Introduction to Fluid Mechanics and Fluid Engineering

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Lecture – 50
Introduction to Fluid Machines (Contd.)

We were discussing about rotodynamic fluid machines and as an example we discussed some of the characteristics of the centrifugal pump. Now centrifugal pump is not the only example of rotodynamic machines but you could have other rotodynamic machines. In fact, you could have turbines also operating in the rotodynamic principle. To understand that what are the important parameters which govern the behaviour of such devices.

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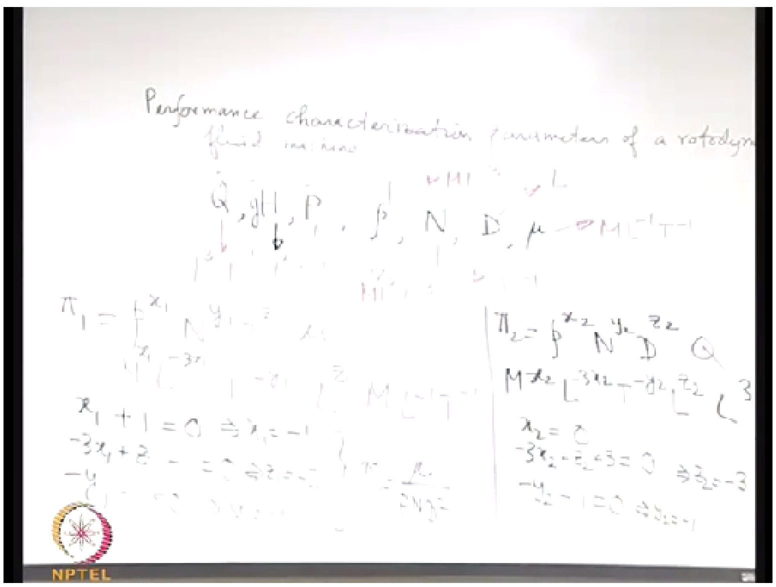

Let us try to consider a more generic example where we try to have a performance characteristic assessment through the performance characterisation parameters of a rotodynamic device, rotodynamic fluid machine. We will keep in mind here that we are not really treating the most general case where the density could also be a variable. Here we are considering a constant density case.

So if you look into the output parameters of performance, we have looked into 2 important output, 2 important parameters already, Q and H. If you recall in the characterisation of the centrifugal pump, we plotted a HQ characteristic. So that means the head and the discharge were important and eventually the power is also important. The power is more important when you consider that as an output parameter. For example, for a turbine, at the end you are interested to get a feel of what is the power output from the turbine.

So Q H P, these are some of the important output parameters. Now one of input parameters which dictate the variations in these. One may be of course the density of the fluid, then when you have a rotodynamic device, you have its rpm. So N which is the rpm. You may also write in terms of omega or the radian per second but typically we write it in the rpm. Then the diameter of the rotor and possibly the viscosity of the fluid.

This could be the input parameters which should govern the behaviour of this output parameters. So in totality we are getting sort of 7 number parameters. There could be more parameters if you look into more and more sophistication that is the relative surface roughness and all those things but we will not go into that sort of details. We will try to get a gross picture. So these are the parameters.

Now we have to see that when you have these parameters, some of these are dependent and some of these are independent variables. Now how these parameters combine to give certain more meaningful collection of parameters typically non-dimensional parameters. To do that, we will be using the Buckingham pi theorem. So we have to understand therefore that or first we have to figure out what are the dimensions of the individual quantities or parameters.

So let us just write the dimension. So what is the dimension of Q? It is like meter cube per second. So L cube T to the power -1. Usually when you consider the head, it is combined with the g. It is just a tradition. It makes no difference except the dimension but g being a constant, gH you know that the V square in scale with gH. So it gives a sort of a feeling of energy per unit mass. So in that way considering a g as a prefix of this H.

It does not disturb the nature of the variation because g is the constant as such but it gives a sort of a feel of energy directly. So then if you consider gH, then what is its dimension. **"Professor - student conversation starts"** (()) (05:04). L square T to the power -2, okay. Then power? Yes?

(()) (05:17) So it is just force * the velocity. Then density, kg per meter cube, right. N, yes? (()) (05:43) T to the power -1, right. Then D, L. Viscosity, ML to the power -1T to the power -1.

So now how many fundamental dimensions are there? M, L and T, 3 fundamental dimensions are there and how many parameters are there? 7. **"Professor - student conversation ends"** 7. So you expect how many non-dimensional parameters or pi terms, 7-3, that is 4. So let us try to identify the pi terms. To do that, what we will first do. We will have to choose the repeating variables.

So this is the most important stage because the choice for repeating variables is, it is not a trivial one. You may have many choices but whatever repeating variables you chose; they should satisfy certain characteristics. What are the important characteristics? First of all, what is the number of repeating variables. That is equal to number of fundamental dimensions. So here 3 number of repeating variables.

The important thing is that, in the repeating variables, you should not put the dependent variables. So that means you should not put this Q, gH, or P as repeating variables. So you have really 4 possible parameters out of which any 3 you can take as repeating variables. But you must be sure that when you consider the collection, the collective repeating variables should contain all the dimensions, none of the repeating variables should have the same dimension and none of them should be dimensionless.

And here you can see that any 3 out of this 4 if you chose, that will satisfy that, right. But if you just consider say as one of the examples, let us say rho ND we chose as repeating variables. It does not mean that we cannot chose rho N mu like that but this is just an example. It will not matter eventually because depending on the choice of the repeating variables, you will get different dimensionless terms.

But combinations of dimensionless terms also dimensionless terms; therefore, whatever dimensionless terms are of your physical interest, usually the dimensionless terms of physical interest are which give the ratios of certain important forces like that. And those you may retrieve from the combinations of the different non-dimensional numbers, even if you do not get them directly. So let us say that rho ND are repeating variables, then pi1.

So pi1 we call as rho to the power x1N to the power y1D to the power z1 and then may be one after the other each variable. So let us say mu. So that means in terms of dimensions, rho to the power x1 is M to the power x1L to the power-3x1. N to the power y1 is T to the power -y1. D to the power z1 is L to the power z1 and mu is ML-1T-1. Since pi1 is dimensionless, the power of each of the dimensions should be 0 in the right-hand side.

That means you have x1+1, that is for M, =0. For L, -3x1+z1-1=0. For T, -y1-1=0. So from here you will get x1=-1, y1=-1a and what is z1, z1 is -2. So what is pi1? Mu/rho NV square, right. You can see that it is a sort of Reynolds number because D*N, sort of D is the velocity which is like a tangential velocity. It is just like V=omega R, that one. So therefore it is like mu/rho*sum velocity*D. So 1/Reynolds number type of feel it is giving.

We will not concentrate so much on these dimensionless as parameter because many times for very high Reynolds number flow, the effect may not be so sensitive to the Reynolds number, that we have seen. But other parameters should be of greater importance and we will concentrate more on the pi2, pi3 and pi4. So let us consider the pi2. So let us say rho to the power x2N to the power y2D to the power z2. In place of mu say let us take Q, okay.

So you have M to the power x2L to the power -3x2T to the power -y2 L to the power z2 and the unit of Q, L cube T to the power -1. So in terms of the dimensions, you have first of all x2=0 -3x2+z2+3=0 and -y2-1=0. So y2=-1 and z2 is -3, right. So what is pi2? Q/this one ND cube, right. Let us consider similarly pi3 and pi4.

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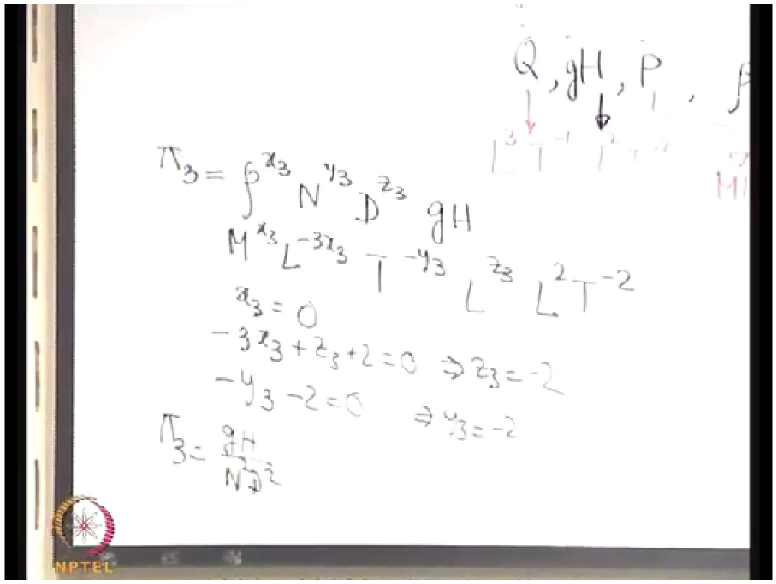

Rho to the power x3N to the power y3D to the power z3*gH, okay. So you have M to the power x3L to the power -3x3, then T to the power -y3L to the power z3 and this is L square T to the power -2. So you have again x3=0, then -3x3+z3+2=0 and -y3-2=0. So what is z3, -2 and y3 is also -2. So what is pi3, gH/L square D square, okay. Let us consider the final one, pi4.

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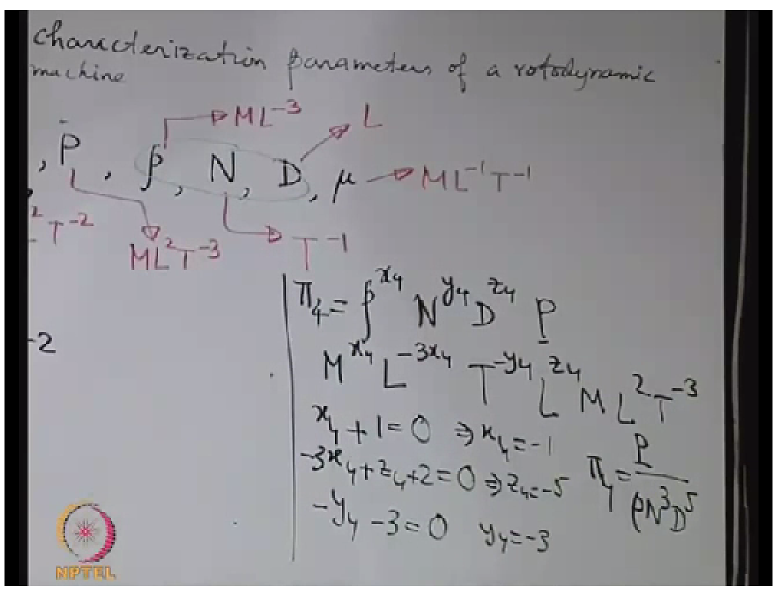

Rho to the power x4N to the power y4D to the power z4*the power. So that means N to the power x4L to the power -3x4T to the power -y4L to the power z4 and in terms of the power, ML square T to the power -3. So you have x4+1=0, -3x4+z4+2=0, -y4-3 0. So x4 is -1, y4 is -3 and z4 -5. So pi4 is P/rho N cube D to the power 5, okay. So from this we can see that the important parameters, the output parameters which are of our interests, forgetting about the Reynolds number dependence, the important output parameters are related someway to the characteristics of the rotodynamic machine.

What are the 2 important characteristics of the rotodynamic machine? One is the rotor diameter. Of course it may derive from the inner to the outer but whatever is the local diameter, the rotor diameter and the rpm. So you basically have that if you have geometrically similar machines and they are also cinematically similar and they are also dynamically similar. So if you consider all sorts of similarities into account that means you call them as a machine of a homologous series, basically similar types of machines in all respects.

Then for those, you must have pi2, pi3 and pi4 to be the same. That is they should not change from one machine to the other if they are of the same homologous type.

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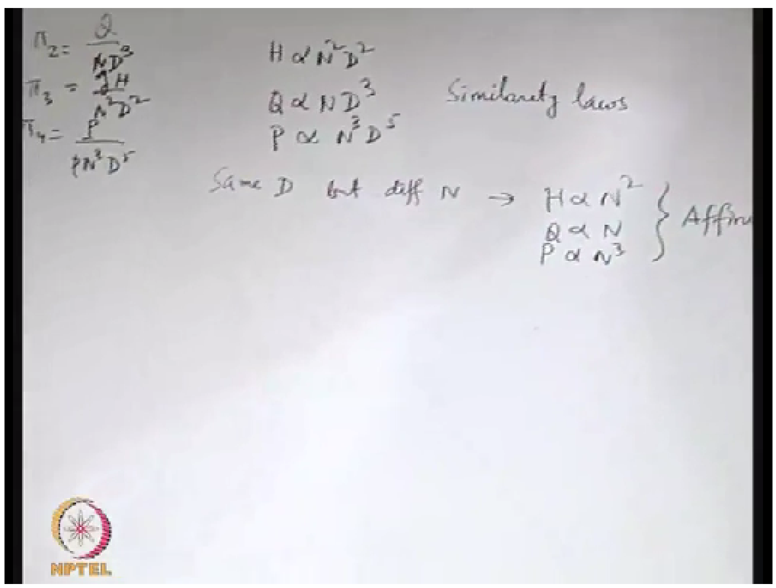

What it means is that you have Q/ND cube, that is 1 parameter. So let us just write those again, pi2, pi3, g/N square D square and pi4 as P/rho N cube D to the power 5. Now if we consider that if there are machines which are of the same type but they only vary in terms of either the rpm or the diameter. So from here we can conclude that you must have H varies as N square D square. Q varies as ND cube and P varies as N cube D to the power 5 with a note or with an understanding that rho and g are constants.

Of course, if those are variables, then you have to consider the variations of those also but we are considering so what we are considering? Say you have a centrifugal pump of a particular size and rotating with a particular rpm. You want to make a model test of that, so you make a model of a different size and the model rpm you have to design. So if you have designed it with a particular model rpm and a particular model size.

Then the ratio of the heads developed in the model and the prototype, the flow rates in the model and the prototype, the power in the model and the prototype, they should be varying in accordance to this relationship. So these are known as similarity laws for a rotodynamic fluid machine. Sometimes what you do is, you do not change the machine but a one particular machine you run with a different rpm.

That is, you keep D fixed but you run it with a different rpm and many times that is important because if you are doing an experiment of a performance test, then you are not really running it with a single rpm but running with different possible rpms and important thing at the end is that no matter with whatever rpm you run, the machine has a rated rpm and all its characteristics are quoted at the rated rpm.

Rated means a sort of design rpm. So if you want to convert your experimental result at a particular rpm to the rated rpm, then you may use these relationships again with an understanding that D does not change. It is the same machine run at different rpms. So then if you have same D but different M, then it is just H varies with N square, Q varies as N and P varies as N cube.

This is known as affinity law. So of course it is a special version of the similarity laws. Now the next important thing is from these characterisations, is it possible to come up with a signature of a particular type of a device. So when we say signature of a particular type of a device, again we have to be a bit more specific. That is, we have to see whether we are thinking about a pump or a turbine. So if you are thinking about a pump, important characteristics are H and Q.

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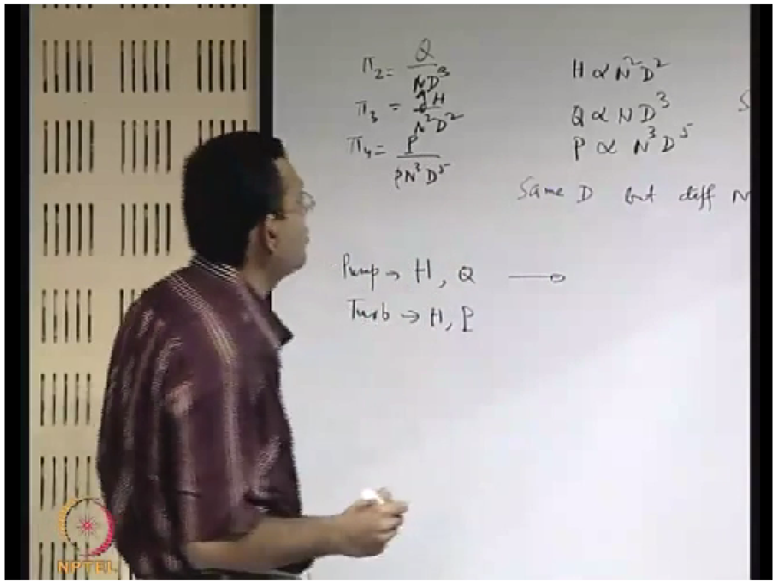

In fact we have seen an example where we tried to characterise the prominence of a pump with the HQ curve. On the other hand, if you have a turbine. For a turbine, the important characterisations are H and the power. Because for a turbine, it is not the flow rate or the discharge that is explicitly important, it is the power at the end that is important and therefore for a particular type of pump or for a particular type of turbine, you should have for a pump as an example, for a rotodynamic type of pump, you should have a characterisation involving H and Q.

And for a pump of similar type, that characterisation should not be dependent on D because if it is of a homologous series, the characterisations should be sort of universal or general and that generalisation should not be diameter dependent because then for the same type of pump but with a different diameter, the characterisation will change. So if you want to get a sort of general picture independent of the diameter.

Then your next objective would be to somehow combine these ones to eliminate the diameter. It is just a simple algebraic elimination. So for example let us concentrate on the pump, as an example, centrifugal pump.

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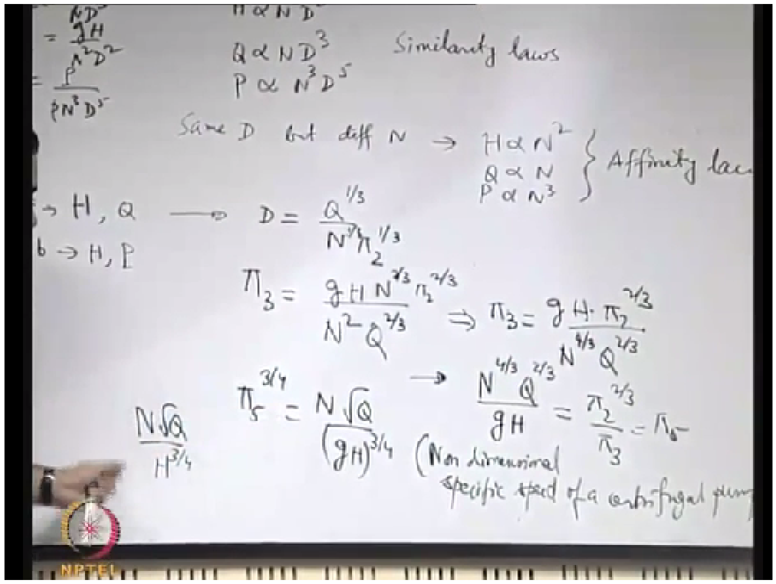

So you can write D as Q/N pi 2 to the power of 1/3rd, right. So now if you write pi3, it is gH/n square. Now D square is Q to the power 2/3, then N to the power 2/3*pi2 to the power 2/3. So we have just eliminated D from this. So what we get out of this is let us say that we want to write a non-dimensional number involving pi2 and pi3 where D is eliminated. It can be written in many ways but first let us simplify this is pi3=gH, now, *pi2 to the power 2/3rd/N square.

And then N to the power -2/3, so N to the power 4/3rd and Q to the power…So you can write N to the power 4/3rd*Q to the power 2/3rd/gH as pi2 to the power 2/3rd/pi3. Let us call it, this is a non-dimensional number. Let us give it a name, say pi5. It is a combination of non-dimensional numbers, so it has to be a non-dimensional number. Now if you want to write it with N as a parameter. That means you want to see that very simply if you vary N, then what happens with the parameter?

Then it is N to the power 4/3rd, if you want to write it in terms of N, you just take the 3/4th power of this term. So if you consider pi5 to the power 3/4th, then that becomes what? N root Q/gH to the power 3/4, right. This is known as non-dimensional specific speed of a centrifugal pump. Now you can see that what it tries to represent, let us say that you are writing this expression in a dimensional form, that is see this is a dimensionless parameter but you have to keep in mind that g is something which does not vary.

So an equivalent of this parameter in a dimensional form could be written as N root Q/H to the power 3/4. It is going to give the same meaning as this parameter because g is a constant but only thing is that this is not a dimensionless parameter but let us say that you forget about the dimension, you use some consistent dimensions that is you say consider Q=1 and H=1. Then this in whatever dimensions, then this will give some speed N, it will give back N. So that we call as something as NS, this is a dimensional specific speed.

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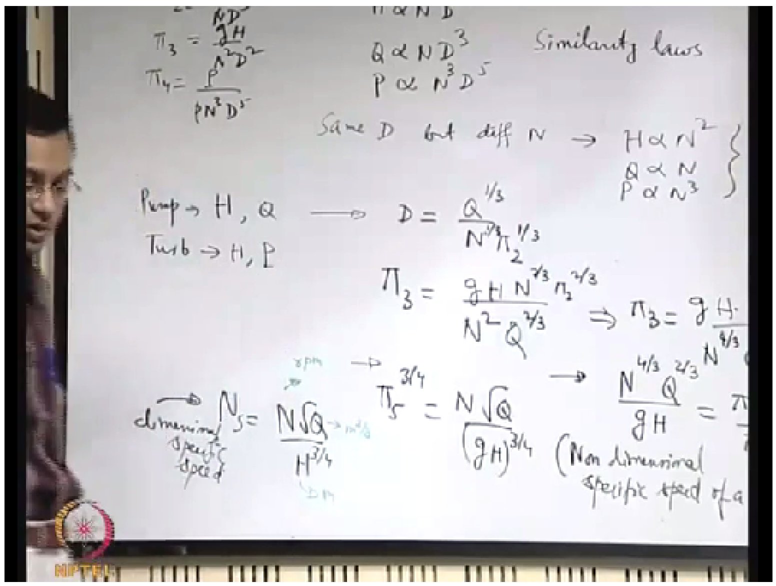

Why we are going through this, fundamentally from fluid mechanic's point of view we should have stopped here but this is what is the industrial practice. So we have to see that like, the industrial practice is not that it is deviated from the fundamentals but it is somewhat simplified to take into account certain things. Since g is no way going to influential your behaviour, so you get rid of the g and you call it as a speed keeping in mind that this is not actually unit of speed.

So this is a misnomer, this is not a speed but it is as if like if you forget about the units and if you put Q=1 and H=1, you get N=Ns. That means specific speed is sort of an equivalent speed of a geometrically similar pump, say specific speed of a pump, centrifugal pump, is the equivalent speed of a centrifugal pump, rotational speed of course, which is developed under unit head and unit discharge for the geometrically similar type of pump.

So if there are geometrically similar rotodynamic pumps, then for another geometrically similar pump, the speed is same as specific speed if Q=1 and H=1. This is just a way of interpreting this but important thing is that still it holds that idea that this parameter or in fact this pi5 to the power 3/4 is an important signature of homologous types of fluid machines, say homologous types of pumps.

So when you have different N and Q and H, and these are important parameters for a pump and then they should be related if it is pumps of a homologous type, this specific speed should be a constant. It should not vary from say one particular pump to the other particular pump and here the advantage of this is that you have written this in terms of a parameter that is independent of the diameter.

So you are explicitly writing it in terms of the operating parameters N, Q and H. The geometry is not explicit in it but it is implicit in it because we are considering only geometrically similar pumps to have kinematic similarity and dynamic similarity for which you have relevant dimensionless parameters combined one with the other. So you cannot really compare say 2 different pumps or say one pump with the turbine as an example.

But this gives you a bit of more flexibility then the similarity laws in a way that you could compare the specific speeds of 2 different pumps and try to have a cross assessment. That means you may definitely have a relative assessment of specific speeds of one type of pumps, say you have radial flow type of pump. So radial flow type of pump may have different ranges of specific speeds.

So different radial flow pumps, you may have different specific speed but say you have an axial flow pump. So for the axial flow pump, the geometry is a bit different. The flow nature is a bit different but these are the important non-dimensional parameters which are still valid for that. And then for that type of a situation, you are having this characterisation independent of the rotor geometry and therefore, even if it is not geometrically similar, you can have a sort of comparison between pumps of different types as an example.

So that is why this parameter is considered to be a very flexible parameter which does not contain explicitly any information on the geometry and therefore, it is not always necessary that you compare the specific speed of say one pump with another geometrically similar pump. You may have even the comparison with another geometrically dissimilar pump provided these are the important characteristics and yes for a roto-dynamic device.

These are the important characteristics. Now the next thing is that when in industry these types of parameterisations are used since this is a dimensional parameter, it should depend on the units that you are putting for N, Q and H. So different countries and different industries have different ways of like standardising these and for example one may have a standardisation which say N as rpm, Q as meter cube per second and H as meter and sometimes then this specific speed dimension of specific speed is given a sort of unit of revolution or something like that but it is usually, I mean the unit is not quoted by the industry.

So these are certain conventions. If you know that what are the units that you already put for N, Q and H and that you are going to consistently put, then whatever changes are there, only changes in terms of numbers and therefore, this number will reflect some sort of this non-dimensional behaviour but in a fashion where you are putting dimensional parameters. So different pumps will have different specific speeds.

And we will try to compare different pumps with different specific speed when we come across few other types of pumps beyond the standard radial flow pump that we have seen. Now if you consider a turbine. If you consider a turbine, the exercise should be very very similar. Only thing is that your now focus is H and P. So you will consider pi3 and pi4.

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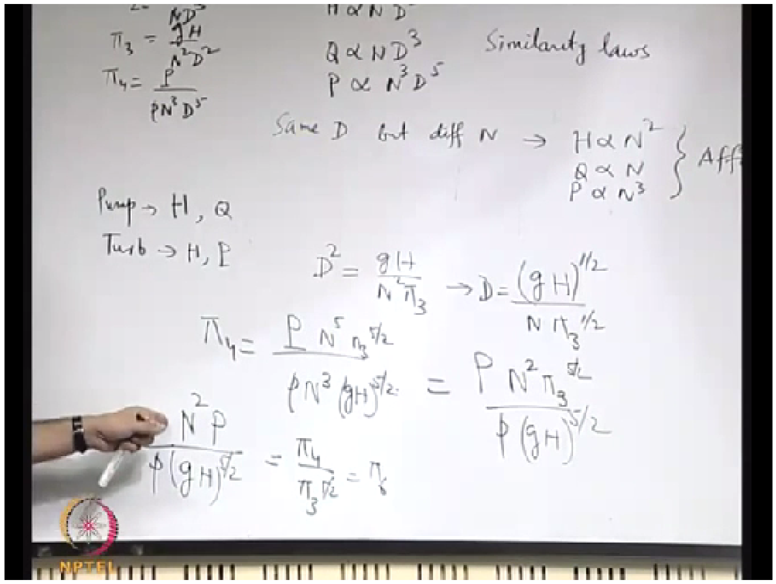

So from pi3, you get D square=gH/N square pi 3. That means you get D as gH to the power 1/2 together/N*pi3 to the power 1/2. Then you come to pi4. Pi4 is P/rho N cube, then these to the power 5. So gH to the power 5/2 N to the power 5pi3 to the power 5.2. So this you can write PN square pi3 to the power 5/2/rho gH to the power 5/2. So you write N square P/gH to the power 5/2=, sorry, rho gH to the power 5/2=pi4/pi3 to the power 5/2, let us call it pi6.

So when you want to write it in terms of the similar type of dimensionless parameter as that of the pump, then what you should do? You have to keep in mind again N is an important parameter. So you want to write N. So just take a square root of this.

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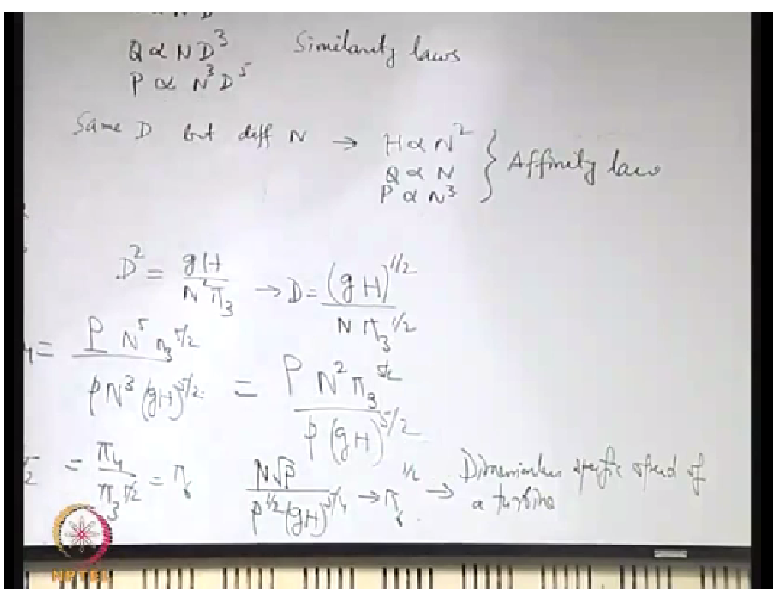

So you get N root P/rho to the power 1/2*gH to the power 5/4, that is pi6 to the power 1/2. This is dimensionless specific speed of a turbine, okay. Now here also you can have equivalent dimensional form, what will be its equivalent dimensional form?

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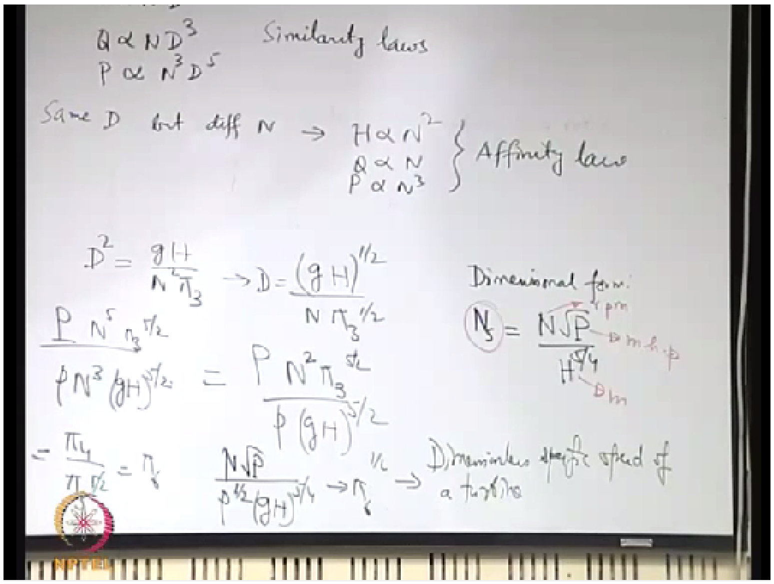

So if you have a dimensional form NS=N root P/H to the power of 5/4 because rho and V are non-variables that you are considering, right. So this is a dimensional form of a specific speed of a turbine and again the interpretation is very very similar as we had for a pump. The units again it depends on the country and the standard units for these which are used for the typical industries.

For example, in most of the industries here we have N used in the rpm unit, P as metric horse power and H as meter. So 1 metric horse power is 735 watts, okay. So that unit if it is used, then the specific speed is quoted and that is quoted in terms of a number. These are conventions in the industry, not that it is a correct convention. I mean, the correct and the fundamental conventional which should make it independent of whatever is the country and whatever is the units being used, is to use the non-dimensional form of this one but somehow industries have developed independently in different countries.

And that is how they have developed their own conventions in terms of quoting the specific speeds. So for a particular type of pump, a particular type of turbine, may be different specific speeds are quoted in different handbooks which quote the values of specific speeds as obtained from experiments and one has to keep in mind that these differences or sometimes the difference are of wide range, may be based on the different basic units which are used for calculating the specific speed.

Nothing more serious than that. The other thing is that when you consider these P, H, or whatever like or Q H in the case of a pump, what are the corresponding values of Q and H or P and H that you will substitute because a pump may operate with different Q and different H, still satisfies the HQ characteristics. A turbine may also have different power versus H characteristics.

So different H, you will have different P but what combination of H and P for a turbine and H and Q for a pump you should substitute, that very important convention is that you should put the rated conditions. Rated means at the best efficiency condition. We will see that what is the best efficiency condition but at least we should keep in mind that the parameters which we substitute for evaluating the specific speed should be the rated parameters that is parameters under the best efficiency conditions that is one very important note here.

The other important note is let us just go back to the specific speed of a pump.

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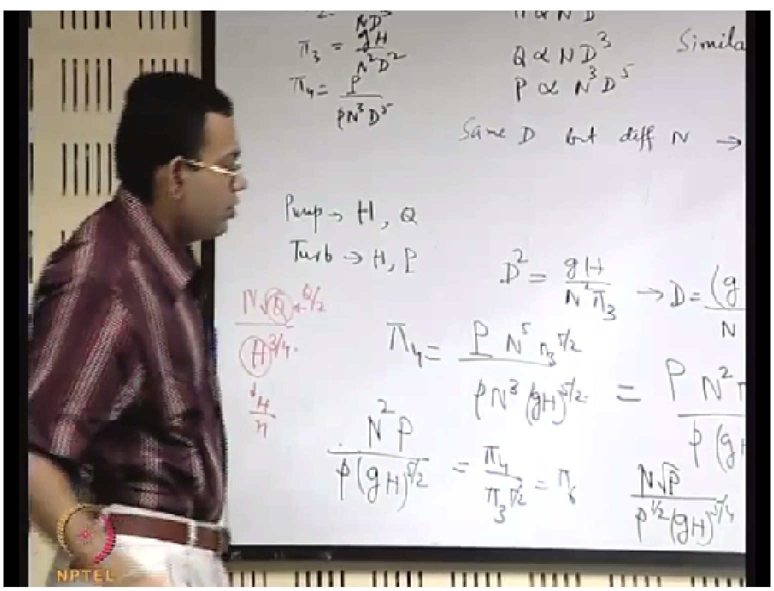

So when you consider that N root Q/H to the power 3/4. Now there may be different types of impeller. For example, we have looked in to an example of an impeller which is a single suction type. That is, it is sucking the fluid, it is accepting the fluid through one suction but if there are double suction types, that type of impeller also may be possible. Then this has to be for each suction, what is the Q?

So if there are 2 suctions, you have to consider the total flow rate/2 here, if it is a double suction type. So if you have n number of suctions, this Q has to be replaced by per suction and this H is also per impeller because you have many such impellers put in cascade and then the total head may be quite large but your important characterisation in the signature of a single impeller. So this head should be, let us say there are n number of impellers, then this should be replaced by H/n.

So this is head per impeller. So per suction Q and per impeller head, that is we have to substitute for getting the specific speeds, okay. Now so from this discussion, we have got an understanding that how the performance parameters may be related one with the other but the next objective will be to see that how to get these performance parameters. To do that, we will now consider bit of a generalisation of the centrifugal pump as an example.

We will consider the centrifugal pump but kept in a system. That means till now we have considered as if the pump is isolated. That means the pump is there, some fluid is entering the pump and some fluid is leaving the pump. But in reality when you have the pump, it is not isolated. It is there in a piping system. So the pump is transferring some fluid from a reserve to another reservoir.

So the supply reservoir from which it is taking the fluid is typically known as a sump. So from the sump the pump is taking some fluid and it is discharging it to some delivery reservoir or some discharge reservoir.

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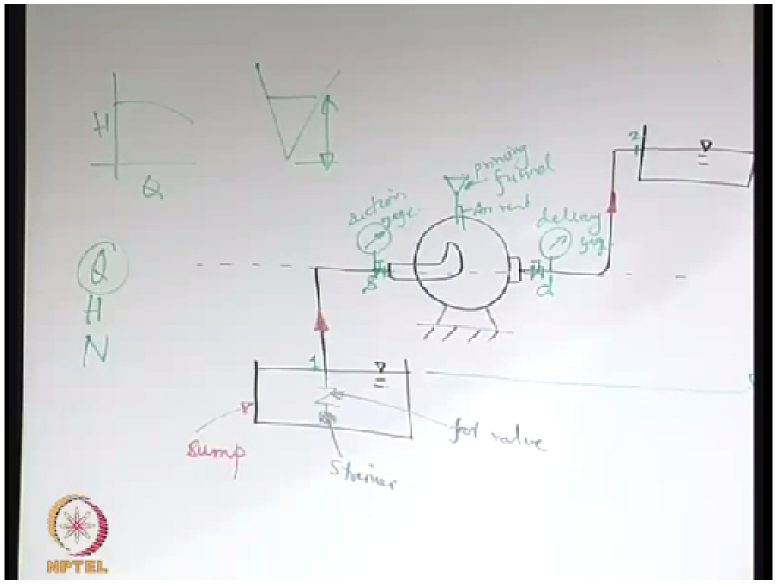

So if you have such a pump in a system, so let us just try to sketch it. Say you have, we are just drawing it very very schematically. So you are considering that there is a pump which is there in a system and so the direction of flow is, the pump is sucking the fluid from the supply and delivering it to the delivery and this is just a schematic way of representing the impeller because here our focus is how the pump behaves in a system and not so much on the details of the impeller.

Details of what happens in the impeller that we have seen already. Now just let us try to characterise these names. So this is known as a sump or a supply reservoir. So the side from which it sucks, so this is known as the suction side and this is known as the discharge or the delivery side and these names are quite obvious, just standard English names. Now if you want to have a characterisation of like what are the pressures at the suction and the discharge side.

So typically one may keep certain gauges here. This is like suction gauge and this is delivery gauge. Of course, it is not always that the suction and delivery are operating. So you may have certain valves at the suction and the delivery side which you may keep as closed or open depending on your requirements. So you may have suction valve and the delivery Valve. So you may have a suction valve on this side which is like, if it is closed, then there will be no sucking.

If there is a delivery valve and it is closed, so let us say that you have some valve here and may be some valve in the delivery side. So if you have these valves as closed, then you do not have any flow through the pump and when a pump is being tested, this is not really a configuration for testing of a pump and the real configuration for testing of a pump is something which is a bit more involved than this.

I will not go into all the details, of the intricacies of the testing of a pump but the notes that I have provided you, if you go through that you will understand that what are the detailing involved in the testing of a pump but important thing we have to understand is that when the pump is in a system, what are the important characteristics which are there for testing of a pump in a system.

So one of the important characteristics is that you have to measure the flow rate definitely. You have to measure the head developed and you have to measure the rpm. These are the 3 things that you have to measure because we have seen that these are 3 strong parameterisations of the performance of a pump, centrifugal pump as an example. So let us say that you have a suction side say s and you have a delivery side say d.

Now we just consider these locations as 1 and 2 and there is a difference in height between the 1 and the 2. Let us say that is the static lift of the pump, that is the height to which the pump is lifting the water. Now before the pump is testing, certain things are there, although we are not going into the details of the pump testing. Let us just try to see or try to understand that how a pump is actually tested in practice.

So to do that, first of all, I mean there are certain fittings which are there in this pipe. So there is something called as a strainer and there is a particular valve known as the foot valve. So these are certain objectives to fulfil. What does the strainer do? There may be some unwanted particulates in the flow. So it just gets rid of the particles. This is just like a sieve. So what it does is it get rid of these unwanted particulates, say some debris or whatever is there and allows the fluid that you want to flow.

Foot valve is a one-way valve. So it allows the fluid to move up but it does not allow to come down. So it is a one-way type of valve. Now when the pump is tested, first of all, you have the suction and the delivery valve, both are closed. You have to make sure that when whatever is there inside the impeller, you do not have any trapped air inside because this is air trapped inside, that will create lots of problems.

We will see that later on that what types of problems it may create. So what is basically done is there is a funnel on the top of it which is known as a priming funnel. So through this priming funnel, you add water and then when you add water, what happens is that? If inside there is some air that is entrapped, that is forced to leave. So if you keep a vent here, it is like a air vent, some small hole, air will now leave through that hole.

So that is known as the air vent. So this operation is known as priming. It is very very important to have a priming operation before starting of a pump. So once that is done, then you know that this is filled up with the liquid and entrapped air is not there. Then you may slowly… So first when this impeller was filled with water, then obviously what you did, you opened the suction valve.

Otherwise, how water will come. So suction valve is first fully opened and then priming operation is done but till the time the delivery valve is closed. So then what the impeller is doing, it is just churning the liquid inside. Then you slowly open the delivery valve and there you will see that there is an increased value of the discharge Q. So that means by playing with the opening of the delivery valve, you change the values of Q because if you want to have a performance estimation, you want to see that how H varies with Q.

So you therefore can vary Q. Q is like an independent variable. So if you see that when you have plotted the HQ characteristics, whatever is there for a pump, see Q is there in the horizontal axis. Always remember that whenever you have any experimental data where something is put in the horizontal axis, that means that is an independent parameter for the experiment. It is not mathematics that as you will put H here and Q here.

You have to keep in mind that what is your independent parameter that you can vary with experiments and what you cannot. So here by playing with opening of the delivery valve, you can play with the variation in Q. So with different Q, you will get different H. How will you get different H? That is by the readings of these gauge that we will see that by taking the readings of these gauge, you will see that what is the head developed and how will you measure Q?

Basically this flow that you are discharging, you may discharge it on to a flow measuring device. One of the important flow measuring device is which we have not covered as a part of this course is known as a V-notch Weir. It is just like a flow taking place over a free surface having the section of the flow like a triangle. So depending on the height from the apex, the flow rate is characterised.

I mean there are formula involved. If you look into the principles of flow measuring devices and some of the notes that I have provided you earlier, although we have not discussed it in this class about this device but I have outlined the basic principles of these V-notch or rectangular where. So there is different type. This is a V-notch Weir. Similarly, you may have rectangular Weirs. What are the basic principles you may see?

But I mean this is not a part of this course. Just for your own interest, you may look into that but important thing just to recognise that there is some way by which we are measuring the flow rate. So that is measured. H is measured by the readings of these gauges and the rpm, how it may be measured? You may just use a tachometer to measure the rpm of the rotor. So it is possible to measure H, Q and n from the experimental conditions.

So now how to relate that H, Q and n. First of all, let us try to apply the energy equation between 1 and s. So let us just give certain lengths, say dimensions, say this is hs, this is hd. These are the static lifts of H, the suction and the delivery side.

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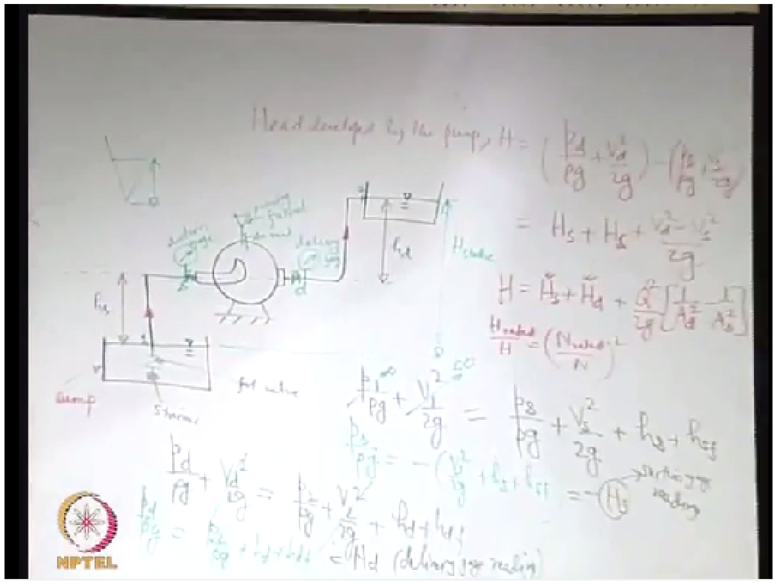

So we can write p1/rho g+V1 square/2g. So we are considering that time taken at the correction factor is very close to 1, +z1=p2/rho g. Here 2 is the s. So ps/rho g+Vs square/2g+hs+the head loss, say hsf. So we are only considering the major losses. Head loss in the suction pipe. So what we may say from here. First of all, if you just consider the gauge pressure, that is related to the atmospheric pressure.

You can see that pressure at 1 is the atmospheric pressure. So we consider it as a 0 reference. So all other pressures we quote in terms of a gauge pressure. Velocity at 1 is much much negligible as compared to velocity at s because area at 1 is very large. So this is very small. So you have ps/rho g=-ps square/2g+hs+hsf. You can clearly see that this is negative because Vs square/2g is positive, hsf is a head loss which is a positive quantity that we have seen, hs in this configuration is positive.

But let us say that if we put the sump at the top of, at the higher level as that of the pump, then this could be negative. Our reference is this one. With respect to this, this is positive because it is below the reference line. If it was above the reference line, it could be negative and that could be one way of reducing the negativity of this one. We will see that why that may be important at the end because it may have some detrimental consequences that we will see.

But in this configuration, you have this pressure as negative. So here the gauge you have is a suction gauge which reads the magnitude of this one because it is a gauge that will read the negative pressure or the below atmospheric pressure which is the suction. So that is why it is called as the suction pressure. Similarly, if you apply the energy equation between D and 2, so what you get.

Pd/rho g+Vd square/2g=p2/rho g+V2 square/2g+hd+hdf, right. Now V2 and Vd are the same because it is same pipe, right. So they are the same. So you have pd/rho g=p2/rho g+hd+hdf. Let us say that this is equal to -hs because hs is, this is nothing but the suction gauge reading in terms of head, okay and let us say that this is equal to hd which is the delivery gauge reading. Suction gauge is like a vacuum gauge but delivery gauge is not because here it is not the same condition that you are having at the suction.

So now what is the total head developed by the pump? The total head developed by the pump say H, this is nothing but the total head at d-the total head at s, that is the total energy that has been imparted to the fluid by the pump. So that is pd/rho g+Vd square/2g-ps/rho g+ps square/2g. The elevations of s and d are so close that the difference in height between that is neglected. So this is just the difference in head between the 2 sections.

So this you can write that is nothing but Hs+Hd+Vd square-Vs square/2g. Where Hs is the suction gauge reading and Hd is the delivery gauge reading. Their expressions are given in this equations before. So you can have Hs+Hd, now if you know the diameters of the pipes, so you can write B as Q/A, so Q square/2g1/area of the delivery pipe square-1/area of the suction pipe square.

So if you have the reading of Hs and Hd from the 2 gauges and if you know the diameters of the pipe, then you will get HQ characteristic at the speed at which the pump is running. You may convert it to the rated speed by noting that H varies as N square. So from the speed at which the pump is running, if you convert it to the rated speed, then it will be like H rated/H=N rated/N square for the same pump, right.

So this is the way to get the H, the head. The other important thing to note is that like if you want to have more head, then which pipe you want to have a better diameter, the suction pipe or the delivery pipe. See the delivery pipe should be such that the velocity should be more, then this is more positive and that means this diameter should be less. So that is very simple understanding on one of the principles by which you may have different diameters for the suction and delivery type, okay.

Let us stop here for this lecture and we will continue with this in the next lecture. Thank you.