much gas as possible before going into the pump intake. The sizing of the equipment allows for slower fluid velocity, allowing more gas to break out of the solution. More fluid can enter the artificial sump and sending gas to the pump downhole can be mitigated. Sizing the BHA properly and/or using the adaptability of the VFD (setpoints for both min and max speeds), the operator can save money with the type of BHA used or improve the fillage of the pump by adjusting the setpoints on the VFD and using the artificial sump to break out as much gas as possible.

Field Results:

Operator field tests showed improvements in rod loading, pumping efficiency (fillage), failure frequency and wear, and energy consumption. Data varied between operators and regions, and results varied.

- Rod loading improvements included reducing the compression on the downstroke and reducing tagging in a test from 4 wells. H. Janjua, 2024.

- Gas interference was reduced by changing set points and slowing down VFD to meet certain pump fillage (Figure 1-2.). A.P. Allison, 2018.

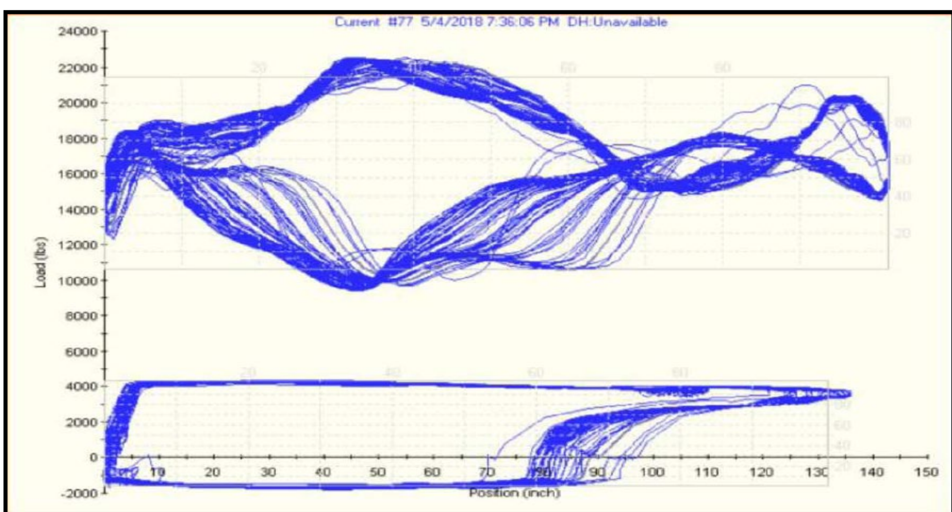

Figure 1. Dynamometer card for well p experiencing gas interference running at 7 SPM

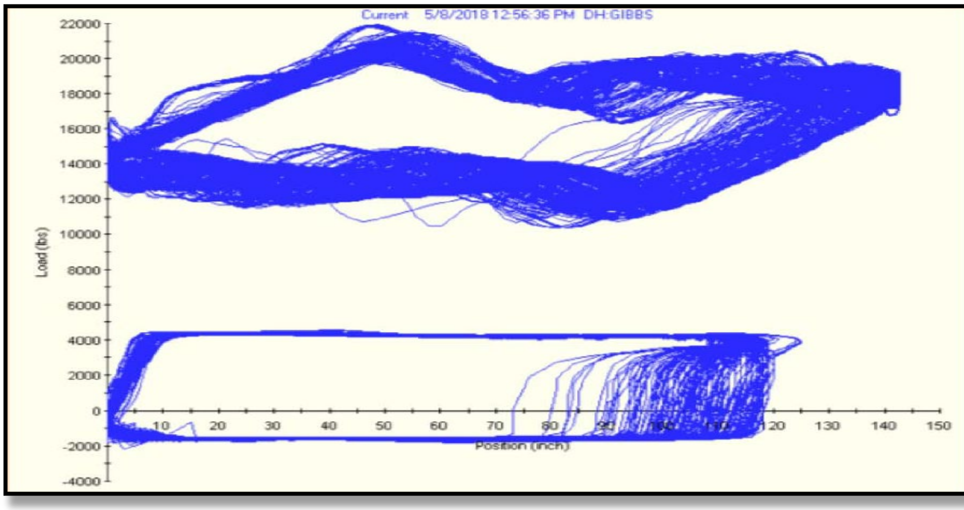

Figure 2. Dynamometer card for well p experiencing gas interference after VFD installation running at 5.6 SPM.

- Production improvements are seen in matching the flow from the reservoir and control of pump speed using VFD. R. Peterson207, 2006.
- Energy consumption could be reduced by reducing the pump's cycling, HP, and/or gearbox torque.
- Failure frequency is reduced by keeping SRPs running at varying speeds and reducing cycling, and potential solid build-up. Downtime due to failure is also less but requires a higher maintenance cost. D. Lee & S. Gault

Conclusion:

VFDs can offer operators a solution to handle gas interference, fluid pound, and changing conditions efficiently. It is important, however, to distinguish which wells require the installation of VFDs as opposed to a POC and how to operate those wells by understanding dynamometer cards and downhole equipment to optimize the well to its best-producing capability while also reducing wear on equipment and frequency of failures.

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