MARINE ENGINEERING

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Lecture16

Centrifugal pump

Now you have seen closed impeller, and open impeller. Like now I can draw again. This is my impeller and I have blades. These are called blades I already told. Now you rotate impeller at very high speed in this direction.

This is my back plate. This is my back plate. okay rotate a very high speed what will happen so fluid will be coming through this i'm making dotted line you can see and it will be going like this okay now what will i do i'll make one casing like this okay so casing will be collecting all the fluid here and it will be delivering okay so this is called delivery side And suction will be like this. So because three-dimensional I cannot draw here, so I will be drawing side view.

Side view is like this. So this will be, let us say I have one tank, water tank. And my suction pipe, this is called suction pipe. This is delivery pipe. So, fluid will be sucked and will be delivered.

And suction, so total head, total pressure, total energy required to deliver the fluid will be like suction side HS and HD. HD means delivery is how much pressure it is developing because pump location is here and you are delivering fluid here. So, you need certain energy to lift the fluid, right? And water level is here maybe. So, you are sucking this fluid.

So, total energy required to deliver fluid this much plus this much. So, your total energy or head will be required HS plus HD. I can put small d. So, this is called suction head. normally the suction head and delivery head it will be unit will be meter normally it will be meter if you are using SI unit if you are using FPS or other unit then unit will be different but normally we use SI unit so in that case we will be using meter as a head and if we say head instead of pressure and if you want to convert pressure, pressure will be h rho g, h already your head this means this is head and rho density and acceleration due to gravity.

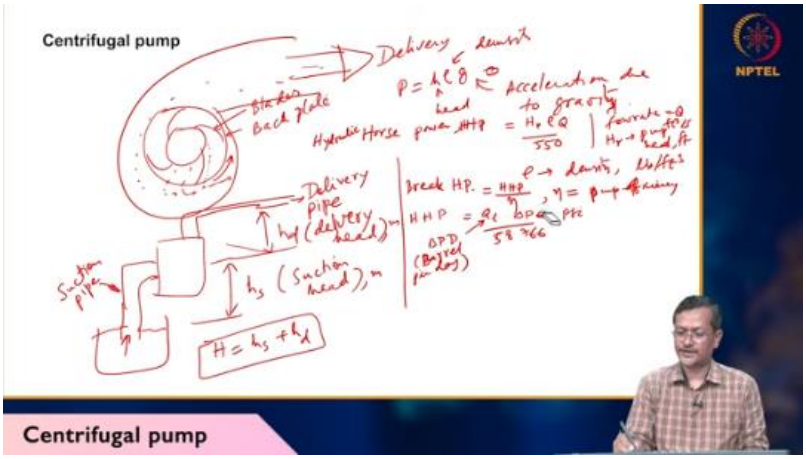
horsepower or HP, the formula will be like HP suffix P rho Q by 550. Q is flow rate. Q already I told. H is your pump head. HP pump head.

feet pump head in feet density row density unit will be pound per cubic feet and flow rate unit is cubic feet per second okay this is called hydraulic horsepower actually hydraulic hydraulic horsepower or HHP. Now, another term will be coming, brake horsepower. Brake horsepower equals HHP divided by eta. Eta equals pump efficiency.

Okay, hydraulic horsepower is like how much fluid you are delivering, so that much of energy. And brake horsepower means like you have one pump, okay, impeller. And you have motor and you are trying to restrict this one. So, motor will have load. So, it is the actual power the system is using.

So, this power, motor power economy will be higher because there will be certain amount of losses. Then you are getting hydraulic horsepower. So, brake horsepower means actually how much power motor will be giving to you. That is called brake horsepower. So, that is why this efficiency term also came up.

and HHPQL del P58766. So, if we are using PSI and QL is, if you are using for oil related calculation then BPD, barrel per day, barrel per day. So, normally we will not use for marine applications, but if we are calculating for oil industry, how do we cost power? So, in that case, you can use this formula barrel and PSI. Now, we will discuss about some experimental setup about centrifugal pump.



So, centrifugal pump you have, I already told this is centrifugal pump. So, centrifugal pump if you want to do experiment or if you want to use for certain application, then you have to know its functioning, how it works. So, in my laboratory, I had actually one tank. You can see the left side tank is written there. So, tank will have one pipe to pump.

This is my pump. It is written there pump and there is one pump connected to motor. This is pump. So, motor will be running the pump and this is suction pipe. This is suction pipe.

Then this is delivery pipe. So fluid will be delivered and it will be going back to my tank again. For experimental case, we use flow meter. This is flow meter. We will have pressure gauge.

And I have one VFD. VFD. So, it is called variable frequency drive. Variable frequency. So, variable frequency drive function is that it will be changing electrical frequency.

It changes electrical frequency. So, because VFD is changing electrical frequency, that frequency it is going to motor directly. So, motor speed will change. So, then motor speed will change. During our laboratory experiment, we want to check

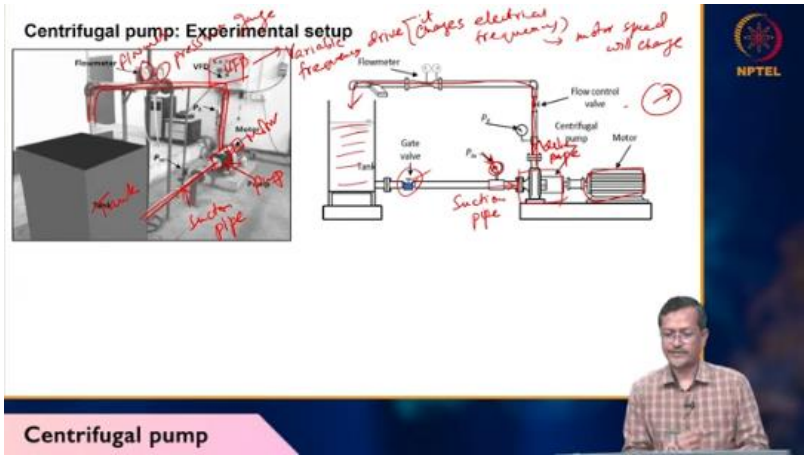
pump speed different pump speed and fluid delivery how much flow rate is it is happening how much pressure is developing with different speed okay that's why you put one vfd variable frequency drive just electrical control change electrical frequency, motor speed will change, motor speed, motor is connected directly to your pump. So, pump speed will change. So, pump speed changing means my flow rate will change, my pressure will change. So, that we wanted to do research using this explanatory facility.

So, right side you see actually the schematic diagram, the tank will have water, same thing actually right left side actual snap from my laboratory and right side the line diagram one gate valve is there actually in suction side gate valve may not be required and one inlet pressure gauge is there There will be different types of pressure gauge. One will be bourdon type pressure gauge. So, bourdon type pressure gauge is actually very simplest type.

It is available in the market. So, it will have one needle and if pressure is increasing, so needle will be changing its location. Because of changing location, you can see pressure is increasing. So, you have to take care or you have to record the pressure that way. and this is my pump actually this is centrifugal pump so if you see this centrifugal pump in impeller it is picture is taken from this side okay and it is suction fluid is suction pipe and this is delivery pipe okay delivery pipe delivery pipe

okay and the centrifugal pump is here motor is here you can see already written there and it will be delivering fluid through this and it will go like this okay this same experimental setup i use for positive displacement pump testing and centrifugal pump testing okay radial axial head flow rate this slide says like i have to discuss regarding radial flow axial flow so this impeller you can see this impeller, fluid is entering through I, then it is taking 90

degree turn. So, from side view if I draw, it will look like this. My shaft is here, my impeller back plate is here and fluid is entering and then it is going 90 degree. From this side also, it will be going 90 degree and it will be going out.



From this side if I am seeing, but from this side I cannot draw like this. So, this is called radial flow. This fluid is trying 90 degree, radial flow impeller. Now, this will be having lower, low Q, high head or pressure, h or p, whatever you can write. Another type is there, axial flow.

Axial flow means you have ceiling fan, you have seen. Ceiling fan, you have ceiling fan blades. If you rotate at very high speed, fluid will be moving axially, actually. Or wind turbine, you have seen. So that is, axially fluid will be flowing.

So wind turbine is not giving direction to the flow. Similarly, your ceiling fan over your head, that will be giving axial flow, actually. From top, it will be delivering flow to the bottom. This is called axial flow pan. fan or pump or turbine, whatever you say.

Axial flow. Axial flow impeller or machine. Machine is better. Now, what is the property of axial flow? Axial flow property is that Q is high.

Very high flow rate if you need, then you can go for axial flow system. But in that case, your pressure will be very low. So, if you want to get very high pressure, for example, you want to lift fluid from ground floor to the top floor. So, axial flow will not work because pressure will be very low. High flow rate it will give, but pressure is very low.

So, that will not be useful. But in some cases, ceiling fan application, you do not need very high head or high pressure. You need very high flow rate. So, in that case you are using axial flow and many cases scientists thought very high flow rate I do not need, very high

pressure also I do not need, I need in between something. So, they developed something called mixed flow impeller.

So, mixed flow system is like this, I have back plate and my impeller will be designed such a way that fluid will be, it will be designed like this, fluid flow direction. so it will be around 45 degree okay fluid will not be completely 90 degrees here fluid is entering it is becoming completely 90 degree this is axis perpendicular to axis okay but axial flow it will not be perpendicular to axis fluid is entering it will be going parallel to axis okay so axial flow means parallel to axis means parallel to axis to axis and radial perpendicular axis, perpendicular to axis. So, mixed flow in between. There will be many type of application where mixed flow also is.

For example, oil and gas industry, sometimes they will be using mixed flow, even surface application for a machine, shipping machine also many time. Mixed flow will be used where you have to comprise the system pressure and flow rate. So left side picture you can see as it is the same impeller picture is here. So that one was fitted inside this volute casing. So what happens in impeller?

Impeller will be creating very high velocity to the fluid. Impeller creates high velocity to the fluid. impeller creates high velocity to the fluid, high velocity to the fluid, impeller creates high velocity of the fluid or to the fluid, to the fluid. And impeller will be connected to volute part, so that is called diffuser. diffuser reduces velocity and gives static head.

So, impeller gives dynamic head or kinetic energy to the fluid. But diffuser, there will be one connected diffuser, so that will be reducing its velocity and it will give high pressure or high static head. So, fluid velocity will be reduced, it will be increasing head. Why this head and velocity conversion is there?

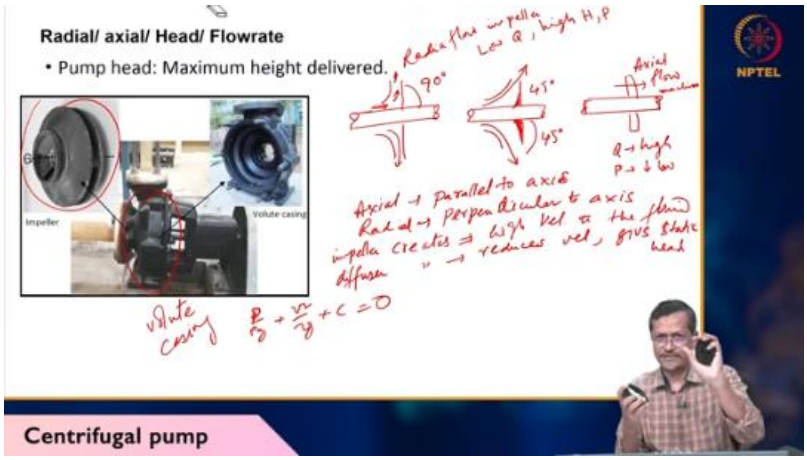
You can remember the Bernoulli's equation, P by rho g plus V square by 2 g plus equals 0. So, if you are increasing pressure, V will be reducing. If you are increasing v p will be reducing so vice versa right so if you are reducing velocity pressure static pressure will be increasing okay so that is why there will be one diffuser so i will be showing another impeller many time your Single impeller will not be developing very high head, which will be required for a specific application, for even a deck machinery application.

Maybe you need very high pressure, certain amount of fluid velocity plus very high pressure plus certain amount of fluid. For a deck machinery, you need very high pressure and certain amount of fluid flow rate. So, single impeller may not be sufficient. So, in that

case, you use multiple impeller. you produce multiple impeller or you use multiple impeller one by one.

So, this is giving let us say fiber pressure, add one fiber pressure, one fiber pressure, one fiber pressure, many stages, it is called stages. So, multiple stages if you make, then you can get total pressure is very high, total static head is very high. So, for that we will have multiple stage centrifugal pump okay this is one centrifugal pump system multiple stages it's very small used for oil industry application so this this oil industry they will be using 100 to 100 stages but normally in our normal application two three stages will be common for a deck machinery or any other industrial application so what happens in this case it will have one impeller okay instead of very big diffuser it will have very compact diffuser diffuser means it will be like similar to impeller but opposite way it will be fixed here so impeller this impeller okay you can see i think this is impeller i and very thin narrow channel is there so when it is rotating very high speed 3000 rpm maybe fluid will be coming out when it is coming out this fluid will be collected into this cavity okay

and it will be entering to this white portion is there you can see white portion is for diffuser diffuser is having also small small holes okay so that fluid will be collected from this side and it will be exiting from this side okay so my impeller is here it is taking fluid impeller i is here it is taking fluid fluid will be exiting from here okay it is connected like this and it will be entering to this white portion white is called diffuser diffuser means it will be giving static head It will be reducing velocity. Impeller is giving velocity, high kinetic energy. Diffuser will be reducing kinetic energy. It will create static head.



So, fluid will be exiting. Then it will be entering to another impeller stage. So, one impeller stage, one impeller and diffuser is called one impeller stage. One impeller stage. plus one diffuser called one stage.

Now, I have one stage. I have another stage. What it will do? Impeller I is here. Diffuser exit is here.

Impeller I bottom side. Diffuser exit top side. Now, I will have another impeller diffuser and I will be connecting this one like this. okay so so so this is impeller i here i have impeller i here so i exit i exit okay so i am putting like this so fluid entering diffuser reducing velocity it is increasing static pressure then it is entering to my next impeller i Again, increasing kinetic energy, diffuser reducing velocity, again exiting with higher static head.

So, initially 1 bar pressure, maybe here 5 bar pressure, 5 bar pressure it is taking, then again it is developing 5 bar pressure. So, after exiting, 10 bar pressure I am getting. I have here, how many stages? 1, 2, 3, 4, 5, 6, 7. 7 stages. If one stage is developing 5 bar pressure, then 7 stages, 5 into 7, 35 bar pressure I am getting.

So, very compact system people can design using this one. And it will be connected to the single shaft. Single shaft will be rotating. And all the impellers will be rotating. And the stator...

white portion will be hold, you have to hold properly and impeller rotating continuously rotating impeller. The 7 stage if I am assuming this is 5 bar may not be 5 bar. I am just giving example, if one is 5 bar, 5 bar, 5, 5, 5, 5, 5, so 7 stages means 7 into 5, 35 bar pressure I am getting. but same flow rate flow rate is not changing so many compact application oil industry application or many surface application also people will be using multi-stage these pumps are in series series okay so this is called multi-stage pump okay multi-stage centrifugal pump and this is again radial flow radial flow why radial flow it can make very complex very compact system okay and if i use axial flow axial flow system is it will be very long high flow rate i will get but it will be very long that cannot be manageable for your real actual application for very high head narrow application for the oil industry application rather already told so in that case actually this multi-stage centrifugal pump

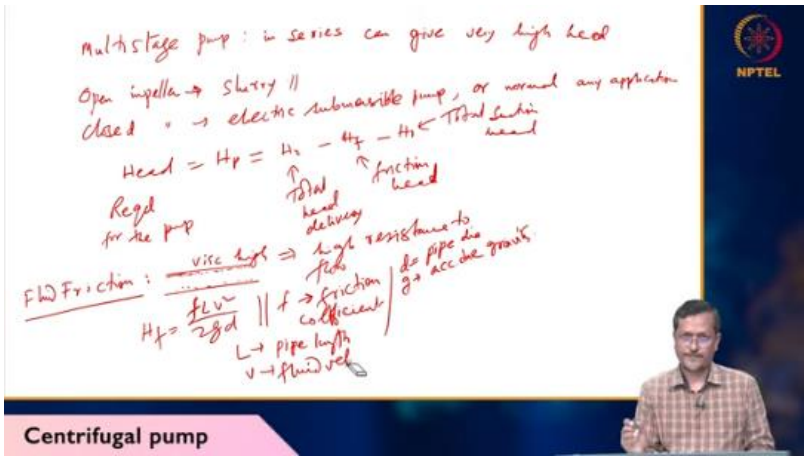
in series would be very good application multistage in series series can give very high head okay in previous slide i told about open impeller it is very good application for slurry Let us say you have lots of slurry and you want to pump from one point to another point. Let us say some dust particle is there, small sand particle is there. So, in that case, you can use open impeller. But closed impeller, you cannot use for slurry actually because the small narrow gap, you have seen three gaps are there in between channels.

So, that gap can be blocked if you have small sand particle or some debris or anything. So, that is why normally people will be using open impeller for slurry applications. and this can be used for let us say electric submersible pump, electric submersible pump or normal any application, normal any application. And head formula HP equals H2 minus HF minus H1.

So, required flow required for the pump and H2 is the total fluid head delivered, total head delivered and h f is the friction head friction means because there will be several losses. So, friction head and h 1 is total suction head total. So, I will talk about friction head okay so fluid friction when fluid is flowing through pipe it will get resistance because of this friction so normally pipe or any surface we assume very smooth looking like but when fluid is flowing fluid will get some resistance because of unevenness on the surface okay so you are trying to deliver certain fluid from one point to another point and because of friction actually will not be able to deliver because some energy will be lost and fluid will get

resistance backward okay and if you have high viscosity fluid it's water viscosity one and if you have very high viscosity oil grease or something other you are transporting so high viscosity means high resistance to flow so viscosity high implies high resistance to flow any fluid high viscosity high resistance to flow and although you are assuming any pipe It will have smooth surface, but fluid will feel that some resistance is there. Resistance means something is trying to pulling back the fluid. So, that is called fluid friction. And fluid friction formula, F L V square by 2 G D H F. F is the friction coefficient.

friction coefficient, L is the pipe length, V is the fluid velocity and D is the pipe diameter and G already you know acceleration due to gravity, due to Now, friction factor depends on your fluid velocity and field of viscosity. So, and this value can be calculated from empirical relation or you will have some Moody's friction chart from there also you can calculate the value. So, normally the value will be 0.003. So, that very low, but when it is having very long pipe, so that will be significant, that friction will be significant.



If again fluid velocity very high, there also fluid friction will be significant now why i am telling about this friction because whenever you have suction pipe you have delivery pipe suction pipe you selected very narrow okay when you select very narrow that means your flow through the pipe will be very high velocity fluid velocity will be very high okay fluid velocity very high that means you can see the formula hf proportional to velocity square so velocity increasing means your friction loss will be very high Again, if your delivery pipe also having very long thing, then L is high. Suction or delivery, whatever, long pipe, small diameter, your HF will be very high. Again, viscosity will be affecting F or friction factor.

So, very high viscosity also will be giving very high frictional losses. So, whenever you are calculating energy required for a pump, so you have to calculate friction also. Friction and some other parameter will be there, so we will discuss later, but basically friction loss, your suction energy required, delivery energy required, all these things you have to calculate to get total amount of energy required to deliver fluid from one point to another point.