Principle of Hydraulic Machines and System Design

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Lecture – 18
Pumping system design-1

So, we will continue our discussion on Principle of Hydraulic Machines and System Design. Today we will discuss about Pumping system design, before I go to discuss about the design of pumping system rather several aspects that we need to consider while designing a pumping system. Let us first try to discuss about one important another important feature of the pump is the specific speed, probably we have discussed about the affinity laws in my last lectures.

But, today I will discuss about the specific speed that is very important, when we are selecting the pump and probably I have said that the whenever you are selecting a pump, I mean that pump designer and pumping system designer these two are not same. So, whoever is designing the pump he should consider all those things blade angle at the inlet outlet, you know the impeller diameter speed of the pump shape of the impeller, then casing design if it is you know there are diffusion diffuser waves or not.

But, the pumping system designer is something that, he or she will select the pump based on the requirement of the system and, based on the requirement of the you know total head, based on the requirement of the total discharge and also. But pumping system designer should also know about the specific speed that is very important. So, today I will briefly discuss now before I go to discuss about the pumping system design, there are several aspects of this pumping system design specific speed this very important.

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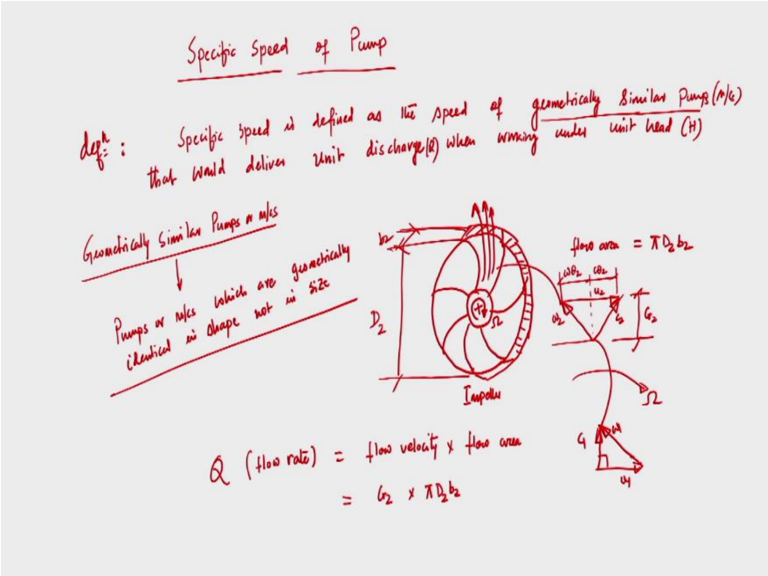

So, specific speed is very important for the pump, I mean whatever pump, it is either radial flow pumps you know mixed flow pump or axial flow pump. So, if I now talk about let us say one case a particular case radial flow pump. So, what is specific speed and why it is so important? So, specific speed definition is there. So, if I write the definition from definition itself I will come to know what it is, but apart from its definition we will try to drive the expression, how we can have the you know mathematical expression of the specific speed; so, specific speed of pump. Similarly, we will discuss when will you know discuss about the hydraulic turbines, then what is the specific speed of turbines.

So, what is specific speed of the pump? So, specific speed of a pump is so, let me write the definition, from definition itself we will come to know what it is but the definition itself is not the important rather will drive why and how it is important to select a pump. I mean pump designer he should he or she should have a shunt knowledge about this specific speed that is true on the earth and, wherever designing the system at the pumping system he or she also should know about the specific speed, because why it is important as far as the pumping operation in concerned.

So, definition is this is speed of a specific speed is defined so, specific speed is defined as the speed of very important this is speed of course, speed so speed of you know geometrically similar pumps, I am writing machines in bracket that. Geometrically similar pumps that would deliver that, is very important unit discharge under unit head rather when walking under unit head. So, deliver specific speed is the speed or it is defined as the speed of geometrical similar pumps, I will clarify what do you mean by geometrically similar pumps, that to deliver unit discharge when walking under unit head so, H Q. So this is very important; that means, what is geometrically similar pumps; that means, if I allow a pump to work under unit head, it will be able to deliver unit discharge and the speed at which it will do so, that is a specific speed.

So, what do you mean by geometrically similar pumps or geometrically similar machines? Geometrically similar machines are identical in shape not in size, this is very important so, this is the definition of the pump. I have I am now underlining this you know a group of words, that what is geometrically similar pumps or machines. What is geometrically similar machines or pumps that is machines which are geometrically identical in shape. So, pumps or machines which are geometrically identical in shape, but very important is not in size. So, pumps or machines which are identical geometrically which are geometrically identical in shape, but not in size.

So, size may differ, but shape has to be geometrically similar that means, machines which belongs to homologous series; that means, size may change from one from either in decreasing order or increasing order, but their shape will remain same and then those series of machines are known as you know geometrically similar machines or machine belongs to homologous series. So, now let me clarify it in a bit more you know accurate manner. So, if I say that I have a system, where I would like to install a pump rather to of course, to meet the demand by the system; that means, what will be the head and what will be the discharge and there I would like to install a radial flow pump.

So, now, whenever I am installing a particular pump that is radial flow pump may be if impeller is you know you know circular. So, it might happen that may be after a few days or after a few years system to meet the system requirement, again we need to install another pump. So, I will definitely try to procure the pump on same manufacturer, or it may not be if it is not possible to procure or to purchase or to buy the pump on the same manufacturer, then of course we need to go for another pump that will be supplied by a different manufacturer.

So, whenever we are purchasing a pump from different manufacturer a pumping system designer should try to supply the H cube curve of the pump existing, that will help the pump designer to make up you know another pump that will try to match the pump which is there in the existing pump house. Now, whenever the new pump is coming if I know the specific speed of the existing pump and if new pump when that is being installed. And, if I know if the pump or if the new pump is geometrically similar geometrically similar to the existing pump; that means, if the new pump is having the same I mean impeller is supply impeller diameter may vary depending upon the design, but and size may change, but the shape has to be circular.

So, now what will be the you know advantage if I know the specific speed of the existing pump. So, if I know the specific speed of the existing pump, then and if I know the you know specific speed of the new pump also, then probably I can predict what would be the head developed by the pump for a given amount of discharge, if both of the pump belongs to homologous series. If they are geometrically similar that is geometrically identical in shape, but not in size may be size may differ, but if they are geometrically identical in shape.

So, how can you now drive rather how can we mathematically express, you know specific speed of a pump. So, again if I take an example let us say the radial flow pump I have taken this example many a times. So, if I try to draw the impeller of a radial flow pump. And suppose this is the impeller of a radial flow pump and pump is say rotating at an angular velocity omega in the clock wise direction and, I have discussed many a times that normally, it is I mean advisable or suggestive of having pump, I mean impeller equipped with a few backward curve bends, because forward curve bends as I said that although efficiency will be I mean head developed by the pump will be higher it is equipped with the few forward curve bends, but it is having another problem.

So, if I have an impeller with you know backward curve bend. So, this is the impeller of a radial flow pump impeller and if I draw the; you know so, this is the three-dimensional view and this is the flow area. So, this is the flow area so, water will, or fluid will go out from the impeller through the passes between to adjacent blades. And, if the diameter of the impeller is let us say D which is circular in shape and, if this width is diameter is D 2 and width is b 2, then flow area this is very important flow area = $\pi D_2 b_2$.

So, this is the flow area through the flow area through which liquid is flowing out from the pump. And, again I need to draw the velocity triangles because, I am trying to express

I am trying to obtain the mathematical expression of the specific speed and for that of course, I need to use the definition that see this speed of a geometrical similar pumps, or machine that would deliver unit head unit discharge when walking under unit head.

So, again if I take this blade a particular blade and if I draw the velocity triangle at the outlet that is very important. So, this is my blade velocity a tangential velocity at the outlet, this is relative velocity and this is the flow velocity Cr2 and this is C_2 and this is w two this is u 2 and these are the components so, this is u 2 this is $C_{\theta 2}$ and this is $W_{\theta 2}$. So, and it is rotating let us say at an angle of velocity omega and if I assume no so, all at the inlet so, velocity triangles at the inlet will be like this w 1 this is c 1 and this is u 1. So, I mean what is the volume flow rate through the pump so, Q that is flow rate flow rate through the pump will be equal to how much so, flow rate through the pump will be equal to flow velocity into flow area in to flow area.

So, this is very important flow velocity into flow area. So, what is flow velocity here that is Cr2 and flow area is $\pi\ D2\ b2$. So, this is the flow rate that I can expect from this pump and Cr2 only depends upon the you know fluid velocity at the outlet and, that also will depends up the blade angle at the outlet and flow angle. So, now, discharge cube from this expression I can obtain that discharge Q I mean pi is constant.

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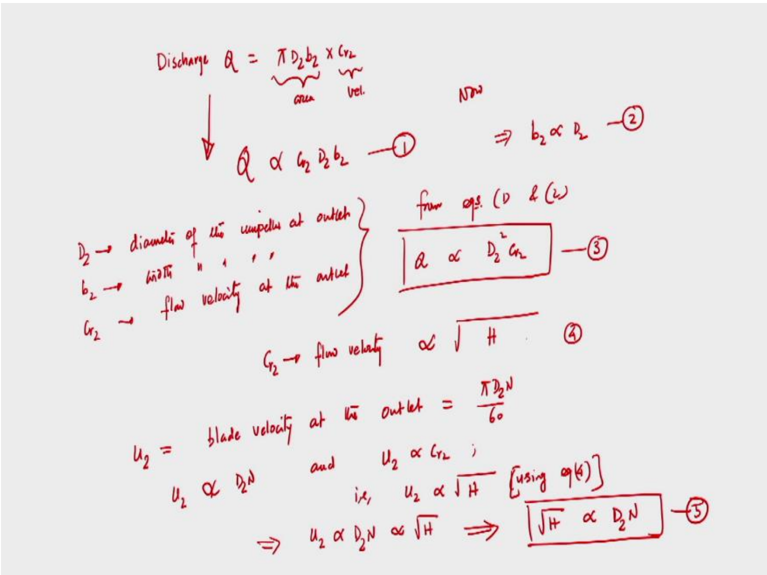

$Q = \pi D2\ b2\ Cr2$

$Q \propto Cr2\ D2\ b2$

$D2 \propto b2$

$Q \propto D_2{}^2\ C_{r2}$

$C_{r2} \propto \sqrt{H}$

$u_2 = \frac{\pi D_2 N}{60}$

$u_2 \propto D2\ N$ $\qquad u_2 \propto Cr2$

$u_2 \propto \sqrt{H}$

$D2\ N \propto \sqrt{H}$

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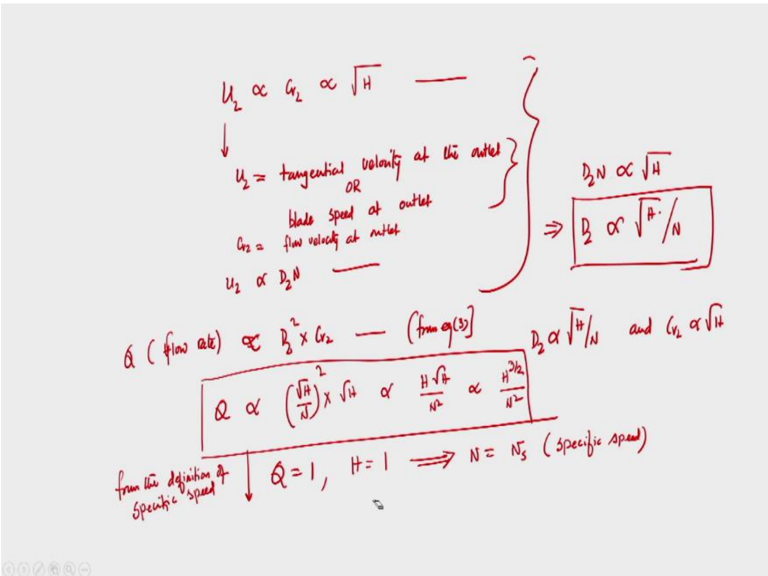

So, what you obtain that u 2 so, what you obtain that u 2 that is the blade velocity at the outlet, which is you know proportional to the flow velocity C r 2 and that is proportional to root H that is the head being developed by the pump. Now, u 2 that if we can try to recall our you know previous equation, where u 2 that is tangential velocity at the outlet, tangential velocity at the outlet. Or sometimes it is known as blade speed at the outlet, outlet this u 2 varies as D 2 into N from its definition. So, from this two I can write from this two expression I can write say from this two expression, I can write that D 2 N varies as root varies as from this two expression I can write D 2 N varies as root H therefore, I can write this is very important.

$$u2 \propto Cr2 \propto \sqrt{H}$$

$$u2 \propto D2\, N$$

$$D_2 \propto \frac{\sqrt{H}}{N}$$

Now, if I try to recall the volume flow rate expression of volume flow rate. So, what is the expression of volume flow rate note that C r 2 where C r 2 is the flow velocity at the outlet, flow velocity at outlet. So, we have seen that you know b 2 proportional to D, because if I would like to obtain higher Q, then if I need to increase D 2, then b 2 has to increased.

$$Q \propto {D_2}^2\, C_{r2} \qquad D_2 \propto \frac{\sqrt{H}}{N} \qquad Cr2 \propto \sqrt{H}$$

$$Q \propto \frac{H^{\frac{3}{2}}}{N^2}$$

Now, I would like to use the definition based specific speed, that is speed of a geometrical speed of geometrical similar machines or pumps that would deliver unit discharge, when walking under unit head. That means, when Q is equal to unit, then head the pump will deliver unit discharge walking under unit head of course, and that time the speed end should be the specific speed or N s of the pump that is from the definition.

If Q = 1 , H =1

N = Ns(specific speed)

So, now, if I write Q the if I remove the proportionality; that means, from this expression I can write Q will be equal to rather.

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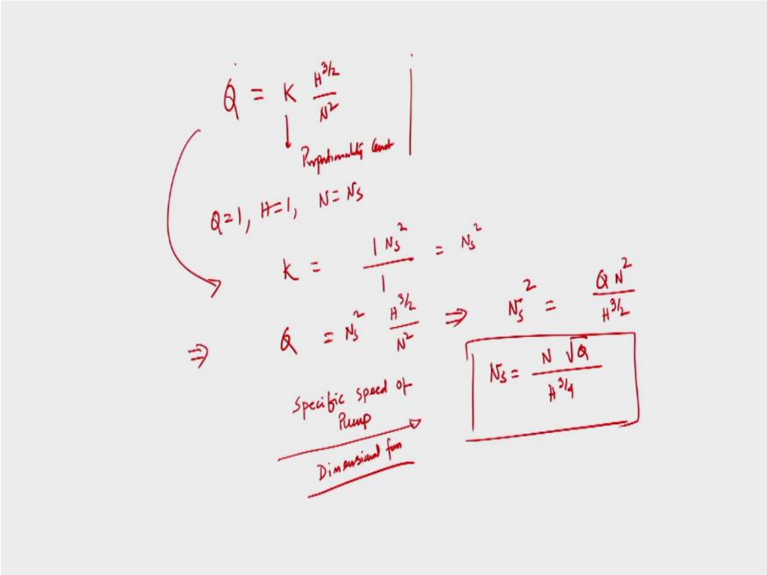

$$Q = k\,\frac{H^{\frac{3}{2}}}{N^2}$$

Q = 1, H = 1, N = Ns

K = Ns^2

Specific speed $N_s = \frac{N\sqrt{Q}}{H^{\frac{3}{4}}}$

So, this is the specific speed of pump. So, this is the specific speed of the pump, in the dimensional form, this is dimensional form so, why it is important we need to know because as I said you that these specific speed is important this is the speed of the geometrical similar machines that is geometrically identical in shape, but not in size. So, if we may vary the diameter of the impeller, but still knowing the specific speed of a pump, we can predict the you know geometrical similar machines the rather performance of the geometrical similar machines; that means, what would be the head rather what would be the head developed by the pump, if I would like to obtain this much amount of discharge, if I know the specific speed. And if I allow the pump to run at a at certain speed.

So, this is very important to predict the performance of a pump rather predict the performance of the pump belongs to homologous series; that means, the pumps of geometrically similar in shape, I mean geometrically identical in shape, but not in size may differ, but if they are you know shape, then specific speed can be utilized to predict the performance. Now, with this will proceed towards to discuss about a few at our several aspects of pumping system design. So, now I proceed to see what the different aspect are our several issues of pumping system design, this is very important rather this is very important to the system designer, you know industrial engineer rather practicing engineer.

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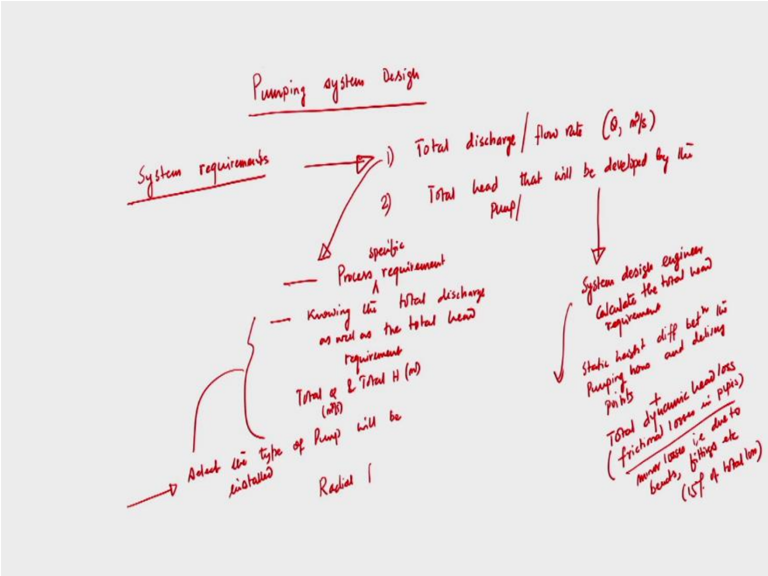

So, I will now discuss about pumping system design, this is very important. So, let me discuss a few important issues, we will take up an example and we will see how we can really calculate, what will be the flow rate when the pumps are connected in parallel, I mean when I means two dissimilar pumps are connected in parallel. And of course, what are the remedies how we can overcome that what are what will be the problems and what are the remedies to overcome that problem will discuss by taking up an example, but before I go to discuss that let us first discuss about several aspects of pumping system design.

So, while we are designing a pumping system as it is pumping system design engineer, I should know the what kind of pump we need to install in that system. So, we first need to calculate that system requirement, it is very important system requirement, what are the requirement of the system requirements; that means, while we are going to design a pumping system we need to know three important quantities, one is rather two important quantity is very important for the pumping system designer specific speed is also important, because I mean if I know the specific speed, then I can calculate performance of a pump performance of pumps will belongs to which belongs to homologous series.

So, what is the total discharge this is very important, total discharge or flow rate Q that is meter cube per second. So, this is very important; that means, what is the total amount of discharge that pump needs to supply rather a group of pump needs to supply, when I am designing a pumping system. Number 2 what will be the total head that pump need to develop that is total head, that will be developed by the pump or pumps rather pump.

So, now depending upon the requirement of total discharge that is process requirements; so, this is process requirement, this is process requirement it is very specific and it varies from process to process, if it is a power plant industry we may require one certain discharge, if it is a any cement industry we made by the discharge. So, it is very you know very much specific would be processed. So, this is process specific requirement. So, this is process specific requirement this is total discharge someone should know and that should be supplied to the design engineer, whether to a pumping system design engineer by the process people.

So, this total discharge of flow rate that information should be supplied to the pumping system design engineer by the process people will, because this is process specific requirement it varies from process to process knowing. So, this is very important knowing the knowing the total discharge, that we now select pumps of course, and the total that head that will be developed by the pump that a system designer needs to calculate, how that means, system engineer system design engineer.

So, I will calculate rather will calculate system design engineer, we calculate we will calculate here she will calculate, the total requirement total head requirement total head requirement, by how because it has two component; that means, the static height, static height difference between the pumping station and the delivery points. Static height difference between the pump you know pumping, house rather pump impeller axis level and delivery points, delivery points plus total dynamic head loss.

So, static height difference between the pumping system rather the pump system (Refer Time: 33:58) axis of the impeller the where the pump house is located and the delivery points, rather where pump should supply or discharge water or any fluid. And the total dynamic head loss which will takes in to account the losses, in the frictional that will take in to account the frictional losses, frictional losses in pipes and also there will be some bents, fittings, valves.

So, you need to take in to account another you know minor losses, minor losses that is due to bents fittings etcetera. Normally we take fifteen percent of the 15 percent of total loss, that we need that we consider normally to keep the system in a safer side. So, a system designer he or she will calculate the total head requirement by calculating the frictional losses using Darcy's law equation in the pipeline, because if we know the recommended speed.

So, while we will discuss in detail about how we can calculate the total frictional losses, if we applied Darcy's law equation to calculate frictional head loss. And then as I said you that whenever we are having a pumping system, which should have a few valves to control the flow rate there will be bents fittings all those things. And we need to take into account the losses because of the presence of all those things.

And we normally consider 15 percent and we call it the minor losses 15 percent of the total loss. So, calculating this total head loss, we know that what will be the total head requirement from that pumping station pumping station. And we know the discharge rather flow rate that it is a process specific requirement that will be supplied by the process people that ok, we need this amount of water in this place this amount of water in this place.

So, knowing fully the total discharge as well as the total head requirement, total head requirement that is total Q and total H right, meter cube per second and meter this is meter and, this is meter cube per second. A designer should select what kind of pumps would be suitable for that particular system. So, based on the requirement of total discharge and total head that we need to develop that the total head that the pumping system need to develop, pumping system designers should select the pump. Should select the type of pump will be installed, this is very important. So, as I said you if you can if you try to recall that in a in my first lecture, we have discussed about the pump classification and why we have clearly stated that normally, we go for radial flow pump. So, if I write in the next slide.

So, what is the next one that? The system designer knows the total discharge that we need to obtain from the pumping system and the total head the pumps should develop. Now, system designer should select the pump that is what I am telling that in my first lecture, I have discussed that we normally go for radial flow pump.

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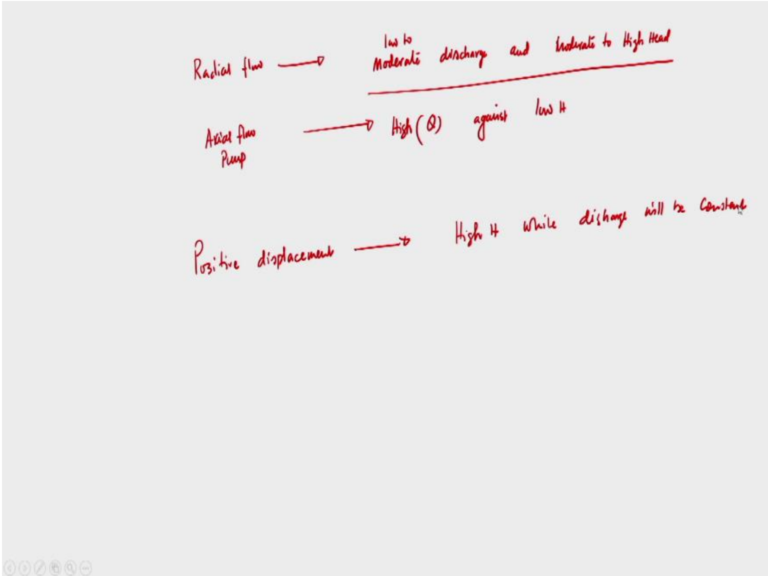

Because this is very important that what kind of pump, we need to develop what kind of pump, we need to install rather what kind of pump we need to you know procure to meet the demand, radial we normally go for a radial flow pump when we require actually. So, we need to go for radial flow pump, when we normally require requirement is you know low to moderate, low to moderate discharge and moderate to high head, it is very important that we normally go for radial flow pump, when we need low to moderate discharge against moderate to high head.

If our situation is that because that is very clear. So, while we are calculating total head and total flow rate then it is clear that ok, what kind of pump I need to install over there, or else if we need that high amount of discharge, whether a high Q that is very important in mines coal mines and also irrigation purposes that I discussed, against low head, then normally we go for axial flow point normally we go for axial flow point.

So, this two are normally in employ normally install these two you know two types of pumps are normally you know install. So, either you have to go for radial flow pump or of the axial flow pump, depending upon the requirement and their requirement will come from the system, total discharge requirement will come which is very much process specific that will come from the process people.

And total head that a system designer will calculate and based on these two quantities, a designer should select that whether I, he or she will go for the radial flow pump or the axial flow pump. Sometimes we need to go for positive displacement pump that is a separate topic and, I will discuss the positive displacement pump. This is also another kind of pump and we have discussed why it is called positive displacement. So, positive displacement pumps are very much suitable for very high head for very high head while discharge will remain constant, will be constant that means, if we need to supply a constant flow rate against very high head, then we go for the positive displacement pump and we have to install positive displacement pump fine.

So, far what we whatever so, far whatever discussed today and we understood that we need to calculate first two things, whenever we are going to design a system, first we need to work out that what will be the total discharge that pumps or pumping system should apply that will come from the process and that varies from process to process because this is very much process specific. And knowing the information from the process people, we can calculate fine this much amount of water we need to supply from this pumping system. Against the head and that will be calculated by the system designer by calculating that static height difference between the pumping station at the discharge points, as well as the total loss frictional losses in the pipelines. And we need to take into account the minor losses, because of the presence of valves bents fittings and that is normally taken fifteen percent of total loss.

So, knowing this two quantities designer should select that whether he or she will go for the radial flow pump, or axial flow pump. And then another aspect will come that fine, if we go for radial flow pump and axial flow pump sometimes may be it might happens that after 5 years or after 10 years or after 2 years down the line again for higher process requirement, we need to install another new pump.

And, then how can we connect the pump if we need to supply more amount of you know flow rate, then probably we need to supply you install pump in parallel. And then what will be the problems and how we can sort out the problem that, I will discuss taking up an you know example. On the other hand we also go for positive displacement pump, where we require very high head against a constant flow rate.

So, with these I stop here today and I continue with this discussion in next lecture.

Thank you.