Upstream LNG Technology

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Lecture - 66
Pumps in Natural Gas Systems – III

Welcome. Now we shall be learning a few more detailing about the pumps before we end this particular lecture on the pumps as.

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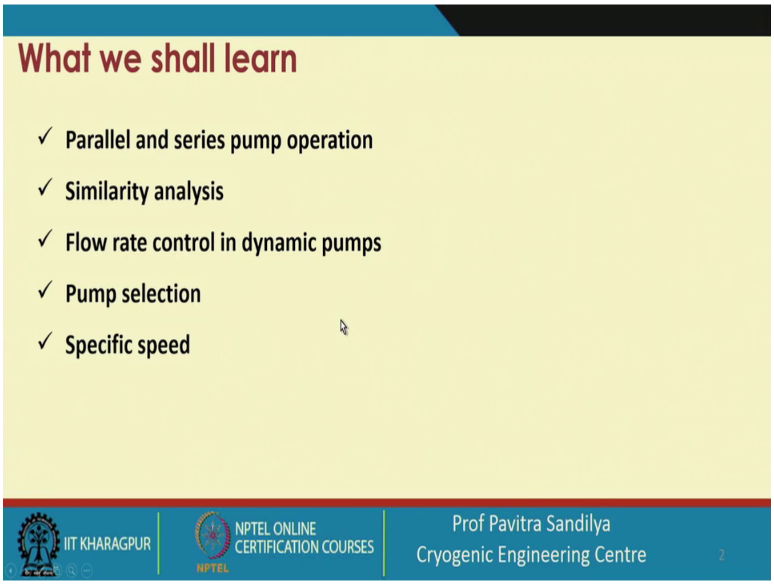

So, in this particular lecture we shall be learning about the parallel and series pump connections operations, and the similarity analysis, how we control the flow rate in a dynamic pumps, the how to select the pumps and about the specific speed.

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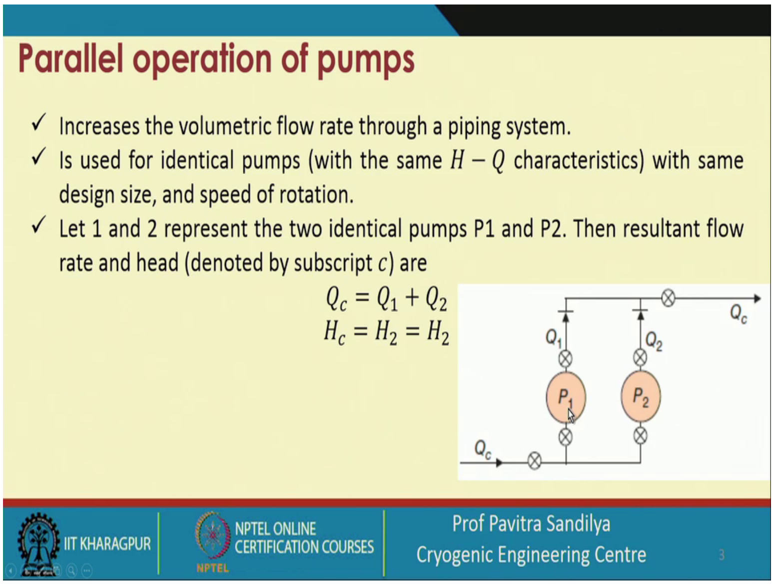

Now here we first see the parallel operation of pumps and why do we need to make the two parallel connections; now you see here that we have two pumps P 1 and P 2 and parallel means. That we are getting from some particular source is same this flow rate and which is being distributed between these two pumps they are getting parallel and then from the outside these two pumps are producing this flow Q 1 and Q 2 and ultimately these two things are coming together and going outside.

So, the total flow rate remains the Q c total fluid from the here to here the total flow rate is remaining the same only thing is this we are just distributing the flow rates through these two pumps. So, what happens is; this increases the volumetric flow rate through a piping system and that means, if you are not able to handle this total flow rate by a single pump then what we are doing, this total flow rate is being divided between multiple pumps to handle the total flow rate.

So, is used for identical pumps that means, these two pumps must be identical that means, they can be identical if they have the same H versus Q characteristics that is the head versus the flow rate characteristics. That is how we identify the identical pumps. And they must have the same design size and the speed of rotation. Now if these are two as I told you that the total flow rate Q c is equal to Q 1 plus Q 2 that is the summation of the flow rates given by each of the pumps.

On the other hand the head generated by each of the pumps remains the same that means, both H 1 H 1; so H 1 H 2 will be the same for each of the pump. So, we are just gaining the total flow rate, but not on the head.

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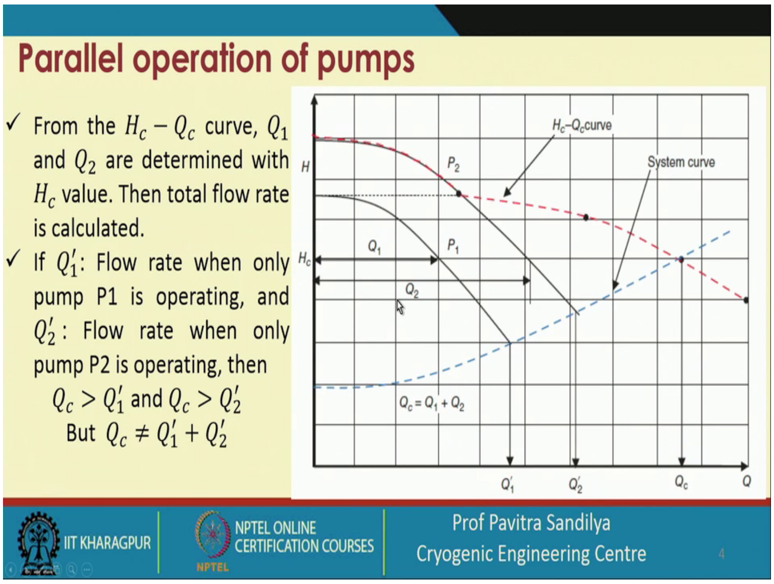

Now, here we see the H c curve that H c Q c is the overall head versus flow rate curves. So, here we are plotting all these. So, we can see that here we have this curves this particular thing this red one which you can see this is the H c Q c curve and whereas, this black one this is for pump one and this black one is for pump two. So, from these we can find out the flow rate which you need and here this blue dotted one is showing the overall power resistance curve.

So, here we find that wherever it is intersecting the overall H c Q c curve this is the point of operation of the pump. And whatever flow rate we are reading by coming vertically down this is the total flow rate which will be given by this parallel combination. On the other hand we see that here we are also showing this Q 1, this Q 1 is the flow rate if pump one is operating alone and Q 2 is the flow rate if the pump one is operating alone and these things we are getting from their individual system curves. Now what we find that Q c is equal to Q 1 plus Q 2, but if Q 1 prime and Q 2 prime this Q 1 prime is the flow rate when only pump P 1 is operating and Q 2 prime is the flow date when pump only P 2 is operating then we find that Q c will be more than this Q 1 prime and the Q 2 prime. And that is what we will find that the Q c will not be equal to the summation of the individual or standalone pump flow rates.

So, it will be the flow rate whenever these two pumps are operating together at that point whatever flow rate we are getting that is only Q 1 and Q 2 only then that is the flow rate when summed up give us the actual flow rate and not when these two pumps are operating as standalone.

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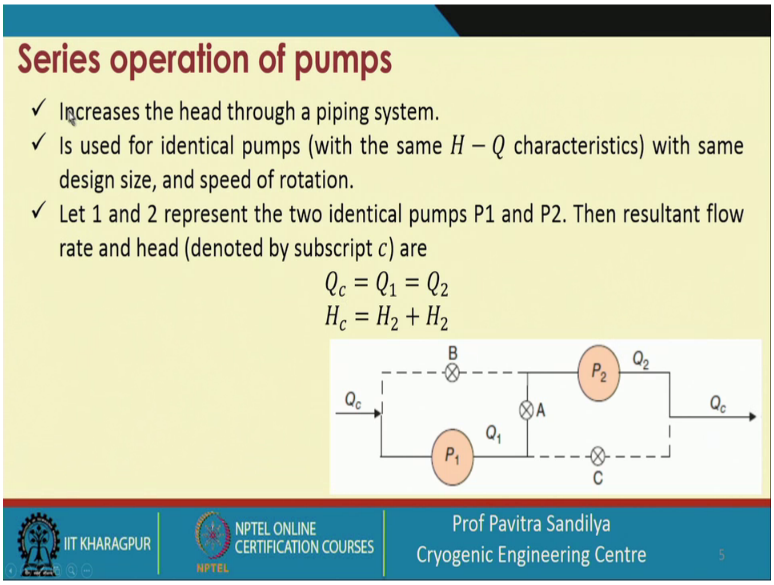

Now here we have the series operation of the pumps. So, let us first see that how these two pumps are arranged. So, this is the total flow rate which is coming and this total flow rate is going fully into this pump one and then it is going to the pump two and before it is coming out of this

So, what we find that each of the pumps unlike in the case of parallel connection each of the pumps is able to handle the total flow rate. So, that is why we are writing Q c is equal to Q 1 is equal to Q two. And on the other hand we are writing this here that this is the total head will be equal to this will be H 1. So, this H 1 plus H 2 will be the head given by each of the pumps; that means, whenever we need to increase the head we are we shall be without increasing the capacity we will go for the series connection and if we want to keep the head constant, but want to increase the capacity then we will go for the parallel connection.

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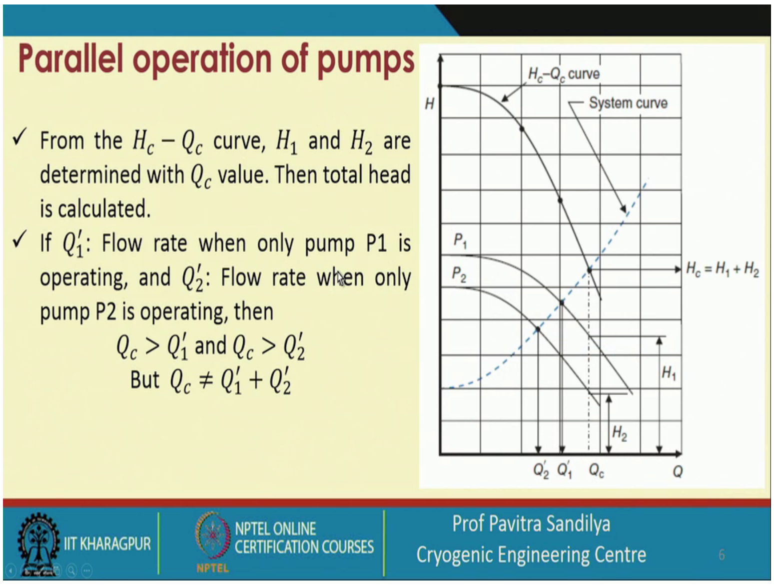

Now, here again as we saw for the parallel connection again we have the overall H c Q c curve over here. And this blue line is the overall system curve and wherever they are intersecting from this we can read out the total flow rate here, and this is the total head generated by the pumps, this is H 1 plus H 2 on the other end.

If I look at the standalone pumps that is this is the standalone H Q curve and just standalone H Q curve of pump 1 and pump 2. And if we are locating this, wherever these things are intersecting this two this is the Q 1 prime and Q 2 prime this is a system head. And we find that this Q c is more than either Q 1 prime and Q 2 prime, but Q c total the Q c will be more than the summation of this Q 1 prime and the Q 2 prime.

So, we have to figure out that in practice when these two pumps are in action together whatever Q 1 and Q 2 are generated they will be equal to Q c and not the individually they are acting individually we cannot the sum those Q 1 Q 2 to find out the Q c values. So, this we have to take care of.

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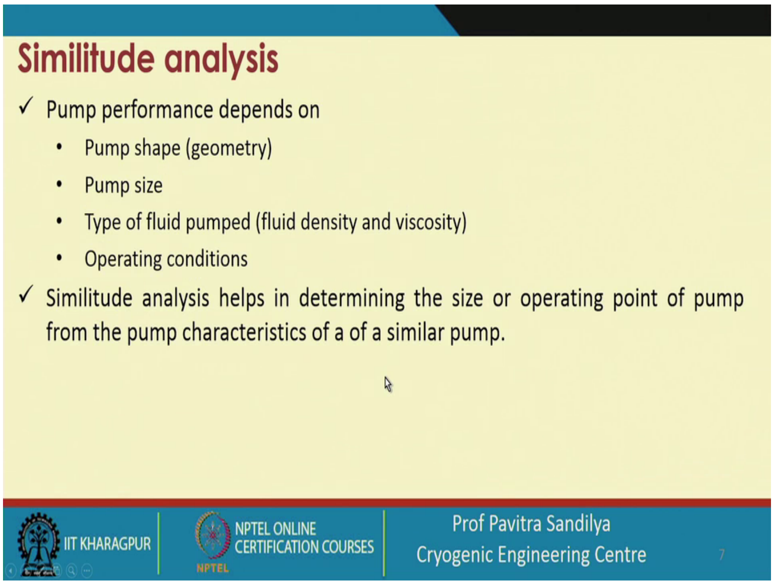

Now we come to something called the similitude analysis. In this I shall not be doing the detail derivation which you can find out in the books and other subjects.

So, here this we shall be seeing that why we need it this pump performance depends on the pump shape the geometry or the pump size the type of the fluid being pumped that is the viscosity of the liquid, the density of the liquid and the operating conditions that is the temperature pressure etcetera. Now this similitude analysis helps in determining the size or operating point of the pump from the pump characteristics of a similar pump.

So, if I know for given pump some particular condition I know, suppose I know the rotational speed supplying know at the rotational speed I know the h and Q value, but now if I want to know for some other Q I want to have from the pump that is I want to change the flow rate then what kind of rotational speed I must use. Or if I am changing the rotational speed what kind of flow rate and what kind of head are expected from the pump, or if I want to reduce my head then what kind of speed I should create. So, all these combinations, all these things can be predicted if I know the similitude do the similitude analysis. .

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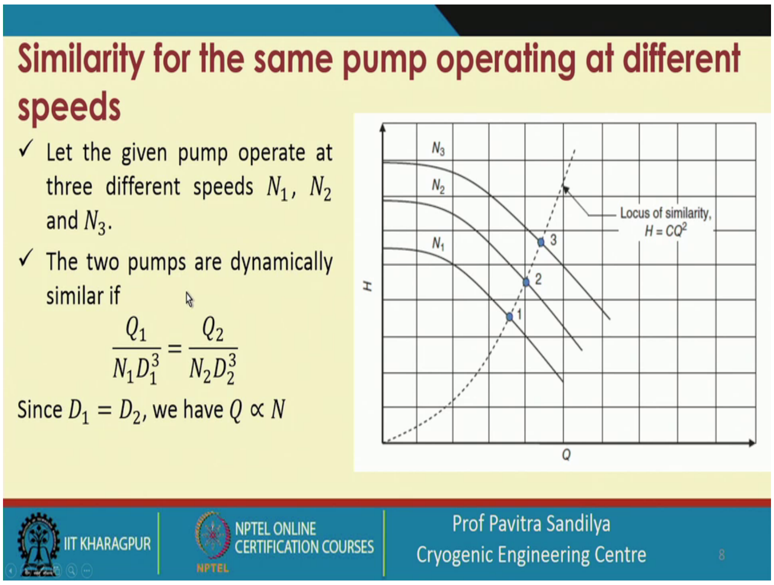

So, here we have the things that here we have first you see that similarity of the same pump operating at different speeds. So, let us see that N 1 N 2 N 3 are the various types of speeds of the pump.

And without the derivation we see that for dynamically similar pump this is the relationship by we find here this how the flow rate is related with the speed and the diameter of the impeller. So, in this case we are saying that we have the same pump; same pump means that the diameters are the same. So, D 1 is equal to D 2, but this same pump is operating at two different speeds.

So, if we change the speed how will the flow rate will get changed that is what we want to see and we find from this equation that Q is proportional to N. That is if the rotational speed is doubled then the capacity will also get doubled it is if the rotation speed is halved then the capacity will also get halved. So, that is the meaning of that direct proportionality and this is about the capacity.

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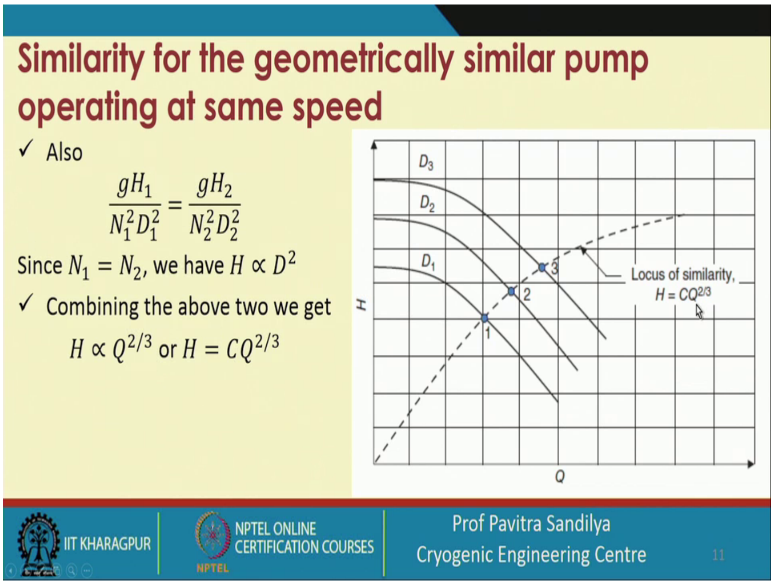

Now, we also see how the head will vary with the pumping rotational speed. So, here again we take this equation without any derivation.

So, here we see that again D 1 is equal to D 2 and we find that head varies with the square of the rotational speed. That means, if we are doubling the speed of rotation then we will find the head will increase four times. And if we are halving the speed of rotation then the head will decrease by one fourth.

So, this is how we relate these head versus the speed and if we combine this equation with this equation that is instead of this N we put Q here we find that head is also varying with the square of the capacity that means, that if we are having this two similar pumps and we want to know that if we are changing the capacity of the pump then how will the head vary.

So, this is the particular relationship we can follow and this is from this is the characteristic curve of this kind of pumps at different speeds. And this particular equation that the system curve is nothing, but the H equal to C square which we have just derived. So, this particular thing represents that and this C value will have to be given by the manufacturer as per the different types of pumps.

Now we have another situation. In this case what we have we have geometrically similar pumps, but operating at the same speed now the they are geometrically similar you understand that means, their sizes are not the same, but they are running at the same speed. So, for that again now we have D 1 D 2 D 3 as the diameters.

And now we again use the same equation for the dynamically similar pumps, and in this case what we have this N 1 is equal to N 2. So, we put N 1 equal to N 2. So, we find that the capacity varies with the cube of the diameter; that means, if we are doubling the diameter of the impeller then what we are finding that the capacity will increase 8 times. So, if we are halving the diameter then the capacity will come down by eight times that is one eighth it will become one eighth of the original one.

So, this is how we shall be able to relate here we see again this particular curves that here we are plotting the various types of diameter for the H c curves H Q curves the different diameters and this is the system curve and how we get this c cube 2 by 3.

We shall see now here that here we are finding the head versus the diameter and the speed of rotation again we put the N 1 equal to N 2 and we find head is varying as the d square. That is if we are doubling the impeller diameter then the head will also increased by four times; if we are halving the impeller diameter then the head will come down four times that is it will become one fourth of the original value.

And if we combine this equation with this equation what find that H is equal to is proportional to the capacity raise to 2 by 3. And this is exactly this curve this particular curve represents, this particular system curve this is capacity head versus capacity. And here we are plotting again the various diameter H Q curve and from this we can find out the various types of operating point for the different diameters of the dynamically similar pumps.

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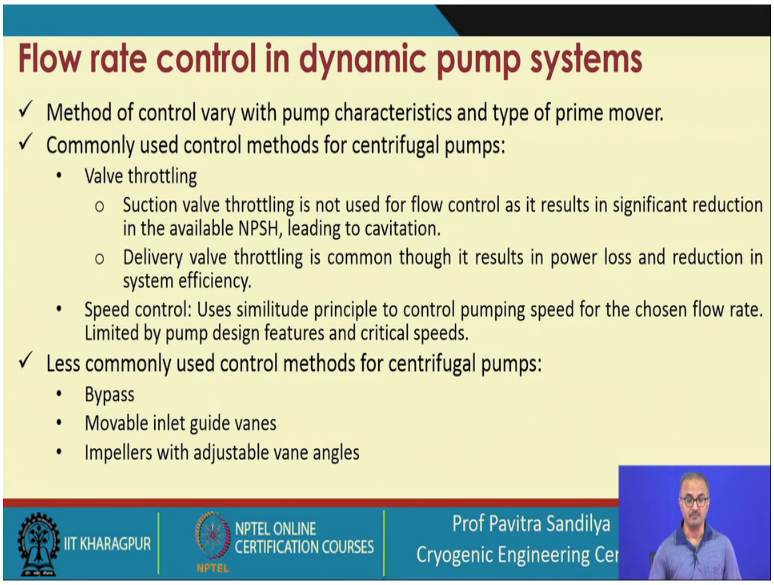

Next issue comes whenever we are going for the pump operation how to control the flow rate. Now the control the flow rate we have various methods and this method of control will vary with the pump characteristics and the type of the prime mover that is the rotor ok.

Now, commonly used control methods are either by valve throttling or by speed control. As we have learnt earlier the speed can control the capacity. So, valve throttling means it can be either the suction side or can the delivery side. Now let us see whether we should throttle; throttle means partially closing not fully closing that is meaning throttling. So, we are a bit of pinching we are doing.

So, whether we should go for the throttling on the suction side and not let us see that if we are doing this throttling it is not recommended why because if we are throttling the suction side what will happen the N P S H will come down. And as we have learnt earlier that if N P S H come down there is a high probability of cavitation.

So, generally it is not recommended to throttle the suction side valve, rather than that usual practices to do the throttling of the delivery side valve though even though it results in some power loss and in some the reduction of the overall efficiency. So, despite these two losses we still do not mind because we do not have any other option, but to do so, so we will throttle the delivery side to adjust the flow.

Next is speed control and this speed control is based on the similitude analysis we have just seen and depending whatever on the capacity required we will change the speed of rotation. And there are other less commonly used methods like bypass we can use some bypass to reduce the flow in the mainline or the increase the flow in the mainline then we have movable inlet guide vanes or some impellers with adjustable vane angles.

So, all these vane angle also has a effect on the pump delivery or the fluid delivery these things we have not done in detail, but these are some of the factors which may be used for the controlling the flow rate, but these are not the usual practise.

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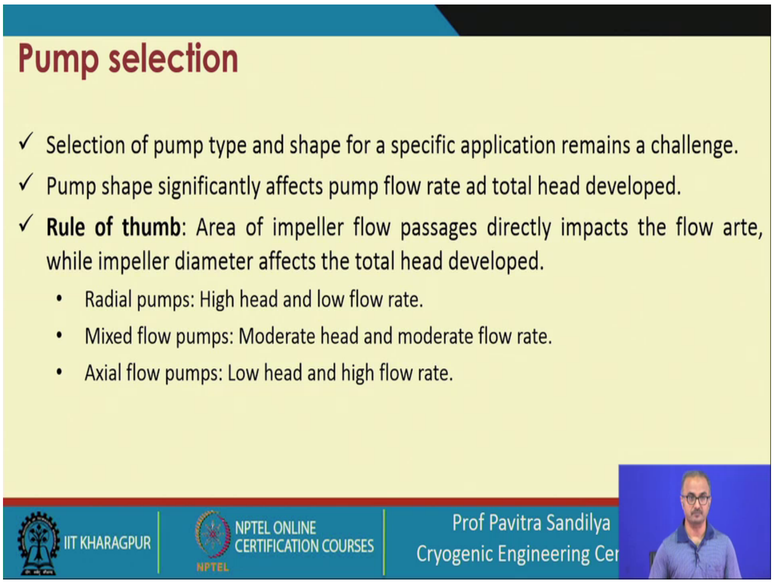

Now we come to the selection of the pump. Now selection of the pump type and shape is always a challenging task for any engineer for some specific application and there are some thumb rules developed. And this we know that pump shape significantly affects the pump flow rate as well as the total head developed. So, it is challenge for us to find out the right type of pump. And the rule of thumb is this the area of impeller flow passages directly impacts the flow rate whereas, the impeller diameter affects the total head developed.

So, these are some experience people have developed this kind of thumb rule that if we can change the impeller flow passage; that means, the clearance between the casing and the impeller then it will change the affect of flow rate more and if we change the impeller diameter it will affects the total head developed.

Then now here we have some with this thumb rule we have some kind of guidelines you can say the radial pumps are used if we want high head, but at low flow rate. We can use mixed flow pumps if we need moderate head and moderate flow rate and axial flow pumps are used when we need low head, but at high flow rates.

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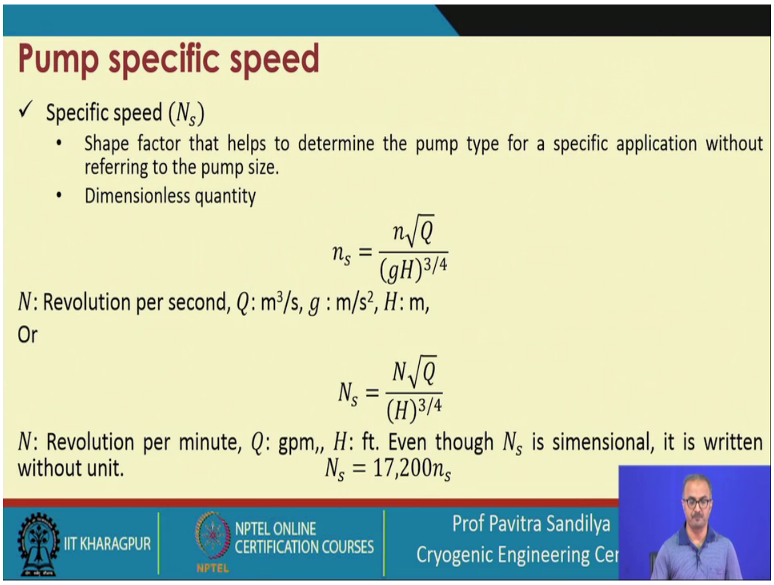

So, these are the some guidelines. Next we come to another very important parameter that characterizes a pump and that is the pump specific speed. Now this pump specific speed is a kind of a shape factor that helps us to determine the type of the pump for a given type of application without really knowing the pump size. So, it is not important for us to know; that what is the pump size for a given application without that we can find we can recommend. We have some way to find out what kind of pump can be selected.

And this is a dimensionless quantity and here it is defined like this n s is the specific speed and this n is the speed of rotation which is there in the pump and it is given as in revolutions per second. That means, this depending on the actual operating parameters we are finding this values that operating means whatever the best design parameters we have developed from our design analysis based on those numbers we are getting these values of n then Q is the is in metre cube per second and g is the acceleration gravity due to this metre per second square and H is in metre. So, if you are using this S I units whatever value we are getting this is the specific speed.

On the other hand which is very more common is this we are getting this same specific heat, but we are just dropping the g and we are getting this particular equation it is similar to the previous one. Here we have capital N and capital N S and Q and this h. Now in this case what happens this capital H is in revolution per minute Q is in gpm and H is in feet and even though n is dimensional, dimensional it is written without unit and this N s and n s are related by this particular factor. That means, this capital n s is equal to 17200 into this small n s.

So, that is how we are converting one from the other.

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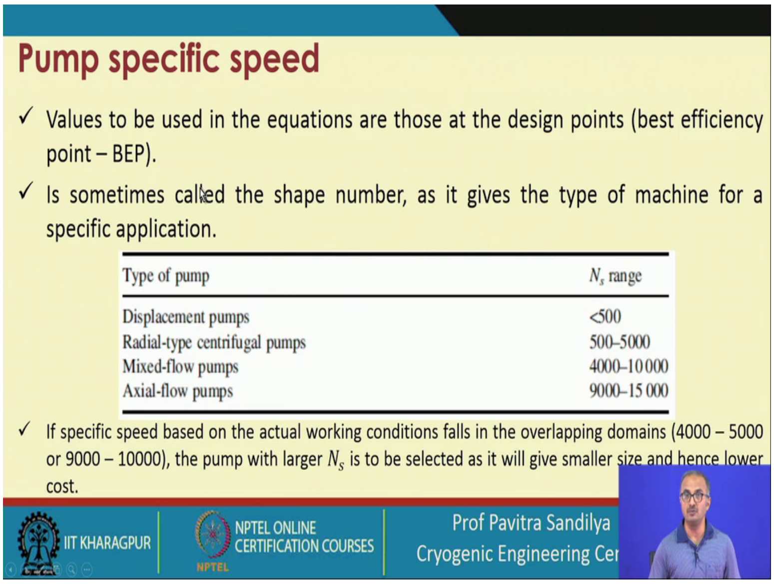

And the values for the Q n h etcetera as I told you they should be the values which are obtained from the design point of view. So, the best efficiency point from that whatever in rotational speed whatever capacity whatever head we obtain that is to be used to find out the specific speed of the pump.

Now, it is also sometimes called the shape number as it gives the type of the machine to be used for a given application and here we are showing a typical figures various of the N s for different types of pumps. So, we find that for the displacement pumps this these are lowest n s whereas, for axial flow pumps we have the highest value of the specific speed and in between we have the radial type and the mixed flow type pumps.

So, now, we find that if the specific speed based on the actual working condition falls in the domain of say 4000 and 5000 or say 9000 and 10000 that means, there is a overlap we have finding, but it is not either it is overlapping in this region or it is overlapping in this region. Then in that case what to do whether we should go for this one or this one or this one this one to choose that what we do the pump with the larger specific speed is to be selected.

That means suppose I am getting a value of 4500. Now 4500 belongs to both this and this. Now in that case what I will do, I will not take this one I will go with the one with the higher range that means, I will select a mixed flow pump. Similarly suppose I have a value of say 9500 then what I should do then I have two choices either I go with this mixed flow or I can go with axial flow, but I will choose the one with the higher range. So, I will go with the axial flow pump.

So, these are the kind of guidelines with which we can select the pumps based on the specific speed.

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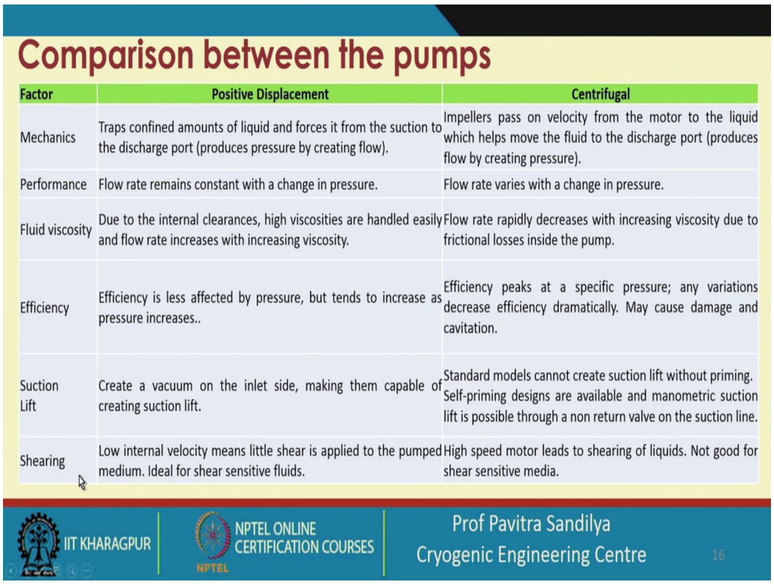

And here is a small comparison between the different types of pump this is a positive displacement pump and the centrifugal pumps. And their differences are on various basis like the on their mechanisms, their performance, then fluid viscosity they can handle the efficiency the suction lift and the shearing.

So, we can find that the as we learned that positive displacement pump, they trap some certain amount of liquid and push it whereas, in centrifugal we are imparting the energy by providing the centrifugal force energy on the liquid and then we are converting that energy to again the pressure head. Then performance wise the flow rate remains constant even with a change in the pressure whereas, in case of centrifugal pump that we find the flow rate varies with a change in the pressure. So, this is how we are finding that the displacement pumps are not affected by the pressure much. Then if we talk of fluid viscosity we find that these high viscosity fluid may be handled conveniently by this positive displacement pump, but on the other hand centrifugal pumps will not be a good choice, because there will be lot of frictional loss during the rotation of the fluid.

Efficiency wise we find that the these kind of pumps are less affected by the pressure, but tends to increase as the pressure increases. On the other hand in case of centrifugal pump we find the efficiency reaches a maximum at some specific pressure and this variations decrease the efficiency at dramatically.That means, we after this maximum is arrived we find that other than the maximum point we find the efficiency decreases very very fast and may cause damage or cavitation which we do not find the problem of cavitation in case of the positive displacement pump.

Then we have suction lift as we saw earlier that suction lift may cause the priming problem. In this case of this positive displacement pump we find there is no problem with the suction lift whereas, in case of the centrifugal pumps we need priming and if you do not have enough suction head we find that the pump may be filled with air and if it is filled with air then we cannot draw the liquid inside and pump will not work and first we need to drive out the air and for that what we often do that we pour the particular liquid which we pumped.

So, what will happen the liquid: will be poured from the delivery side and. So, that it will be taking all this trapped air will be taken out from the pump and once taken out from the pump then only the pump will be able to again suck up.

Or sometimes what we do that we are using some non return valve on the delivery side. So, that even if the pump is not under operation it will not be draining out; sorry which is this is put on suction side that we are putting some kind of non return valve. So, even if there is no liquid or pump is not under operation the liquid will be retained inside the pump and that will not allow the air to go in and that is how we shall be able to again re operate the pump after sometime without any priming problem.

And nowadays also self priming pumps are also being manufactured. And as far as shearing is concerned we find the low internal velocity in this kind of pumps will be meaning that less of shearing action will be there and what will happen that if there are some kind of liquids which we get destroyed due to shear.

So, those kind of the liquids which are shear sensitive may be handled by the this positive displacement pump whereas, on the other hand this there is a high shear in case due to the rotation of the impeller. So, what happens in the centrifugal pump we shall be having high shearing and due to which these kinds of pumps are not recommended if we are going to have shear sensitive liquid.

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And here are the few references which you can refer to for more detail about this kind of pumps.

Thank you.