Artificial Lift

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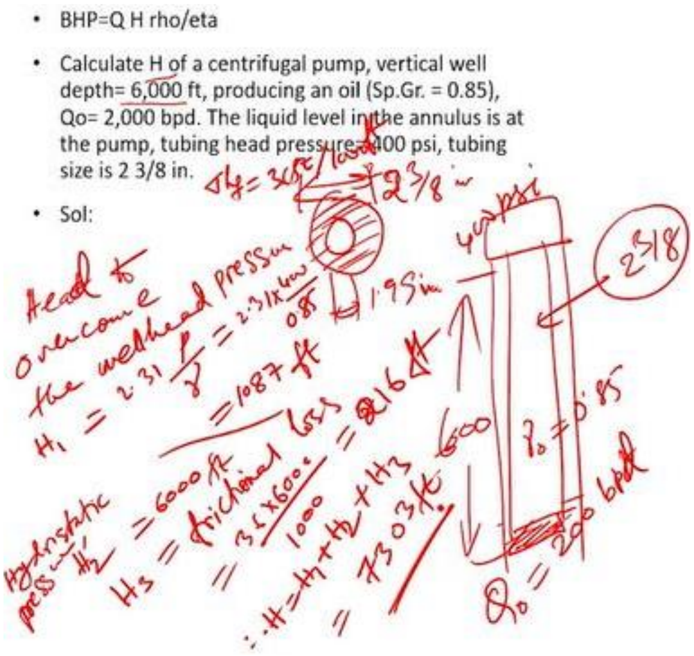
Lecture-44 ESP Numerical Problems-Part 2

Now, let's work on a small calculation problem. You see, we need to calculate the head of a centrifugal pump with a vertical well depth of 6000 feet. Oil is being produced, and its specific gravity is given as 0.85, with a flow rate of 2000 barrels per day (bpd). The liquid level in the annulus is at the pump. The pump and the liquid level are as shown. The tubing head pressure is 400 psi, and the tubing size is given as 2 and 3/8 inches.

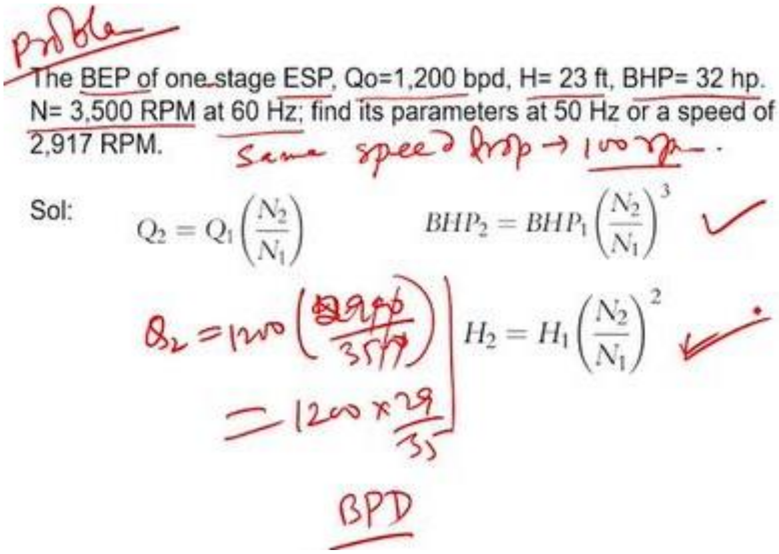
I'll show a tubing chart later to demonstrate how data is taken. Normally, tubing sizes are provided by the American Petroleum Institute (API). For instance, it's mentioned as 2 and 3/8 inches. These sizes are given in inches, but if you consult an API chart, you'll also find them listed in centimeters and millimeters. Typically, tubing size refers to the outer diameter, so you'd need to find the inner diameter from the table. In many problems, I may not provide data, so students should assume the given value as the outer diameter and calculate the flow through the pipe using the inner diameter.



- BHP=Q H rho/eta
- Calculate H of a centrifugal pump, vertical well depth= 6,000 ft, producing an oil (Sp.Gr. = 0.85), Qo= 2,000 bpd. The liquid level in the annulus is at the pump, tubing head pressure=400 psi, tubing size is 2 3/8 in.
- Sol:

For this particular case, let's solve the problem step by step. To calculate the head needed to overcome the wellhead pressure (h1), we can use the formula: h1 = 2.31 * P / γ, where P is the wellhead pressure (400 psi) and γ is the specific weight (0.85). Calculating h1 gives us 1087 feet.

So, the pump should be able to work for this total head.



Proble

The BEP of one stage ESP, Qo=1,200 bpd, H= 23 ft, BHP= 32 hp. N= 3,500 RPM at 60 Hz; find its parameters at 50 Hz or a speed of 2,917 RPM.

Same speed drop → 100 rpm.

Sol:

$$Q_2 = Q_1\left(\frac{N_2}{N_1}\right) \qquad BHP_2 = BHP_1\left(\frac{N_2}{N_1}\right)^3$$

$$H_2 = H_1\left(\frac{N_2}{N_1}\right)^2$$

$$Q_2 = 1200\left(\frac{2900}{3500}\right)$$

$$= 1200 \times \frac{29}{35}$$

BPD

In this case, the speed drop is 100 RPM. If 60 hertz has a speed drop of 3600 (ideally should be synchronous speed but actual is 3500), then for 50 hertz, we assume a drop to 2900 (ideally should be 3000).

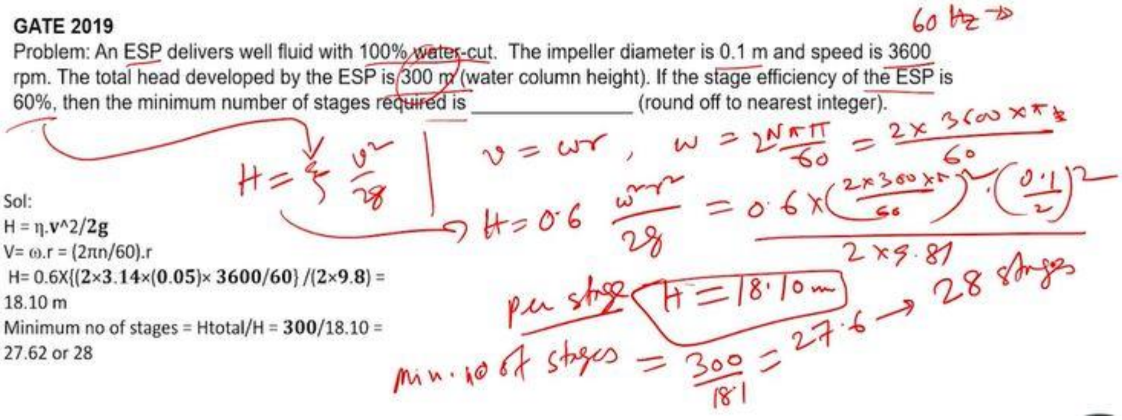
Finally, we can calculate the new flow rate, which is given as 1200 * 2900 / 3500, resulting in a flow rate of this much.

I hope this clarifies the steps of the calculation. If you have any questions, please feel free to ask.

Now, let's consider a problem. Suppose we have an ESP delivering well fluid with 100 percent water cut. This implies there's no oil; it's 100 percent water, meaning we consider the properties of water for viscosity and density. When the water cut changes to 40 percent or 60 percent, the viscosity and density will come into play. However, for this problem, we're assuming it's 100 percent water with no change in viscosity and density.

The impeller diameter is 0.1 meter, and the speed is 3600 rpm. Here, we assume there are no losses or slip, and the motor operates at the ideal synchronous speed of 60 hertz (3600 rpm). The total head developed by the ESP is 300 meters. The question is, how many stages are required to reach this head? The stage efficiency of the ESP is given as 60 percent, which is quite low compared to the 73 percent efficiency reported previously on the SLB website. In this problem, we aim to find the minimum number of stages required.

Here's the solution:



GATE 2019

Problem: An ESP delivers well fluid with 100% water-cut. The impeller diameter is 0.1 m and speed is 3600 rpm. The total head developed by the ESP is 300 m (water column height). If the stage efficiency of the ESP is 60%, then the minimum number of stages required is ______________ (round off to nearest integer).

Sol:

H = η.v^2/2g

V= ω.r = (2πn/60).r

H= 0.6X{(2×3.14×(0.05)× 3600/60} /(2×9.8) = 18.10 m

Minimum no of stages = Htotal/H = 300/18.10 = 27.62 or 28

60 Hz →

$H = \xi \frac{v^2}{2g}$

$v = \omega r$, $\omega = \frac{2N\pi}{60} = \frac{2\times 3600\times\pi}{60}$

$H = 0.6\,\frac{\omega^2 r^2}{2g} = \frac{0.6\times\left(\frac{2\times 3600\times\pi}{60}\right)^2\cdot\left(\frac{0.1}{2}\right)^2}{2\times 9.81}$

per stage $\boxed{H = 18.10\text{ m}}$

min. no of stages $= \frac{300}{18.1} = 27.6 \rightarrow 28$ stages

This was a question from the GATE exam. The computer typically defines a range for the correct answer when solving such numerical questions. If your result falls within that range, the computer accepts it as correct and awards points. Small variations within the range are usually acceptable. The exact range may not be disclosed to the exam-taker.

Regarding thrust in centrifugal pumps, these pumps generate thrust when the impeller rotates and delivers fluid. In some cases, thrust bearings support the centrifugal pump to prevent excessive force from being transferred to the shaft. The shaft is connected to the motor, and if it experiences excessive force, the load is transferred to the motor. Therefore, the presence of thrust bearings is essential. Additionally, radial bearings are used to prevent radial loads or vibrations on the shaft, along with the vertical load. The shaft is connected to the impeller but not to the diffuser; there is a gap between the shaft and the diffuser.

The diffuser is connected to the outer casing, and the outer casing is stationary; it doesn't rotate or move. The impeller and shaft are integrated parts that do rotate. As the impeller rotates, it exerts an additional load on the shaft. This load should not be transferred to the shaft, which is why thrust bearings are essential. Thrust bearings are designed to support the load of the shaft, preventing any additional load from being transferred to the motor system.

Now, let's discuss NPSH (Net Positive Suction Head). NPSH is a critical parameter that I have mentioned in a previous lecture. It's vital to understand this concept. Companies provide NPSH requirements for their pumps, which you need to meet. Your NPSH (Net Positive Suction Head) must be greater than the required NPSH (NPSH R). Cavitation will occur if your NPSH A (available) is insufficient and falls below NPSH R. So, it's essential to ensure that NPSH A is greater than NPSH R.

To determine this, you can use the following formula: NPSH A equals Surface pressure (fluid or air pressure) + Positive head (the vertical height from the impeller center) + Piping losses (friction in the pipes) + Vapour pressure.

Piping losses occur as the fluid flows from your tank to the pump. Using narrow pipes with high friction will lead to significant pressure loss. If there's substantial friction due to the narrow pipe diameter, your actual pressure will decrease as the fluid passes through the pipes.

Vapour pressure is dependent on temperature. Water at normal temperatures, such as the typical 30 to 40 degrees Celsius in Chennai, will not boil. The vapour pressure at these temperatures isn't sufficient to create bubbles. However, bubbles begin to form as the temperature increases, particularly after reaching 100 degrees Celsius at normal atmospheric pressure.

Vapour pressure is temperature-dependent. As the internal vapour pressure increases with rising temperature, it eventually creates large bubbles that move away from the water surface. Imagine using a small straw (like a drinking straw for mango juice) instead of a 1-inch or 5-inch pipe. The pump is attempting to draw in fluid, but due to the pressure drop, it can't do so effectively, resulting in the formation of vapour bubbles. At low pressure, water begins to boil. Water will start boiling if you create a very low-pressure environment in a closed vessel (by removing air from the vessel).

As pressure decreases, bubbling occurs. When you increase the temperature in a low-pressure environment, bubbling becomes more rapid. So, when using a pump, it's crucial to consider temperature. While the pump company provides a curve and certain operating conditions, they might not know the temperature you plan to work with. If you overlook temperature considerations, your pump may start cavitating because you didn't account for this crucial variable. Thus, you need to consider all these parameters.

When we talk about piping losses, it's not just about friction pressure drops; it includes factors like bends, connections, and sharp corners. These elements contribute to losses. Ideally, you want to create a smooth pipe, rather than a pipe with sharp turns and fittings, to minimize losses. Creating smoother entries for tank connections is also beneficial because fluids prefer smooth pathways over tortuous, convoluted ones. Fluids experience less friction on smoother paths, leading to better NPSH. When you have high NPSH available compared to the required NPSH, your pump operates smoothly. However, if you create a situation where NPSH available is lower than required, cavitation can occur.

Speaking of cavitation, it is a condition caused by NPSH. When your NPSH is too low, it leads to the formation of bubbles. These bubbles initially expand, but when the pressure increases near the impeller's exit, the bubbles implode or collapse.

When a bubble is created and subsequently collapses, it results in cavitation. This cavitation process generates shockwaves, vibrations, mechanical damage, pump failures, and loud noise. It's crucial to avoid cavitation at all costs. If you search for cavitation pumps on Google, you'll find numerous images where cavitation has caused extensive erosion, resulting in significant damage to the pump.

Vapour pressure refers to the pressure at which liquid molecules transition from liquid to vapour. It increases with temperature. At 100 degrees Celsius, water boils, reaching its boiling point. The pressure at which molecules transition from liquid to vapour is known as vapour pressure.

In the context of cavitation, there is a formula: $P - Tv / 0.5\rho v^2$, which calculates the cavitation number, CA. It's defined as a measure of how close the pressure in a liquid flow is to the vapour pressure. Cavitation may occur if the cavitation number (CA) is less than

1.5. Pay attention to the units used in these calculations to avoid any issues with unit conversions.