Artificial Lift

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Lecture-35 Progressive Cavity Pump-Part-4

This is a PCP rotor. Actually, what I was discussing about in the PCP experiment. In the experiment, we use one PCP with this rotor, and I have one stator. You can see the stator has one hole, and it's not a circular hole; it has a wall-type shape. So, this end will go there. When this rotor continuously rotates, it moves from one end to another, moving and rotating, moving and rotating, one end moving and rotating.

This is a two-stage PCP. How can I say it's two-stage? I cannot see it from the outside, but I can calculate how here. If you see this helix and this helix, one pitch, two pitches, three pitches, four pitches. Four pitches are there. One, two, three, four. Four pitches are there, which means the stator will have four divided by two, meaning two pitches. That means this is a two-stage PCP. Now, you have a two-stage PCP, and when you connect it to the motor, as I mentioned, it rotates continuously, moving forward, backward, rotating forward, backward, rotating, and forward, backward. So, you need a proper coupling.

Here, I have a coupling, actually. I removed everything. You can see this. This is a coupling, a small shaft or connector. This is a connector. So, you put this connector; one pin is there. You can see this hole. One pin is here, a pin, and here is one hole. You can see there is one hole. So, you put it here, put one pin. I will put my pin here. I have a pin; it's like a pencil. Where is my pencil? The pencil is here. So, assume this is my pin. Where is my pin? Yeah. So, now it is fixed. Now, if it's rotating continuously and moving forward, backward, I have lots of flexibility here. You see this end is flexible. This end is fixed, but this end is flexible. While rotating, moving, it will have forward, backward motion or rotation. Both, there will be no issue. PCP fails because of elastomeric failure. Why does elastomeric failure happen? The rotor continuously rubs against the stator. I already mentioned that.

You can remember that this is the rotor. The rotor is moving forward, up and down. If this is my stator cavity, and this is the rotor. So, when it is moving in this direction, rotating this way, it is walking, and in the opposite direction, it's rubbing. So, one surface will be rubbing, and the other surface will be walking. Walking means it is rolling, and the other surface is rubbing. So, the rubbing surface will erode quickly. Elastomeric erosion will occur. And if I have hydrogen, hydrogen pitting will happen. H_2S will react with the elastomer, creating a hard surface instead of the softer elastomeric material. So, it will create some harder material, and it will break. There will be wear and tear, erosion, wear, and pitting.

You can see this rotor here. I think you can see the color here on the camera. Rotor, some erosion is there. Some rust is here. Rust is present because of rubbing action; the surface coating, usually nickel coating, gets removed. As the nickel coating is removed, the surface becomes rough. A rough surface will cause further erosion on your stator, creating stator wear. This will lead to further wear and tear, and the whole system will fail. Leakage will increase. Rotor, bearing, and other mechanical failures may also occur. Surface dry beam, stuffing box, and other failures may be common. Typically, the PCP life will be 4 to 6 months. Why 4 to 6 months? Because of wear and elastomeric failure. The rotor can also fail, as shown here. The rotor can break, or it can get clogged if some sand enters. Sand may get trapped in the clearance zone between the rotor and stator interface. When sand is present in the clearance zone, it will rub against the surfaces, creating a rough surface that further deteriorates the system.

Next, we have the calculation of pump forces and torques. The minimum pump displacement, Q_{amin}, equals $Q_{aactual}$ divided by omega eta, with units in barrels per day per RPM. Then, Q actual is in barrels per day, rotor rotation, and volumetric efficiency. The recommended RPM depends on viscosity. If you have less than 500 viscosity cP, your RPM can be approximately 200 to 300 RPM. If you have viscosity between 500 and 5000, then the speed can be in the range of 150 to 300 RPM.

If you have a viscosity of more than 5000, then your speed can be set between 100 to 250 RPM. As you can observe, as viscosity increases, speed also increases. When you have low viscosity, you must run the pump faster to reduce leakage. However, if you have high viscosity, you should operate the pump at a slower pace. Furthermore, if you increase the flow rate significantly, you will encounter a high frictional pressure drop.

You can recall the formula:

$\Delta P = (fLV^2)/(2gd)$

With high fluid velocity, the pressure drop will also be high. Therefore, when dealing with high viscosity, where fluid friction (f) is already high, and fluid velocity is increased significantly, the pressure drop will be even higher. To mitigate a high frictional pressure drop, reduce fluid velocity, and your pressure drop will decrease.

Let's talk about net lift,

$(P_{lift}),=(P_d - P_i)$

P_d represents pump discharge pressure, and P_i represents inlet or intake pressure. It's crucial to maintain consistent units for both variables. For instance, if you use psi for Plift, P_i must also be in psi. What does P_i consist of? P_i will be equal to P_{ch} (casing head pressure) plus P_g (gas pressure) plus P_l (liquid pressure) minus P_{tilde}. P_{tilde} represents tail pressure, which is essentially suction pressure. It includes pressure losses associated with auxiliary components, such as inlet gas separators, and so on.

Now, let's examine pump discharge pressure (P_d). P_d is calculated as follows:

$P_d = P_{th} + P_l + P_{losses}$

With this formula in mind, let's tackle a problem. In this scenario, we have a vertical wellbore with an expected production rate of 629 barrels per day using a PCP. We are assuming a conventional PCP, with oil gravity at 12 degrees API and oil viscosity at 1000. The casing size is 7 inches in outer diameter.

If the outer diameter is not specified, we still assume it refers to the outer diameter. Let's start by drawing a diagram on the casing perforation depth. The perforation depth is given as 3281 feet, and the fluid level is at 1968 feet. This represents the tubing, with the fluid level located at 1968 feet from the surface. The flow line pressure at the tubing head is 218 psi, denoted as P_{th}.

A vertical well is expected to produce 629 B/D using a PCP.

Given data:

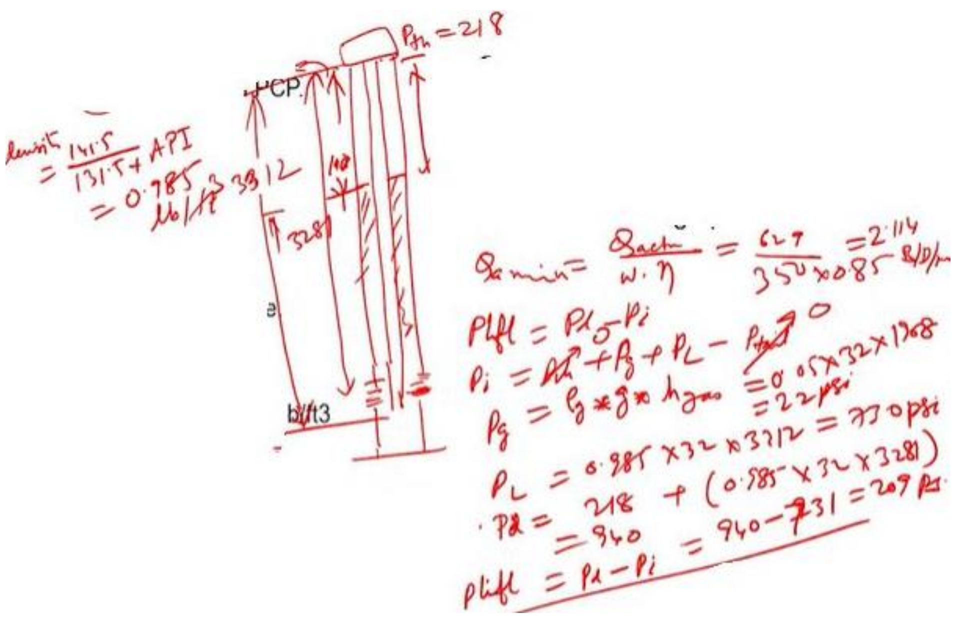
- Oil gravity: 12°API.
- Oil viscosity: 1000 cP.
- Casing size: 7 in. OD.
- Casing perforation depth: 3281 ft from surface.
- Fluid level: 1,968 ft from surface at desired flow rate.
- Flowline pressure or tubing head pressure: 218 psi.
- The pump was set below the perforations at 3312 ft.
- Average gas density: 0.05 lb/ft3, luquid density 61.4 lb/ft3

Assume:

- The casing is vented to atmosphere.
- Flow losses are negligible.
- Suction losses are negligible.
- No water, gas, or sand is there with the oil production.
- Pump speed < 350 rpm.
- Pump length is 33 ft.
- The pump should not be loaded above its rated pressure.
- The pump operates at 85% volumetric efficiency.

Calculate (answer in field unit):

a) Minimum pump displacement
b) Net lift required
c) Pump intake pressure
d) Pump discharge pressure



The pump is positioned below the perforation at 3312 feet, which means it's situated here. The actual perforation depth is 3281 feet, but the pump is at 3312 feet. Average gas density is specified as 0.5, and liquid density is given as 61.4. We assume that the casing is vented to the atmosphere, meaning there is no pressure present in this area; it is open to the atmosphere. We neglect flow losses, including friction or pressure drop in the suction line. Suction losses are also considered negligible, and P_{tail} is set to 0. Casing head pressure (P_{ch}) is 0, and we assume no water or gas is present; it's pure oil.

The pump operates at 350 rpm, as indicated, which is less than 350 rpm. The pump length is 33 feet and should not be loaded above the rated pressure. The pump's efficiency is 85%, denoted as eta = 0.85.

We need to calculate the minimum pump displacement, net lift, pump intake pressure, and pump discharge pressure. The minimum pump displacement formula is

$Q_{actualminimum} = Q_{actual} / (W\eta_{volume})$

We have the value of Q_{actual} as 629. Therefore,

$Q_{actualminimum}$ = 629 / (350 * 0.85) = 2.114 barrels per day per rpm.

Next, we calculate P_{lift}, where $P_{lift} = P_d - P_i$,

$P_i = P_{ch} + P_g + P_l - P_{tail}$.

Given that P_{tail} is already 0, it simplifies to $P_{ch} + P_g + P_l$.

$P_g = rho_g * g * h_{gas}$, where h_{gas} is 1968 feet.

So, P_g = 0.05 * 32 * 1968 = 282 psi.

P_l is calculated as 0.985 * 32 * 3312 = 730 psi.

Finally, $P_d = P_{th}$ + 0.985 * 32 * 3281 = 940 psi.

Therefore, Plift = 940 - (282 + 730) = 940 - 1012 = -72 psi.