Artificial Lift

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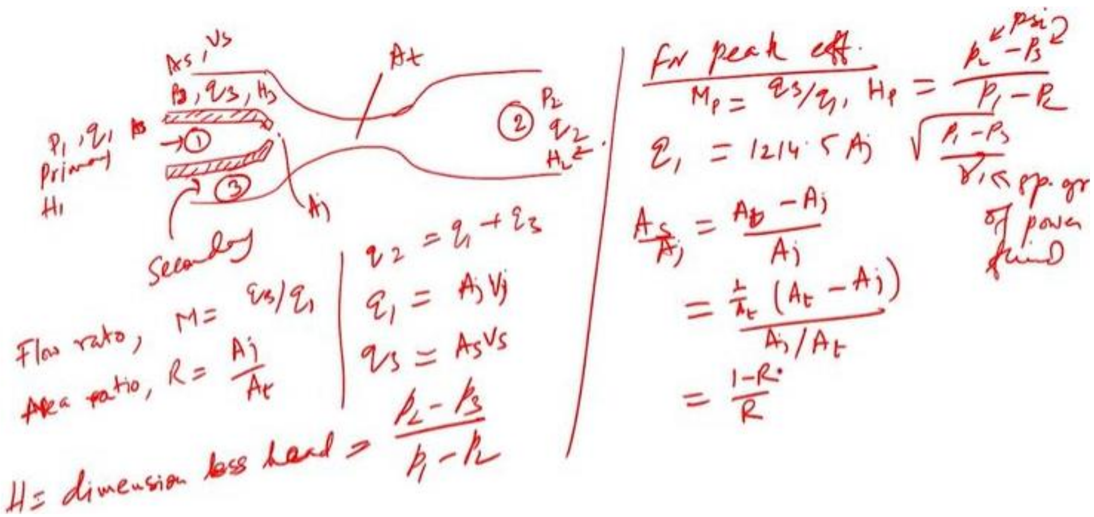
Lecture-56 Hydraulic Engine Pump Fundamentals - Part 2

Now, let's revisit some formulas for jet pumps. Jet pumps can be depicted in various ways, and there are no strict rules for drawing them. For example, it can be illustrated like this: a nozzle is represented as a cross-section. I've shaded it to indicate a cut-out view; this is the primary fluid and the secondary fluid. The primary fluid is associated with pressure P_1, flow rate Q_1, and energy h_1, while the secondary fluid is linked to pressure P_3, volume flow rate Q_3, and energy h_3. The discharge pressure P_2, flow rate Q_2, and energy h_2 are associated with section 2. This is section 1, this is section 3, and this is section 2.

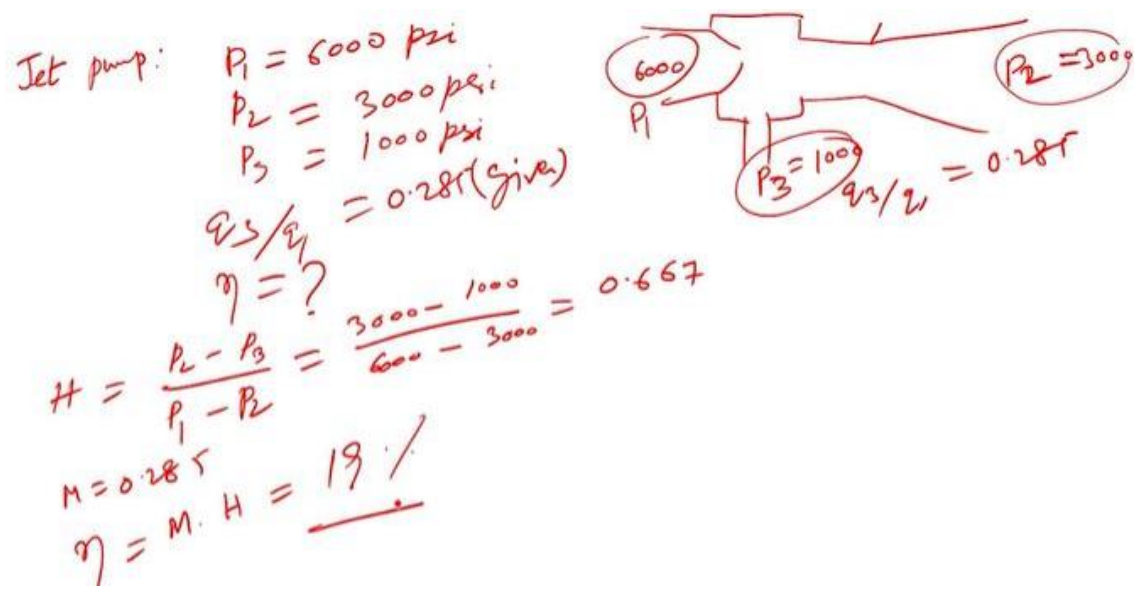


For peak efficiency (Mp), the mass ratio (Mp) can be calculated as Q_3 / Q_1, and the dimensionless head (Hp) is given by P_2 - P_3 / P_1 - P_2. The formula for Q_1 is 1214.5 Aj $\sqrt{}$(P_1 - P_3) / γ, where γ is the density or specific gravity of the power fluid. These values are given in psi, with P_1, P_2, and P_3 all in psi as well.

We also have A_s / A_j = A_t - A_j / A_j, which simplifies to 1 - R / R, giving us the area ratio. This chart is a representation of data that can be useful when conducting experiments or mathematical problem-solving. It shows the relationship between flow ratio (m) and head ratio (h).

For different area ratio (R) values, you can observe how head (h) changes. The efficiency (η) tends to remain below 25 percent and doesn't typically exceed 30 percent. Using this chart, you can tackle various mathematical problems. Let's consider an example problem where we need to find the efficiency (η) of a jet pump with given pressures P_1, P_2, and P_3, as well as Q_3 / Q_1. By calculating the head (h) using the formula, we can then determine η.

Keep in mind that you shouldn't expect efficiency values higher than 30 percent. If you get an efficiency above this range, double-check your data and calculations to ensure their accuracy.

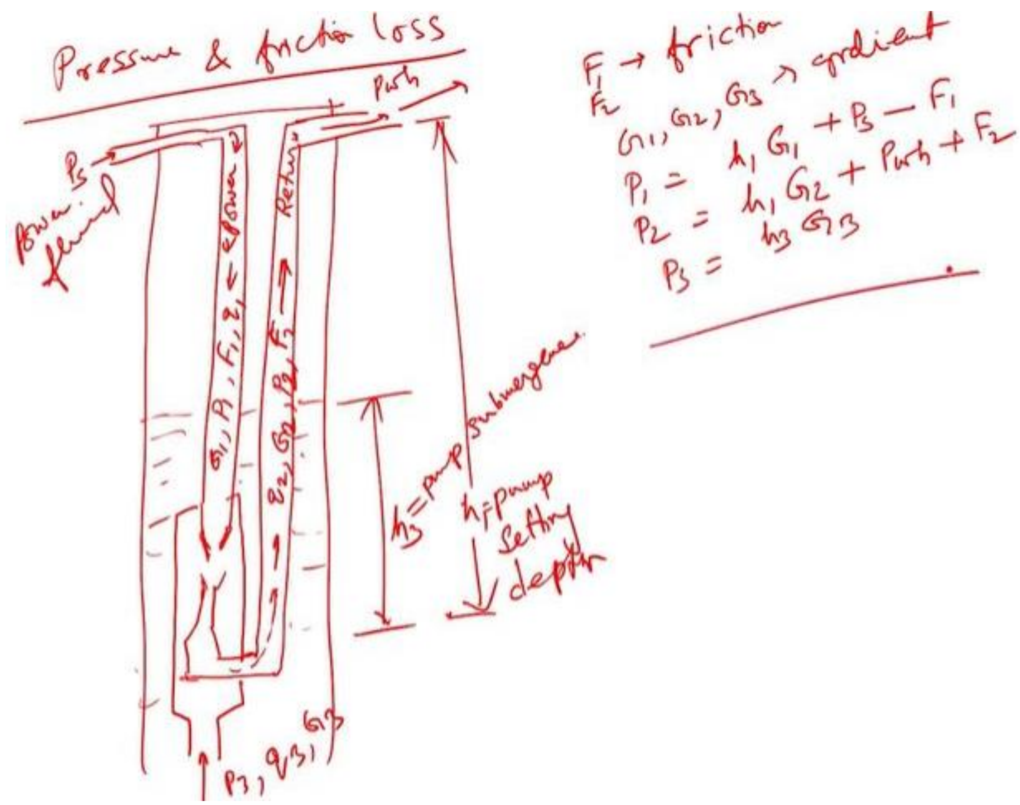


This problem illustrates how you can modify the given data to solve for different parameters, such as P_1, P_2, or flow rates. Charts like the one presented earlier can also be employed to perform these calculations effectively. The information provided on the chart can be a valuable resource for problem-solving.

We have previously discussed how pressure and friction losses can affect hydraulic engine pumps. Similar principles apply in the case of jet pumps, and we will further explore these concepts with the help of appropriate figures and formulas.

So, here's the configuration: we have a jet pump situated here, with suction on one end, followed by a diffuser section, and it discharges fluid. This configuration goes like this, and it's the same as the one above. Now, we have a wellbore that looks like this. At the surface, we have pressure, and we're delivering fluid, which is the power fluid. This is the return tube for the power fluid. The power fluid is moving down, and the return fluid is coming out from the wellbore. This is the jet pump. Both fluids must be mixed within the jet pump. You can choose to mix or avoid mixing the fluids in hydraulic engine pumps. The wellbore and pump fluid (power fluid) are mixed in the jet pump case. Let's label it as suction with P_3 pressure, Q_3 flow rate, and G_3 gradient. The power fluid has a gradient of G_1, P_1 pressure, friction F_1, and flow rate Q_1.

For the return fluid, you can label it with the same parameters: Q_2 flow rate, G_1 gradient, P_1 pressure, and consider G_2 gradient, P_2 pressure, and friction F_2. At the initial stage, we assume that the fluid level is up to this point. This is H_3, and the entire column is H_1, representing the pump setting depth. This is the pump submergence.



The fluid is served because of the nozzle created, allowing fluid to enter and move through the return channel. It returns as fluid enters the power fluid. We consider frictional pressure drop for F_1, F_2, and F_3. For F_3, we assume there is no friction on the suction side, and we ignore the frictional pressure drop due to lower velocity.

Now, when we talk about pressure values:

- P_1 is calculated as H_1 * G_1 plus P_s (the surface pressure) plus the gradient. Surface pressure is the pressure from the surface where pumping is taking place.
- P_2 is calculated as H_1 * G_2. Since the power fluid is mixed with wellbore fluid, the gradient (G_2) will differ from G_1. You also have to add the wellhead pressure, P, and the frictional pressure drop F_1, which accounts for resistance as fluid goes down.
- P3 represents suction pressure, calculated as H_3 * G_3. We assume there is no frictional pressure drop, as the velocity is lower here.

When we look at the effect of efficiency and design variables, the relationship between H and M appears as a curve, and efficiency (η) can also be plotted on this curve. There is an efficiency limit; in our case, we observed a maximum of around 35% efficiency in the simulation. The chart typically shows an efficiency range of 10% to 30%, which is considered reasonable.

What are the design parameters that affect the design variables? For instance, the nozzle angle, nozzle size (represented by dn), and the nozzle hole angle all play a crucial role. The mixing chamber's length and size, denoted by L, mixing chamber diameter, diffuser length (L_2), and diffuser angle (α_2, α_1) are additional factors that influence the design. When optimizing these design parameters, they can vary based on the specific application. Changes in fluid, pressure, and suction fluid can lead to alterations in these parameters. No one-size-fits-all jet pump design is optimal for all parameters, including viscosity, temperature, flow rate, and pressure. The optimal design depends on the specific application, such as handling high-viscosity fluids, sandy environments, or the presence of gas.

In the case of gas in the wellbore, it can reduce the pump's performance. When gas is present during suction, it expands and mixes, leading to decreased efficiency and performance.

Despite its relatively low efficiency, jet pumps are preferred because they have no moving parts and experience minimal failures over a 4-5 year period. Hence, they are a reliable choice. We conducted numerous Computational Fluid Dynamics (CFD) simulations for jet pumps, and in a published paper by Nizamuddin in the Journal of Fluid Machinery, we observed that changing viscosity, represented by head ratio (H), results in varying performance. Lower viscosity fluids yield higher head ratios and better performance. Viscosity changes also impact efficiency; as viscosity increases, efficiency decreases. Please note that the primary fluid remains water in both cases, and only the viscosity of the secondary fluid is altered. These changes in viscosity directly influence the pump's performance.

In your wellbore, if viscosity is different and higher, the performance of the nozzle or jet pump will be lower. This will affect efficiency and head ratio. Now, when selecting an artificial lifting system for your well and jet pump, here are some considerations:

1. **High Sand Content:** Jet pumps handle high sand content well because sand can be sucked and mixed, then moved up. A certain amount of sand is acceptable.

2. **Gas Presence:** Jet pumps can handle a certain amount of gas.

3. **Corrosive Fluids:** If corrosive fluids are present in the wellbore, you can inject specific chemicals from the surface into the power fluid. This neutralizes the corrosive fluid, allowing the jet pump to operate effectively.

4. **Deviated Wellbores:** Deviated wellbores are acceptable because high-pressure gas and liquid are injected, mixing the wellbore fluid as it moves up. The system is short, with no long tubing or cable.

5. **Depth:** Jet pumps can operate at significant depths, including depths of up to 20,000 feet.

6. **Viscosity:** While increasing viscosity reduces performance, you can handle a certain level of viscosity. Injecting high-pressure power fluid can raise the fluid temperature in the wellbore, reducing its viscosity. However, the viscosity of the secondary fluid can affect performance. To address this, you can raise the fluid temperature or use a thinner fluid as the power fluid to adjust the viscosity of the wellbore fluid.

7. **Volume:** Jet pumps are high-volume pumps with infrequent servicing needs. They typically run for 4-5 years before requiring retrieval or reinstallation.

8. **Offshore Applications:** Jet pumps are suitable for offshore applications.

9. **Temperature:** Jet pumps handle high temperatures without issues. They are constructed with metallic components, including the nozzle and diffuser, making them suitable for high-temperature environments.

So, these are the factors to consider when selecting a jet pump as part of your artificial lifting system for a well.

Life is very long; however, there is a problem with very low efficiency. Because of the efficiency, many people may not like it. Still, due to the extended lifespan and other benefits, people tend to prefer using jet pumps. You need a certain amount of inlet pressure, known as NPSH (Net Positive Suction Head), to prevent cavitation. Maintaining this pressure and adhering to the designer's criteria is essential for reducing cavitation and extending the pump's lifespan.

Now, if we consider the same factors for hydraulic engine pumps, we find that they are not well-suited for handling sand, as even a small amount can be problematic. However, they can handle gas and corrosive fluids. Deviated wellbores, varying depths, viscosities, and lower volumes are generally acceptable. These pumps may require servicing due to the presence of moving parts. Offshore applications are feasible, and they can withstand high temperatures. These pumps often have higher efficiency and typically do not experience cavitation due to their low flow rate. Some inlet pressure, however, is still required.

Thank you very much for this lecture on jet pumps. In the next lecture, we will delve into a different topic.