Oil Hydraulics and Pneumatics

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Part – 3: Ideal Pump, Pump Losses, Efficiency Curve, Constructional Features and Operations of External Gear Pump

Lecture - 15

Hydraulic Pumps

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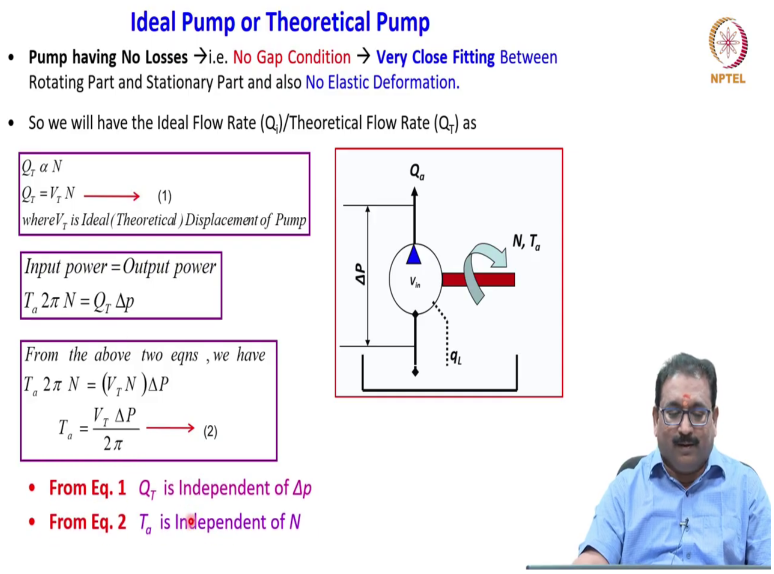

My name is Somashekhar, course faculty for this course. Let us we will move on to the ideal pump; what is the ideal pump? It is also known as sometimes a theoretical pump. Please note friends, pump having no losses meaning; no gap condition meaning; a very close fitting between the rotating part and a stationary part and also no elastic deformation.

You may ask me whenever there is a moving element clear and should be there. But assume it now there is no gap between the rotating element and the stationary element and no elastic deformation which is a prime requirement in the ideal pump, theoretically we have to do this.

Now, I will show you here you all see here this is a pump friends pump connected to the tank then Q a is a out outlet where the flow will go out due to the delta P. What is the delta P here? At the section here always a vacuum and tank pressure is 1 bar ok.

Then whatever wherever the rotating elements are there then there is a leakage q L is the leakage which is connected to their electric motor. Meaning pump will receives the mechanical energy through N and torque to rotate this then it will give the hydraulic energy as I have told you.

Now, we will see friends. So, we will have a ideal flow rate Q i and also known as theoretical flow rate Q T as theoretical flow rate is directly proportional to the speed N or Q T equal to V T into N. What is this V T? V T is a ideal or a theoretical displacement of the pump.

Also we know that the input power whatever you are giving is equal to T a into 2 pi N is equal to Q T theoretical flow rate multiplied by this delta P. This is a ideal pump friends, please remember. Ideal pump, what is the ideal pump? No gap condition and no elastic deformation, but all pumps are not ideal.

Always there is a clearance always there is elastic deformation, but assuming to arrive this these two things I have made a assumption that no gap condition, no elastic deformation that time theoretical flow or ideal flow is proportional to N which is equal to V T into N; V T is the ideal displacement of the pump.

Similarly, input power equal to output power; input power is from the electric motor T a into 2 pi N is equal to Q T into delta P. From the above two equations because I want to equate now see friends what happen. Now, I am equating T a 2 pi N, the Q T I am substituting here, Q T I am substituting V T into N here then delta P.

Meaning I am interested in to know the actual torque T a equal to V T into delta P divided by 2 pi. These are the two very very important equations for the ideal pump Q T equal to V T into N and T a equal to that is a torque actual torque is equal to V T into delta P by 2 pi.

Please note from equation number 1 and equation number 2; equation 1 you will see the theoretical flow is independent of delta P, no delta P term here. Similarly, from equation 2 the T a actual torque is independent of N important observation from the equation 1 and equation 2.

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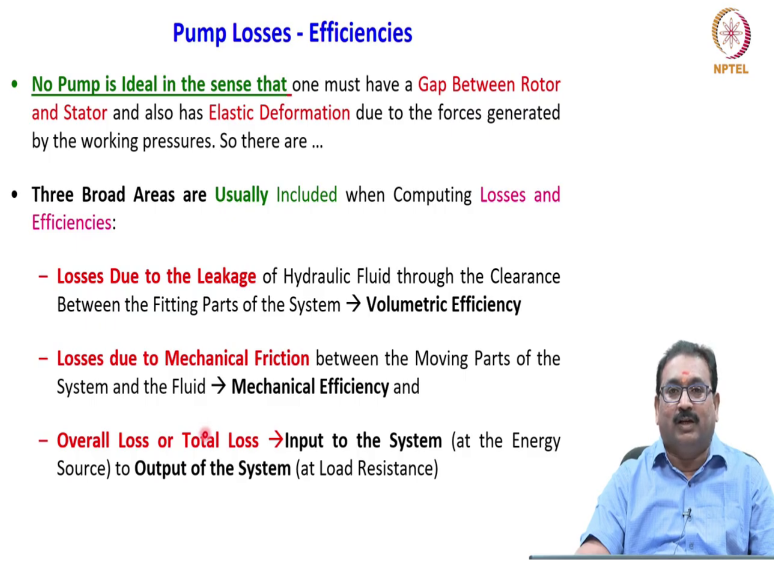

This is what we can call the ideal pump, but as I have told you there is no ideal pumps exists. Always there is a loss. To understand this we must know the, what are the pump losses that is efficiencies.

No pump is ideal in the sense that one must have a gap condition between the rotor and the stator and also has a, elastic deformation due to the forces generated by the working pressures. So, there are three broad areas are usually included when computing the losses and efficiencies. What are those?

The losses due to the leakage – the leakage occurs due to the clearance between the rotating element and the stationary element. This you have to considered, that is losses due to the leakage of hydraulic fluid through the clearance between the fitting parts of the system that is what we can call the volumetric efficiency. Volumetric efficiency is closely related to your theoretical flow and actual flow. Actual flow is differ from the theoretical flow.

Then losses due to the mechanical friction between the moving parts of the system and the fluid that is very very important thing is the mechanical efficiency coming into picture when you are considering the mechanical friction between the rotating parts and the fluids. Third one is the overall loss or a total loss meaning here input to the system meaning at the energy source to output of the system that is at the load resistance.

These are the three broad areas where you have to concentrate to ascertain the losses in the pumps.

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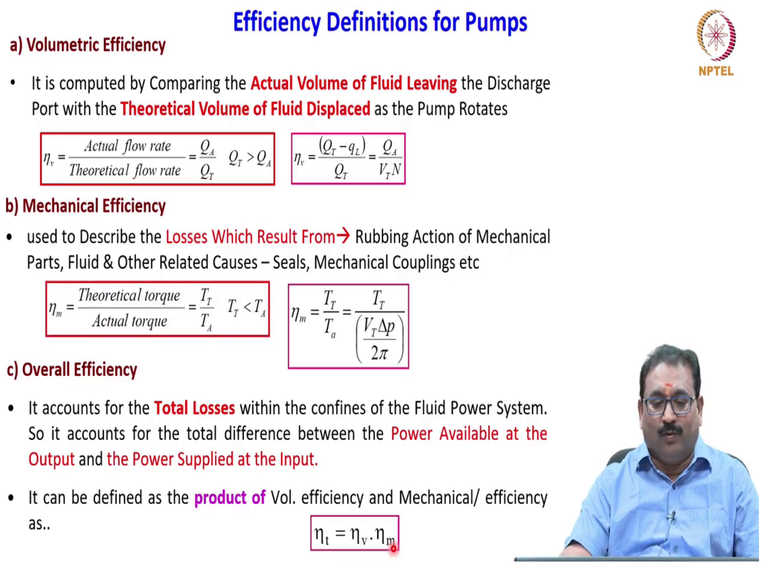

Let us we will see these efficiencies of the pumps: first one as I have told you volumetric efficiency. What for it is? Due to the leakage; you know that it is computed by comparing the actual volume of fluid leaving the discharge port with the theoretical volume of the fluid displaced as the pump rotates.

Meaning, what it is? The volumetric efficiency is the ratio of actual flow rate to the theoretical flow rate that is Q A by Q T. Always you will remember friend theoretical flow rate is greater than Q A, actual flow. Actual flow is always a less because there is a leakage between the rotating and the matting meaning housing.

There is a clearance if clearance is goes on increasing leakage is more, then volumetric efficiency will be less, but we want to get the maximum volumetric efficiency meaning there is a close tolerance between the rotating element and the housing; understand this very important.

Then Q A as I have told you it is always it is a less. How much it is? By leakage how much it is? q L minus q L. I have shown you in the previous figure theoretical flow minus q L divided by Q T r it is a Q A by Q T equal to what V T into N.

Now, we will see the mechanical efficiency: used to describe the losses which resulting from rubbing action of the mechanical parts fluid and other related causes like a sealed mechanical coupling etcetera which can be defined as you will see here mechanical efficiency is the ratio of theoretical torque by actual torque which is equal to theoretical torque, actual torque is already we know that V T into delta P by 2 pi.

Then last one is a overall efficiency or a total efficiency, how to define this? It accounts for the total losses within the confines of the fluid power system. So, it accounts for the total differences between the power available at the output and the power supplied at the input. It can be defined as the product of volumetric efficiency and mechanical efficiency. The total efficiency is the product of volumetric efficiency and the mechanical efficiency.

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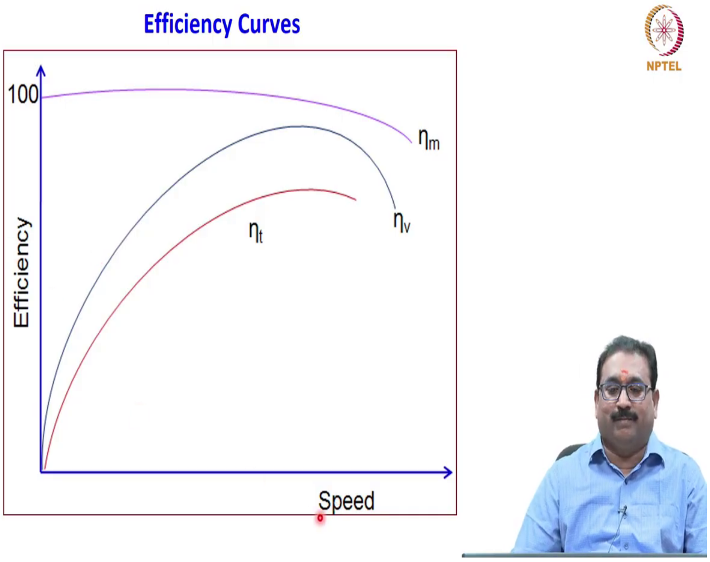

This I will show you in the curves you will see this efficiency along the y-axis along the x-axis speed. You will see friends always volumetric efficiency goes on increasing and later it will decreases. Similarly, the mechanical efficiency 100 percent as the speed increases it goes on decreasing due to the rubbing action between the seals and between the matting elements of fluid etcetera.

This is a mechanical efficiency, this is a volumetric efficiency, then total efficiency is add together I will get here that total efficiency. Please understand the curve efficiency versus the speed.

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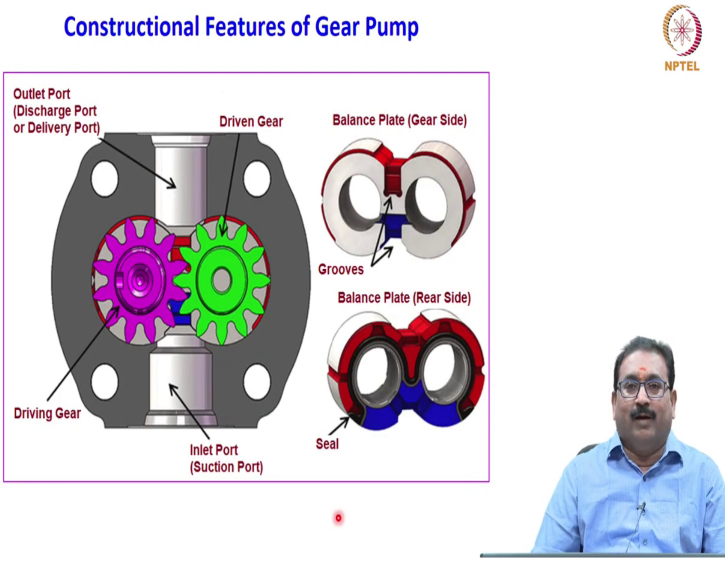

Now, let us begin now with the constructional features of the first and prime pump in hydraulics is the gear pump. Just you will observe the figure friends as I have shown you the cut section model of the gear pump what it consists we will see here.

Now, we will see it consists of the two gears enclosed in the housing. Then the inlet port is there, outlet port is there. Please observe the clearance between the gear and the housing very very small very very small it is. Then it is a the balance plate gear side and a balance plate rear side is there closing this cut section you know it will close it.

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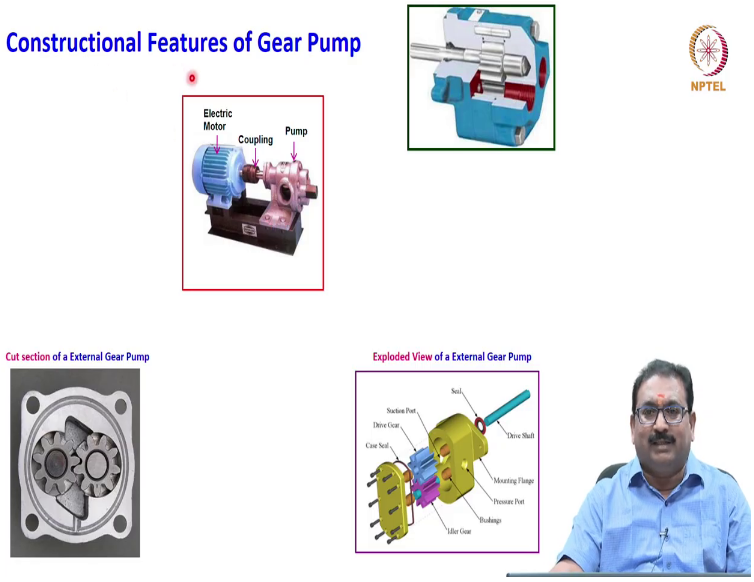

Then we will also I will show you how it is you will see here friends this is a pump. What you are seeing the cut section is a pump. The to the pump and the electric motors are connected through the coupling here you will see here pump shaft how it is one gear what we can call it is a driver and a driven gear is known, correct?

One is a driver, another is driven gear enclosed in the housing meaning please understand the electric motor shaft and the pump shafts are coupled using the coupling. When electric motors starts rotating the gear what it will rotate it is a driver. Another one is a driven gear follower it is. All are housed in the housing you will see the exploded view of the gear pump.

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Let us we will see the constructional futures in detail. As we know it consists of the two matting gears driver and the follower; driver is one which is connected to the electric motor shaft through the coupling, follower is one which follows the driver. Driver is connected to the driver shaft we will see here driver shaft of the prime mover, follower as it meshes with the driver.

You understand friends the different types of gear profiles they are using in the pumps – the spur gear, helical gear, herringbone gears – you already studied these things. The gear profiles, based on the gear profiles the different types of pump categories are available in the external gear pumps, spur gear, helical gear, herringbone gear.

Each having it is own advantages and disadvantages we will see in the next slide. But, you will understand a pair of gears housed in the housing this gear profile may be the spur, helical or a herringbone type.

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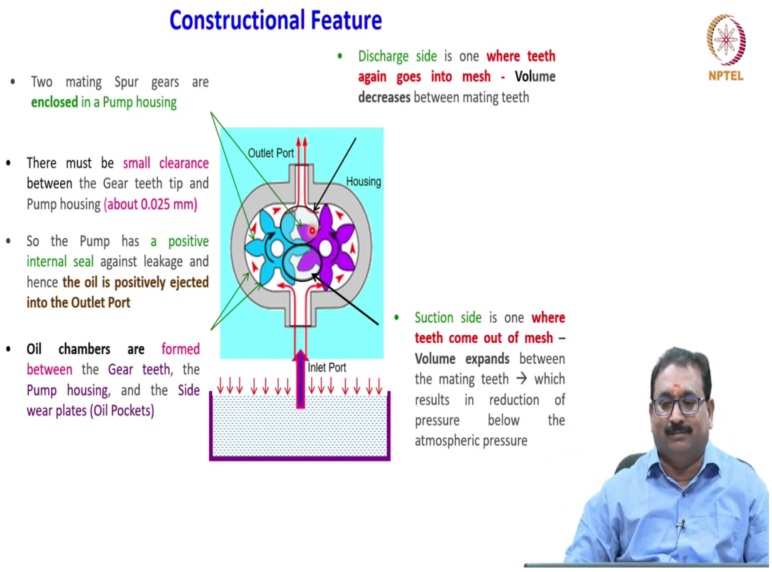

You will see now as I have told you two gears in the housing the inlet is connect inlet port is connected to the tank; outlet is connected to the walls and the actuator. I have not shown here, only outlet I have shown here. Here you will see the two matting spur gears are enclosed in the pump housing. Any type of gear I am telling you, two spur gears are enclosed in housing.

There must be a small clearance between the gear teeth tip and the pump housing. There is a small clearance it is because they should rotate, that clearance is very very small how much it is 0.025 mm.

So, the pump has a positive internal seal against the leakage and hence the oil is positively ejected into the outlet. Also please understand note friends in hydrostatic pumps, the outlet and inlet us are completely separated. Only small gap is there between this. They are separated.

See here oil chambers are formed between the gear teeth, the pump housing and the side wear plates, oil pocket. These are see here friends once oil is catched here it will transport the fluid at the outlet along the periphery, how? These are the oil pockets, it will discharge.

Half revolution oil will be suckered here another half revolution it will positively adjust because of the internal seals. See here is a suction side as I have told you. The suction side is one where teeth comes out of mesh volume expands between the matting teeth which results in reduction of pressure below the atmospheric pressure.

Then what happens here the discharge side is one where the teeth again goes into mesh, volume decreases. You will hold the hand and you will see when the downside when the gear unmesh suction, when it will mesh again what it is volume decrease small volume decreases ejects.

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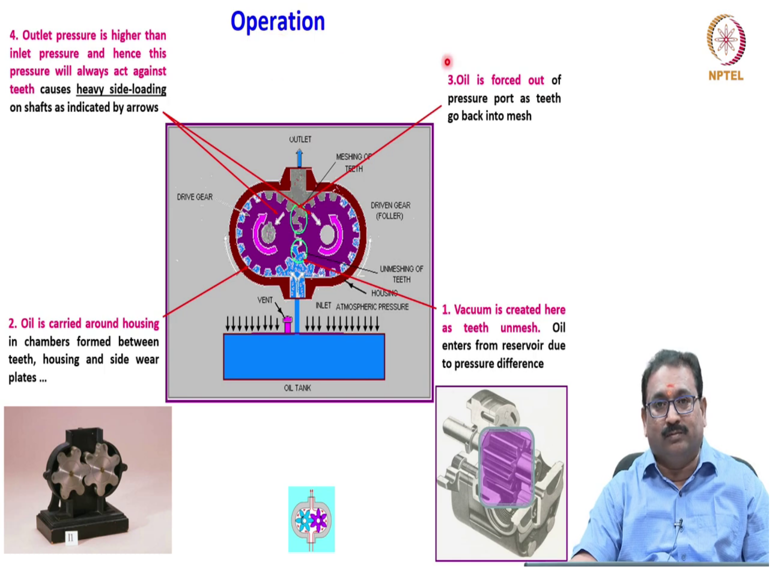

Operations very quickly I will show you how it operates. Here correct we will see here the gear unmeshes, vacuum created it will sucks due to the differential pressure vacuum and one bar pressure always a vent is there meaning always air is acting over the tank surface.

Then oil is carried around the housing in chambers formed between the teeth, housing and a side wear plate. And, here oil is forced out of the pressure port as a teeth goes into mesh, their mesh here.

We will see here friends very important, always the outlet is pressurized due to the load from the actuator and inlet is always a low pressure meaning the one bar pressure. This imbalanced pressure, the outlet pressure is higher than the inlet pressure, always there is a side loads what we will call a heavy side loading on the shafts as indicated by the arrows. That is why it is called unbalanced vent pump because the inlet is low pressure one bar the outlet is very high pressure based on the actuator load.

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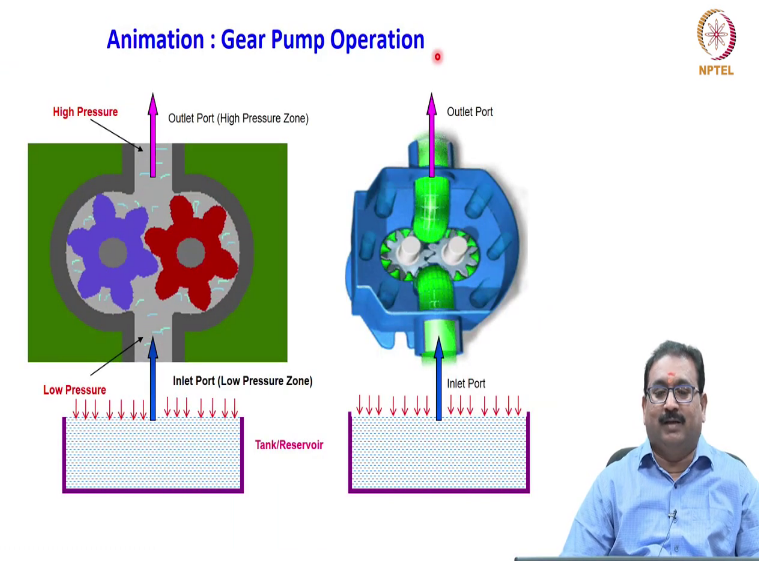

See friends, quickly I am showing you the animation here how the fluid particles will move here you will see. Positively they will eject here no passage to come here, apart from small leakage here otherwise whatever the flow will come here it should escape. Otherwise the pressure builds here. Please understand this, inlet port outlet port two gears in the housing and the small clearance.

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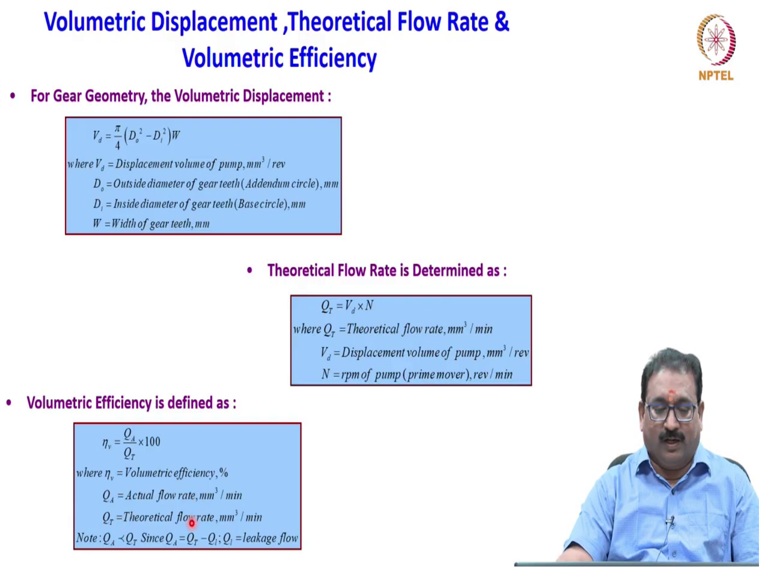

Now, based on the geometry we have to calculate the volumetric displacement, theoretical flow rate and a volumetric efficiency. For a gear geometry the volumetric displacement V d is pi by 4 D o square minus D i square into W. What is this friend? V d is a displacement volume of the pump in mm cube per revolution and D o is a outside diameter of the gear teeth, what we can call? A addendum circle diameter in meter mm or a meter.

D i is a inside diameter of the gear teeth, that is what we can call the base circle again millimeter or a meter whatever you will use it. W is a width of the gear teeth millimeter or a meter whatever you will use. But, please understand friends, this is the volumetric displacement based on the geometry outside diameter, inside diameter and the width of the gear.

Theoretical flow rate again here it is calculated Q T equal to V d into N; the V d is a displacement volume what you are calculating here and N is a rpm of the motor. Please understand here whatever the pump will rotate for one revolution fixed quantity itself, but only flow rate we will increase or decrease by rotating the shaft, but one revolution remains same.

That is why gear pumps are always a positive displacement pumps, no variability is available. You do not think if I am increase the speed of the pump more you will get more flow, not like this. But, one revolution again it remains the same there is a beauty in the gear pumps.

Then volumetric efficiency is defined as Q A by Q T into 100, 100 percentage. The Q A is the actual flow always less than the theoretical flow as we have seen already, correct friend? The leakage is prone to occur due to the gap provided in the matting elements.

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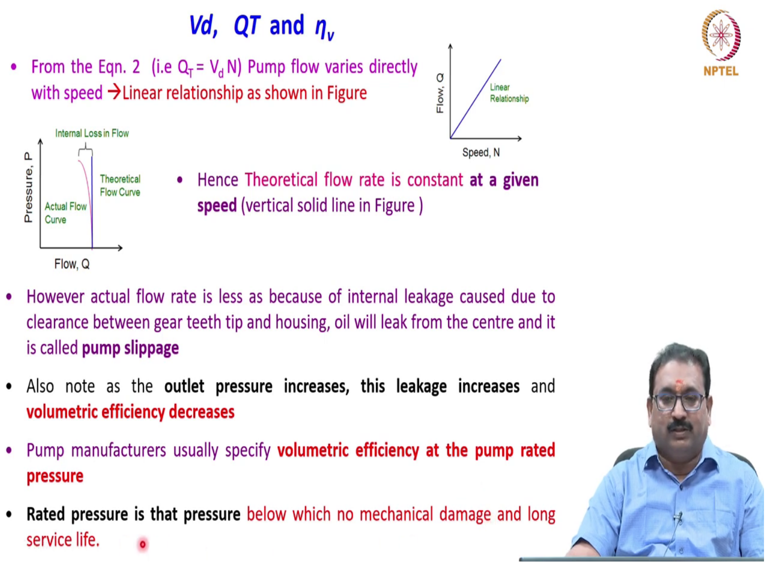

Now, quickly you will see this V d, Q T and volumetric efficiency how to write it? From the equation 2 Q T equal to V d into N; meaning what? Pump flow varies directly with the speed. As the speed increases, flow increases in case of the theoretical pump meaning there is a linear relationship between the flow versus speed characteristics in case of the theoretical pump or ideal pump linear relationship.

Hence the theoretical flow rate is constant at a given speed. The vertical line what I have shown theoretical flow rate is a constant flow rate is constant for the fixed displacement pump. However, the actual flow what I have shown here you will see this is the theoretical flow vertical line.

However, the actual flow is less because of the internal leakage caused due to the clearance between the gear teeth tip and housing. Oil will leak from the center also and it is called a pump slippage is nothing, but the leakage. Always you will see that is why there is a curve is like this, actual flow is not linear relationship it is like this. This is what we can call the internal loss. Internal loss is due to the clearances provided in the housing and the matting elements

Also note as the outlet pressure increases, this leakage increases and the volumetric efficiency decreases. Pump manufacturers usually specify the volumetric efficiency at the rated pump pressure. Rated pressure is that pressure below which no mechanical damage and long service life.

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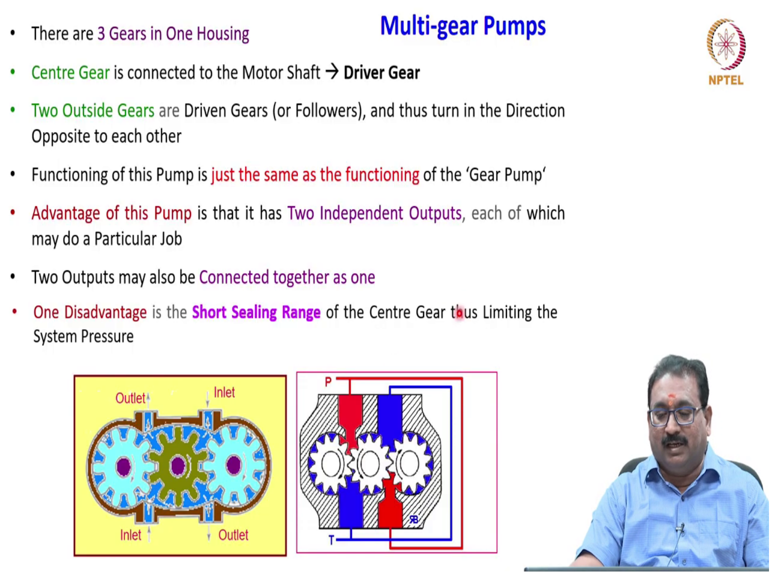

This is regarding the gear pumps. Now, we will see the multi gear pumps designs are also commercially available in the market to suit the customers. What is this multi gears? You will see here what is the multi gear.

There are three gears in the housing. The center gear we will see here friends center gear is connected to the motor shaft what we will call it is a driver gear which is connected to your prime mover. The two outside gears are known as a driven gear or a followers, and thus turn in the direction opposite to each other correct direction is opposite to each other.

Functioning of this pump is just same as the functioning of the gear pump. Advantages of this pump is that it has two independent outlets. You will see here both gears are rotating in a opposite direction, outlet 1, outlet 2, inlet 1, inlet 2 meaning you use these outlet flow to do the different works. Or you want the high flow rate or high pressure ratings what you will do? You connect these two inlets and outlets meaning like the two outputs may be connected together also possible look here are connected.

One disadvantage is that the short sealing because here oil will leak short sealing range of the center gear, thus limits the system pressure. You will not get the system pressure what you are getting in the two gears in the housing. The number of gear increases the what they will call the gaps and clearance increases, leakage increases, the volumetric efficiency will be down which it will be down automatically the total efficiency also down it is less.

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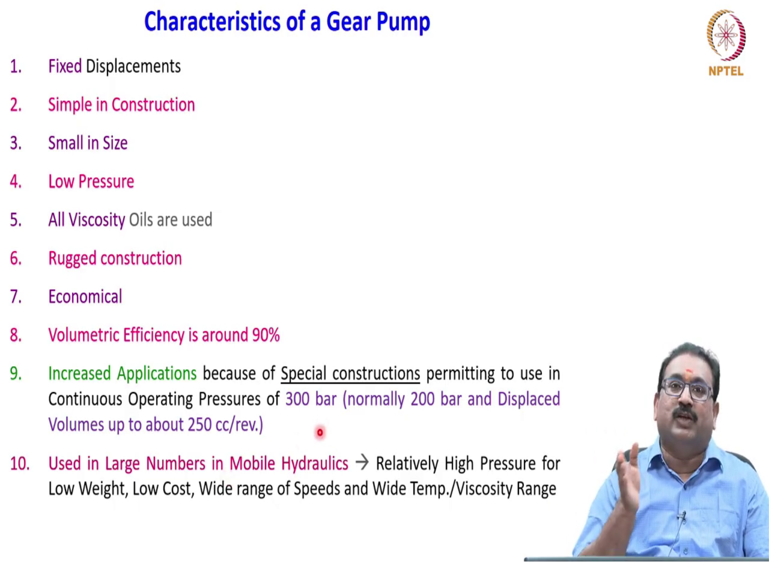

You will see very quickly the characteristics of the gear pump friends, they are the fixed displacements. Simple in construction; small in size; low pressures, low pressure in the sense compared to piston pumps and vent pumps; all viscosity oils are used; rugged construction; economical; volumetric efficiency is around 90 percent and even more also.

Increased application because of the special constructions permitting to use in the continuous operating pressure of 300 bar, displaced volume you will see up to this 250 cc per revolutions. Used in large numbers in mobile hydraulics where the power pack can move from one place to another place in construction, agricultural and many places, relatively high pressures for the low weight low cost and wide range of speeds and wide temperature and viscosity range is possible.

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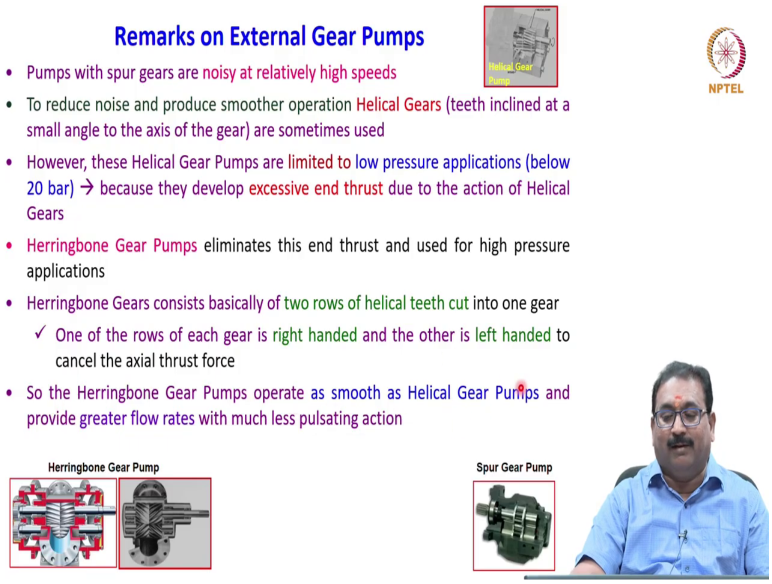

Also some remarks on the external gear pumps very quickly. Pumps which spur gears are noisy at relatively high speeds. To reduce a noise and produce a smoother operation helical gears already we know that teeth's inclined at a small angle to the axis of the gears, you will see here to reduce a noise we are using the helical gears, but expensive because again you have to cut to the teeth in the some inclined manner know it will expensive compared to spur gears.

However, these helical gears are limited to low pressure applications the below 20 bar because they develop a, excessive end thrust due to the action of helical gears. So, herringbone gears eliminate this end thrust and used for high pressure applications herringbone gears consists of basically two rows of helical teeth cut into one gear.

One of the rows of each gear is right handed and other is left handed to cancel the axial thrust force. Meaning here, so, the herringbone gears operate as smooth as helical gear pumps and provide a greater flow rates with much less pulsating action.

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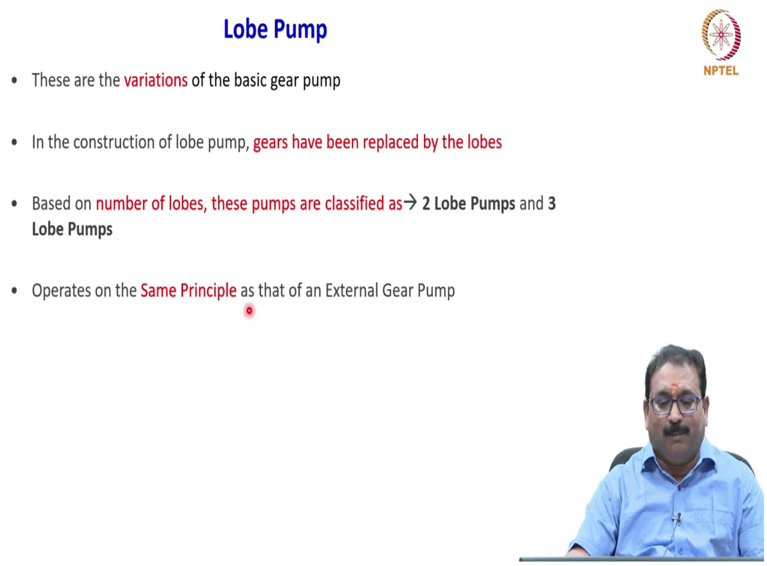

Then quickly we will see the other categories of the gear pump itself, one more is what we can call the lobe pump friends. What is these lobe pumps? These are the variation of the basic gear pump itself. In the construction of lobe pump gears are replaced by the lobes here.

Based on the number of lobes these pumps are classified as 2 lobe pumps and a 3 lobe pumps, both are available commercially in the market. Lobes are nothing, but the gears, but the shapes are different, I will show you in the next slide. Operates in the same principle as that of the external gear pumps.

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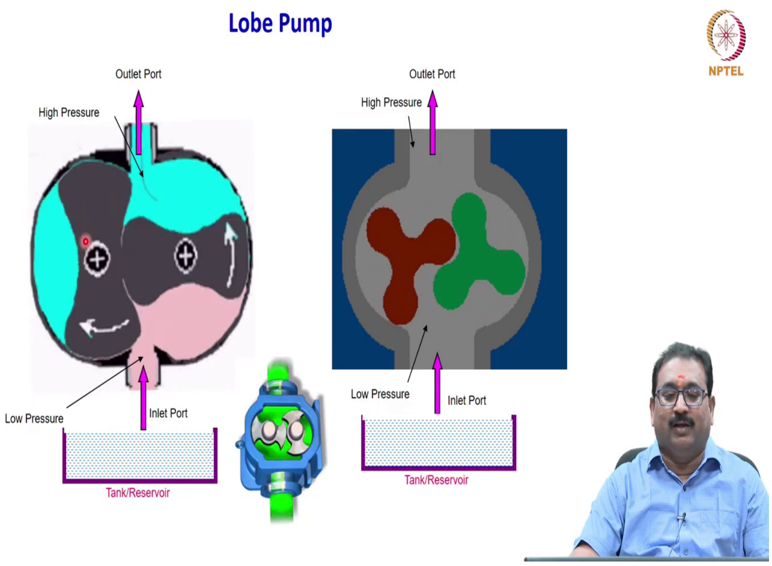

See here this is the 2 lobes are there see the shape of the lobes how it is enclosed in the housing. Again here increasing volume sucks the fluid and transport around the periphery. You will see here the 3 lobes, again it is a inlet, outlet, fluid is transport along the periphery, pockets formed here.

But, here you will get to the large pockets, but in case of the external gear pumps what you are seeing? The small pockets are there.