Artificial Lift

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Lecture-53 Hydraulic jet pump fundamentals - Part 1

Good morning, everybody. In the last lecture, we covered the basics of hydraulic pumping. Hydraulic pumping is structured as follows: you need a surface unit that delivers high-pressure fluid to your wellbore. This illustration shows my casing and my tubing, with tubing possibly having a packer. You then inject high-pressure fluid through the tubing and obtain production through your annulus.

This high-pressure fluid, denoted as HP fluid, is derived from the produced fluid after being conditioned. Conditioning involves removing any unnecessary particles, fluids, or gases.

Next, you generate high pressure using a multiplex pump. As we'll discuss later, multiplex pump typically consists of several cylinder pumps. From there, you store the high-pressure fluid in a tank, and it is this tank from which you inject high-pressure fluid into your wellbore.

For injection, a hydraulic engine pump or jet pump is utilized. The hydraulic jet pump or hydraulic engine pump functions by harnessing high-pressure fluid pumped from the surface to create low pressure or flowing pressure, which, in turn, enhances production. The method to generate low flowing pressure hinges on the flow rate and Pwf (flowing pressure). When drawing the IPR (inflow performance relationship) curve, it looks something like this.

Imagine that your initial curve represented the outflow or tubing performance relationships. Due to the presence of the jet pump, the hydrostatic pressure or Pwf is reduced. This moves your point from A to B. This change in pressure leads to an increase in flow rate, Q, as shown, and a decrease in flowing pressure. You are, therefore, able to obtain more production fluid. To achieve this increased flow rate, selecting the right artificial lift method is crucial. The choice of the proper artificial lift method involves various criteria, as I previously discussed and will revisit in the final lecture.

Ultimately, you decide to use hydraulic pumping. When it comes to hydraulic pumps, you have two options: hydraulic engine pump and hydraulic jet pump. In this lecture, we'll delve into the hydraulic engine pump. We'll discuss the hydraulic jet pump later on.

So, what is a hydraulic engine pump? The hydraulic engine pump features a reciprocating engine connected to a pumping unit. The engine and pump are linked through a rod or connecting rod. If you recall how a sucker rod pump operates, you'll understand. A sucker rod pump employs a beam and a horse head that drives a polish rod, which connects to a sucker rod and plunger assembly.

Now, in hydraulic engine pumping, you have a reciprocating motion without the need for a long sucker rod. You instead have a smaller rod, and the hydraulic engine, which I'll explain later, is powered by hydraulic fluid.

This high-pressure fluid, which you obtain by pumping at the surface, was mentioned previously. There is a high-pressure pump at the surface, which can be a duplex, simplex, triplex, or multiplex pump, among other types. Typically, a multiplex pump is used to generate high pressure, and this high-pressure fluid is pumped through this pipe. It may go through the annulus or tubing, or a separate tubing can be inserted. This high-pressure fluid powers a certain type of engine, which I will explain later. This engine creates a reciprocating motion in this rod, marked in red. This rod experiences reciprocating motion, and it operates the pump.

As seen, this red rod has a reciprocating motion. This reciprocating motion operates the pump, which has a traveling and standing valve, similar to the setup in a sucker rod pump. A sucker rod pump has a plunger, a traveling valve, and a standing valve. We also have a plunger, a rod, and an air rod in the hydraulic engine pump. However, the hydraulic engine pump uses a short sucker rod or a connecting rod.

This short sucker rod, or connecting rod, serves the same function. The pump part works with a traveling and standing valves, with the piston moving up. When the standing valve opens, the traveling valve delivers fluid, and when the piston or plunger moves down, the standing valve closes the pathway, causing fluid to move upward. In this way, the pump part operates. The hydraulic engine pump consists of two parts: the pump end and the engine end.

This is operated entirely by fluid, without a long sucker rod, as it uses only a connecting rod. It's designed as a complete assembly that combines both the engine and pump, which can be inserted into a very long wellbore. Its operation is similar to a sucker rod pump, with comparable issues such as gas lock or gas interference. However, it doesn't face problems like long rod breakage because the rod is short. Other problems that exist in the hydraulic engine pump are related to the engine itself.

Gas, sand, and flow-related issues resemble those encountered by a sucker rod pump in the bottom hole assembly. Unlike traditional units like the beam, nodding donkey, or horsehead, the hydraulic engine pump does not have surface equipment. Instead, a fluid system on the surface creates high pressure. This high-pressure fluid travels down through your tubing or a separate inserted tubing, driving the engine and enabling production.

I mentioned terms like simplex, duplex, and single-acting and double-acting pumps in the system. Single-acting pumps, for example, are represented by sucker rod pumps, where a single plunger moves up and down, causing the standing and traveling valves to act continuously. Production occurs during the upstroke while the standing valve is closed during the downstroke. In essence, single-acting pumps only produce during one cycle phase.

Now, if we consider double-acting pumps, they work differently. In a single-acting pump, we have a valve here and a valve there. I am explaining this single-acting pump to lay the groundwork for the next lecture when we will discuss pumps and compressors. Here, this is valve 1, this is valve 2, this is the plunger, this is the rod, and this is the piston.

Now, when the piston is moving from A to B, the rod moves from B to A. So, as the rod moves from B to A, the piston moves from left to right. During this time, v1 will be open, while v2 is closed. V1 is open, and v2 is open to suck in fluid.

When the rod moves from A to B, meaning the piston moves from left to right, v1 closes, and v2 opens, allowing fluid to exit through v2. This is an example of a single-acting system.

In a single-acting system, fluid is delivered when the plunger moves from A to B, and no delivery occurs from B to A. It's similar to a cycle pump, where pushing it down delivers air to your cycle tire, but during the upward motion, no delivery occurs; instead, it sucks in fluid from the atmosphere or surroundings, followed by another pushing cycle. This results in intermittent flow.

You can use a double-acting piston to avoid this intermittent flow and create a more continuous flow. A double-acting piston works as follows: I'll draw a similar figure with a sealing arrangement. The piston is located in the cylinder, with very limited clearance. The piston operates in two directions, A and B, making it a double-acting system.

Now, let's consider how the double-acting piston works. Let's say the piston is moving along with the rod, represented by B to A. The same phenomenon occurs as the piston moves from B to A: v1 closes and v2 opens.

Fluid enters the cylinder when the piston is moving from B to A. The opposite happens during A to B motion, where V1 closes, and V2 opens, allowing fluid to exit through V2. So, the basic operation in this part of the explanation is the same for both single-acting and double-acting systems.

However, for double-acting systems, there's an additional valve, located near A, which comes into play when the piston is moving in the opposite direction. When the piston moves from B to A, it acts as a suction valve, and the delivery valve operates when the piston moves in the other direction. This creates a more continuous flow. So, you have V1, V2, and additional valves, like V3 and V4, for fluid entry and exit.

In the case of V3, when the rod is moving from B to A (left to right), one side allows fluid to enter, while the cavity (represented by dots) in the cylinder is filled with liquid. The fluid then exits through V4 when it's open, with V3 being closed. Fluid enters the cylinder (cylinder I or II, for example) and exits, creating a smoother pressure pulse.

For a double-acting system, the piston moves from B to A, and two cylinders (I and II, for instance) are involved. One is filling with fluid, while the other is delivering fluid. The process is reversed when the piston moves from A to B, ensuring continuous fluid movement in both directions. This results in a smoother pressure pulse compared to the single-acting system. Double-acting pumps are also referred to as "duplex" at times.

If you have multiple cylinders, that pressure pulse can be smoother. However, a single-stroke or double-stroke engine can be used for my hydraulic engine pump. This continuously results in one or two pulses as the piston moves up. The red rod I've drawn here represents the piston rod, which moves up during delivery and down during pumping. This creates a double flow rate. In contrast, flow occurs only during the upstroke in a Sucker Rod Pump (SRP). Whether you choose a single-acting or double-acting system depends on your preference or specific requirements.

Now, the pump can have either a single-acting or double-acting mechanism. Similarly, the engine side can be either single-acting or double-acting. Here, the piston is connected to the pump piston, and there's a sealing arrangement. The piston is connected to the rod, which interacts with the sucker rod pump mechanism. When the high-pressure fluid enters the cylinder through valve 1, it pressurizes the surface. This surface pressure attempts to push the rod down, causing the piston to move, similar to a sucker rod pump mechanism. The fluid entering and exiting here in this section is the produced fluid or pump fluid, and the other fluid is the power fluid. The power fluid comes from the surface, where a high-pressure pump provides it. This high-pressure fluid then pressurizes the piston, which is linked to the plunger assembly for the pump. As the piston moves down, the pump delivers fluid, and when the piston moves up, the pump continues delivering. Both the engine piston and the plunger for the pump move together because they are connected.

Moving down, it delivers fluid, and when moving up, you close V1 on the engine piston or plunger. This setup is called a hydraulic piston pump or hydraulic plunger pump, also known as a hydraulic piston engine or hydraulic engine pump.

For the engine piston, high-pressure fluid serves as the power fluid or motive fluid. High-pressure fluid enters through VE1, causing the piston engine to move down, as I'll randomly name it here. This downward movement drives the pump piston, which moves down together with the engine piston. Next, you close valve V1, and then you close VE1 while opening VE2. The high-pressure fluid in cavity 1 exits and reaches the surface through a different tubing. The exiting fluid will have lower pressure because a certain pressure was initially applied to the pump as it was pushed downward. It retains a lower pressure as it moves up to the surface. This same fluid can be reinjected, creating a continuous flow.

The same process occurs on the pump side. You'll have another set of valves if you employ a double-acting piston. VE3 will be present, along with VE4. When the piston is moving down, VE3 and VE4 are inactive, meaning they are not creating any pressure; they simply allow fluid to exit. VE3 is opened to deliver high-pressure fluid during the piston's upward movement. This high-pressure fluid enters chamber 2, creating a vacuum or a region with very low pressure.

Due to the high pressure, the piston moves up. So, the PE piston moves up. During this motion, you are getting high-pressure fluid (PE piston moving up). When the piston is moving down again, the opposite happens. VE3 allows fluid to exit from cavity 2, while cavity 1 gets filled with high pressure fluid, resulting in the piston moving down due to high pressure. Once again, you are getting very high pressure at the bottom when the piston moves up. Continuously, you are operating two valves. There will be some mechanism to automatically operate the valves, one valve opening while the other closes. So all four valves will be working simultaneously, allowing you to achieve continuous piston movement up and down. This reciprocating movement causes the pump plunger to move up and down, and you can also create a double-acting pump.

Engineers will design it in a similar manner to how single-acting and double-acting pumps work, enabling you to deliver fluid effectively. Since this is a short pump with a length less than that of a sucker rod pump or beam pump, you can use it for very deep wells without encountering issues associated with long sucker rods and surface motion. However, it is a low-flow rate pump and may face problems with gas and sand. Typically, it is not used for gas well deliquification due to the high gas volume it would handle. If the piston speed is very high, it can lead to failure, and you'll need to control the pressure from the surface to reduce the speed. A sealing section with metal-to-metal seals is usually present to prevent mixing of power fluid from the engine side and produced fluid from the pump side. The piston size for 2 1/2-inch tubing varies and can be around 1 3/4 inch, 1 5/8 inch, 1 1/2 inch, 1 1/4 inch, or 1 1/16 inch. These piston sizes are suitable for 2 1/2-inch tubing.