Artificial Lift

Prof.Abdus Samad

Department of Ocean Engineering

Indian Institute of Technology Madras, Chennai

Lecture-018 Pump Classifications

Now, let us see different types of pumps, and one pump is there, let us say pump types, so pumps. So, basically, we divide it into two types, one will be like positive displacement type, displacement type, another will be kinematic, kinetic. So, positive displacement type pump, when you are saying your heart is a positive displacement pump, so human heart. So, it is taking a certain amount of fluid, the same amount of fluid is delivering, when it is expanding and contracting, volume A, same volume A delivered, same volume taking, same volume delivering. So, a fixed amount of fluid is taken and delivered, and if your body needs a higher amount of fluid.

What the body will do? Because the brain controls the heart, although we say everything is based on heart, language, or creative writing language, the heart is also controlled by your brain. So, what will you do? If the body needs more fluid, for example, you are running and need more fluid? What will you do? Your dhadkha nahi (Hindi), your heart beats will be increasing, number of beats that means, one time if he is giving X volume per minute maybe 72 times or 100 times beating will be there, so 72 times 100 times, 72 times it will be delivering fluid. And, if you are running, your heartbeat will be increasing so that it will be pumping more, your beating rate will be more, and the total volume of fluid will be more. So, the same volume of fluid will be delivered, and because the beating rate is increasing, the total amount of fluid will increase. So the heart is there, your injection syringe that is also reciprocating pump actually, you are taking a certain amount of fluid, the same amount of fluid you are delivering, one time, but it is also pumping.

So syringe, injection needle is a syringe or cycle pumper, the time you are delivering a certain amount of air, but if you are doing very fast and quick, in that case, you deliver more actually. So, in a positive displacement pump, if you increase the pulsating or rotation rate, in that case, you deliver more fluid. These are examples, so there will be a reciprocating pump; normally, it will be a reciprocating pump, so I will delete this one and will be rotary type. I said rotary type pump, reciprocating type pump like injection syringe, heart or cycle pumper or your hand pump, water hand pump, or more examples from your daily life application. Rotary type pump, rotary type pump one is centrifugal, centrifugal pump is not rotary type pump here as per my definition, a rotary pump is that positive displacement pump, and it will be linked with your speed, if you are changing speed, your flow rate will change. So, the example is the PCP you use for the artificial lifting system, progressive cavity pump (PCP). There will be a scroll pump, volute

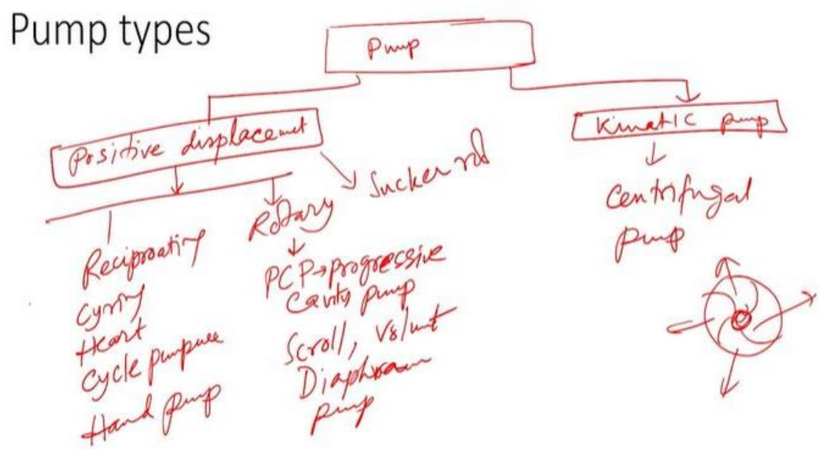

Fig. 1.Pump classifications

pump, and diaphragm pump, so there are different types of PCP, volute pump, scroll pump, and diaphragm pump those are all come under positive displacement type pump, sometime it will be rotary, sometime it will be reciprocating. The reciprocating pump is arranged to look like a rotary pump. Normally, this positive displacement pump will have very high-pressure development; you can develop any amount of pressure using one reciprocating pump, but the flow rate will be very low. A lower amount of fluid will be delivered using a positive displacement pump, but it will take a certain amount of fluid, and the same amount of fluid will be delivered. So, volumetric efficiency ideally will be 100%, and there will be no volumetric losses. Other losses like friction losses will be there anyway because whenever any machine is running, there will be a certain amount of loss you cannot recover. For example, because friction will be there, molecular collisions will be there, so that amount of energy you cannot recover so that losses will be there every time.

The engineers or scientists designing new types of pumps or modifying or upgrading the pumps will be considering how to reduce the losses. Now kinematic or kinetic pump will give energy due to very high rotation, for example centrifugal pump. So the centrifugal pump is like this: if I take this one, if I rotate it, if I rotate a very slow speed, so it is doing like this, but if I rotate very high speed you see this end, this tip of this pen is becoming almost horizontal. So because of the centrifugal action, this end will be trying to move away from my hand, and if this rotation speed is low, then it will be like this: rotation is very high, increasing like this. And if I have a certain mechanism called an impeller, the impeller will have a certain flow channel like this, and the impeller center this, if I am taking a certain amount of fluid and if you rotate at very high speed, the fluid will be going away from this one because of centrifugal action. If you rotate at a very high speed, this impeller will be going away from the impeller because of the centrifugal action fluid.

When fluid is going away, you collect that high-velocity fluid and deliver it somewhere else, called a centrifugal pump. There are several types of centrifugal pumps, axial flow, mixed flow, and radial flow; there will be a very small pump, there will be a very big pump, there will be single stage pump, there will be multi-stage pump, you can connect serially several pumps or you can connect parallelly many pumps. So, in your artificial lifting system, you connect one pump, two pumps, three pumps, and four pumps, and one pump will be delivering a certain amount of pressure, and subsequent pressure from other pumps will add up. So finally, 100, 200 stages, maybe two, three storeys building equivalent to a total length that much of length is required to develop pressure maybe 5000 or 10000 bar pressure, 3000 psi pressure, 3400bar. If you can connect that centrifugal pump properly, you can lift wellbore fluid with present condition. Centrifugal pumps will have several restrictions or limitations that we will discuss when discussing ESP systems. But the positive displacement pump we use for the wellbore application is called the sucker rod pump (SRP). So how does a sucker rod pump work? If you have a hand pump for a household application like in a rural area, the one pump water supply system, or your cycle pump or system, I told roadside cycle shops they will have that is similar mechanism actually, reciprocating action you are giving and you are lifting fluid or you are delivering fluid at high pressure. Another type is that it uses a progressive cavity pump.

So, this is actually a rotary-type pump; later, I will bring some models and explain how it works. So, if you rotate one rotor slowly, it will take a certain amount of fluid it will deliver the same amount of fluid continuously. If you increase the number of rotations, the total amount of fluid will increase, but pressure development will be the same. Ideally, we will have no losses in PCP or sucker rod pump. But practically, there will be certain limitations we will discuss later. Centrifugal pump is a multistage pump generally used in the oil industry, and it has a very high volume flow rate, but pressure development will be lower than a positive displacement type pump. Because of the lower pressure development, we often do not use centrifugal pumps—for example, your high-pressure application for field injection in engines. So, normally, we try to use a positive displacement-type pump. But you want to deliver a high volume of water for your fast flow water cleaning purpose. So, in that case centrifugal pump is a very commonly used pump centrifugal pump on normal household applications.

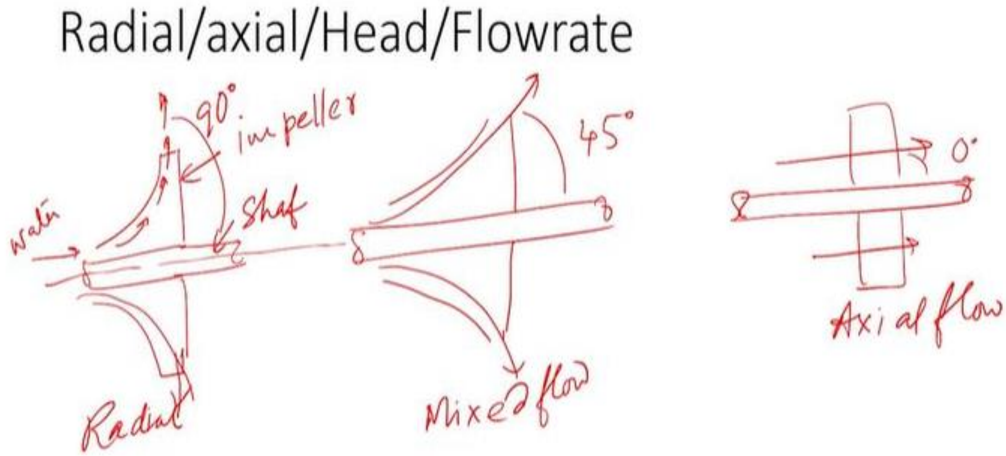

Fig. 2.Radial, mixed and axial flow centrifugal pump.

Radial/axial/ head/flow rate

Centrifugal pumps typically have three types. One will be radial type later I will bring some models and explain. This is just a basic idea to give a basic idea to you. So centrifugal pump, normally, fluid will be coming like this: this is the shaft. This is called an impeller. If the shaft is rotating, the impeller will be rotating also. When the impeller rotates, the water or any fluid will enter the impeller. The impeller will have some cavity or channel through which fluid will enter and move upward. So, fluid enters axially into the shaft. If this is a shaft, fluid is entering here, but finally, you see the fluid is entering and going perpendicular to the shaft. This is called radial flow. So, fluid direction, this is 90 degrees. This is your radial flow impeller. Radial flow impeller will have higher pressure development (or) high head, but the flow rate can be lower. Another type of impeller is called a mixed-flow impeller. So I can draw similar figures and fluid entering and exiting like this. So you can see this is almost 45 degrees. Similar sort of arrangement. So, this is called a mixed-flow impeller.

Later, we will discuss this in detail. Another type is called an axial flow impeller. So the impeller is like this, and fluid is entering like this. So this is 0 degrees. Fluid enters parallel to the shaft. So fluid and shaft angle is becoming 0. This is called an axial flow pump. So radial flow pump will be commonly used for your ESP electric submersible pumping application.

In some cases, you use a mixed-flow impeller, but normally surface applications many times people will be using many. Radial flow is normally not used in the oil industry because it is developing very low pressure or head. We use the term head instead of pressure in fluid mechanics of pumping systems design. Head means how much water column it can rise, it can raise. Let us say one impeller is increasing one bar pressure. Take one pressure measuring device and see one bar pressure equivalent to a 10 m water head. So we say head 10 m. So, the pressure or head will be high, the pressure will be low, flow rate will be high. Here, pressure is high, and flow rate is low. If you use a radial flow impeller, getting very high pressure, the flow rate will be lower. But if you use an axial flow system, pressure will be very low, and a very high flow rate will be there. So, to mix up two concepts, radial and axial, people develop the mixed flow impeller. So that will also have a bit higher pressure and a bit higher flow rate. But typically, I said, the oil industry uses basically radial, sometimes mixed flow impellers. And the exit pressure or outlet pressure of the impeller, we say head, not bar, or something like the meter of water equivalent to a column of water head. The term is used. We have a centrifugal pump with radial, axial, and mixed flow. Now, which one to use where? Let us see the specific speed.
One formula is there for a specific speed where ‘n’ is rpm, ‘Q’ is flow rate, let us say m^3/s. So, ‘N_s’ is not dimensionless here, you can see. ‘N_s’ has a dimension.

$$N_s = \frac{n\sqrt{Q}}{(H)^{\frac{3}{4}}}$$

So, if I draw one line for a specific speed exact value, we must check from books. Some values will be there: A, B, C, D. So, very low specific speed will be like a reciprocating pump. Reciprocating or positive displacement type pumps will have very low specific speeds. Then, it will come radial flow impeller. Then, you need axial flow impellers and axial flow rotating machines at a very high flow rate. Or progressive cavity pump, gear pump, screw pump, or diaphragm pump will come under low flow rate conditions, and their head will be very high. So, low flow rate and head high. Flow rate low, here flow rate high, head low. So, if you are using a certain pump for a certain application, you have to know how much flow rate and pressure you need. Based on that, you must decide which type of pump you need for your application, maybe in surface or subsurface applications. This specific speed gives an idea of what type of pump should be used for which condition. You can go mixed or axial if you have a very high flow rate condition. But if you have very high-pressure requirements, such as a Sucker rod pump, they use 10,000 feet of water wellbore depth. So 10,000 feet wellbore depth is there, and very high pressure is required but a very low flow rate is required. For example, in gas well deliquification, maybe per day, 5 barrels of liquid may get deposited, or liquid is held up at the bottom. So that liquid you have to remove otherwise, your flow rate will not be proper. So, to remove that small amount of gas held up, that liquid held up at the bottom you need, you do not need a centripetal pump; a centripetal pump will have a relatively

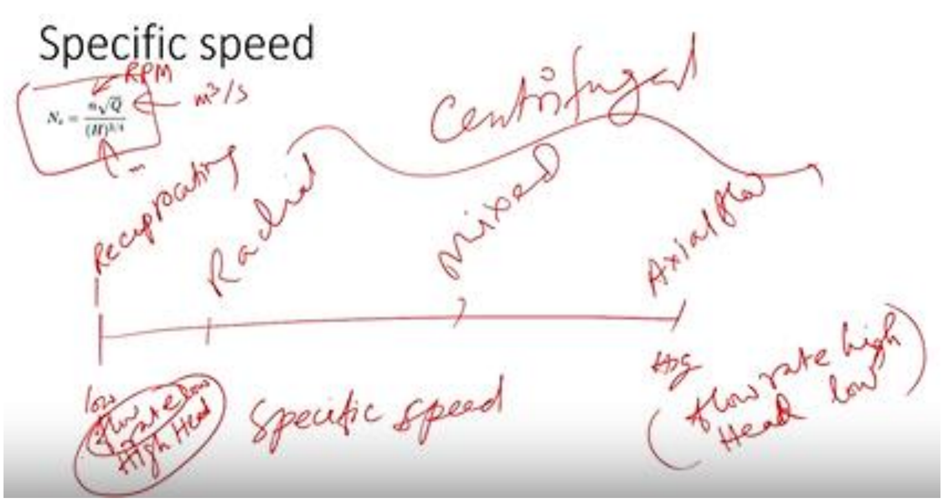

Fig. 3.Pump selection based on specific speeds (N_s).

higher flow rate. So, in that case, you use a reciprocating pump, very simple per few strokes per day, or continuously run with a very small flow rate that will be okay. But you need a flow rate in certain cases, like 5,000 barrels per day. So, in that case, if you are trying to use a sucker rod pump, that will need too high flow rate for a sucker rod pump. In that case, you must use a centrifugal or radial pump. These are radial flow, mixed flow, and axial flow; these are centrifugal pumps (represented in the screenshot). You can use axial flow among these three very high flow rates, but normally, we do not use axial flow pumps for artificial lifting applications. This is too low a head, so too low a head will not help, although the flow rate may be high. So we can use a gas lift or other mechanism if a very high flow rate from the wellbore. So, before you understand centrifugal or positive displacement pumps, I developed some experimental facilities at IIT Madras. So the experimental facility is like this: this is an actual experimental facility, one tank. So, the tank is connected to one pump. This is a pipe, and there is one motor between the motor and the pipe the pump is located. From the pump, fluid goes through the flow control valve. From there, water is falling into the tank again. This is a continuous loop, and to do the experiment, we put one flow meter here; you can see the flow meter and variable frequency drive here on the wall; it is a fixed VFD or variable frequency drive. Why variable frequency drive is required? Because you want to check your pumping performance at different speeds, I told you that the heart beating rate

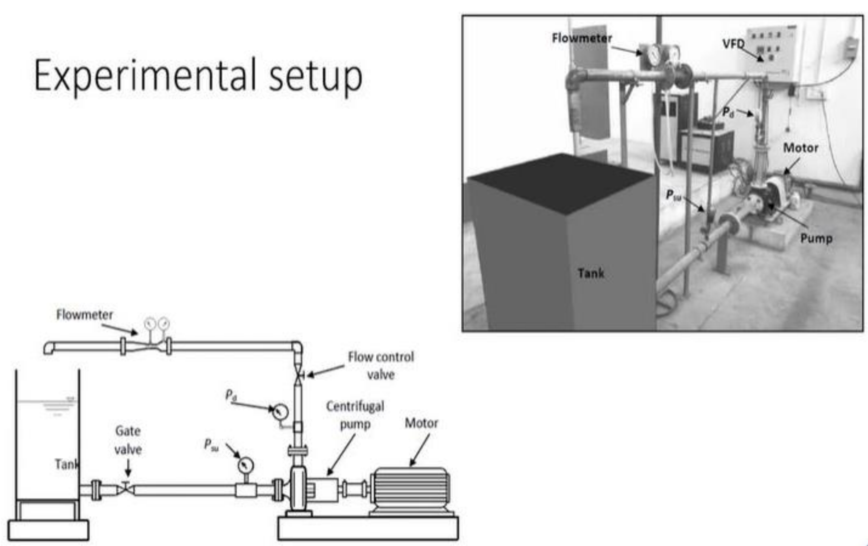

Fig. 4.Experimental setup of the centrifugal pum in IIT Madras.

changes, so your flow rate changes when you are running; you need more fluid or blood flow in your body, so your heart beating rate will increase. So, the brain is controlling that. So, in our case, maintaining our brain is here VFD. So, VFD will be giving different frequencies to the motor. So motor frequency will be, electrical frequency is changed so motor speed will change because of electric frequency change.

When the electric frequency changes, the motor speed changes, and it will change the pump speed, and my flow rate and pressure will be changed. So, if I see the line diagram, I have a tank. So tank has one pipe directly going to my pump. Pump to one pressure gauge here, the pressure gauge, and the flow control valve attached between the pump and flow-meter. Then I have one flow meter, and water is falling into the tank. Why did I develop this experiment setup? Actually, I wanted to check the fluid flow under different emulsion conditions, and if I have emulsion flow or multiphase flow, let us say gas is also injected there, then what will be the performance centrifugal pump? What will be the base design for the centrifugal pump, which will be working for wellbore under multiphase or emulsion conditions? Let us say I have a 10% water cut, 5% water cut, or have a 5% gas volume fraction or 10% gas volume fraction; then if we change this gas volume fraction or water cut, centrifugal pump or axial pump or radial pump whatever or PC progressive gravity pump, the performance will change. If performance changes, what will be the base design for our pump? So, we are trying to design, optimize, and experiment. So lots of things we are trying to do. So, this experiment, how to do it? So, in the experiment, first, you must draw the HQ curve when experimenting. H means head or pressure, and Q means flow rate. How to get the flow rate? I have one flow meter. The flow meter will give the flow rate. So here is the flow meter; it will give an H. How to get H? I have a pressure gauge.

The pressure gauge will give the H value. Now, initially let us open the valve, which is the flow control valve. So open the flow control valve. Now fluid is not getting restricted. Switch on the VFD, it will give electricity to the motor, motor will start running. When a motor is running, the pump will be delivering fluid. The pump is delivering fluid means if you do not have any restriction at the delivery pipe, this is called delivery pipe, delivery pipe, this is called suction pipe. If we do not have any restriction in the delivery pipe then fluid flow will be maximum. So initially, we assume there is no restriction in the delivery pipe, and your pressure gauge will show very low pressure. So that time, your flow rate is very low or very high. Now, if you are using a centrifugal pump, the radial flow, axial flow, mixed flow, that type of pump, then you close the flow valve, there is one flow control valve, and you turn a little bit. So, the flow will be restricted. Flow restricted means your flow rate will be slightly down and your pressure gauge will show slightly higher pressure. Again, you increase this turn. So slowly, you are closing the flow path, restricting, and choking. When you are choking, your pressure will increase in the pipe before the pump and the delivery flow control valve; between the pump and flow control valve, the pressure gauge will show a higher pressure value, and your flow meter will check how much flow rate you have. So, your flow meter will check the flow, and you will get this curve. This is called the HQ curve. The HQ curve for the centrifugal pump is done for one speed. Now, you change the VFD frequency again. When you change, let us say you reduce the frequency; if you draw the curve, the curve will be like this. Again, you reduce, again you reduce, so if you reduce the frequency, the motor speed will be reduced, the impeller speed reduced, and the rotating speed of the impeller reduced, so it is giving less centrifugal force, which means your head and flow rate will be going down, head or pressure development and flow rate will go down. Again, you change the impeller speed using your VFD or variable frequency controller further up, so you will get a curve like this.

You can get many curves like this. This is called the HQ curve for centrifugal pumps. Now instead of a centrifugal pump, if I use one positive displacement pump, let us say sucker rod pump or PCP, how will the curve look like? In the same way, I will try to experiment. So I will take Q and H. This is called a positive displacement pump. What will I do? Initially, everything in the flow control valve is open completely, you get a very high flow rate, then you close a little bit flow control valve. Your head or pressure will increase, but the flow rate will not change. Again, you close a little bit, the flow rate does not change. Again, you change, again you change, flow rate not changing. So, you are getting an almost vertical curve. So if you use a positive displacement pump such as a sucker rod pump or your progressive cavity pump, you will get a curve almost vertical.

That means it can develop any amount of pressure, but if you use a centrifugal pump, you can see that the pressure is limited. It is going up to a certain limit. If you see the HQ curve of the centrifugal pump, pressure is limited, but in a positive displacement pump, SRP, or PCP, your pressure is not limited. So you can go an infinite amount of pressure. So now see the difference. If I take one human heart also, you will see that same tendency as a positive displacement pump because when you are running the same amount of fluid, you are delivering, and your heartbeats increase, and the volume flow rate increases. If you are not changing that heartbeat, you are restricting, then the flow rate will be the same, but your pressure will be higher. But when running, you must have a higher volume flow rate, and your beating will increase. So, whatever we tested in our laboratory, one impeller is shown here. This is one impeller. Later I will bring one model, and I will explain. So, how to draw the HQ curve? So I already told HQ curve means flow rate. For the centrifugal pump, I have seen this one, the centrifugal pump, which rotates at a very high speed and is used for common household applications, but the other type of pump I told is completely vertical. This is called a positive displacement pump. Now, how to draw it? So let us say you have one data table, serial numbers 1, 2, 3, 4.

You take some data. So what do you do? Flow rate, head, and then your electric input. So initially, the valve is completely open to get a very high flow rate, say 10. The head will be almost 0, and electric power consumption may be 10 watts. Now, you close the valve a little bit for the centrifugal pump. So the flow rate will be slightly reduced, H will be increasing, and Q will be slightly increasing because you are restricting, so maybe it will be increasing, so you take data. So, finally, you produce your curve for the centrifugal pump. So same data table, if I want to produce, then Q and H, so Q will be the same every time. H will be changing 0, 2, 4, and you will be producing the figure, if you take electrical data also and if you calculate efficiency, then your efficiency curve will be like this for the centrifugal pump. For centrifugal pump efficiency curve η, this is efficiency. The efficiency curve will be like this. Why efficiency curve will be like this?

Because it will be consuming efficiency at a certain point, your efficiency will be very high, and if you are changing the valve continuously and finally your efficiency will be down. So you will have one best efficiency point. So, where do you have to run your pump? So, if you are running your pump left side or right side of the best efficiency point, your electric consumption will increase, possibly creating cavitation and other issues.

So normally, the designers or engineers will try to run the pump at BEP or the best efficiency point. So, you can change your pressure or flow rate, use VFD, or change the whole pumping system. And here, when you are experimenting, one question is there: Do not close the valve completely. Why? For example, positive displacement pump, your pressure line is going up vertically. So if you close the valve, the pressure will be too high. This flow rate is the same: your pump is continuously running, and your pressure is showing high; it will go to infinity. So that time your motor can fail, electric, the piping system can burst, or some leakage can occur so an accident can happen. So, you do not close the flow control valve completely whenever you experiment with any centrifugal, reciprocating, or positive displacement type pump. When it reaches a certain level, stop and draw the approximate curve, which is okay. For example, centrifugal pump, when the Q and H curve is drawing and the curve moves towards H, so do not close completely.

So keep some gaps, stop your experiment, and say okay, done. And if you have a completely proper safety system, then you can use that is okay. But for normal laboratory applications in India, whatever laboratory practice we do, please do not try to close the valve completely. That will be for safer instruction. Again, whenever you are doing an experiment laboratory, you must follow certain safety protocols. If you are not using specific safety protocols, accidents might occur. So we do not want that unwanted issues. Inlet pressure, so when using any pumping system, centrifugal pump or positive displacement pump, gas leak or jet pump or okay. So, you need a certain amount of pressure before the pump. So let us say one reservoir, and you have one tubing, reservoir perforated here, and the wellhead is here, and you have choked. Now, P_r, $P_{wf,}$ and you are putting one pump here, and let us say pressure is so low that liquid can reach up to this level. So what will happen? There is a pump you switch on, the pump will try to suck the fluid. If the pump is trying to suck the fluid, what will happen? That formation volume factor, solution gas well ratio, can you remember that if you reduce pressure, some gas can come out of the system. If gas is coming out, the centrifugal pump will be having, will be facing difficulty in pumping liquid.

Suckers pumps will have certain difficulties called gas interference. Some other types of pumps also will have some difficulty. So you need a certain initial pressure so that the pump does not get your free gas or dissolved gas okay. So typical NPSH (Net positive suction head) in centrifugal pump pumping term they called net positive suction head, net positive, net positive suction head. When running a centrifugal pump, standard water application requires minimum inlet pressure. Otherwise, the water will evaporate and be entangled with an impeller, and there will be cavitation, erosion, and some other issues and vibration, noise many problems will arise. But when you use an oil and gas wellbore, in that case again, when pressure is going down because of this issue, you are not maintaining a certain amount of pressure; the gas will be coming out from your liquid. So, the gas will be interfering again with the pumping operation. Then the pumping operation is interfered with, resulting in vibration, noise, cavitation, erosion and maybe some other issues. So you have to maintain a certain amount of pressure. Especially centrifugal pump needs more inlet pressure because it is sucking high fluid.

But when you use a sucker rod pump or PCP and another type of pump, they are very low flow rate pumps. A low flow rate pump means it is pumping, say, 5 barrels per day, but in the 24 hours, maybe 5 barrels will be liquid coming into the wellbore, and slowly, you are filling the cavity or gap or void area, and you are pumping. So that may be okay. But when you are pumping using a centrifugal pump, that will deliver a very high amount of fluid, so the reservoir may not deliver that at that rate. So, in that case, one gap will be created, and the pressure drop will be there. When a pressure drop is there, free gas will come out, and your dissolved gas will come out. So, that will be a massive problem for your pumping operations. So that is why the term centrifugal pump needs one term net positive suction head. So, later, we will discuss in detail when we will be teaching you ESP systems.

Affinity law.

$$Q_2 = Q_1\left(\frac{N_2}{N_1}\right)$$

So, usually, the designers consider the affinity law. Affinity law is like this: flow rate will change if speed changes. Similarly, pressure will change if speed changes, or sometimes trimming of the impeller will also be possible. The impeller is 10-20% in diameter; if we change, your performance will change. So that also many engineers or designers will be doing. But as a production engineer, you do not have that much scope for modifying an impeller system because you are focusing more on the production side, not on the design of the impeller. So, surface and subsurface pumps are different. I told them that the subsurface pump will have dissolved gas-free gases, and they have very narrow space. So wellbore properties and narrow wellbore formation volume factor and formation volume factor is solution gas oil ratio those things also will be one parameter. So wellbore, usually the diameter will be 5-6 inches maximum. However, the diameter is not restricted when we use the specific pump at the surface.

So you can use a very large diameter pump also. For example, ESP will be 100-200 stages for 500 bar pressure or 400 bar pressure, but you can generate on the surface using lower number of stages in that same pressure. Why? You can use a larger diameter of the impeller. So, when using a larger diameter, you have larger space. So, in that case, your number of stages will be reduced. So your life will be less problematic, but you have a very restricted area in the wellbore. So restricted areas, you must have cable to fit your impeller, diffuser, protector, motor, and cable systems. So that is a more complex area. Again, if you have a solution gas oil ratio, solution gas creates a two-phase flow when it starts pumping, or if you have certain corrosive gas, multiple issues will come. So, that is more difficult than the surface production system. On the surface, when you are getting fluid, you have many options to modify the fluid, but in the wellbore, you have a very restricted area so your options are minimal. So, the task is more challenging.

So, in this course, I will explain how engineers or scientists handle the wellbore pumping problems when depleted reservoir is there and you have to get more production or make the well economical. So priming and foot valve. So, you use the centrifugal pump, ESP, PCP, or SRP. So, in some cases, you have to fill the pump first, then start running.

If you do not fill it out initially, there will be multiple issues. For example, if you see a centrifugal pump handling fluid and giving very high rotation of the impeller because of the high rotation, the fluid particle will go out of the impeller. The fluid will be high density, so it will create more force and be sucking fluid it will be delivering. But what will happen instead of liquid if you are giving gas? You create rotation centrifugal force but centrifugal force because the gas particle will have very low density because of low density will not be able to suck the fluid. Because of that, your pump system can fail. So what do you have to do? It would be best to fill the pump with liquid, then switch on electricity, and it will work. So, this term is called priming.

You are filling the pump. Fill the pump before starting and fill it with liquid. Whatever liquid you are pumping, whether the water you are pumping that filled with water, if you are pumping oil filled with oil, then you switch on, it will start delivering fluid. Often, you use a foot valve, especially when using the pump for your agricultural application or maybe surface production application, for example, dealing mud handling system or somewhere. So, in that case, you may need to use one food valve. The foot valve is like this you have one pump, and you have, let us say, some tank, and you are sucking fluid; this is a suction pipe, and you are delivering somewhere. So suction pipe, if there is one debris or something that should not enter the pipe. If waste or something enters, it will interfere with your impeller operation. So, it will clog the impeller path or create more erosion. So, in that case, when you do one valve, you create a one-way valve. So, that valve will allow only one-way flow. When filling the impeller area for priming purposes, you are giving water so that water should not go out to your tank.

This foot valve will have a one-way valve, so it will close the path when you give water from the top side. It will open like this when it is sucking fluid from the wellbore or tank. Again you switch off the pump, it will be closing the path. So when you are priming it so the valve is closing the pipe, the suction pipe will be closed, and you fill it, then switch on the pump, and when it is sucking fluid, the valve will be automatically open. It is a one-way valve that will be operated automatically without manual operation. That is called a foot valve. It is required for priming processes and will avoid taking other debris or other things into your pumping systems because it will have small pores, so pores will not allow the bigger particles to enter your pumping systems. So this is the suction side, this is the delivery side. So suction side when an impeller or any pumping system sucks fluid, the suction side will be limited; it may be a maximum of 10 feet for water, but if you have solution gas there and if you are not maintaining pressure, then the suction side length must be lower or you must the impeller must be submerged into the liquid so that the inlet pressure should not go down below this bubble point pressure. If it is bubbling, then it will be creating cavitation. So, on the delivery side, there is no such restriction. It will depend on your pump design and the number of stages, so the length of the delivery pipe depends on your pump performance, but the suction side depends on your fluid properties. Cavitation will be possible if the fluid has lots of gas and bubble point pressure near your pumping operation area. So you have to consider all these parts. So thank you very much.