A COMPARISON OF API ROD PUMPS, MODIFIED API PUMPS, AND SPECIALTY PUMPS

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ABSTRACT

This paper will discuss the two API pump designations the rod pump and the tubing Pump. The rod pump is occasionally referred to as an insert pump and has three variations; stationary barrel top anchor, stationary barrel bottom anchor, and traveling barrel bottom anchor. Available modifications that are not covered under API but are commonly used to improve run time or efficiency will be discussed. Several special design pumps will be described along with their advantages. A reader will be able to recognize the standard API pump designs, API designs with modifications, and specialty pumps. In the end, the reader will be able to evaluate which application of each pump design should be used.

INTRODUCTION

Sucker Rod Pumps are the most popular artificial lift method in the world. Some of the reasons are their toughness, ease of automation, energy efficiency, and having the highest drawdown capability.

BACKGROUND

Conventional API rod pumps can be used in nearly any well with fluid volume and depth being the main limiting factors. Modifications to API pump designs can be slight up to a complete change in configuration. Modifications are made to pumps that will improve their performance in certain well conditions. The most common of these are gas, solids or both that are causing poor pump efficiency or high failure frequency. High fluid levels can be another reason to run a non-API pump design. The American Petroleum Institute 11AX Specification for Subsurface Sucker Rod Pumps and Fittings lists all the various API recognized rod pump designs. Pump designations are given an Alpha-numeric number for easy recognition. This number will quickly identify the tubing size, pump size, pump type, barrel type, plunger length, upper extension length and lower extension length.

DISCUSSION

Rod pumped wells in conventional mature fields are often produced with conventional API design pumps because those wells may be free from particulates and gas. In most instances, a well that is completed with enough room below the perforations to sump the pump will be free of gas interference and do not require any specialized rod pump. In some cases, lowering the pump below the perforations may increase particulates the pump must handle. Today's horizontally completed well will always need to separate the gas or handle it with the pump. These unconventional wells are also subject to having sand in the produced fluid, and many will have high fluid levels. It is common for more than one or two of these well conditions to be present and a combination or specialty pump design would be chosen to produce the well.

API PUMP DESIGNS

Insert Pumps are chosen by operators because they can be installed and retrieved from the well with the rod string. These pumps are the bottom hold-down, top hold-down, and the traveling barrel pumps. When higher volumes are needed a tubing pump design will be used. The barrel assembly of the tubing pump becomes part of the tubing string allowing larger diameter pump bore installation. The negative to this design is the tubing must be pulled to service the barrel.

API Bottom Hold-down

The most popular of the API pumps is the bottom hold-down insert pump. This pump has the advantage of pressure equalization inside and outside of the barrel allowing installation to a greater depth. A heavy wall bottom hold-down insert pump can be installed to depths of between 18,323 to 31,672 feet depending on the pump bore and metallurgy. Because the hold-down seal assembly is at the bottom of the pump particulates can build up between the pump and the tubing wall. This causes the pump to get lodged in the tubing and can only be retrieved by pulling the entire tubing string. There is also a stagnant fluid area on the outside of the barrel and sometimes can lead to corrosion on the OD of the barrel or the ID of the tubing.

API Top Hold-down

The API top Hold-down pump is used to help reduce the chances of a pump becoming stuck in the tubing. Fluid being discharged at the pump limits a buildup of particulates on top of the seating assembly to about three inches. There is no stagnant fluid issue with the top hold-down because produced fluid is circulated on the outside of the pump. The length of the pump goes through the seating nipple assisting in producing low fluid level or gassy fluids by having the standing valve submerged in fluid. When installing a cup type hold-down seal assembly one seating nipple design is used for either a top hold-down or bottom hold-down. The mechanical top hold-down and its seating nipple are different from a mechanical bottom hold-down and its seating nipple. Tubing must be pulled, and the seating nipple changed out to convert the mechanical top lock to a bottom lock. A disadvantage with top hold-down pumps is the possibility of the barrel splitting or parting. The barrel is suspended from the hold-down seal assembly, and the fluid load on the down stroke puts the barrel into a tensile load condition. In addition, the hold-down seal holds the hydrostatic load above the pump, and there is no equalization on the outside of the barrel. The possibility of a barrel failure increases as the pump setting depth increases. Metallurgy bore size, and type of pump will designate how deep the top hold-down pump can be installed. Before installing a top hold-down pump, you should consult the API 11AR recommended setting depth or a subject matter expert.

API Travel Barrel

The API Travel Barrel pump is designed where the barrel moves with the rod string, and the plunger is stationary. The pump design is good for wells that produce a lot of particulates that can stick bottom hold-down pumps in the tubing. Both valves use open style cages that allow particulates to pass through and reduce wear and valve interference in the cage. The traveling valve will close during intermittent shut down periods keeping solids out of the pump. The pump limitations are wells that have a low static fluid level since the standing valve is the top plunger cage. When that valve is closed on the downstroke, the load is transferred to the pull tube seating assembly. Pump length and setting depth will be limited due to the standing valve location on top of the stationary plunger. This exerts the hydrostatic load to the pull tube, causing it to bow. This will increase friction on the pull tube and then is transferred up through the rod string.

API Tubing Pump

When an insert pump cannot keep up with the well’s fluid inflow, a tubing pump must be used. A larger bore size pump can be installed with this design versus an insert pump. The tubing pump barrel assembly is installed with the tubing string at the depth you want to produce the well. The plunger, traveling valve, standing valve, and hold-down seal assembly is installed with the rod string. Tubing pumps have depth limitations because the hydrostatic pressure is only on the inside of the barrel. It is difficult to get the traveling valve spaced close to the standing valve this leads to poor compression ratio making it difficult to handle gaseous fluids. The plunger, traveling valve, standing valve, and hold-down seal assembly can be serviced by pulling the rods. The tubing must be pulled to service the barrel assembly.

<u>MODIFIED API PUMP DESIGNS</u>

Two-Stage Hollow Valve Rod Pump

There are many variations of additions or design changes on the standard API pump designs. The one that is very common is the Two-Stage Hollow Valve Rod pump. This pump can either be a top hold-down or a bottom hold-down in an insert pump design. There is also a tubing pump design, but it is seldom used due to its many components. The two-stage pump replaces the valve rod with a hollow pull tube and adds an additional valve on top of the pull tube. This valve can hold the hydrostatic load from the traveling valve allowing it to open sooner on the down stroke. It can also close off the pump during periods of shut down to exclude solids from settling on top of the plunger. If the pump is designed properly for the downhole stroke, a two-stage effect can exist as the plunger reaches the top of the stroke. The pump can handle moderate particulate amounts through the .030" of clearance between the pull tube and guide. The two-stage effect is lost when pumping at slow pumping speeds due to fluid slippage through the .030" clearance fit.

Top and bottom hold-down valve rod pumps have a rod pump accessory available that mimics the two-stage HVR. This Sliding Top Valve placed at the top of the pump closes at the start of the downstroke, creating a low-pressure chamber above the plunger. Due to this low pressure, the traveling valve opens quicker, allowing a more efficient displacement of gas and fluid from below the plunger. It also closes during a shutdown period to prevent solids from entering the pump.

There are endless rod pump accessories that are marketed for a top and bottom hold-down insert pumps. Collet connections are available for both top and bottom hold-down, valve rod, and pull tube pumps. These connections add strength to the threaded portion of the valve rod and pull tube. Almost all pull tube and valve rod failures are at the threads. Seals can be added to the top of bottom hold-down pumps to reduce the chance they will become stuck in the tubing. These are just some examples of items that can be added to pumps to enhance their handling of solids and gas issues.

SPECIALTY PUMPS

Gas Handling Pumps

I consider specialty pumps as a pump design to overcome one well condition. Many manufacturers make ones that are very similar and market them with various trade names of their choosing. Let's first discuss pumps for gas interference. There is one that would be considered for the worst gas conditions such as if pumping below a packer. This pump has two plungers and seal areas, creating two compression chambers. On the first upstroke, the gaseous fluid is drawn into the lower compression chamber. Then on the first downstroke that fluid is transferred into the upper compression chamber. Then on the next upstroke that fluid is compressed once again forcing it out through the upper plunger. This pump is the only pump I am aware of that should be spaced to the top. A big advantage of this pump is that there is no need to compress gas on the downstroke. This helps lower rod on tubing wear that is common in pumps with gas interference. Solids can be a challenge for this pump because when the fluid is being compressed in the upper chamber, it must leave the pump through the small plunger. This sometimes traps solids in the upper compression chamber damaging this seal area.

Another pump design for gas operates on the principle of pressure equalization just before the plunger reaches the top of the stroke. The pump has two barrels a lower conventional API RH barrel connected to a specially designed upper barrel. This upper barrel has a slight taper in the bore increasing barrel to plunger clearance the farther the plunger moves up. This resulting pressure equalization will allow the traveling valve to open quickly on the down stroke. The pump card will show a slight dip at the top of the stroke and no gas curve on the downstroke. We must keep in mind that gas is taking up space inside both pumps and that this gaseous fluid will result in a lower pump efficiency than a pump that is not in a gaseous environment.

Gas Separating Pump

There is a pump design for gas that separates the gas up the tubing-casing annulus and produces almost gas free fluid up the tubing. This pump is available in a top hold-down and tubing pump configuration and not in a bottom hold-down design. The gas separator pump has two plungers in tandem and a barrel with a vent hole at a strategic position. The placement of this vent hole is based on the downhole stroke. The upper plunger holds back the hydrostatic load while the lower plunger sweeps the gas out the vent hole and up the tubing-casing annulus.

Solids Handling Pumps

It is often said with solids you must separate them from the produced fluid prior to the pump or design your pump to handle the solids. A pump that can handle a high volume of solids without failing is a Three-Tube pump design. Three loosely fitted tubes telescoping together are assembled into a pump to produce sandy or dirty fluid. The overall clearance between the tubes is approximately .014". The outer barrel and inner tube or plunger travel together and have the advantage of being a travel barrel and stationary barrel at the same time. A portion of the fluid is discharged at the bottom of the pump to help avoid a stuck pump. This pump will have a depth limitation and may need to be stroked faster because the greater clearance and high slippage rate.

A completely different designed pump is one that has a long plunger and a relatively short barrel. Due to the length of the plunger, the ends do not enter the barrel section at the top or bottom of the stroke. The plunger is wiped clean every stroke and doesn't allow particulates to enter the barrel plunger interface. The pump is designed with a traveling valve on top of the plunger that closes during shutdown periods. This will prevent sand from the tubing string from settling inside the pump. The long plunger and short barrel designed pumps are available in insert traveling barrel and stationary barrel designs. They are also available in tubing pump designs for higher volume wells.

There are many designs that attempt to exclude solids from the plunger barrel interface by stopping it above the plunger. Some designs add simple wipers above the plunger and can add additional run life to the pump. These designs have an issue with the hydrostatic load quickly wearing the soft cup or ring design. Two or more manufacturers have designs that equalize the pressure above and below the wiper section and increase their life. Other designs add a sharp leading edge to the plunger to trap the particulates above the plunger barrel interface. The design also discharges fluid up eliminating a stagnant area above the plunger.

High Volume Rod Pumps
The other consideration from varying from standard API pumps is pump volume. Once a conventional tubing pump can no longer produce all the wells inflow capacity a high-volume specialty pump must be used.

Double-Displacement Pump
Some operators choose to use a Double-displacement pump. These pumps can either be a travel barrel or stationary barrel. The pump consists of two barrels and two plungers in tandem connected with one set of valves. The pump is installed and pulled on the rod string and seated in a conventional seating nipple. The 1-1/2" bore pump has approximately 14% greater capacity than a 1-3/4" tubing pump and the 2" bore pump has approximately 29% greater capacity that a 2-1/4" tubing pump.

Over-size Tubing Pump
The other choice to produce high volume wells is an oversize tubing pump. It is referred to as oversize because the plunger is larger than the tubing above it. The entire tubing pump including the plunger is installed with the tubing. The plunger will have the lower section of an on and off tool at its top. The upper section of the on and tool is installed into the well on the bottom of the rod string. The on and off tool is latched together and the well put on the pump. When the pump needs to be serviced the on and off tool is unlatched, and the rods are pulled. The over-size tubing pump assembly is then pulled with the tubing. The tubing will have fluid above the pump, and special rod lift accessories will need to be added to drain the fluid and avoid pulling a "wet string."

Casing Pump
One additional pump for high volume is the casing pump. This pump is used in a well without any tubing only casing. Because there is no tubing, the largest pump size can be installed into the casing. The pump is designed like a bottom hold-down insert pump. The pump is installed into the well on the rod string and then held in place with a packer. The packer works as a seal and hold-down and will stay set until the producer pulls the well.

Slim-hole
Occasionally producers have wells with smaller than normal tubing installed. Special consideration must be taken to install rod pumps into these wells. Insert and tubing pumps, are used but both are considered special due to the size restriction. In addition to the pump size consideration is the sucker rod and polished rod size. Many wells with bad casing have been saved by re-completing the well with smaller casing, tubing, rods, and pump.

CONCLUSION

API rod pump assemblies are used in many fields and achieve excellent performance. Modified API pump assemblies can extend run life or improve performance over the conventional API in some applications. Many of the new unconventional wells will require specialty pumps, especially when the well is first converted to artificial lift or from other forms of artificial lift. Slugs of gas and fluid carrying sand will reduce the run life and efficiency of conventional pumps. Many operators' choice of one pump fits all is a poor choice when operational issues of solids, gas, or high volume are considered.