MARINE ENGINEERING

By

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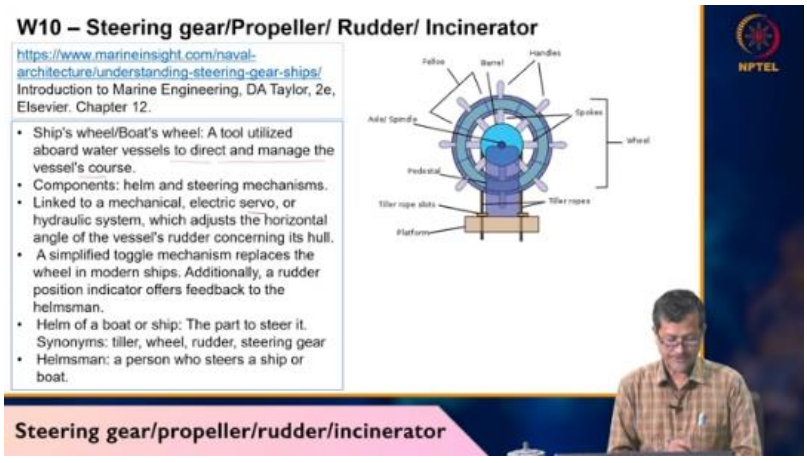
Lecture67

Steering gear/propeller/rudder/incinerator

Now good morning everybody. Today I will start the topic steering gear, propeller, rudder, incinerator. This is an integral part of your shipping or offshore ship applications. So let us see some basic idea I will give on these topics. So first let us define ship, wheel and boat wheel.

A tool utilizes a board, water vessel to direct and manage the vessel's course. And what are the different components? Helm will be there, steering mechanism will be there. a mechanism electrical servo motor may be there hydraulic system will be there mechanical system will be there so the several systems are integrated together for manufacturing or moving the ship from left direction right direction okay a simplified toggle mechanism replaces wheel in modern ships additionally a radar position indicator offers feedback to the helmsman helm of a boat or shape the part of steer it synonym Similar names also people will be using like tiller, wheel, rudder, steering gear.



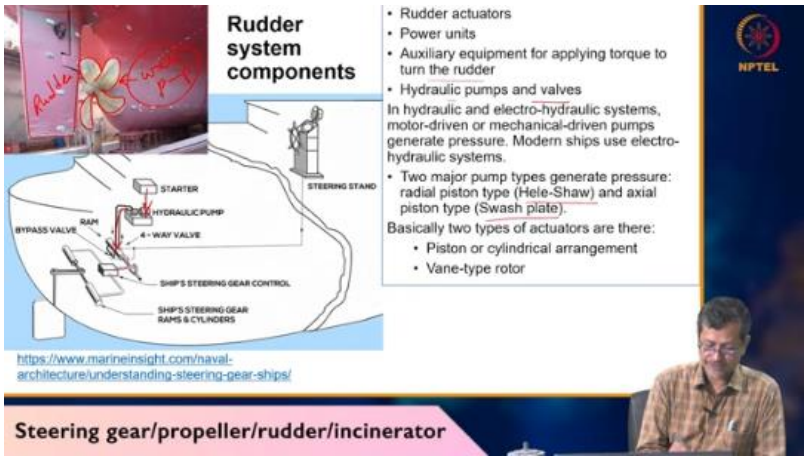
Several names also people will be using. Here right side you can see one wheel like cotton coil wheel you have seen. So similar way if you steer rotate left side to right side your ship

will be moving left side and right side. Now how it will be moving I will discuss later. Here you can see rudder.

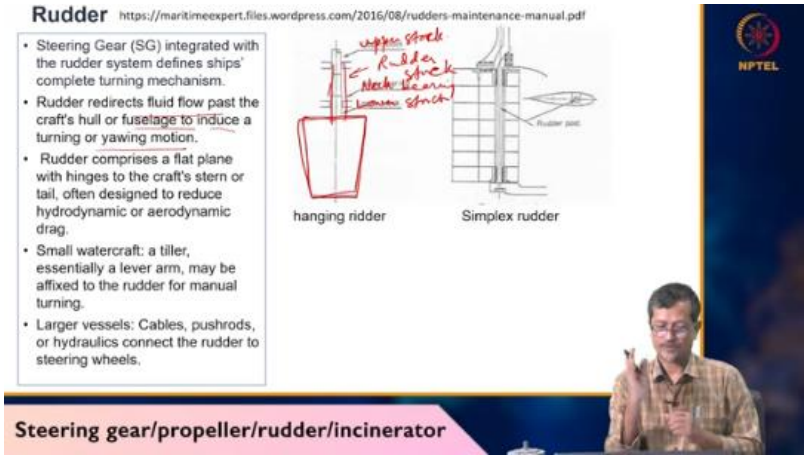
This is rudder. You see this top picture. This one vertical flat plate sort of thing is called rudder. okay rudder and there is one propeller propeller you can see special shape is there okay so this will be propelling water water pumped so purpose of water is to give energy to water so water because water is getting energy so water is giving the repulsive force or third law of reaction Newton's third law you can remember that if propeller is giving energy to force to water water will be forcing propeller backward so that force will be driving your vessel or ship forward and rudder will be guiding left side right side okay now different auxiliary mechanism also will be there auxiliary mechanism apply top to turn the rudder

Hydric pumps will be there. Valves will be there. Okay. Two major pump type generally they will be using like Helle Shaw type and Shrush plate pump. We will discuss later.

There will be piston cylinder arrangement. So, like you rotate several tons of your wheel but your rudder will be rotating only few degree angle so then you need one mechanism so that uh like one rotation 360 rotation of your wheel will not rotate the radar 360 rather only few degree rotation will be there uh so that mechanism how this will work i'll explain you can see this bottom picture so starter is there hydraulic pump is here from pump you have certain ram mechanism or one-way valve mechanism is there so finally that is converting to some degree angle of your rudder so this is a rudder okay so whenever whenever you are rotating the wheel rudder will be rotating but through different mechanism so what is rudder so rudder actually it will be redirecting your vehicle so it will be giving energy to fluid so fluid will be giving reaction force so that reaction force will be driving your vessel left side right side aft or port or starboard side so rudder redirects fluid past that crab's hull or fuselage to induce turning or yawing motion rudder comprises a flat plane with hinged so this is a flat plane surface actually

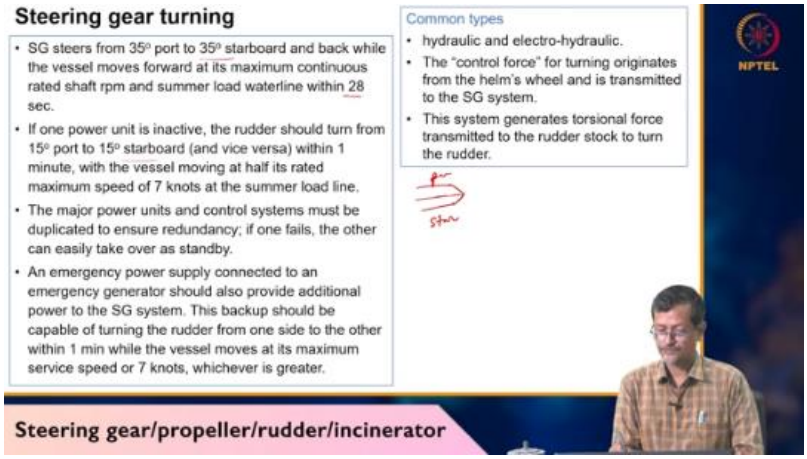


and this will be hinged okay this is called rudder stock this is called rudder stock so here neck bearing is there so this is called lower stock this is lower stock this upper stock okay and when rod is coming load or shaft is coming shaft is rotating your rudder and there will be bearings otherwise this water force will break whole thing so bearing will be holding in place and shaft will be rotating your rudder so different types of rudders are there one is hanging rudder another is simplex rudder so many types of rudders are there rudder shape if i take one cross section so anytime it will be like airfoil shaped okay so let's say take one cross section here AA will be showing like this okay one cross section will be like almost airfoil symmetric airfoil so steering gear turning the steering gear steers from 35 degree port to 35 degree start board and back while the vessel move forward and maximum continuous rated shaft rpm and summer load water line within 28 second if one power unit is inactive then the rudder should turn for 15 to 15 degree port to 15 degree starboard side. So port side means left side, starboard means right side.



If you see one vessel, so one side will be port, one side will be starboard. And if you see from your ship, so left side is a port, right side is a starboard. the hydraulic mechanism will

be there and actually you are using wheel you are giving some force to your vessel to move left side or right side motion here one GIF picture is there it is taken from Wikimedia Commons you can see this wheel is getting rotated here at the top and that is that force is going through this sheave sheave or pulley this is sheave and this will be going through this one and then this side also left and right side both side is going like this and finally you are rotating this one okay this is connected directly to your rudder so here is rudder okay and this expanded form is here this is expanded form here so lots of gear mechanism is here gear mechanism although you are rotating your wheel several turns but gear mechanism will give you only small turn and here one thing like

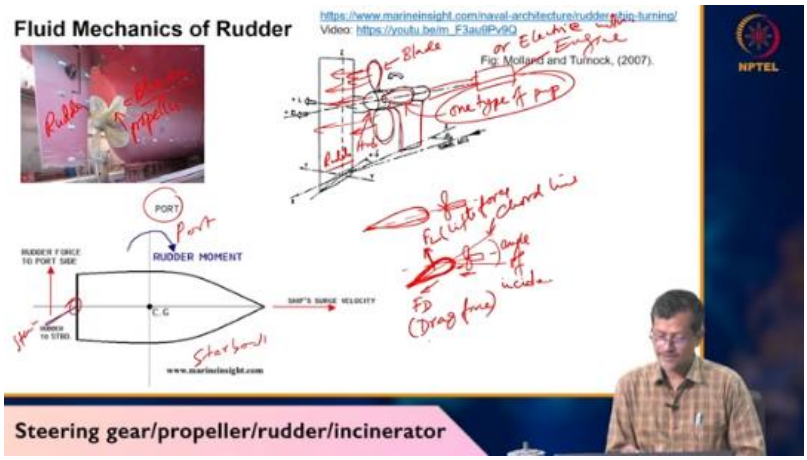


when you are rotating wheel you are giving small amount of force but you give me several turns so that force is converted into power okay so let's say you are giving total power t into omega torque you are giving and omega is here okay lots of turn you are giving same power here it is going to your propeller sorry rudder but in this case your torque will be increasing omega is reduced okay torque is increasing so in that case you are giving more torque to your rudder because heavy vessel needs larger amount of force so that way you are giving lesser amount of angle but you are giving larger amount of torque so that will be helping to move your vessel left side or right side or port side or starboard side so one ship will have port side I already told and this will be starboard and this will be stern side okay so normally your propeller will be here and propeller in front of propeller there will be rudder okay so i have okay so here you can see this top picture sketch propeller blades are here these are called blades in if you can remember the pump lecture and turbine lecture there we said these are our blades so propeller blades will be rotating and this is hub okay and this is giving energy to fluid so it is it will be coming under the category of pump not turbine turbine takes energy from fluid and it converts into electricity but in this case you are giving energy to fluid so and pump also does the same thing the pump will be giving

energy to fluid so the same function is there so actually propeller is actually one type of pump pump category okay so propeller or your ceiling fan those are actually pump category and propeller will be delivering fluid at very high velocity so that high velocity fluid is passing over your rudder this is your rudder okay this is your propeller these are blades actually these are blades

okay so propeller blades will be rotating at high velocity and the propeller will be connected directly to your engine or maybe electric motor okay this may be engine or maybe electric motor in pod podded propeller or separately installed propeller so those will be run by electric motor directly normally heavy machine heavy ships they will have the propeller shaft connected directly to engine through some different connection mechanism okay now propeller delivery fluid propeller those fluid will be passing through your it will be touching the surface of your rudder this is rudder okay now you turn the rudder let us say my rudder airfoil is like this my propeller is here okay now propeller initially it was let us say completely on the axis same as same axis as your propeller rudder and propeller axis same then in that case vehicle or vessel will be moving in straight direction that you are not turning but in certain case you have this one propeller axis is here now rudder you move like this okay rudder angle you made so what is happening actually you change your flow angle okay fluid angle is here this is your angle of incidence angle of okay you can remember your aerodynamics angle of incidence changed so because of angle of incidence change so fluid is going straight but your propeller angle change so because of that fluid will be forcing in this direction the propeller okay so force it is getting so because of the force propeller will be reacting right so when propeller is reacting the vessel will be moving when rudder is turned so it will have certain lift force

and one force will be the drag force drag force will be along the chord line this is chord line okay this is lift force lift force this is drag force so drag force will try to reduce your speed of vessel while lift force will be giving the leftward or rightward motion or port side or starboard side turning so that way the prop the rudder is helping to turn your vessel right or left okay okay i started early so that i can leave quickly because i have passport appointment so about 11 30 i'll try to finish 11 11 54 okay 12 30 around i'll leave okay So, attendance sheet is there that we will complete. So, now I will discuss about two pumps actually basically. One is flush pump, one is radial pump.



So, these two pumps is used for your steering gear mechanism. So, what are these two pumps? These are actually reciprocating type pump. These are reciprocating type pump. okay so responding pump means like you have one cylinder you have one piston and you will have valve mechanism so when piston is moving forward and backward fluid will be entering in one port and it will be exiting another port so this way you are delivering and this is actually fixed volume pump if you have rotational speed fixed then same amount of fluid will be delivered every time and volume flow rate is low but pressure development will be very high so this is high

pressure low flow rate pumps this is a reciprocating or positive displacement pump displacement pumps okay these are so positive displacement pump will have different types one will be reciprocating type one will be rotary type so many other types also possible now so this swash pump it is also reciprocating pump but one beautiful thing is that it will be giving constant pressure this reciprocating pump like piston cylinder is there one time moving up down it will be delivering pressure they say when it is moving up pressure is delivered pressure develop pressure develop okay but when it is fluid is sucking it's not developing any pressure when you're delivering only developing pressure so you are getting discontinuous pressure But if you have multiple cylinder then actually discontinuity will not be there. You have 2 cylinder, 3 cylinder, 4 cylinder. Many cylinders are there.

Actually average pressure will be almost constant. So this swash type pump they are having such mechanism. So this is called swash pump. Swash pump is like this. It is also piston cylinder arrangement pump.

So here I think you can see in camera. Here pistons are there. If I rotate it, this is shaft. I am rotating this one. Shaft rotation and you can see this black dots, holes are there.

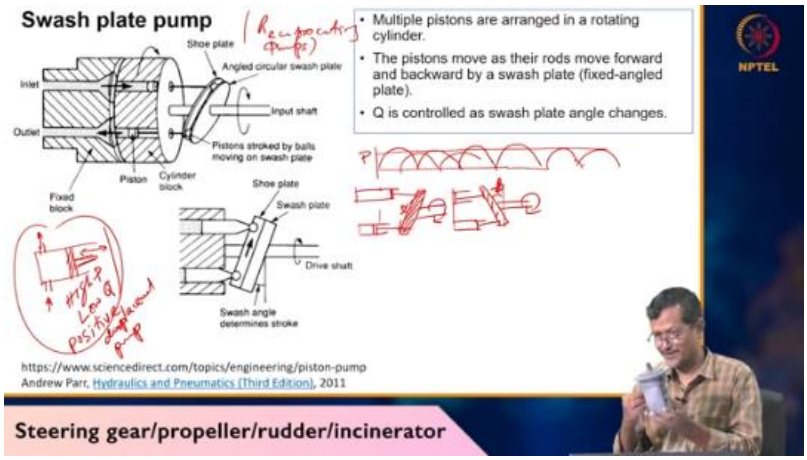
Here hole is there. Hole will be changing location. You see this hole size is changing. okay i am rotating slowly and you see whole size changing this is cut out view and if i have complete pump then whole size means actually cylinder and piston this one is piston and hole actually cylinder if i rotate it the piston is moving up and down actually okay you see slowly so you see small hole is there and when i am moving towards this direction hole size increasing you see this whole size increasing if i rotate in opposite direction again whole size going down okay so this is called swashbuck several pistons are there and one inlet port another outlet port is there this is inlet port maybe this is maybe out outlet port so water will be sucked or any fluid will be sucked and will be delivered there

and all the piston and cylinders this cylinder and piston they are connected to this inlet port and outlet port so you rotate it and the cylinders will be delivering one by one when it is creating bigger space that means it is taking fluid from your source water source and when this the size is going down let's say this direction i am rotating going down so that means she is delivering okay so gap is created let's i'll draw like this i have one swash plate and this is called swash plate one slant plate is there okay slash slant plate is called swash plate okay so it is arranged such a way that let's say you see the rotation swash place also rotating this is also rotating actually this swash plate this slant plate is also rotating and this plate and this both are rotating okay and both rotation is creating reciprocating motion of the piston okay you can see right not visible visible right piston so because this Schwarz plate this angle plate and this plate the piston moving up and down and you are getting continuous flow almost continuous because several pistons are there okay it is creating continuous flow but why this type of design one beautiful thing is there i will explain so let's say this is my swash plate i am making this a swash plate and i have one system piston here piston here okay piston will be here and this is this one i'll make same size maybe okay you see this my picture on a slide and you see this wash plate is here this one here piston is here if i rotate piston moving up and down now you see this one this created one angle alpha now when it is rotating the situation may be like this also piston is here

piston here piston rotating this is rotation rotation you are giving so in this case piston here in this case piston here okay you can see this alpha beta maybe i can put some other values maybe beta you can see alpha convert to beta when i am rotating okay so that time you see the piston location changing so volume piston going to near top dead center to bottom dead center okay so that way normal piston pump working right like your cycle pumper also working the same way moving up and down so this is also giving moving up and down so one thing easier here if i change the angle of this flash plate my volume flow rate will

change okay let's say alpha initially i make zero you rotate it alpha means this angle this angle right if i make the both are zero instead of angle make parallel to this plate so in that case piston will not move up and down piston will not move up and down so there will be no flow but if i make maximum 45 degree maybe so that time piston will be touching top dead center to bottom dead center so volume flow rate will be high so only changing my stress placed angle i can change volume flow rate instead of changing my other parameter if i change if i can change my such plate angle my flow rate will be changing okay so this mechanism is used for your stray steering gear mechanism okay so they'll be changing small part they'll be changing flow rate so accordingly your rudder angle will be changed okay how much volume flow volume you are giving based on that your rudder angle for 35 degree 10 degree 20 degree so that angle will be changed okay so this is called swash plate pump okay and it is continuous flow and it will and variable flow rate just you change this one you can change your flow rate so you can create variable flow rate just rotate slowly you can see this piston moving up and down okay so this side i am rotating so slowly the piston gap is created this it is sucking fluid okay

sucking fluid means it will be sucking then when it is moving towards this one again it will be delivering also in one rotation suction delivery suction delivery will be happening okay i have a swash plate connected to okay now i have this is coming like this then now this side also having this is passing through some bearing okay and it is giving rotation so this bearing bearing is here and it is giving rotation okay this is called coupler and output link this is output link output link and this is input okay so this will be having reciprocating motion or piston will be here and okay reciprocating motion will be here so fluid will be taken in fluid out fluid okay now draw this pump and stretch plate so especially we connect to the input shaft and this is here so that means my piston will be here piston is connected to this this side here piston will be connected to this okay and the center distance is d this angle is alpha so this is drive shaft and this is called shoe okay uh now cylinder block this is called cylinder block cylinder block d is called piston circle diameter this is called piston circle diameter



dia D and Y number of piston Y number of piston N piston speed Qth theoretical flow rate theoretical flow rate and A piston area Piston area means this area. If this is small d, so it was pi by 4 d square. Now alpha offset angle. Alpha is called offset angle.

Alpha offset angle s piston stroke length. Many terms are there in pump lecture also. So, if some term unknown. So, you go to the pump lecture I think week 2 or 3. So, there also you get definitions.

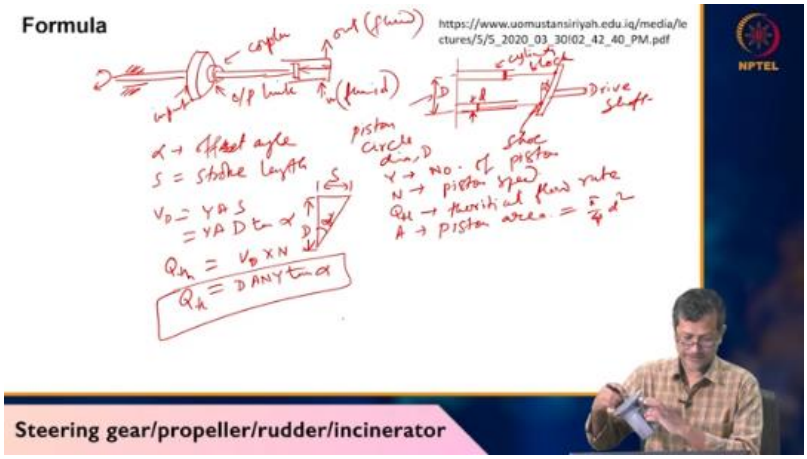
So, VD volume flow rate equals YAS equals YA D tan alpha. It is like this. Alpha is there. D is here. okay and this is s stroke length so y a s s equals d into tan alpha okay now theoretical flow rate v n v d into n so d a n y tan alpha

Okay, this is your theoretical flow rate. If there is any leakage, then you can get actual flow rate. So, then you can calculate percentage also. So, normally we will ask to calculate theoretical flow rate. But if I give you actual flow rate, then you can calculate the percentage also.

Okay, so you can see again the pump. This is first plate. This is angle alpha. Okay, and stroke length means if I rotate one time, how much piston moving from top to bottom. So, that is your stroke length.

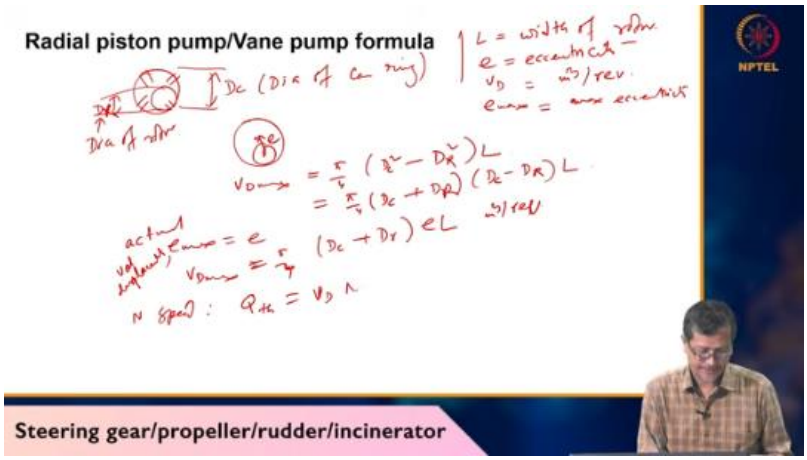
and area area means piston top cross section area and in number of piston number of piston is here one two i think four or six pistons are there in this case uh and what are the theoretical fluid number of piston speed n n means how what is your rpm okay so that is your n and ac stroke length you already got so theoretical flow you can calculate dny tan alpha so remembering also easier danny so another called helle shaw pump helle shaw pump this is also again reciprocating type pump the different mechanism they use but basic funda is that reciprocating piston type pump or positive displacement pump okay so they

have given the name helle shaw pump helle shaw pump is an axial radial piston pump okay so how it is radial you have one shaft is rotating this one you see this picture and slide and it is connected to your pistons okay so different pistons are there and the shaft is eccentric so because of the centricity shaft will be moving inside because of moving your piston will be moving forward backward okay that way you are getting flow rate okay this is inlet this is output out uh this is outlet okay uh there is piston cylinder arrangement so flow rate is small n nas small is number of pistons so number of pistons here how many are there one two three four five six six pistons are there in this picture a piston area piston area means like this is your piston piston area okay this is your area okay s piston stroke length uh n is driving drive speed so how much rotation is there so normally it will be rpm okay so if it is rpm then you have to convert into rps so how how much how many times it is rotating per second okay so for that uh we have formula also uh let's say this is my outer diameter this is the centricity of shaft okay my pistons are like this



So, maximum dia DC and this dia is DR. So, DC is dia of cam ring. This is called DC dia of cam ring. The name they have given dia rotor. This is dia of rotor L width of rotor. okay how wide it is there eccentricity eccentricity means one circle another circle is there big circle center is here small circle center is here this is eccentricity okay the centricity vd pump volume flow rate meter cube per revolution

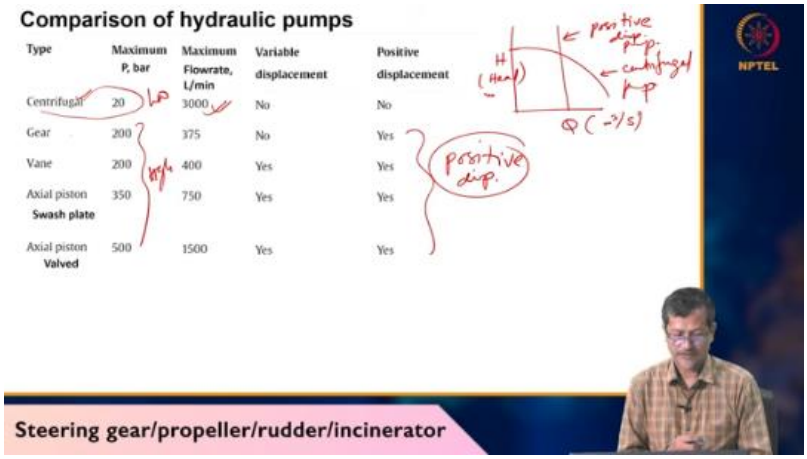
and e max maximum with centricity max okay so v d max equals pi by 4 d c square minus d r square into l equals pi by 4 d c square plus d r square d c d c minus dr capital R I think so I'll put capital R L now actual volume displacement E max equals E actual volume of volume displacement displacement when E max equals E. So, V d max equals pi by 4 dc plus dr El meter cube per revolution. So, when rotor speed n. theoretical flow rate VDN because pi by 2 DC plus DR EL meter cube per minute.



So, this is your formula. So, if any problem simple problem is given you should be able to use this formula and you can solve. So, already we know that different types of pumps are there and the pump pumps are having their own characteristics. So, normally positive displacement pumps will have vertical h q you can remember a head or pressure development head in meter normally flow rate meter cube per second or liter just you see different unit will have different values but i am trying to write in si unit so this is positive displacement displacement pump and centrifugal pump will have this type of characteristics entry

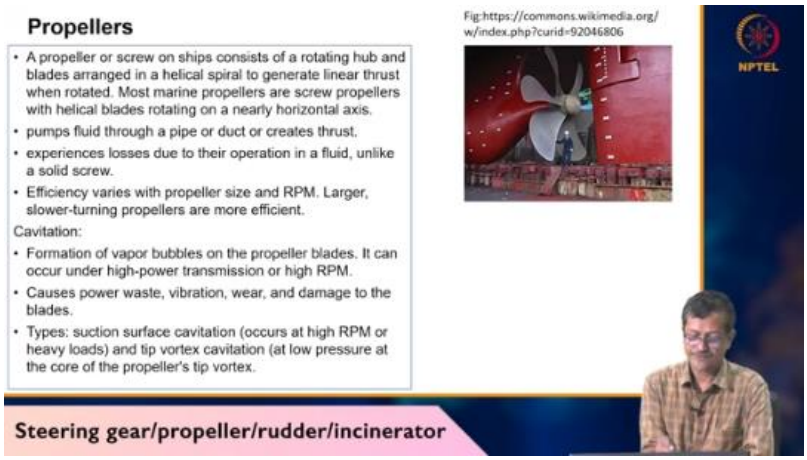
okay pump so centrifugal pump you can see it is developing maximum head at within certain limit so it cannot cross more than that limit for certain flow condition speed but positive displacement pump you see hq curve it is completely vertical that means it can develop any amount of pressure okay so you can see that centrifugal pump it is having maximum pressure 20 bar and flow rate higher 3000 while other pumps gear vane actual these are actually positive displacement okay this positive displacement pump are having lower flow rate but pressure is higher you can see this pressure is high but while this one low okay but flow rate you can see centrifugal pump is higher flow rate but your positive discharge pump has lower flow rate comparative to centrifugal pump. now centrifugal pump you cannot use for all the applications because of pressure limitation in certain cases you need very high pressure but volume flow rate lower is okay so in that case you can use a centrifugal pump very high pressure and lower volume flow rate you can use positive decision work but in certain cases you need very high flow rate pressure may be lower okay the centrifugal pump okay but many cases multiple staging of centrifugal pump also helps okay so based on your application you have to see which pump will be applicable for your case for example very high pressure development for your engine so in that case centrifugal pump may not work you can go for positive displacement pump so positive

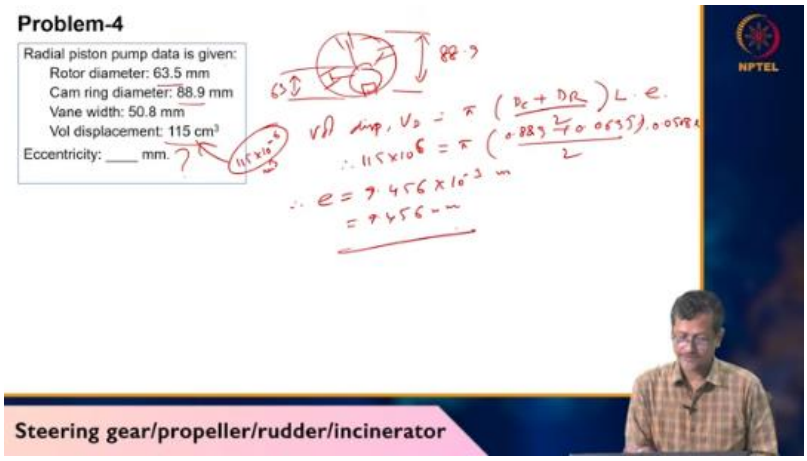
displacement pump many types are there for example your steering in a mechanism they are using like swash pump or radial pump many cases oil and gas industry they will be using gear pump vane pump also there okay



So, based on your application, you have to select. So, let us see one simple problem. A radial piston pump, radial piston pump I already told, the eccentric shaft is here and pistons are here like this. And you are delivering fluid. So, radial piston pump data is given, rotor diameter 63 and cam ring diameter 88.

so this is 63 cam this is 88 cam ring 8 this is 88.9 or 19 and this is given 63 and when width 50.8 so when width is 15.8 given volume displacement also given 115 the centricity you have to calculate okay center switch center distance so volume displacement pi dc plus dr by 2 l into e. So, this value will be 115 into 10 power minus 6 and this minus 6 because you are converting 115 to meter. So, 115 into 10 power minus 6 actually meter cube then pi And values are DC 0.889 plus 0.0635, 63.5 millimeter is given and divided by 2 and L value 0.0508 into E. Therefore, E is coming 9.456 into 10 power minus 3 meter equals 9.456. five six millimeter so this is your value so this type of simple problem i can ask in your exam i will go through some basic fundamental of propeller thing in other course you may be studying in details of about propeller but here just to introduce propeller what is this how does it work a propeller or screw on a ship consists of rotating hub so hub will be rotating this is hub okay hub will be connected to shaft and shaft will be run by your





engine okay these are called propeller blades i already told you okay so most marine propellers are screw propellers with helical blade rotating on a near nearly horizontal axis in many cases some slanted axis also possible It pumps fluid. So you can see it pumps fluid or delivers fluid and the reaction force will be driving your vessels or vehicle or ship. Propeller expression losses due to their operation in fluid. Efficiency varies with propeller size.

A larger size propeller will have higher efficiency. A smaller size propeller will have little bit lower efficiency. And propeller will be experiencing cavitation. So cavitation already you may be knowing. So due to cavitation there will be vibration, noise and system failure.

So, you have to avoid cavitation. So, very high speed or very high load you have to check whether propeller will be cavitating or not. If it is cavitating then you have to take action or you have to change material or you have to change design. or you have to change your vessel speed or condition so that system can be safe and be running for longer period. Marine incinerator.

So another equipment will be there on your ship called marine incinerator. A marine incinerator or a ship incinerator is used on board ship to burn solid waste. So because of Marple instruction, you cannot dispose your solid waste or oil or anything in the water. So what you have to do, first you have to burn and then you can dispose. That's okay.

So, it will be decreasing waste volume by 90% and it will be minimizing the space needed for waste because when you are going for long shifts or lots of passengers are there, waste will be very large. So, in that case, you burn and reduce your waste. And again, if it is producing combustible burnt product or gas, harmful gas, so that also you have to take care. okay and those the high temperature gas can be used for power generation also in many cases so manually operated or automated possible manual operated in works loading waste ignite it and monitor the combustion process automated system just you put your waste and it will take automatic action and normally international maritime organization imo has the regulation and you have to follow that regulation and here one incinerator picture is there here all the waste will be burnt inside one closed vessel and then you control the the pressure temperature and whatever gas it is producing you have to control so thank you very much for today's lecture next day we will start new topic thank you.