Artificial Lift

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Lecture-34 Progressive Cavity Pump-Part-3

Good morning, everybody. Today, I will discuss the surface unit. The surface unit comprises several components responsible for driving your PCP. Let me illustrate how it looks. Imagine this is the surface, and you have a casing. Inside the casing, there will be tubing, and within the tubing is your pump.

Let me hatch this section to indicate the pump. The pump is powered by a sucker rod, which in turn is driven by a motor and drive system.

Here's the motor. Typically, it's a three-phase induction motor, usually four-pole or six-pole. There will also be a belt drive and a speed reducer. The motor's speed is usually around 3000 RPM, such as 50 or 60 Hz, but since PCP operates at a lower RPM, typically between 3 to 500 RPM, and sometimes as low as 100 RPM, depending on your wellbore conditions, you need to adjust the speed accordingly. You can run at a slower speed for very thick fluids, while thinner fluids often require higher speeds.

Now, the sucker rod comes down to this section, where you have the polish rod. The polish rod looks something like this. Attached to it, there's a stuffing box. This stuffing box is connected to the main sucker rod. When you need to reduce the speed, you may use a belt drive, or sometimes a gear drive, to adjust the speed accordingly. You don't connect the motor directly to the sucker rod due to speed considerations, so you must use these mechanisms to achieve the desired speed.

By the way, I previously discussed belt drives and gear drives in the context of the sucker rod pumping system, so if you'd like more details about them, please refer to that section.

This polished rod and stuffing box serve a similar purpose to the stuffing box in a sucker rod pump – it's a sealing section. The stuffing box, in other words, functions as a seal section. It ensures that the wellbore fluid remains properly contained.

So, the wellbore fluid should not cross the seal section; instead, it should flow through your pipeline, leading to the separation system. This way, the wellbore fluid you're producing remains contained. If it were to cross the stuffing box, it would result in leakage. On the left side, you can see a picture I've taken from the Weatherford catalog, and the link is provided below.

Here, you can see the motor, the drive system, typically with a belt, and there's the stuffing box. Inside the stuffing box, there's the polished rod, although you can't see it here. Then, there's a T junction where your fluid goes to the separator, and the polished rod connects directly to your wellbore. The sucker rod is also part of the system, although it's not visible in this image. As I mentioned earlier, the sucker rod primarily receives torque.

In the case of SRP (Sucker Rod Pumping), the sucker rod experiences tensile strength, tensile stress, and tensile load. Now, let's move on to the next slide. The surface unit is equipped with a variable speed drive, VSD, or variable frequency drive, VFD. If you have a VFD, it's essentially an AC drive, and you can connect it directly to your induction motor (IM). However, if you have a VSD, you can connect it to either an AC or DC motor. Typically, we use AC induction motors, three-phase motors, so you can use either a VFD or VSD. This becomes part of the surface system, allowing you to have more control over your pumping speed. It enables you to adjust the pump speed, for example, from 300 to 250 RPM or from 300 to 350 RPM.

Then you cannot change your belt drive or gear system because those mechanical components would need replacement. Instead, you have a VFD or VSD control unit where you can adjust the frequency or parameters, and it will automatically change the speed. So, you can change the pump speed easily using VFD or VSD, eliminating the need for mechanical adjustments. This unit will be connected to your motor.

The VFD or VSD is connected to a motor, and the motor's power goes to the belt drive. From there, the power is transmitted to the polished rod, then to a pony rod, followed by the sucker rod, and finally, to the pump. This sequence of power transmission drives the positive displacement pump. The progressive cavity pump, or PCP, is capable of pumping very high viscosity fluids.

Regarding belt drive, I've taken this picture from one of my friends who owns a husking mill with a belt drive system. I hope it's clear to see in the image. You can observe the flat belt drive and the V belt drive.

So, what's the difference between a V belt drive and a flat belt drive? A V belt drive can transfer more power, and it often consists of multiple V belts connected, usually with 5 or 7 belts connected together. These belts run on pulleys, sometimes referred to as sheaves. In this case, a small pulley is connected to the motor and a larger pulley is connected to your sucker rod.

Why is the big pulley connected to the sucker rod? It's because you are reducing speed. Imagine a small pulley with a diameter 'd' and a large pulley with a diameter 'D'. The speed change is proportional to the diameter ratio D/d. If D/d is two times, then the big wheel's diameter or seave diameter might be 1 meter, while the small one is 10 centimeters. In this case, the speed reduction will be 10 times. So, if the motor runs at 3000 RPM, the sucker rod speed will be 300 RPM if D/d equals 10. If your diameter ratio changes to 1/10, the speed will be reduced to 1/10th. The same principles apply to gear drives when it comes to changing speed.

In belt drives, several factors come into play. In the case of V belts, they are designed to carry higher power, which is essential for PCP systems that require significant power. The V belt has a cross-sectional shape with several layers of cotton and rubber. The pulley has a V-shaped groove, ensuring that the belt fits securely and maximizing surface contact. More surface contact means more friction, allowing the smaller wheel to turn the bigger wheel without sliding. If there is insufficient surface contact, the wheels may slide. In contrast, flat belts have less surface contact area, resulting in lower power-carrying capacity.

In cases of very high power transmission, flat belts are not used. Instead, V-belts are employed because they offer more surface contact. If you look at this picture, I'm illustrating the entire contact area for V-belts. With higher tension, the belt securely grips the grooves of the sheaves or pulleys, ensuring the transfer of more power. Therefore, even in your PCP surface drive and sucker rod pump (SRP), which you may recall as beam pump, V-belts are used to transmit power from the motor to the gearbox.

The Polish rod is similar to the sucker rod pump (SRP), but there's a distinction. In SRP, it reciprocates within the seal section, while the Polish rod rotates in the PCP. The seal section, known as a stuffing box, needs to ensure proper sealing to prevent fluid from entering and passing through. If the Polish rod's surface finish is uneven, it can damage the seal surface over time, leading to leaks.

In the case of SRP, the rod moves up and down, so no thrust bearing is required. However, in PCP, the rod rotates, necessitating a thrust bearing. So, why is a thrust bearing necessary? Imagine one bearing here, and you provide rotation to it. Two races are present with numerous balls. Due to the load, it may move downward. Multiple bearings are placed to prevent this downward movement, and a flat plate is inserted in between with many balls. These balls allow smooth rotation of the flat plate while supporting the load. Even though the black component is pulling downward, the upper plate remains fixed. It rotates continuously without allowing the assembly to move downward due to the lack of friction.

In this way, you create a thrust bearing that takes on axial loads. Thrust bearings are not designed for radial loads but exclusively for axial loads. The drive head will encompass all these parameters, such as the motor, belt drive, and gear mechanism. This allows you to adjust the speed. Additionally, there will be a stuffing box, and a backspin controller will also be present. If, due to certain reasons, your motor is not working and rotation stops, the entire fluid column will exert force on the pump.

The pump will attempt to rotate, and this could be disastrous. Therefore, you should have a braking or backspin controller system to stop the pump. This is known as a backspin controller.

When discussing sucker rods, there will be a table for sizing them. The nominal diameter of a sucker rod, which is used to determine its weight, needs to be considered. For example, a 3/4 inch sucker rod has a nominal diameter of 19 millimeters and a weight of 2.37 kilograms in air. If you have a larger diameter sucker rod, for instance, 7/8 inch, then the weight will be 3.17 kilograms. The weight of a 1-inch sucker rod will be 4.20 kilograms per meter in air. If you have a 1 1/8 inch rod, the weight will be 5.36 kilograms per meter. Knowing the rod size allows you to calculate the weight exerted on your thrust bearing.

The thrust generated by the head rating of the pump can be calculated using the formula I have previously provided:

Thrust generated, $F_b = (\pi * \Delta P * (2E + D)^2) / 4$

I explained this formula in the last lecture.

The total stress on the driving system denoted as 'f,' is equal to 'f' plus 'f_b,' where 'f' represents the fluid load, and 'f_b' represents the system's weight. The formula for calculating stress is '

$Stress = 0.4 / (\pi * d^3 * f^2 * d^2 + 64 * t * \tau^2 * 10^6)$.

So, the stress in MPa, total stress 'd' is the diameter of the driving string, the diameter of the driving string, which is the sucker rod. 'Tau' represents the resistance torque, and 'sigma t' is the stress in MPa.

Now, there are two types of rod grades: C and D. In the API table, you can find the C type grade with a minimum of 620 MPa and a maximum of 793 MPa; for the D type, the maximum is 965 MPa. Tubing is used because the sucker rod is a long rod, and when it moves through the tubing, it is possible to bend or become slanted. In such cases, centralizers need to be installed. A centralizer is a mechanical device designed to allow rotation but prevent contact with the tubing. It is placed around the sucker rod in a mechanical arrangement, ensuring that it stays centralized inside the tubing when it rotates, hence the name 'centralizer.'

A few centralizers (4 or 5) are typically sufficient in vertical wells. However, in crooked wellbores, multiple centralizers must be used; otherwise, the sucker rod string may touch the tubing. When this happens, the tubing can undergo constant erosion due to friction from the rotating rod, potentially leading to tubing leaks or sucker rod failures. Centralizers can also reduce vibrations and serve the additional function of preventing tubing from touching the casing when bending. Centralizers effectively centralize the system, minimizing vibration and preventing rubbing, which can extend the equipment's lifespan.

We've previously discussed ESP (Electric Submersible Pump) in other lectures. You can refer to those lectures for more information. In this case, we use a centrifugal pump with ESPCP.

When discussing ESPCP (Electric Submersible Progressive Cavity Pump), we combine PCP (Progressive Cavity Pump) with ESP (Electric Submersible Pump) because the term 'ESP' is already associated with centrifugal pumps. Therefore, designers use 'ESPC' (Electric Submersible PCP) to distinguish it. Just as in ESP, ESPCP includes a squirrel-cage induction motor protected by a protector. Electric cables run to the motor, and power passes through the protector. From there, the cable leads to the intake section and further to the pump section.

In a similar manner to ESP, but with a different pump type, ESPCP employs a multi-stage PCP (Progressive Cavity Pump). As previously mentioned, each stator pitch length represents one stage. Multiple stages involve multiple pitch lengths. This results in a progressive cavity pump that can be several meters long, specifically designed to handle viscous fluids, high viscosity substances, or heavy oil.

The surface unit for ESPCP remains the same, including features such as gas venting, a VFD (Variable Frequency Drive) system, and a control system. The primary difference lies in the motor used. Additionally, when the motor speed is higher, a gear drive is necessary to reduce the speed. Typically, you would use either a 4-pole or 6-pole configuration for an induction motor. At 50 Hz, the speed is 300 RPM for 4 poles and 200 RPM for 6 poles. At 60 Hz, the speed becomes 360 RPM for 4 poles and 240 RPM for 6 poles. A gearbox system with a gear ratio of 1:5 or 1:10 is placed between the motor and the pump, effectively reducing the speed and ensuring that the pump operates at the desired speed.