COMMON PROBLEMS AND SOLUTIONS FOR SUCKER ROD PUMPING APPLICATIONS

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ABSTRACT AND SCOPE

This paper will cover common problems and misunderstandings that lead to sucker rod pumped well failures and some of the solutions to avoid failures and optimize the sucker rod pump system.

The mechanics of the sucker rod pump design and modifications to improve performance in harsh well environments and failure data collection and performance measurement will also be examined.

MECHANICS AND PHYSICS OF THE SUCKER ROD PUMP

A big part of sucker rod pumping problems are still due to misunderstandings of how a sucker rod pump really works. When pumping a fluid that is in its liquid state, such as oil or water the pump functions by positive displacement of the fluid. The sucker rod pump is a simple machine that can work with only 3 moving parts. The plunger or barrel must reciprocate and you need 2 check valves, a standing valve and a traveling valve. Both valves open by pressure and close from fluid flow. If the pump is in the vertical position then gravity will assist in closing the valve but fluid flow is what really matters. This is why you can lay a pump in the horizontal position and it still functions.

The standing valve opens on the upstroke of the plunger once the pump chamber pressure drops below the pump intake pressure. This pressure drop is due to the traveling valve closing on the upstroke and the plunger vacating the pump chamber. As long as the plunger- to- barrel seal is sufficient to keep leakage back into the pump chamber to the small amount planned for lubrication and cooling, then an effective pressure drop occurs in the pump chamber and fluid enters the pump. On the downstroke the standing valve closes as fluid tries to flow out of the pump chamber (opened by pressure, closed by flow) trapping the fluid brought into the pump inside the pump chamber. Once the standing valve closes the liquid (water, oil or a mixture) builds pressure rapidly due to the liquid state of these fluids being almost incompressible. Once this pressure that is under the traveling valve exceeds the hydrostatic load on top of the traveling valve, the traveling valve opens and the fluid in the pump chamber is displaced by the travel of the plunger to the bottom of the pump chamber.

If the plunger is solid and a bottom discharge valve is used for a traveling valve, then the fluid will be discharged out of the pump chamber through the bottom discharge valve on the downstroke and the image of this being a positive discharge pump is pretty clear. The traveling valve does not “travel” but its position makes it open on the downstroke and so it still functions as the “down stroke check valve”.

It is when you use a hollow plunger and the traveling opens on the downstroke and closes on the upstroke that the “displacement” is not as clearly visualized. In the first case with a solid plunger the fluid enters the pump chamber from the bottom of the pump and is then discharged out through the bottom of the pump so the filling and emptying of the pump chamber is easy to visualize. When the plunger has a solid bottom that in effect “disappears and then reappears” in mechanical function then it is less clear. The traveling valve when closed provides a “solid plunger” and when the valve opens a hollow plunger. If you visualize the plunger being solid on the upstroke when the valve is closed then it is easy to picture it in you mind as it vacates the pump chamber as it travels upward. On the downstroke the plunger displaces fluid through the traveling valve (just as it does with the solid plunger) and the plunger falls through the fluid. So our “solid plunger has “disappeared “ in effect and a hollow plunger has taken its place simply by the traveling valve opening and changing the mechanical function of the plunger.

On the upstroke both the solid plunger and the hollow plunger (made solid by the closing standing valve) will lift a column of fluid across their effective cross-sectional area. The solid plunger will have an effective cross-sectional are of its diameter minus the rod connecting it. The hollow plunger will have its complete cross-sectional area exposed and a higher load will exist. This is the reason that the concept of what is being called a “downstroke” pump is popular. On the surface this seams like a good way to pump. With a solid plunger we displace the fluid with

rod weight and on the downstroke and on the upstroke we would have less fluid load to lift and a lower peak polished rod load but the physics do not allow for a free ride. The problem is what we commonly call pump friction and the same thing that lowers the load on the solid plunger will now cause it to have the full brunt of the fluid force on the bottom of the plunger during the downstroke. The hollow plunger however will only have part of its area subjected to this force once the traveling valve opens. It is commonly accepted that sucker rod strings do not go into compression unless excessive fluid pump friction (plunger drag) occurs. When we use a solid plunger we will cause this excessive pump friction to occur unless very small plungers are used. The larger the plunger then the larger the areas the force works on is and the greater the bucking tendency. To offset this and prevent sucker rod buckling, sinker bars can be added and typically when the total weight of sinker bars is reached that will keep the rods in tension the peak polished rod load has returned to what it would be with the hollow plunger.
To sum up;

- All sucker rod pumps are technically positive displacement pumps
- All sucker rod pumps require the upstroke and the downstroke to complete the pump cycle
- Technically all sucker rod pumps fill the pump chamber on the upstroke and displace fluid on the downstroke. Where the peak loads occur can be changes to a degree but there is no free ride.

PUMP FRICTION

Pump friction is another area of misunderstanding and pump slippage is related. There are two parts to pump friction. One is the plunger and barrel interface. The barrel if made to API specs will be nominal size minus nothing plus .003" for a precision barrel (for metal plungers) and the plunger is then ground for the actual "minus" fit. This minus fit is the amount undersize a plunger OD is from its nominal size. For example a 1-1/2" plunger with a minus 4 fit will be .004" under the nominal 1.500" for an OD of 1.496". Add another minus .001" for the average barrel tolerance and we now have a minus fit of .005" or five thousands of an inch. This fit is part of the friction in pump friction and is present on the up-stroke and down stroke although but it is the downstroke part that is the greatest concern. The other part of pump friction is the fluid passing through the traveling valve and the plunger on the downstroke. This can be changed with valve design and plunger ID increases but usually is only necessary if pumping heavy crude or when pumping at high linear speed. So the big thing we can change easily is the plunger minus fit to ease pump friction in order to keep rod buckling above the pump.
Sucker rod and valve rod buckling is a big part of catastrophic type pump failures that cause premature pump failure. Broken plunger pins, valve rod breaks and top plunger connectors are examples of fatigue type breaks often found due to deflection. Opening up the plunger barrel clearance and reducing pump friction can often prevent this type of breakage.

Slippage is the function of the clearance between the barrel and plunger, the pressure on the plunger (hydrostatic load), viscosity and seal length. So opening up the clearance will increase slippage but if this is calculated in to the production needed then the pump will be sized accordingly. This then leads to the next problem of pump efficiency.

PUMP EFFICIENCY

How efficient does a sucker rod pump have to be? I have deliberately designed some pumps to be only 60% efficient to allow for the clearance needed to pass sand through the pump with minimal damage and to not stick the plunger in the barrel. If you are not able to properly separate gas in a pumping well and a large amount of gas goes through the pump and it is only 50%-60% efficient may well have to be the way it is pumped. So in the end it is not how efficient the pump is but does it give the production required. If the goal is to make 200 barrels of fluid per day (BFPD) and it does just that, do not get too hung up on efficiency. If you start out making 200 BFPD and then efficiency drops off and you drop to 150 BFPD then that is a different matter and this change in efficiency is important.
Often though we have the largest pump that our pumping unit can handle and then if the pump is less than 80% efficient and the production goal is not being met pumps are pulled and others tried or plunger clearance is tightened to increase the production. This scenario will often include a high SPM and long stroke further compounding the problem when the real answer is to get a larger pumping unit with a longer stroke. I big part of deflection problems is due to tight plungers, high linear speed, fluid pound and gas pound.
In the end we often equate making money simply with making more oil and forget that long term lifting costs will often go up due to wear and tear on equipment.