Artificial Lift

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Lecture-25 Sucker Rod Pump (SRP)-Part-4

Good morning. We have studied sucker rod pumping, also known as pump jack, beam pump, Nodding donkey, or beam pump. As I mentioned earlier, this pump is a reciprocating pump consisting of one surface unit and one subsurface unit.

As discussed in a previous lecture, the surface unit includes the ground level where you can find the walking beam. There is also a stuffing box-like component through which a T junction is connected. The entire rod assembly extends down to the pumping assembly and passes through the tubing, which is inserted into a casing. The casing is typically properly cemented, and perforations are made in it. These perforations provide access to the oil and gas zone, which may contain water. These three fluids can flow through these pores.

If the water level is low, you can extract oil and gas. However, there is a significant amount of gas in many cases, making it a gas well. In other instances, when there is a substantial quantity of oil, it becomes an oil well. Regardless of whether it's an oil or gas well, a pumping mechanism is required if the reservoir pressure is low. Sucker rod pumping, or SRP, is a reciprocating or positive displacement pump used for this purpose.

It requires a very low volume of fluid to be pumped. Different types of pumps are available when dealing with a very high volume of fluid, but for low-volume flow rates, we primarily use the sucker rod pumping system. Additional considerations include viscosity and the condition of the wellbore (crooked or straight), among others. However, the SRP (Sucker Rod Pump) can be employed assuming a straightforward and straight wellbore with moderate viscosity and minimal sand or gas content. SRP is the most commonly used artificial lifting system in the oil industry.

Whenever you observe pictures related to the oil industry, you will often see images of a sucker rod pump because it is prevalent and easily visible from the surface. The surface unit includes components like the pitman arm, crank, gearbox (connected to a motor via a V-belt), and the working beam. Additionally, there is the stuffing box. We covered these details in the previous lecture. Now, we will delve into the subsurface part, which is located below the ground.

The part below the ground consists of your sucker rod or metallic rod, as the term "sucker rod pump" implies. The rod is a sucker rod because it sucks up the wellbore fluid and delivers it to the surface. It sucks and provides the energy to the surface. This part comprises a Bottom Hole Assembly (BHA) or simply a bottom-hole assembly.

The BHA, or bottom hole assembly, includes a plunger and barrel containing standing and traveling valves. Additionally, it incorporates elements like a sliding nipple used to secure the pump at the bottom of the wellbore. These are part of the mechanisms discussed when exploring the subsurface unit of a sucker rod pump.

A sucker rod pump has two main parts: the heavy unit near the surface and the more straightforward one inside the wellbore. However, even though I describe it as more straightforward when dealing with long rods of, say, 2 kilometers, 3 kilometers, or depths of 5,000 to 10,000 feet, the weight of such long rods becomes substantial. A high level of stress analysis is necessary to manage the movement of this heavy mass up and down and maintain the required momentum.

If proper analysis is not conducted, the rod can break at a certain point, usually due to tensile rather than compression forces. When the rod breaks, you have to remove and repair the entire rod, which can be costly. Therefore, when completing a wellbore or implementing any additional lifting method, the goal should be to ensure that the wellbore can be produced for an extended period at a consistent production rate.

Frequent changes to the sucker rod pump or any other additional lifting system, such as every 3 months, 6 months, or 1 year, will increase your costs. To reduce costs, you must synchronize all elements from the reservoir to the bottom hole assembly, the rod, and the surface unit. This synchronization ensures no imbalances or extra forces, resulting in stable and continuous production for a specified duration—this should be your target.

However, if a wellbore experiences regular failures, it is often called a "problem well." In such cases, installing a pumping mechanism may lead to repeated failures, and engineers will repeatedly repair it. The engineer's objective should be to avoid failure and maintain system stability, even if it means achieving lower production rates for an extended period.

First, you must understand the bottom hole assembly (BHA). The BHA includes a plunger, barrel, standing valve, and traveling valve, and it looks like this:

The barrel has a hole, and the plunger, which resembles a piston in IC engine terminology but is referred to as a plunger in the oil and gas industry, moves up and down inside the barrel. Inside the barrel is a small ball known as the standing valve. The barrel remains fixed while the plunger moves vertically. A ball inside the barrel is called the traveling valve when it is stationary.

You have the standing valve, the traveling valve, the plunger, and the barrel, and the plunger will be connected to your sucker rod. The barrel is here, with the plunger inside, and you have to secure the barrel properly. So, there should be a specific mechanism, especially tubing. Sometimes, there is a nipple where you insert the pump, barrel, and standing valve inside the tubing, and there will be some holding device. You insert it, and the holding device keeps the barrel in place.

If you do not secure it properly, when you lift the sucker rod up and down, the whole barrel will also move up and down during the reciprocating motion. Therefore, you must hold it in place with some mechanism called a nipple. This is the tubing, the nipple, and you have the standing valve, traveling valve, and sucker rod. This entire assembly, known as the bottom hole assembly, can be inserted into the tubing.

So now, this is called an insert pump. The whole assembly is inserted, referred to as an insert pump. You either design or purchase the barrel, plunger, and traveling valve together, insert them, and there will be some nipple that holds them at the bottom. Then you run your sucker rod, and when you run the sucker rod continuously, you will deliver fluid. This is known as an insert pump.

Another type is the tubing pump. What is a tubing pump? A tubing pump is where you do not separately add a barrel; the tubing itself acts as a barrel. Here's how it works: Imagine this is my tubing, a long pipe, and inside the pipe, there will be a particular mechanism to hold the traveling valve and the standing valve because the tubing is not moving. Therefore, it will create a standing valve. Although the valve moves a small amount, it is still called a standing valve because the whole barrel is not moving. The barrel remains stationary, so this small ball or valve only moves a short distance. Even though it moves a small distance, people still refer to it as a standing valve because the barrel itself is not in motion, so its relative motion is only a few millimeters or perhaps 1 or 2 centimeters. However, the traveling valve is connected to your plunger, and when connected to the plunger, the plunger moves at a very high rate.

When the plunger is moving at a very high rate inside, you can see in the picture that the inner ball is also moving with the plunger. It undergoes a small motion because of the plunger's movement. Due to the plunger's motion, it is referred to as the traveling valve. In this lecture, I will use "traveling valve" to mean TV and "standing valve" to mean SV. The tubing-type pump has a standing valve without any issues. This is the standing valve, and the traveling valve will look like this. They may be threaded together and placed on the ball. As I have noted, this is the plunger, my TV or traveling valve.

The plunger moves inside the tubing, so you don't need an extra barrel. A barrel typically occupies some space. If you want a higher flow rate, you get a better option in the case of tubing pumps or pumps without a barrel because you have a larger space for pumping. I will show the pumping rate later, calculated as the area of the plunger multiplied by the stroke length, which represents how far the plunger travels. This volume will be delivered every time. So, if you use a tubing pump, you get a larger plunger diameter. Let's calculate the plunger's cross-sectional area as AP and the stroke length as L.

The total volume is APL. If I have the same stroke length, representing how far it travels from bottom to top, knowing the stroke length, an increase in AP means an increase in volume. An increase in volume indicates an increase in the delivery of fluid. When using a tubing pump, your volume increases.

Another option is the casing pump. Casing pumps use the casing directly, providing a much larger space. Consequently, the volume flow rate is very high. However, casing pumps are not used every time. Typically, tubing is used because it provides a path for gas and addresses other issues. You can separate the gas and pump liquid through the tubing using the annular path.

On the other hand, insert pumps are easier to manage. You can simply remove the pump and correct it if there is an issue. However, with a tubing pump, if there is a problem with the tubing, the entire tubing needs to be replaced, which can be an expensive affair. The choice between these options depends on your flow rate and economic considerations. Before making a selection, you need to be aware of the different types of pumps, including insert pumps, tubing pumps, and casing pumps, as well as other factors like long-stroke pumps and short-stroke pumps. In practice, API instructions typically focus on insert and tubing pumps, which I will discuss later.

Okay, so we have the traveling valve, standing valve, plunger valve, etc. Now, let's draw the plunger again, but I'll make it slightly more significant because I need to explain this plunger in more detail. Okay, I assume this is threaded connected, and there's a ball here. My barrel looks like this, and the barrel also has a similar mechanism. This one, I already mentioned, is the TV (traveling valve), this is the SV (standing valve), and this is my plunger. I'll hatch this one, indicating that this is the plunger and the barrel. Sometimes, I may refer to the barrel as a cylinder. I will use different hatch lines to distinguish them. Now, you have the traveling, standing, plunger, and barrel.

When the rod moves up and down, these valves will also have some small motion. This valve will have a cage, which is called a valve cage. What is a valve cage? When the plunger moves up and down, the standing valve moves up and down as well. So, the standing valve should not move too high when the plunger is moving up. When the plunger is moving up, the SV should not move too long a distance. That's why they use a valve cage. The valve cage looks like this, with lots of holes, and one ball will move within a certain range, going up and down only within that range.

This area is called the valve seat, okay? This area is the valve seat. So the valve seat area, the ball will fall on the valve seat. This is a hole, and this is a small hole, and the big ball will sit on it, touching the valve seat only. So the valve seat looks like this. The valve seat design will be like this, and the ball is like this. When the ball falls on this valve seat, it creates a leak-free area. This area will be leak-free so that the surface area will be more. The valve seat is designed so that when the ball falls on it, it creates a leak-free space. However, if you have a valve seat like this, you get point contact, which can damage your ball. If there's a very sharp point, and the ball keeps falling on it continuously while the plunger moves up and down or the beam pump works, the ball can get damaged. It can get dented, and if the ball is dented instead of being a circular shape, it can cause leakage. That's why the valve cage and valve seat are designed so that the ball falls smoothly over them, creating surface contact and preventing damage to the ball. The valve seat is smoothly curved, and sometimes it's made of softer material, so wear and tear are not issues. It ensures a leakage-free operation. Now, the ball can be rounded shaped and in different shapes. I don't know if anyone has used them, but in hand pump operations for rural villages, they do not use ball-type valves; they use flat flap-type valves, both for the standing and traveling valves. In this case, the standing valve size will be more prominent, and the traveling valve size will be smaller for the insert-type pump.

As you can see, the traveling valve plunger size is already reduced. So, if you use the same size ball as the standing valve, the flow path through the traveling valve will be very low. This is the flow path, right? Okay, there will be a gap so that fluid will pass through. It will come here, then go there, and then through here, and like this.

Similarly, it will go like this. Fluid from the wellbore to the standing valve to the valve cage. Here also, there will be a valve cage. Forward, put one here. Here also, one valve cage will be there in your traveling valve. Okay, there are two valve cages and two valve seats, and two balls will be there. But multiple ball pumps are also available, but we assume our pump has one standing valve, one traveling valve, one valve seat, one valve seat, one cage, and one cage. When the fluid moves, one by one, these balls will be moving, and you will get production. I will explain later how these balls will operate during pumping action.

Okay. Whenever you talk about the APS subsurface APS surface pump unit, we have seen notations like C-dash XYZ-dash X to Z this way. But when we are talking about the subsurface part, it is taken from API specifications 11. So API spec 11 A X B is something there, which is all related to sucker rod pump. API says what are the different types and what the notation should be. So if you see the table, stationary barrel, when you are saying stationary barrel top-anchored, so you write RHA thin-walled RWA. So H means heavy wall, thin means thick wall. Okay, so barrel thickness will decide whether it will be a heavy or light wall. How stationary barrel works, whatever figure I have drawn previously, okay, you're moving up and down, and this barrel is fixed on tubing. Okay, so the barrel is fixed on tubing, and a nipple is there, so this is called a stationary barrel. The barrel is not moving, but in some cases, the barrel will be moving. How will the barrel be rolling? The design will be a little bit different. This will be like this, and plunger, okay, the ball is here and going down. It will be like this. It will be like this, and there will be one ball here. Okay, and it will be inside the tubing. Let's say the nipple is here, okay? Nipple is here; if you see, this is a rod, sucker rod, rod, and traveling standing. This is TV, this is SV, okay. So you see the picture. This is your plunger, okay. This is your plunger. So the plunger is like this. The plunger is going here. Plunger is going here like this. Okay, this is your plunger. The plunger is fixed. Okay, the plunger is not moving. So you hold the plunger. This is a traveling barrel. This is a traveling barrel, okay. This is a traveling barrel pump. This barrel is moving. Okay, when the rod moves up and down, you see this barrel can actually move. This one, the barrel, okay. The barrel is outside the plunger, okay. So the barrel will be rolling, but your plunger is fixed on the tubing, okay. You see, this nipple, the plunger is fixed on tubing, so the plunger is not moving. But the barrel is moving. But in the previous case, you have seen that the plunger is moving. The barrel is fixed, so both are different. So, if I know this one, traveling barrel option, so this is my traveling barrel option, and stationary barrel option, this one is coming like this, top-anchored, bottom-anchored. What is top-anchored, bottom-anchored? Top-anchored, bottom-anchored means you see this distance, cylinder arrangement. Okay, if I am holding at the bottom using a nipple, there will be a bottom-anchored, but if I have the top of this barrel, it will be called a top-anchored. Okay, so the barrel is there, barrel bottom part I am holding, so that is bottom-anchored, top part holding is top-anchored. Okay, another option is a tubing pump, as I already explained, and H, H means heavy-walled barrel, and W thin-walled barrel. Okay, what other things are there here? Heavy-walled metal plunger. Okay, and here, notation, you note this one. Sometimes, you must remember, so the first notation is typically tubing size, first one with tubing size, second with pump bore size, and then pump type. RHBC, so RH, you see, R means stationary barrel, H means heavy wall, B means bottom-anchored, and C is somewhere to be written there. Okay, C, I'll check later. C is a registered type of seating assembly. C, cup type, or metal type. So, C is cup type, and the barrel is a heavy wall. Then, the nominal plunger length is four feet. They are saying length of upper holding two, lower holding, lower extensions to upper extension, and two. So this way, this is a barrel length. Ten is the barrel length. Okay, so you should understand this notation. So, when fixing any artificial lifting system, you must know the surface and subsurface notation. Whenever you are talking to any customer or vendor who will be delivering a sucker rod pump, or you are designing a sucker rod pump, you should be familiar with these terms or notations. So, based on that, you are buying or using your pumping systems.