Artificial Lift

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Lecture-24 Sucker Rod Pump (SRP)-Part-3

Let's consider a scenario involving a wellbore with water in counterweight systems. Typically, you would have a pulley system like this and a bucket for drawing water. Pulling the bucket from the well requires a significant amount of energy to lift the water out. Conversely, when you lower the bucket back into the well, you need much less energy because you're dealing with the bucket's weight and the rope alone, which descend slowly.

The same principle applies to sucker rod pump systems. During the upstroke, you need a substantial amount of energy when you're trying to lift the entire fluid column. The weight of the fluid column can be calculated based on pressure and area, translating into the weight you're lifting. However, during the downstroke, as the fluid column, rod, and plunger descend, you require much less energy from the motor. Essentially, the motor works harder during the upstroke and requires less energy during the downstroke.

What happens if I don't have any counterbalance mass in my system? Here's how the system looks: I have a motor driving it, and there's no counterbalance mass. During the upstroke, you need a very high amount of power or energy, and the power requirement is significant. However, during the downstroke, you need very little power. This creates a fluctuation in power requirements.

But if we do it differently, I add a very heavy mass during the upstroke. As the fluid is lifted, this heavy mass pulls downward and rotates. When the lifting is completed and the piston starts moving down, the heavy mass moves up.

So, when the heavy mass moves up, the motor provides the energy to lift it. Then, as the piston moves down and starts moving up again, the heavy mass descends by itself. During this time, the piston assists in moving the heavy mass. When the heavy mass reaches its lowest point, the piston is at its maximum distance traveled, and then it reverses direction, moving down while the heavy mass moves up.

The heavy mass, also known as the counterbalance mass, moves down when the piston moves up, and it goes up when the piston moves down. This is why your motor requires half the power. When moving up, the counterbalance mass helps; when moving down, you provide some energy to store in the counterbalance mass. Gradually, you give energy during one half of the cycle and recover energy during the other half.

So, if you calculate the total mass required for your counterbalance, it will equal the maximum force required to lift the fluid plus half of the total force average. That will be your counterbalance mass. Now, you might wonder why the motor still provides power if the counterbalance mass is doing the work. The counterbalance mass assists during one part of the cycle but not the other. The motor continues to work continuously and provides constant power to lift the fluid. If it doesn't provide this power, the system will come to a stop.

The counterbalance mass helps reduce the peak power requirement for the motor. Without a counterbalance mass, the peak power demand would be very high, and the motor might not be able to handle it. During the downstroke, you don't need a lot of power, but energy would be wasted without the counterbalance mass. People use a counterbalance mass to optimize the system and sometimes employ arrangements to adjust the mass as needed.

The term "crank" is used in the context of an ice engine. The crank continuously rotates and is connected to the counterbalance mass. When it moves up, it moves down in the opposite direction. This is also connected to a connecting rod, which is often referred to as a pitman arm in the oil industry.

Moving on, a walking beam and a horse are connected here, and the horse is linked to a bridle. The bridle is connected to a polish rod, which passes through a seal section. This seal section marks the point where the polish rod enters and exits. One pipe will go in one direction, and another pipe for gas venting.

The tubing and casing are essential components. The casing should have perforations. The setup includes a wellhead, casing, reservoir, P_R (reservoir pressure), and P_{wf} (flowing pressure). There's tubing with sucker rods in place. This part of the system features a stuffing box.

Now, the stuffing box serves a purpose. The fluid should not spill on the surface when pumping fluid and lifting it. Instead, it should pass through a Tee junction. The Tee junction directs the fluid to a pipe, and this is where gas venting takes place. Gas comes through this pipe.

When you install a sucker rod pump, it is typically placed inside the tubing. It can be a tubing insert-type pump or a tubing pump. Sometimes, casing pumps are also available. Assume that this is a tubing pump or insert pump.

Fluid is pumped through the tubing, which needs to be connected to another pipe to proceed to the separation system. In the casing area, a gas accumulator may collect and remove gas from this gas line.

Any rod or surface may appear smooth to the average naked eyes, but the surface will reveal its roughness when observed under an electronic microscope or similar device. In the polish rod section, efforts are made to reduce this roughness to minimize friction and leakage.

In the seal section, people employed materials like cotton or other soft materials to create a clearance-free flow path for the polish rod. The polish rod moves up and down, and if a soft material is used, a negative clearance can be created, preventing fluid from leaking out. However, if a tough material with less flexibility is used, a specific clearance must be maintained for mechanical reasons, which can lead to some leakage. To avoid this, softer materials like cotton, asbestos, or rubber are utilized, and multiple seals are employed to prevent leakage completely.

People sometimes use energy seals, which become more active when high pressure is present. The stuffing box and bridle are essential components in this setup. The bridle is essentially a wire that forms an arc, resembling a horse's head. This wire is connected here, creating a continuous tangent with the horse's head. As a result, when the horse head moves up and down, it moves vertically tangentially without lateral movement. This design prevents extra forces from being applied to the stuffing box, reducing wear and tear and preventing leakage.

As previously mentioned, the polish rod must have an excellent surface finish and is the strongest part of the sucker rod system. It serves as the power transmission system in sucker rod pumping and must be longer than the stroke length. Proper sealing is also crucial. The need for strength is evident when considering the horse head, bridle, and polish rod. When the rod moves upward, it requires a significant amount of energy, and this energy is primarily concentrated in the top section. This top section must be robust enough to handle the weight of the entire rod, the fluid, and other frictional forces.

As previously mentioned, it must have a very good surface finish; otherwise, wear and tear will occur. Additionally, it should be longer than the stroke length. For instance, if there is a 74-inch stroke length, the polish rod must be longer than 74 inches. This additional length allows it to pass through the seal section and move continuously up and down. This flexibility in stroke length accommodates changes that may occur, such as elongation or other factors affecting the stroke length, and it aids in sealing within the stuffing box.

Bearings play a crucial role in various components. For example, there are saddle bearings, tail pin bearings, and crank pin bearings. Furthermore, there are gear mechanisms, and gears have specific friction surfaces. Bearings help reduce friction, which is essential because friction naturally occurs when two surfaces move, rotate, or slide against each other. High friction levels can lead to heat generation, spot welding, and changes in surface profiles. These factors can contribute to premature system failure.

It is crucial to inspect the surfaces whenever there is high-speed rotating machinery or even slow-speed machinery. You need to check whether they are adequately lubricated. If not, proper lubrication should be applied. In cases where the surface finish is insufficient, as with the polish rod, poor surface finish can lead to wear and tear in the sealing area. This can result in issues with achieving a leak-free system, which is the desired outcome.

Bearings play a significant role in this context. In the setup, there will be bearings, a motor, and several types of friction surfaces. Friction can occur when one shaft rotates while another slides, when different machine elements have sliding or rotating motions, or even a combination of these motions. Friction generates heat and leads to energy loss. To mitigate this, efforts should be made to reduce friction, typically by ensuring smooth surfaces.

Another approach is to shift from sliding contact to rolling contact. Sliding contact involves one shaft passing through a bearing, potentially causing significant friction. However, by using small rolling elements (like balls), friction can be reduced. This is akin to the principle used in bicycles, where small balls enable smooth rolling motion. Infection can be minimized by introducing rolling or point contact instead of surface contact, resulting in a longer machinery lifespan and lower energy losses.

There are different types of bearings, such as journal bearings, with no balls or rolling elements. In these bearings, the shaft rotates continuously. However, in some instances where a highly frictionless surface is required, small balls are used. When the shaft is inserted into these bearings, it rotates smoothly due to the rolling action of the balls. This reduces friction. Nevertheless, lubricating oil is still necessary even with the use of balls.

Lubricating oil typically consists of long-chain hydrocarbons. If you visit a motorcycle or car shop, you'll find various types of lubricating oils like castor oil and mobile oil. These lubricating oils are essentially composed of long-chain hydrocarbons. The chains in the oil slide over each other, creating a frictionless surface. This works by filling the gaps between microscopic surface irregularities. When two characters meet, a thin film is formed in the gaps, creating separation between the surfaces. This thin film's molecular layer moves over each other during motion, resulting in frictionless contact.

However, friction will increase if you reduce the amount of lubricating oil or the thickness of the lubrication film. Therefore, factors such as temperature and the applied load must be carefully assessed when considering a lubrication system.

When dealing with very high loads, such as in cigarette pumping or motor applications, liquid lubricants may not suffice. In such cases, solid lubricants are necessary. Graphite is an example of a solid lubricant that can be used. Solid lubricants like graphite provide effective lubrication in high-load scenarios.

I previously mentioned liquid lubricants, which typically consist of long-chain hydrocarbons. Sometimes, semi-solid lubricants or grease are used. For instance, thicker semi-solid lubricants are applied to bicycles in cycle shops. These semi-solid lubricants adhere well to the system and last longer, making them suitable for cycling applications. However, solid lubricants like graphite are not used in cycling applications as they tend to be almost dry and unnecessary for lower-pressure conditions. In such cases, liquid or grease-type lubricants are preferred.

The primary purpose of lubricants is to create a thin film between surfaces to reduce friction. When friction increases, heat generation also rises. This can lead to spot welding, increased surface wear and tear, and other problems. In cases where heat generation becomes a concern, cooling mechanisms may be employed. Lubricants also serve as cooling agents in various applications. For example, in internal combustion engines used in motorcycles and cars, the lubricant helps reduce temperatures. As the engine's crankshaft continuously rotates, it splashes lubricant onto the pistons, dissipating heat and lowering the overall temperature. Therefore, lubricants are crucial in reducing temperature and friction, creating a smooth, thin film between two surfaces.

Let's discuss different types of bearings. One type is the journal bearing, which involves surface-to-surface contact without ball or roller elements. In contrast, rolling, point, or line contact bearings have lower friction. These are known as ball bearings. In bicycles and motorcycles, you'll find various ball bearings. Sometimes, in the case of a bicycle that has been sitting unused for a while, you may notice it's not moving smoothly and is making noise. In such situations, you can visit a cycle shop where they will replace the old balls, clean the bearings, insert new balls, and apply grease. This maintenance procedure ensures smooth operation. Similarly, bicycle chains can also produce noise due to friction. Adding grease to reduce friction will make the bicycle run smoothly again.

However, excessive heat generation can be a significant concern in high-speed machinery. This heat can lead to system failure, even causing the metal to melt and resulting in spot welding, ultimately leading to a system breakdown. Low-speed machinery like bicycles dissipates generated heat into the environment more effectively, making heat generation less problematic. Nonetheless, the heat generated in high-speed machinery can be severe and detrimental to the system's integrity.

In the context of sucker rod pumps, we have previously discussed API RP 11. The term "RP" stands for Recommended Practice, and API, the American Petroleum Institute, recommends certain practices and standards through documents like API 11. These documents provide specifications for various aspects of sucker rod pumps, including rod and plunger sizes, pitman arm size, calculations, and dimensions, all presented in tabulated form.

One common designation used for sucker rod pumping calculations is taken from API, and it's denoted as follows:

- C: Conventional pump
- D: Double reduction gearbox
- M: Mark II
- A: Air balance
- B: Counterbalance unit

Additionally, a field code specifies peak torque ratings in thousands of inch-pounds, polished rod ratings in hundreds of pounds, and stroke length.

If you encounter such designations in an exam or elsewhere, you should be able to interpret and extract the relevant values. For more detailed information, you can refer to the book authored by Guo, Ghalambor, and others, titled "Petroleum Production Engineering." Now, let's take a look at the lever mechanism, as shown in the picture, where the horse head moves in a certain way while the load is applied in another area.

In the context of sucker rod pumps, there are different lever classes used:

- Class 1 lever: This is associated with the conventional unit.

- Class 3 lever: Class 3 levers are found in air balance units or Mark II units.

The gearbox speed ratio can be as high as 29:1, allowing for significant speed reduction when using a double-reduction or triple-reduction gearbox.

Sucker rod pumps can be designed for long-stroke applications, with stroke lengths ranging from 20 to 25 feet. In contrast, a normal conventional sucker rod pump typically has a much shorter stroke length of around 40 to 70 inches. This design accommodates the need for very long strokes in specific applications.