Basics of Mechanical Engineering-3

Prof. J. Ramkumar

Prof. Amandeep Singh Oberoi

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Week 11

Lecture 48: Virtual Lab. Demonstration (Fluid Mechanics, Part 2 of 3)

Welcome to the second part of the Virtual Laboratory Demonstration on Fluid Mechanics. We have seen the laboratory demonstration in the virtual world in the first two experiments in the previous lecture, where we talked about determining the loss variables for different types of flow in pipes and open channels. That is, we talked about the Reynolds number determination to find the behavior or the type of flow. Then, we also talked about a variable area duct verifying Bernoulli's energy equation. These were a few experiments based on the theory of fluid mechanics.

Fig. 1: A Gear Pump cross sectional view

Performance Characteristics of Gear Pump
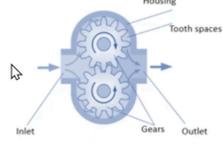
Introduction

The gear pump was invented by Johannes Kepler in around 1600. Gear pump is considered as one of the most important types of pumps among all hydraulic fluid transfer pumps. These types of pumps use gear mechanism for transportation of fluids. Gear pumps fall under the category of positive displacement pumps (rotatory pumps). In general gear pump encloses a fixed volume of fluid by the help of interlocking cogs or by meshing of gears and applies mechanical force/pressure energy on that entrapped volume. The pumping action is a continuous cyclic process which helps to transport the fluid which makes it a non-pulsating or pulse-free flow pump. Even though the pump is considered to be high pressure pump, its size is relatively small compared to other hydraulic pumps. It is used to enhance the pressure of the fluid from inlet to outlet. The outlet pressure in gear pump is further increases by providing casing .

Vlab demonstration (Fluid Mechanics)

Single-acting Reciprocating Pump

$$Q = \frac{A \times h}{t} = \frac{0.25 \times 0.1}{32} = 0.000781 \ m^3/sec$$

$$IP = \frac{3.6 \times 10 \times n \times 1.36}{K \times t_{new}} = \frac{3.6 \times 10 \times 10 \times 1.36}{15.018 \times 50} = 0.6520 \ HP$$

Given

Given

$$OP =$$

$$n =$$

In this lecture, I will talk about pumps and turbines. More focus. First, I will start with the gear pump. You see the experiment number 8 is here. Drawing the characteristic curves of a gear pump.

I will click this. It shows the aim as studying the performance of a gear pump and drawing its operating characteristics. In the theory, we have the gear pump, as you have already seen in the lectures. There are kinds of gear pumps—a gear pump cross-sectional

view where, from one side, the inlet is here; the fluid is coming, the gear will rotate to make the fluid pass through this periphery and pass through to the outlet side. So, this was already invented in the year 1600, but a lot of updates kept coming.

It is considered one of the most important positive displacement pumps. That is the rotary pump. In general, it encloses a fixed volume of fluid with the help of interlocking cogs or meshing gears that apply mechanical force and pressure. So, the parts of a gear pump could include a driver gear. There is a driven gear.

There is a casing. The casing is important so that the fluid or the oil, whatever we're trying to pass through, does not splash out. So, clearance is provided between the gear and the casing so that the fluid passes through this periphery properly. So, there is low-pressure fluid on the left side. On the right side, in the outlet, you can see the high-pressure fluid.

When we say pump, like the heat pump we talked about, a gear pump also transforms fluid from low pressure to high pressure. Now, there are always safety valves in the gear pump. Safety valves or release valves are installed on the start side so that the pump can be protected from damage if additional pressure arises when it is released. Because it is a positive displacement pump, there could be no flow back. So, that is why a safety valve is always there to release the pressure if it exceeds the threshold.

You see here the fluid enters the pump, driver gear and a driven gear both are rotating. And it passes through this casing periphery, inside the periphery of the casing, and it goes as an outlet discharge. This is a gear pump. We have talked about the internal gear pump; this is the internal gear pump, where we have an idler gear inside and a rotor. There is a kind of internal gear pump. The external gear pump is a very generic pump that you have shown in the above figures as well. So to talk about the gear pump, let us try to see a few pre-test questions so that we see if we are ready for taking the simulation experiments. A few pre-test questions. The first question is: What does a gear pump use?

Pistons, buckets, meshing of gears, crankshaft. It uses meshing of gears. The fundamental significance of all the turbo machinery is momentum conservation. It is not heat, mass, or energy. It is momentum conservation because we are talking about turbo machinery here.

The most widely used pump for viscous fluid is the gear pump. The gear pump is a positive displacement pump, as we have discussed in Basics of Mechanical Engineering 1. We talked about the types of gears. There were belt drives, chain drives, and gear

drives. When gear drives were used, gear drives are always positive and are also for heavy power transmission.

So, now here as well, the gear pump is used when there is viscous fluid and a large force is required to transfer the fluid at high velocity or high pressure. Gear pumps are mainly used in chemical installations because they pump. So, among high-density and high-viscous, I will try to pick high-viscous liquid as the right answer. Suction is created in the gear pump due to low pressure on the inlet side. Gear pumps are tangential flow pumps, submersible pumps, positive displacement pumps, negative displacement pumps.

It is a positive displacement pump. That is the first statement I made when I talked about gear pumps. Gear pumps have dash discharge, zero pulsating, sinusoidal, intermittent, linear. They have zero pulsating discharge. And these primarily transfer pressure, speed, fluid, power.

Fluid is the most appropriate answer here. Gear pumps do not require priming. Yes, it is true. At the inlet of the gear pump, suction pressure is created by the rotation of the gears themselves. Let me submit.

I got 10 out of 10. That means we are ready for the simulation. Let me see the procedure of the simulation. They say ensure the complete open position of delivery valve. Measure the height of pressure gauge above the vacuum gauge.

Switch on the pump. Vary the flow rate that is discharged by closing the delivery valve. Adjust the delivery valve accordingly. The pressure gauge reading of 1 kg per centimeter square. Note down the vacuum gauge is reading.

Note down time taken that is for each centimeter rise of the oil. 10 centimeter is the graduated scale that is there in the setup of the experiment that I will show in the next page here. Note down the time taken for n revolutions of energy meters, so they have taken three revolutions here. Repeat the procedure of one kg per centimeter square incremental by closing the delivery wall gradually for 1.0, 1.5, 2.0, 2.5, and 3 kg per centimeter squares. And switch off the power and delivery completely.

Then we note down the readings but these are certain relations which are used to calculate the total head. $h = P + \frac{v}{760} \times \frac{10^5}{\rho g} + Z$

So, this is p pressure gauge reading and v by 760 is also there because we are talking about mercury here. Then we have discharge which is A into h by t that is total volume

per unit time area into height the rise at to which the water rises it is 10 centimeters, that is 0.1 meters.

Output power is ρgQh/1000. And the input power is given as n multiplied by 3600, multiplied by η divided by Ec multiplied by T, where n is the number of revolutions taken in an energy meter, which is 3. η is the efficiency of the motor. The efficiency of the motor is given as 0.8. Then we have efficiency, which is output per unit input.

Let's proceed to the simulation. So, this is a similar interface to what we have observed in previous experiments for the Reynolds number determination experiment. And for Bernoulli's, this kind of setup was also present. Now, here it is a setup specifically for the gear pump. You can see here we have a gear pump; two gears are meshed here, and when we switch on the power—because it is oil, the color is brown—the oil flows through the pipe and stops at the gate valve. Then we can position the gate valve among 1, 2, 3, or 4.

Let me keep it at position 1 first, and it is opened. Now the oil starts entering the tank and is also discharging through the discharge valve. I have to close the discharge valve. That is also an instruction here. Take care of the vacuum pressure gauge reading and the pressure gauge reading, and then close the discharge valve using the 'close discharge valve' button.

So I click on this. The fluid is filled till a 10 cm height in the tank, and the time taken is 19 seconds. Now the vacuum pressure gauge reading is 160 mm of mercury, and the pressure gauge reading is 0.5 kg per cm square. It is the valve position 1. Now, I will start the electric meter for the gear to pump.

The number of revolutions will be 3. For 3 revolutions, it took 28 seconds. All these readings would be noted down here in the observation table. The pressure and vacuum gauge pressure, both of them, are 0.5. Vacuum gauge pressure is 160 g that is in meters in 0.3 time for 10 centimeter rise of water that was 19 seconds. And for three revolutions the time taken was 28 seconds. All these observations are noted here. Now let me bring it to another position in the second position.

I have to close the discharge valve. Now, the time taken is 20 seconds. And the pressure gauge reading is 1. And vacuum pressure reading stays as 160 mm of mercury. I will start the electric meter for 3 revolutions.

Revolution 1, revolution 2, and revolution 3. The time is 27 seconds. I will note these readings as well. This time, the pressure is 1. This stays as 160, this is 0.3. And this value

of g is given here. Datum head is 0.3 meter. Time taken is 20 seconds for filling the tank till 10 centimeter height, and for the three revolutions the time taken is 27 seconds.

Now at the third position closing the discharge valve. 20 seconds again, but this is at a pressure of 1.5 kg per cm². Starting the electric meter for 3 revolutions, that is, rotating the gas. For 3 revolutions, the time is 26 seconds. So, let me note down the readings here. It is 1.5, 160 km.

Again it was 20 seconds to fill till 10 centimeter of water or oil, then comes for three revolutions it was 26 seconds. Now at the fourth position. Again running the electric meter for three revolutions. So, 21 seconds for filling the tank, 21 seconds for three revolutions, and at 2 kg/cm² of the gauge pressure. So here it is 2 kg/cm². Here it is 160 millimeters of mercury, Z stays as 0.3. This time is 21 seconds and for 3 revolution also the time is 21 seconds.

Now comes the calculation table. Total head, flow rate, input power, output power, and efficiency are to be calculated using these relations. Total Head $= H = P + \frac{v \cdot 10^5}{760 \rho g} + Z$ And Q, that is discharge or the flow rate, is in meters cube per second as area into height per unit time. Then we have output power, that is $P_i = \frac{n \cdot T}{\eta} \cdot \left(\frac{3600}{E}\right)$. And efficiency would be output power/input power x 100.

To do this, I will again export this to Excel. And I have already developed an Excel sheet for you. To save time, I have entered all the values of the observation table here. These are the values that we have taken or seen in the virtual laboratory demonstration. Now, for the first value, that is for 0.5 kg per centimeter square of the pressure, and for these times, 19 seconds and 28 seconds for filling of the water or oil, and for three revolutions, respectively.

I have put the formulas here. What was H? H was this formula you could see. It was $P + \frac{v \cdot 10^5}{760 \rho g} + Z$. All the values are entered in this formula. You could see B4 is P pressure, C4 by 760 is v/760.

Then, this is 100000 by 860 x 9.81. So, what is this? 860 is the density of oil. It is ρ x g + Z. Z is 0.3. So, this is the value of the head, the total head that is obtained. Then, for the flow rate, the formula is given here, which is A x h/t. The area would be what? 0.3 x 0.3, that is given, into height is 0.1.

That is entered here: 0.3 x 0.3 x 0.1 by time taken. The time taken is 19 seconds. This is the value that is given in cell E4, which is entered here. So, this gives me the flow rate. Then comes the input power.

The input power relationship that was given here was 3600 x $\eta/E \times T$. This is also put here. n is 3 revolutions, 3600 x η is 0.8/E x T that is given in cell F4. So, you can see here that the energy meter constant, Ec, is 1200, and the time taken is for the specific observation. η, which is the efficiency of the motor, is 0.8. All these values are entered here. 0.8 is the efficiency of the motor. 1200 is the energy meter constant. So, this gives me the value of the input power.

For output power, we have $\rho g Q \times H$. So, this is rho 860 x 9.81 x Q. Q is calculated here in cell E12 x H. H is also calculated here in cell B12. The formula is given. Efficiency is simply the ratio of cell E12/G12 x 100. We have obtained this efficiency.

I have also taken all these readings for observation number 2, observation number 3, and observation number 4 for these three observations. So, let me show you all the readings here. These are the readings, and efficiency is shown at the valve position. In the first position, it is 13.555; for the second position, 20.8; for the third position, 28.207; and for the fourth position, 27.948. I have put exact values which are given in the provided data to the given data and in these formulas and exact observations. Suppose I put all the values here and calculate, then it will show me the results. I can input all the values here. Or there is another quick way if you are not able to reach the final calculations, because if you put any values, it will show the value is not correct, but it will show you the result.

For that, I am just demonstrating how you do that. Though it is not a correct way, I am putting some value maybe. I will put value 1 in each of the cells here. So that at least some data is entered. And if suppose you have missed something in some formula, you are not able to calculate. Then when the values are added I will calculate it. And it will calculate efficiency. Then we can see the result. This is the result. Now all of the values are given red here.

So, that means values are not correct, but this is the calculated value. So, this is also the same efficiency that I have calculated in my result here. You see these values are given 8.7220. Exactly this value is calculated here. I have shown you the formulas here as well of all the values here.

We could do manual calculation. We could do calculations using this. So, this is the simulation. Now let me come to the post-test questions. It says flow rate in gear pump remains constant with increase in pressure, decreases with increase in pressure, increases with increase in pressure, increases with decrease in pressure and is unpredictable.

The answer is, it remains constant with an increase in pressure. Positive displacement pumps work on this principle. What is the principle? Liquids have dynamic action. Liquid is discharged due to positive displacement. Yes, this is the correct answer. Which one of the following is not a positive displacement pump? Vane pump, gear pump, centrifugal pump, screw pump. The centrifugal pump is not a positive displacement pump. The next question is: a gear pump is most suitable to pump.

It is most suitable to pump viscous fluids among air, hydrogen, water, and paint. Paint is the most viscous fluid. Rotation of gears in an internal gear pump is in: independent of each other, opposite direction, same direction. It is in the same direction when we talk about an internal gear pump. Rotation of gears in an external gear pump.

In an external gear pump, the rotation is in the opposite direction. Internal leakage in an internal gear pump is caused due to the higher tolerance level between the meshing surfaces. The relationship between the pressure and overall efficiency of a gear pump is that pressure increases when overall efficiency decreases. Continuous discharge of liquid is achieved in a gear pump when we say continuous discharge; it is always a positive displacement pump, but the discharge could be discrete at some points. To have a continuous discharge, we can have more teeth.

So, here the answer could be by increasing the number of teeth. How does the fluid flow in an internal gear pump? The fluid enters the suction side between the rotor, which is a large exterior gear. So, I think the answer is C here. The fluid enters the suction side between the rotor, which is a large exterior gear, and the idler, which is a small interior gear.

Let me submit. All of them are correct. Let me see the explanation for internal leakage in a gear pump due to the higher tolerance level between the meshing gears. Internal leakage occurs when there is excessive clearance or tolerance between the gears and the housing, allowing fluid to leak back and reduce the efficiency of the pump. That is, if there is a gap or clearance between the casing and the rotating gear, if this is high, internal leakage could also happen.

So, with this, the gear pump experiment is complete. So, next is the reciprocating pump, which is experiment number 7. Characteristic curve of a reciprocating pump: to perform a characteristic of a single-acting reciprocating pump is the aim here. To study the performance and draw a characteristic curve of a reciprocating pump, now you know it is discussed in the theory. It is a reciprocating motion, meaning it sucks from one side and pumps to the discharge side.

It could be single-acting or double-acting. A double-acting pump has double the efficiency of a single-acting pump. How? Let us see the parts of the reciprocating pump. We have the suction pipe through which water or fluid is sucked here, and the piston, when it goes back, is at IDC, that is inner dead center. And this is ODC, that is outer dead center.

At IDC, the water is not there. When it moves toward the ODC, when it moves toward the right side, the valve here at the suction point opens, and water starts coming in. And when it moves from the ODC toward the IDC, that is from the outer dead center to the inner dead center, the water goes out through the delivery pipe. This is the valve that opens here as well. So here is the head difference, HS and HD. HS is for suction. HD is for discharge.

We have a delivery pipe. We call it discharge or delivery. There is a piston rod. There is a crank to run the piston. And there is a cylinder in which the piston reciprocates.

So these are the components as you see: cylinder, suction pipe, delivery pipe, suction valve, delivery valve, piston and piston rod, crank and connecting rod, strainer, and air vessels. So these are all the components which are explained. So this is the air vessel in a reciprocating pump. There are air vessels in which the reciprocating pump has an application. So the difference between a single-acting and double-acting pump is there.

In a single-acting pump, you see, the fluid is delivered during the delivery stroke only, that is, when the crank angle is between 180 to 360 degrees; only then is the delivery of the fluid present. The rest is only suction, that is, this time is completely wasted. That is why we use a double-acting pump as well, in which, in both strokes—that is, the inward or outward stroke—the delivery happens in both the suction and the delivery stroke. How? See, this is the delivery function during the single-acting pump that I have shown you. In a double-acting pump, we have both sides: suction pipes and discharge pipes or delivery pipes.

So, both ways—whether the piston moves left to right or right to left—discharge occurs. That is why you see this is the discharge, how it happens here. So, this is Qd, the discharge rate. So, there are multiple applications of the double-acting reciprocating pump. Now, let me see the pre-test questions.

The first question says: A reciprocating pump is used when there is a low volume of liquid, not when the volume of liquid is large. Pumping high pressure, pumping low pressure. When there is a low volume of liquid, only then is a reciprocating pump used. Second question: Positive displacement pumps are also called as dash pumps. Constant volume, constant heat flux, constant pressure, constant head.

These are called as constant pressure pumps. Daily life example of a single acting reciprocating pump is a syringe. Power operating pump in which both sides are engaged in fluid displacement is known as: centrifugal, double acting, single acting, bicycle. It is double acting pump. Power operated pump in which one side is engaged in fluid displacement is known as single acting pump. When the piston moves forward the liquid draws into the cylinder. Rotary motion of the motor is converted into transducer motion of the piston through plunger, crank, suction pipe or delivery pipe through crank.

Following are the advantages of a reciprocating pump. High pressure, low volume applications, durability—all of these. All of these are the advantages. The up-and-down, back-and-forth translational motion is called reciprocating. Examples of reciprocating pumps include bicycle pumps, hand pumps, axle pumps, and piston pumps. All of these are reciprocating pumps.

Let me submit. I've gotten everything correct. Now, let me come to the procedure. They say to note down the diameter and stroke length of the piston, the wattmeter constant k, and the distances Zd and Zs of the pressure gauges from the pump axis. Start the motor and open the delivery valve fully. Measure the actual discharge Q. Note down the pressure gauge readings, Pd and Ps (for delivery and suction), as well as the wattmeter reading X. Measure the number of strokes occurring in a given time and hence obtain the speed of the piston in rpm.

Change the opening of the delivery valve. Repeat steps 3 to 6: measure the discharge. Note down the pressure readings Pd and Ps. Measure the strokes and change the opening. Then, these are the relations that are used.

Theoretical, the value of $Q_t = \left(\frac{ALN}{60}\right) + \left(\frac{(A-a)LN}{60}\right)$, where L is the length of the stroke and the speed of the crank pin, and small a is the cross-section of the piston rod. Capital A is the cross-section of the piston. This is theoretical. We will have a practical formula that is given in the simulation. Here, this is a setup in which we have Q = A x h/T. P input = (3.6 x 10 x N x 1.36)/K x T revolution.

P output = W x Q x H, and η is the output power by input power. Now, let me run the experiment. Switch on the power first. It has started. Reciprocation has started. You know the fluid is coming here. Valve position at position 1. Now it says close the gate valve. It is very similar to what we have been doing. Now the fluid is filled till 10 centimeters of height.

Now, for 10 revolutions, we will start the electric motor. It is showing 460 rpm, 0.46 kg/cm² on the pressure gauge reading, and 0 kg/cm² on the vacuum gauge. The time to fill the tank to 10 centimeters of height is 32 seconds. Now, let me start the electric motor. It will run for 10 revolutions.

The time is 50 seconds. All these observations should now be noted in the observation table. You can note them down on paper. I have also noted them down on paper: pressure, vacuum gauge pressure, time to fill 10 cm for 10 revolutions, and speed in rpm. This pressure value is 0.46. For the vacuum gauge, the pressure was 0. The time to fill the tank to 10 centimeters of height was 32 seconds, and for 10 revolutions, the time taken was 50 seconds. The speed is given as 460 rpm.

This speed will remain constant because it is a reciprocating pump, which works at a constant speed. The rpm will stay constant here. Now, let me check the second position of the wall opening. Now, I will close the gate valve. Now, it took 33 seconds, and for 10 revolutions, it will run. I will, by this time, note down 0.42 and 1.0. And it took 33 seconds and 43 seconds, respectively, for both water systems running. Now, the valve is at the third point. Water is going in, entering the tank, and closing the gate valve. Water is now filling up. It took 35 seconds. I will run this for 10 revolutions.

I will note down the ratings: 0.42, 2.0, and 35 seconds. 2.0, and it took 35 seconds. So, the time taken here for 10 revolutions is 37 seconds. Now, at position 4, it is running here, and closing the gate valve. It is 0.38 on the pressure gauge reading, 3.0 on the vacuum gauge reading, and 36 seconds for filling the tank till 10 centimeters. 0.38, 3.0 on the vacuum gauge reading in kg per centimeter square, and it took 36 seconds. Next, it took 29 seconds for 10 revolutions. The last position of the valve is closing the gate

valve. It took 37 seconds, and I will start the meter. Pressure gauge rating is 0.4, and vacuum gauge is 3.5. Time for 10 revolutions is 31 seconds. Putting all these values here. It was 3.5 kg per cm² on the vacuum gauge pressure.

The time it took was 37 seconds here. It took 31 seconds for 10 revolutions, and the observation table is now ready. Now, we need to calculate the head, flow rate, input power, output power, and efficiency. For all these, we can use these formulas. We can put all these formulas there and try to calculate.

It is a straightforward thing, putting all these values here. I will quickly do the Q and power input for you. Here, $Q = A \times h/T$. To do this, we have the area given as 0.25, h here is 10 centimeters, which is 0.1 meters, and t, the time taken, is 32 seconds for the first experiment. For input power, it is given as 3.6 into 10 into n into 1.6. And here, it has taken 10 revolutions.

K is given. K is the energy meter constant, 15.018. And the time taken for revolution. Quickly putting this here, we have $Q = A \times h/T$, that is, the area given is 0.25 meters into h, which is 10 centimeters or 0.1 meters, by the time taken, which is 32 seconds. When I calculated this, it came out as 0.000781 meter cubes per second. This is for the reciprocating pump. It is single-acting.

It gives the formula as 10 into number of evaluations into 1.36/k x time for the revolutions. Here, k is given. And n is given. Putting the value $(3.6 \times 10 \times 10 \times 1.36)/15.018 \times 50$ seconds. This value turns out to be 0.6520 HP. Similarly, I am just saving time. You can calculate the output power, and you can calculate the efficiency. You can calculate and put it here.

I have calculated everything, and I will just put the values in the observation table. Total head calculated here is 4.6. Total head calculation is a little vast. Total head can be calculated using the formula that is given in the procedure here. You can see the total head here is using this pressure and volume.

This you have already done in the previous experiment. I will just enter the values here. Flow rate that we have calculated is 0.000781. Input horsepower we have calculated is 0.6520. Output power that is calculated is using this relation: $(W \times Q \times h)/75$, where W is weight of the water 1000, Q is what we have calculated 0.000781, h is the total head that is 4.6 here we found.

We calculated the output power as 0.0479. This gave me an efficiency of around 7.349 only. This was for the first observation. For the second, third, fourth, and fifth observations, you can take the values, input the values, and then draw the characteristic curve. Plot the efficiency based on Q and plot the efficiency based on the head. You can plot this here.

To see the values, I have already calculated all of them. I will just input it here. It is 14.2 here. This is 0.00075. The input power is calculated as 0.7582. The output power is calculated as 0.1434. The efficiency is calculated as 18.9. I will input all the values, then click the word 'calculate.' I have entered all the values. Let me click the 'calculate' button. The efficiency is calculated.

Let me see the results. So, the results are very similar. They have shown a few values as incorrect, which are in red font. So, the values are very close. Anyway, they are showing as incorrect because these are to a very large decimal place.

The efficiency I have calculated is 33.40 for the last observation. Here it is 33.410. Only then is it showing this value. Otherwise, the values are almost all correct. It is correct to less than 1% accuracy. So, this was the single acting experiment, simulation.

Let me see the post-test questions. The amount of fluid that leaks from a high-pressure discharge to a low-pressure discharge is called slip, because it is from a high-pressure discharge to a low-pressure discharge. It is slip that is happening. On which of the following parameters does the slip in a pump mainly depend? It mainly depends upon the wear that is present in the pump.

If slip exceeds 5%, the pump needs to be put into intermittent service or discarded. If slip is more than 5%, the pump must be serviced. The maximum efficiency of a reciprocating pump is up to 85%. For good condition, slip should be below 2%, whatever the minimum value is. Reciprocating pumps have lower efficiency compared to centrifugal pumps.

They have lower efficiency when compared to centrifugal pumps. Which of the following are the beneficial effects of an air vessel fitted to the delivery side of a reciprocating pump? Ensuring a constant rate of discharge, reduction in power consumption, and increase in discharge. Here, ensuring a constant rate of discharge and reduction in power consumption are correct. Increase in discharge does not hold true.

The flow of a double-acting reciprocating pump, compared to a single-acting pump, will almost double. What is doubled? When comparing a double-acting reciprocating pump to

a single-acting one, the flow output doubles. The typical work saved by fitting an air vessel to a single-acting reciprocating pump is 85%, as we are discussing efficiency. Discharge of a double-acting reciprocating pump is where L = length of the stroke, A = cross-sectional area of the piston, and N = speed of the crank.

Here, the discharge is 2 times length into area into number of rotations by 60. This is 2LAN/60. Let me submit. It shows the discharge is this. So, that is the factor of 2 accounts for double action because we are talking about a double-acting reciprocating pump.

Had it been single-acting, the answer would have been (L x A x L/60. B could have been the answer. But now, the correct answer is two times length into area into the rotation speed by 60. By 60 is always added because when we talk about N, it is in rpm (rotations per minute). To convert minutes into seconds, we always divide by 60. That is why it is LAN by 60. Now, with this, I have completed the pumps part. Here, we have talked about the two types of pumps.

We have talked about reciprocating pumps, single-acting reciprocating pumps. We have talked about the gear pump. In the next lecture, I will try to talk about turbines. I will take majorly the Francis turbine, which is the most widely used turbine. And I will also take, before that, a Pelton wheel or Pelton turbine. We will try to see how these work.

Thank you.