Artificial Lift

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Lecture-54 Hydraulic Jet Pump Fundamentals - Part 2

Pump engine ratio. So, let's say piston engine area is "engine piston area" piston area, and a middle rod area, this is the middle rod, then it will be connected to your pump. This is the pump piston, this is the engine piston. So, this pump piston area A_p, this area is A_p, this is A_e engine area, pump piston area A_p.

So, $P/E= A_p/(A_e-A_{mr})$

This is the standard formula if you remember, piston area divided by the area of the engine minus the area of the middle rod, because the middle rod will have a shape like this, so the total volume will be different.

So, the formula for a pump with a balanced middle rod will change to

$P/E= A_p/(A_e-A_{mr})$.

A high P ratio requires lower power fluid volume, A high P by E ratio requires a higher, because a lower power fluid, power fluid, lower power fluid volume. Since on the surface when you are pumping, you have two options. You have central power, central power fluid, power fluid conditioning, and one is a self-contained, self-contained power fluid PF, PF conditioning. The success of an economical operation is based on whether it is self-contained power fluid conditioning or centralized.

Centralized means you have many wellbores, one centralized system, and one whole system is there, and a manifold will be there to control the flow rate and you are delivering fluid using that one. There are two types basically for installations: fixed type and free type. In free type, the system will look like this: you have one tubing, and you have one bottom valve here, standing valve, and you have another tubing or flow line going to the surface. Let us say initially there is no pump, now you put one pump here, so the pump will be like this, just I am drawing a picture figure, and you have an on-standing valve, and your side flow line is here, and this flow line is connected to here, here, and this is going like this. So the pump is in, and you are giving very high pressure here, high pressure is there, power fluid you are giving, power fluid you are pumping, and the pump is going down to your exact location.

So, this is a free installation, but when you change and want to install just using power fluid, you pressurize the system and move on. So normally this free-type system will not be used for your engine pump type system; it should be used for your jet pump type system. So this free-type system also there will be a casing-free design, and there will be a parallel-free design. So these are OFP installation, open power fluid, OPF, open power fluid installation, and another is fixed, this is free type, I put it wrongly, and fixed type. Fixed type, what happens, your tubing and pump will be fixed on tubing, so you are not making it free with power fluid.

So, the fixed type installation, concentric installation, fixed concentric installation, installation option will be there, and the fixed casing type will be there, and another is the wireline type. So, wireline type normally is not used for your hydraulic engine pump, and when your operator will think that I will not remove the whole tubing, so that there will be, you can install the pump anywhere, and the wireline will be used to retrieve or fix it fixed. So this is called the wireline type. So, for a jet pump only, a jet pump only. Open power fluid, casing-free design, and parallel free design.

In the case of casing-free design and parallel fluid, parallel-free design, in fixed insertion type, you have one tubing, put one macaroni, a small macaroni tube, and use that macaroni tube to pump power fluid. So, you can get production through your annular area, or maybe you can get production through this area, and gas can go through this, and this one can be production tubing, and power fluid is going through your macaroni tubing. So, this way fixed insert type works. Another type can be the fixed casing type.

The fixed casing type will not have any macaroni tubing. So, you are pumping here, and you are getting production here through the annular area. Power fluid, power fluid normally there will be two types of power fluid, oil power fluid, and water power fluid. So, what is oil power fluid? This is a good lubricant, and oil means like crude oil, whatever you are getting. So, normally that same thing you are injecting. So, good lubricating capability is there. For the hydraulic engine pump, we use this oil power fluid. So, it will lubricate properly. So, the friction will be lower. So, good lubricating property is there, and you have the hammering effect because of compressibility.

Compressibility is there. So, this will reduce the hammering effect or water hammer or hammering effect you see. It is not water. So, it is not a water hammer; the hammering effect is that when you have a long pipe and fluid is flowing continuously, it may be a horizontal pipe or vertical pipe, it doesn't matter. The fluid is continuously flowing, let's say from top to bottom or bottom to top, and suddenly you close the exit valve.

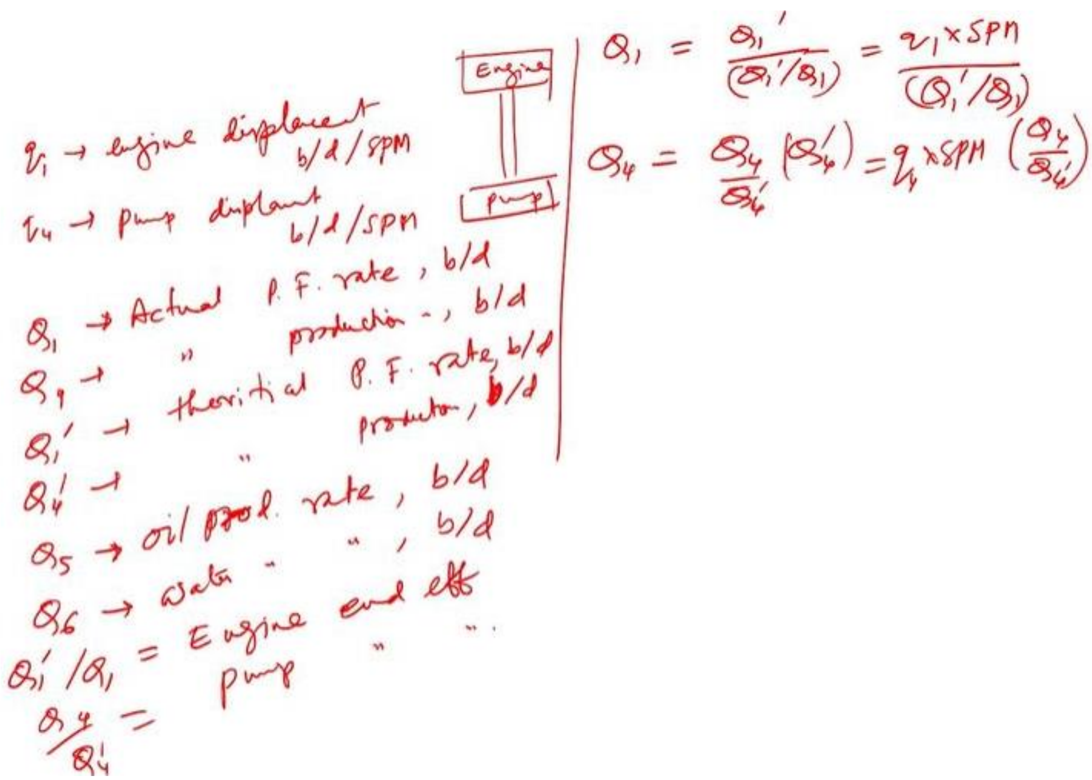
So, what will happen? The fluid has its own momentum, moving, and you suddenly stop it. So, if you stop it, the whole fluid will try to push against the pipe. That will create vibration, shock, and the pipe can burst also. So, that is called the hammering effect. To avoid the hammering effect, normally people will have an accumulator or some extra arrangement for such control.

So, whatever pressure pulse is there because of the fluid momentum can be reduced or diverted to some other piping, tubing, or hole. So, the whole system will not get broken or will not have leaks or bursts. So, this oil is good for that. Next is it has one drawback, it is a fire hazard.

A fire hazard can be an issue for oil as a power fluid. On the other hand, water does not have good lubricating properties; its lubrication properties are definitely lower than oil. Friction loss is high. Friction loss is high here. So, that is why people will be looking at which is better for a certain application based on that they will be selecting the power fluid.

Now, we will try to go towards mathematical problems. So, let us see the formula. Let's say q1 is engine displacement. q1 is the engine's displacement, and this one is the pump. Pump. So, engine displacement, and the unit is barrel per day per SPM, stroke per minute.

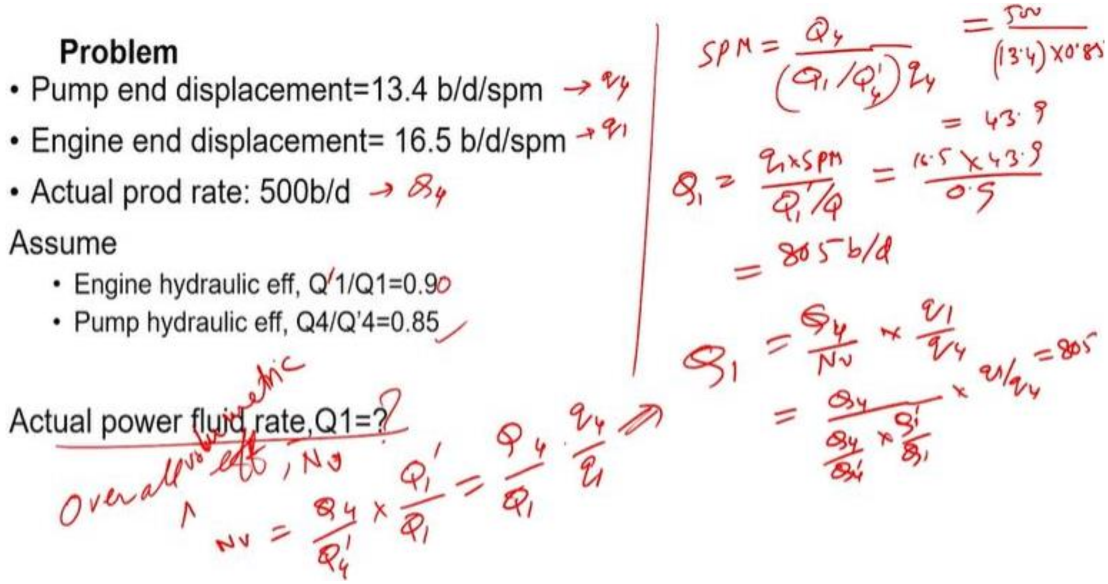
Okay, q4 pump displacement, again barrel per day SPM. Okay, q. This is pump displacement. q1 is the actual power fluid displacement, the actual power fluid rate in barrels per day. q4 is the actual production rate, also in barrels per day. q1 dash is the theoretical power fluid rate, again in barrels per day. q4 dash is the theoretical production rate, in barrels per day. BPD, small b, capital B. So, there is no uniformity yet, actually, many books write different ways. Okay, now q5 is the oil production rate, oil production rate, in barrels per day, and q6 is the water production rate, again in barrels per day.



q1 by q1, q1' by q1 equals engine end efficiency, the engine end efficiency, and q4/q4' pump end efficiency, pump end efficiency.

Okay, now q1 equals q1 dash by q1 dash by q1. Okay, you can write it like this, so this will give q1 into SPM q1 dash by q1. Okay, and q4 equals q4 into q4 dash into q4 dash, the same thing, I am writing it differently. So this will give q small q4 into SPM into q4 q4 dash.

Now, using this formula, we will try to solve the problem. Okay, you see this pump end displacement. Pump end displacement is given; pump end displacement means q4 engine end displacement, q small q1 actual production rate is q4. Okay, so it is given in the problem that the engine hydraulic efficiency q1 dash by q1 is 90 percent. Okay, 90 percent efficiency, pump hydraulic efficiency is 85 percent efficiency. Okay, now using that, you have to calculate the actual fluid rate q1 equals how much.



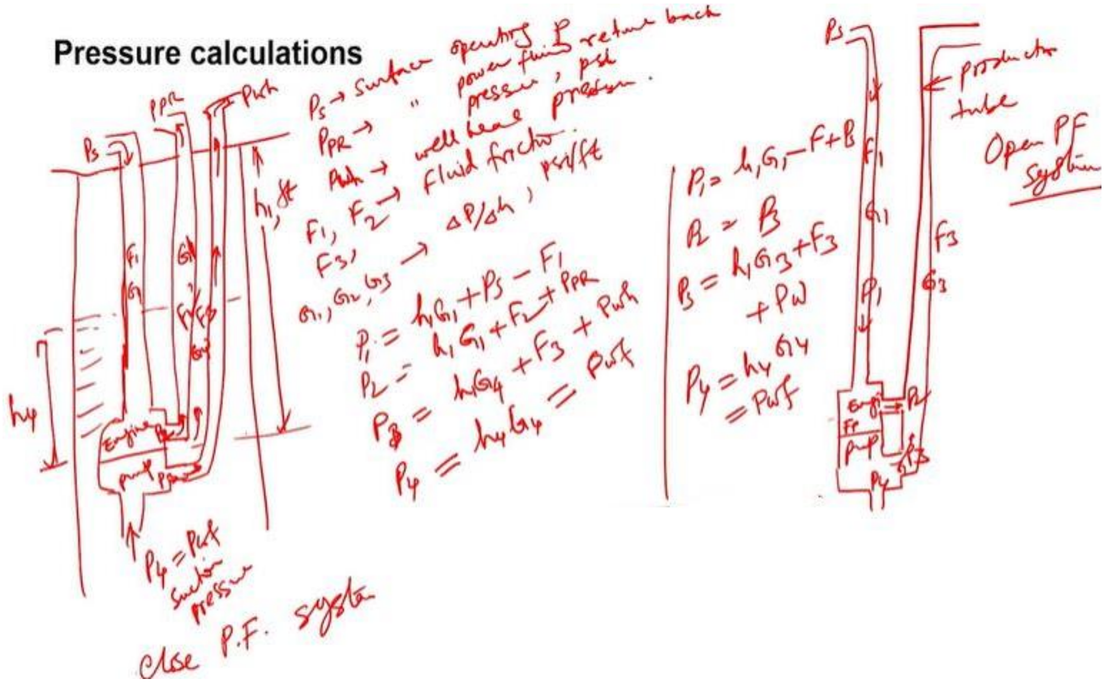
Now, overall efficiency, overall efficiency. If Nv is the overall volumetric efficiency, then it is Nv equals q4 by q4 dash into q1 dash by q1, so that gives q4 by q1 into q4 by q1, so this formula gives q1 equals q4 Nv into q1 q4. So this formula is 500 q4 q4 q4 dash into q1 q1 dash into q1 q4. So, finally, this becomes 805. Okay, the same result you can get; you can use any formula.

Now, how this hydraulic engine pump pressure should be calculated. First, you draw one picture of the closed power fluid system. So, the closed power fluid system is like this.

Materials are moving like this, then there will be an engine and a pump. The engine is there, and the pump is there, and from the engine, there is one pipe going, and from the pump, there is one pipe going. The pump and engine have pipes going to the surface. Okay, this is the surface.

Now, in this case, on the engine side, there is the engine, and on the pump side, there is the pump. The surface pressure is PPR, which stands for surface power return back pressure. High-pressure fluid is going, and high-pressure fluid is returning here. You see from the engine and pump, the fluid is not mixing up. Whatever you are pumping, the same fluid you are getting up, but the pressure is changing, so the surface pressure is delivery pressure Ps. But when returning back, it is PPR, surface pressure.

Psi - all the units will be the same. I'm assuming Pwh, wellhead pressure. Wellhead pressure, f1, f2 are fluid friction. When fluid is flowing, it has fluid friction. F3 is also fluid friction. G1, G2, G3 are all fluid gradients, del P by del h, Psi by ft.



Pump setting depth is the depth where the pump is set, h. H1 is the pump setting depth, h1 in feet. H4 is pump submergence, which means initially, I am assuming the fluid is here. Pump submergence, h4, is the depth to the pump inlet, where this much of the fluid level is already. So, P4 is the suction pressure actually. Suction pressure or Pwf (flowing pressure).

P1 is calculated as P1 equals h1 g1, where h1 is the total fluid column length in feet multiplied by g gradient. This much of the total fluid is pressurizing downward plus the surface pressure Ps. But there's friction force, so that will be subtracted, minus f1.

P2 will be h1 g1 pressure, and P2 is there on the engine side. After the engine, you find P2.

P3 is the pump delivering pressure. P3 pump delivering pressure, and P3 g4 gradient, because wellbore fluid gradient and friction are also different.

Okay, so P4 P3 equals h1 g4. Wellbore fluid gradient is different; that's why it is g4, and friction force also will be acting, plus wellhead pressure. Okay, so P wellhead will be here. This is returning fluid; P wellhead pressure is here; fluid is going from the pump. P4, what is P4? P4 is suction pressure. Suction pressure means h4 g4.

H4 means how much liquid column is there. Pump submergence is what you said, and there will be certain, okay, there is ignoring friction. Okay, equals your flowing pressure, Pwf. Now, this is for a closed power fluid system. Closed power fluid system.

Now, if I have an open system, okay, an open system is mixing up two fluids. Inlet your power fluid and produce fluid, both are mixing up. So, this is going down. Okay, this is going like this. Engine is here. Okay, this is the engine; this is the pump; this is P4, and Ps suction pressure is the same, and friction force we are assuming the same, g1 we are assuming the same, and P1 is acting here. Okay, this is Fp; this is P4, and g4 is here, P3 is here, this is P2, this is g3, this is F3, this is the production tubing. This is the power tubing; power fluid is coming here. Okay, for this one, this is an open system, an open power fluid system.

P1 equals h1 g1 minus F1, friction opposite direction working, Ps surface pressure, and fluid gradient gradient pressure minus friction. P2 equals P3 actually. Okay, so P2 from the engine, whatever pressure is going, and from the pump, whatever pump pressure is going out, so both are mixing up, so the pressure will be the same. P2 P3 is the same, and P3, how to calculate, h1 g3, h1, the same column height, but your fluid gradient is changed, plus friction will be acting. This flow rate will be different. So friction value also will be different, plus wellhead pressure. Okay, and P4, again, the sub and P4, again, the suction side, equals h4 g4, equals flowing pressure. So using this one, we can create some problems, and I can give you. Okay, thank you very much for today's lecture. The next day, we will start jet pumps. Thank you very much.