MARINE ENGINEERING

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Lecture46

Lubrication/Cooling

good morning today we will start lubrication and cooling system. ic engine needs lubrication and cooling system. Lubrication will be removing or reducing friction. friction will have giving negative impact on your system.

Friction will be giving lots of heat generation and system can have wear and tear and system can fail finally. So lubrication system will be reducing all this negative impact to your engine and it will be increasing engine life and your normal smooth operation of the system. Well, cooling system, cooling system is related to high temperature. Engine when combustion is happening, temperature will be very high. When temperature is very high, system can fail.

So, in that case, you have to reduce the temperature as soon as it is getting generated. So, that engine, that melting point of your piston, cylinder or other part of the engine will be within, melting point you cannot change. Rather, you can reduce the temperature so that system can be safe. So lubricate lubrication system if you go to any petrol pump you can see lots of companies they are selling their lubrication system lubricating oil castor oil and many other oils are there. So many time we say mobile oil in common term mobile actually one company name so mostly they sell sold as a mobile product and like lubricating will be looking like this yellowish color but after certain operation it will be blackish.

So why it will be blackish color also I will explain. Okay and for book you can follow internal combustion engine by R K Rajput and several different internal source also I have taken for common discussion but mathematical and numerical problem I will be taking from this book only so that it will be easier to follow a certain book but for a basic understanding you can go through any YouTube video or any normal Google search any document that will be okay. So, lubricating oil so first you draw the IC engine. Your

crankcase, cylinder, piston and connecting rod and your crank. This is piston, piston will be moving up and down and combustion will be happening.

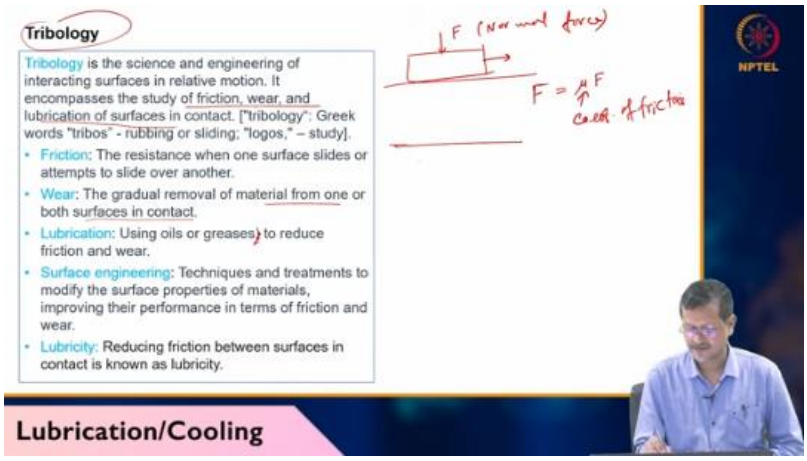
Then lubrication, lubricant will be here at the bottom part of your engine casing. So what happens when piston is moving up and down, the crank is rotating. Because of crank rotation, this lubricating oil will be splashed. It will be soaking this wall. When it is soaking this wall and piston moving up and down, actually piston will be lubricating the whole cylinder system.

When this whole cylinder is getting lubricated, so friction will be reduced, system will be safe. other lubricating system will be there in your bearing systems and other gearing or your gear mechanism, bearing mechanism. So, those things we will discuss later when we will discuss about power transmission system from engine to propeller. So, engine to propeller power transmission is not so easy also at the same time I can say it is not so difficult because we have one shaft and shaft will be transmitting power from engine to your propeller but there will be gearing mechanism there will be bearing systems there will be lubrication system those will be I will be discussing later but presently I am focusing the lubrication system for your IC engine internal combustion engine systems only so whenever you are talking about lubrication system so first term comes in mind tribology tribology is a science and engineering of interacting surfaces with relative motion

Stribolism means you are reducing friction and you are helping machinery to live longer or to consume less amount of energy. So tribology encompasses the study of friction, wear and lubrication of surfaces in contact. You see the term tribology, Greek term tribos means rubbing or sliding surface and logos means study. So two surfaces sliding, let us say piston is sliding inside cylinder, so sliding or maybe your shaft rotating, so that is also sliding actually over something. So the sliding surfaces should have less friction.

Higher friction means high heat generation and system failure can occur. So, friction you are learning from your plus 2 books possibly. Friction you know that one surface is here, another surface you want to slide this one force is F, then frictional force will be mu into F, F or N you can say. Sometimes we say N means normal force. mu is coefficient of friction sometimes we say coulomb's friction now when it is static it is not moving so frictional force will be zero but when you are trying to move so that time you need very high amount of force that is called friction force so that friction force can be reduced if you have lubricating oil in between so why lubricating will be helping we will discuss later

so tribology means it will be discussing about friction wear and lubrication so friction means resistance when one surface slides or attempt to slide over another where the gradual removal of material from one or both surface in contact okay so lubrication using oil or grease using oils or greases to reduce friction and wear so i will explain how these things happen okay surface engineering this will be also part of lubricate tribology because whenever you are moving one body over another or you are giving rotation rotation means friction is happening okay so if surface roughness is there let's say initially smooth surface you are taking another surface you are taking like rough like this so rough surface will have more friction so more friction is more energy loss okay so that surface engineering also you have to study So lubricity, lubricity the definition is reducing friction between surface in contact is known as lubricity.



Lubricant or lube, so sometimes they say lube or lubricant. Lubricating oil or if you go to any petrol pump they will say engine oil. So oil normally in scientific term we say oil means any high viscous fluid, petrol, diesel also that is oil. But petrol pump those people will be assuming oil means lubricating oil. Lubricating oil is a wide array of products composed of several base chemical and additives.

Here two chemicals are used. Base chemical, base hydrocarbon will be there and additive. Additive will be there. That will be changing your viscosity. That will be changing your friction.

Let us say any corrosive fluid is there. Some part you have to protect from corrosion. So you have to add certain additives so that corrosion will be reduced. Viscosity you can change. Many other properties also you can change using your additives.

So crude oil distillate fractions are the most commonly used lube synthetic or plant-based lubricant oil also used used so plant-based or synthetic sometime those will be biodegradable sometime it will be less harmful to your environment so many people will be using this plant-based or meantime water-based lubricant also there especially for your engine propeller area their ceiling is required okay is turn to ceiling so in that case people will be trying to use water-based lubricant So, base will be water and some additives will be there because the lubricating oil will be going to water or lubricant will go to water because it is nearby propeller. So, water splashing will be there continuously. So, that water will be entering into a lubricating system and lubricating oil or lubricating fluid whatever is there it will go into water.

So, that will be harmful for your environment. So, in that case you will be using water based lubricant. But for your IC engine system water based lubricant or synthetic or plant based lubricant will not work because the temperature is very high. So, in very high temperature condition or very high pressure condition. So, all water based or plant based system may not work.

Plant based system is like let us say normal cooking oil you can give right that is also can be acting as a lubricant. But at high temperatures, that fuel or that oil can be broken. The carbon chain will be broken. So, the lubricating property will not be there. But if you have certain lubricating oil which can work for high pressure, high temperature, so those can be used for specific application.

For example, your gas turbine system, for your IC engine systems or many machines where high pressure and high temperature is required. Okay. Generally, lubricating oil comprises 80 to 90 percent petroleum hydrocarbon. So, I am writing HC means hydrocarbon. HC means hydrocarbon.

I am writing HC means hydrocarbon. Hydrocarbon means carbon particle is there in hydrogen and it is creating hydrocarbon. long chain hydrocarbon normally lubricating oil will have long chain hydrocarbon long chain hydrocarbon it will have more lubricating property high viscosity and high boiling point but if you have short chain hydrocarbons say methane ethane these are Such as methane, ethane, these hydrocarbons will have short-chain hydrocarbon and it will have low boiling point. So, at lower temperature it will be boiling and viscosity will be lower.

So, this cannot be used for your lubricating application. So, long-chain hydrocarbon will be having that property of lubrication. So, 10 to 20 percent additives will be provided to

increase specific property of lubricating oil. So, base oil, example will be mineral oil, vegetable oil or synthetic liquid can be used. And additives can be any additives which will be increasing your maybe viscosity or other properties.

So, non-liquid lubricant also there, powder such as graphite powder, carbon, carbon will have different forms, right? So, graphite is one form. So, graphite can be lubricant for heavy machinery, which is carrying very high amount of load. So, in that case, liquid lubricant may not be helping. So, in that case, you have to use solid lubricant.

So, graphite, PTFE or polytetrafluoroethylene, molybdenum disulfide, tungsten disulfide, those things also can be used as a lubricant. And in your cycle or bike, normally grease will be used, semi-solid. Okay. But for your ice engine cage casing, liquid lubricant will be used. Because in that case, solid you cannot use, because you have to splash continuously.

Solid will not get splashed. Okay. You cannot use your synthetic or vegetable oil based or water based lubricant also. This is high temperature also will be there. Okay.

So, at high temperature, you cannot use that one. And because continuously it will splash. Clank case. you have, so their continuous splashing will be happening. So, in that case, you have to use liquid lubricant.

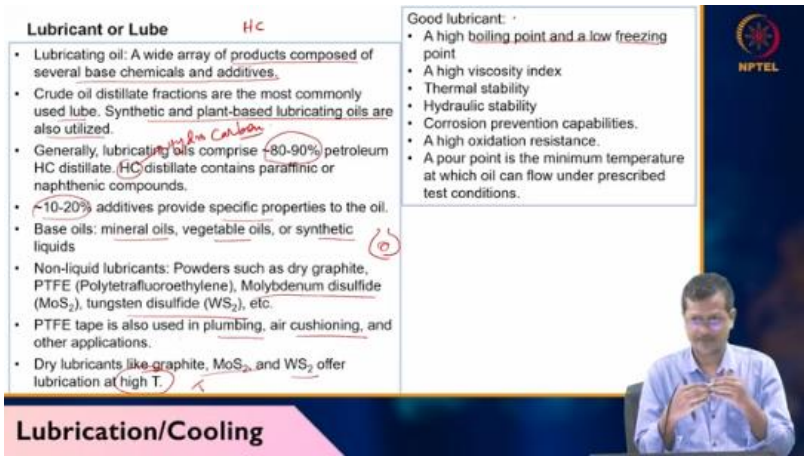
But graphite and other solid lubricant also can be used for different machinery where high load is there. So, PTFE tape is also used for plumbing and air cushioning and other applications. Dry lubricant like graphite, MOS2, WS2. So, here I have given molybdenum disulfide or tungsten disulfide. can be used as a high temperature lubricant.

So, instead of temperature term, I am writing everywhere T. T means temperature for my own notation. So, good lubricant property will be having high boiling point and low freezing point. Why high boiling point? For example, your moving, your ship is moving from one point to another point. Let us say Chennai to Alaska or very cold country.

So, their freezing point So, your lubricant should not get frozen. So, freezing point should be higher and boiling point also should be higher. So, at high temperature it should not get boiled. For example, your IC engine boiling, IC engine temperature, engine temperature will be going more than 1000 degree centigrade.

So, in that temperature it should not get like carbon particle not get broken, carbon, I mean the hydrocarbon chain will not get broken, carbon particle you cannot break. Because this

is atom but the chain of hydrocarbon that should not get broken at high temperature or it should not get burnt. So high boiling point should be there and freezing point should be lower so that temperature going down down but still it should be in liquid form. High viscosity index should be there. So, viscosity should be higher normally.



Thermal stability, so it should be stable in thermal. Hydraulic stability should be there. Corrosion prevention capability, so you have to add some additives so that it should help not to corrode the system. High oxidation resistance must be there. A pore point is the minimum temperature at which the oil can flow under pressure.

So, higher pore point also should be there. So, whenever you are lubricating any system, let us say one surface is here, another surface is here and you are pulling it. Friction force you are giving and this normal force you are giving here. Let us say your piston is moving up and down or maybe you have that shaft is rotating. Crank shaft also is rotating and crank shaft while rotating, it must be within certain bearing.

So, crankshaft will have certain load continuously when piston is moving down it will have big load. Again piston moving up that time load will be reduced. So, continuously cyclic bearing will be facing. So, that time if it is not lubricated properly system will fail. So, two surface normally whatever we see any surface in naked eye like this computer screen or table.

So, it will be like smooth, but actually if you take one microscope it will not be smooth like it will have lots of regions and valleys because surface roughness. This is called surface roughness. Now, if you give lubricant in between. So, what will happen lubricating feel will be created in between the surface. So, rough surface, upper one also you see using some microscope, electron microscope or anything, you get rough surface.

So, bottom surface also having lots of rough surface, upper also having lots of roughness. So, because of roughness, it will be trying to lock actually each other. So, whenever you are breaking the lock and you are trying to move so lots of energy will be lost heat will be generation plastic deformation will be happening okay then things will be moving and when it is moving a plastic from happening micro particle also will be removed from solids okay that is where okay and if you have lubricating oil what will happen it will create a layer in between two surfaces and will not allow of locking so then smooth operation will be there so lubricating oil one layer is stick here another is sticking here and both two layers are there and lubricant layers will be moving okay so these both metal surface will not slide each other other lubricating oil will be sliding each other their layers will be sliding so that will be giving less friction okay

b y capital hydrostatic lubrication so thin film will be created it is called thin film lubrication so between two surfaces a thin film is created and you are moving and thin this is called thin film lubrication another is called hydrodynamic and hydrostatic lubrication hydrodynamic means when during rotation of shaft or system is moving so that time one layer will be created that is called hydrodynamic lubrication and hydrostatic means when system is not moving but still it must be lubricated is called hydrostatic lubrication okay so hydrostatic lubrication pressure is applied to keep lubricant placed between surfaces okay so many machineries where very heavy load is there so in that case you create one extra pressure here and you pump lubricating oil here okay when you are pumping you are forcing two surfaces to be separated okay one surface is here another surfaces they are trying to touch and very force is there because of force the in between the lubricating layer is there that will be getting removed so you try to give some force forced high pressure fluid in between these two so that they will try to maintain certain gap okay so hydrostatic lubricant and hydrodynamic surfaces motion and bearing design pump okay can okay so when hydrodynamic means system is moving automatically the pressure may not be required okay so automatically will be getting lubricated so we call hydrodynamic lubrication because there will be many other type of lubrication system available but normally we are interested in fluid thin film lubrication or hydrodynamic lubrication okay and so whenever two layers are there it will create So, whenever you have dry friction, friction will be higher.

Dry friction means you are not giving lubricating oil or lubricating any semi-solid or solid lubricant. Friction rate is high. But whenever you have any lubricating, lubrication in between two surfaces, although they have unevenness, unsmoothness or roughness, your

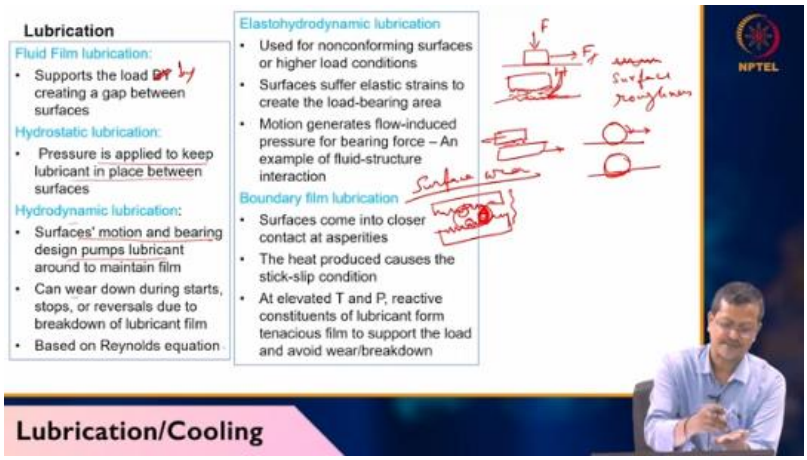
friction force will be reduced. Friction force, moving one or rotating one body over another, that force will be reduced because of hydrodynamic lubrication. So, there are two types of lubrication, basically one will be sliding friction, one moving here, another moving here, in between you are putting lubricating oil, another will be rolling.

Rolling means, although it is not sliding directly, so what is happening when rolling, deformation, micro deformation is happening. How micro deformation will be happening? So, when you are rolling, so this flat, bottom surface will be little bit flat, you can see this one little bit change the upper rolling surface and bottom also little bit change okay I am enlarging or maybe micro level modification will be there so that plastic goes because of the small plastic deformation they will be using certain amount of energy okay but if you have lubricating oil so those the oil will be giving some separation in between so it will be deforming less so that less deformation means less energy consumption okay less heat generation So, any rolling surface also, some surface is rolling and you are giving some lubricating oil, friction will be reduced, your system life will be longer.

Fine? Lubricating, rolling, surface wear. Surface wear. So, this term I am saying again and again, wear will be happening, wear and tear. What happens?

Let us say I have one surface like this. another surface is like this because if you take microscope you will surface like this now you have any sand particle here solid stronger particle so stronger particle what they'll do they'll try to break maybe this one reaches or this peaks will be broken when they're trying to move over one another okay and this sand particle will be breaking the small small particle Or the small particle will be obstructing again, it will be breaking another particle. So, that way wear will be happening. So, some material will be removed from both surface or one surface.

So, they are called wear. So, abrasion wear occurs when a hard surface, loss of material due to hard particles or hard perturbance that are forced against and move along a solid surface. So, in between particle is there, hard particle and it is forced and both surface are trying to move. So, in that case some abrasion will be happening, some material removal will be happening, that is called abrasion. So, friction and heat generation.



So, in sliding operation, the energy dissipation must be there. So, if energy is not getting dissipated, so heat will be accumulated. In many systems, if heat is getting accumulated, it will be reaching up to melting point of the two surfaces, one surface or both surfaces. So, in that case, local galling operation or local welding operation will be happening. What is happening like this?

You have one surface, another surface is here. Now, both surfaces are touching. Let us say surfaces are touching like this. Now, we are trying to move, there is relative movement in between the two surfaces. So, now heat is getting generated and now there is no heat dissipation option.

There is no air blast or any heat sink available nearby. So, what will happen? So, heat will get accumulated somewhere. So, when heat is getting accumulated, so that area melting point, the metal melting top metal or bottom metal any metal can be melted or both metal can be melted when melted and you are trying to move so they will be frozen again whenever there will be any lower temperature zone will be coming so that melted metal will be frozen again or solidified again when solidified again it will be creating small local welding this is called galling okay so this is a local oil welding

so because of local welding your system can fail again because again when system is trying to move you have to break that small welding so that means you need more energy so that finally system will fail right so So, let us see what is written there. The energy transformation involves converting mechanical energy into heat or internal energy. The exact mechanism varies between sliding condition. Typically, it involves plastic deformation leading to heat generation near the surface.

The resulting surface contact temperature from frictional heating significantly impacts the tribological performance. Tribological friction wear, the science of friction wear is called tribology. So, tribological performance will be reducing and can lead to failure. in sliding high temperature influences the friction and wear behavior of the material and lubricants so temperature is high then you have to consider separately whether temperature melting point is important whether your lubricating oil or leave oil temperature is important because level can be broken the chains will be broken and it will produce more carbon and lubricating property will be lost okay temperature gradient around contacts can cause softening and shear failure of the near surface material.

So, that is softening. Then finally welding also possible, small welding or galling I told already. So, friction in sliding is attributed by microscopic property asperity contact creating junction that form and break during sliding. That is why high temperature known as flash temperature occur at various contact spot point. So, various small contact point high temperature will be there.

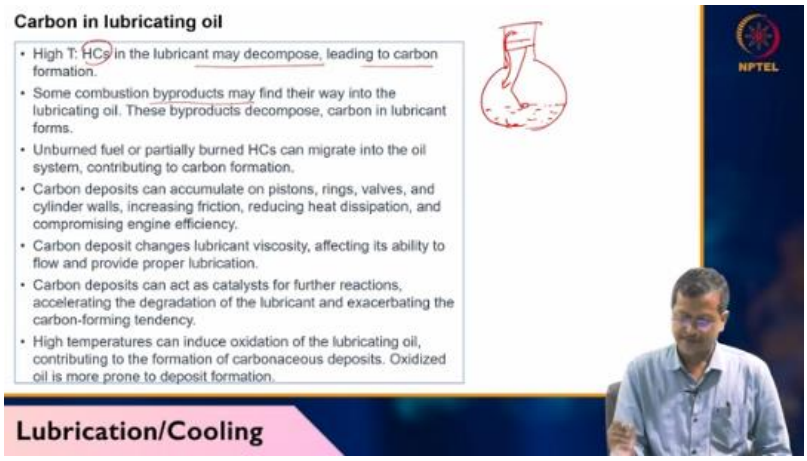
So, those will be creating small welding. In lubricating sliding surface temperature affect durability of the lubricating oil lubricating viscosity mu means viscosity. So, normally we use the term viscosity that is why mu as symbol for viscosity we use. So, carbon in lubricating oil. So, if you have bike at your home or your car at your home, so after 6 months or 3 months or 1 year operation, you go to shop and they will be removing your lubricating oil from the system and you see the black thick lubricating oil and they will be putting yellowish color lubricating oil again.

So, why it is becoming black and thick? The reason is here. At hydrocarbons, lubricant volume is hydrocarbon. Base fluid is hydrocarbon. So, hydrocarbon is the lubricant may decompose leading to carbon formation.

Some combustion by product. So, because piston cylinder is here. Piston is here. So, some burnt gas also can leak and it can be deposited. So, some burnt gas also can be

exiting here or carbon particle can be deposited here okay and this lubricating oil also can be broken and it can produce also some amount of carbon and another is that when friction is happening between piston and cylinder although you have lubricating oil everything but still there will be some wear and tear small amount of that also will be getting deposited here okay so all these things will make this oil thick okay so when it is thick almost blackish color now we are trying to splash so it will not get splashed so it is not getting splashed so your cylinder is not getting soaked cylinder is not getting soaked means your temperature

will be rising in friction will be higher so that's why you have to change your lubricating oil regularly okay if you do not change regularly then system will fail if there is any temperature sensor in your system then system will stop working because temperature is going up beyond certain limit then your IC engine will not start or it will be starting within few second it will getting stop it will get stop all again. But if you do not have that sensor then what will happen the temperature is very high then certain time it can burst or it can fail right. So, unburnt fuel or partially burnt hydrocarbon can migrate into the oil system.



Oil means lubricating oil system contributing carbon formation. Carbon deposits can accumulate on piston, ring, valve, cylinder valve, increasing friction, reducing heat dissipation and compromising engine efficiency. So, so many negative effects are there. So, you have to change your lubricating oil from your bike regularly. Carbon deposits accumulate

change lubricating viscosity affecting its ability to flow and provide proper lubricant. Viscosity means resistance to flow. So, thick fluid will have more viscosity. So, whenever it will try to create splash, when crank is rotating, it will try to create splash. So, that splashing will not be possible because high viscosity is there now, more viscosity.

Certain viscosity required, but because of carbon and other particle deposition, your splashing will not possible will not be possible so friction will be increasing further friction increase further means heat generation further will be there so temperatures if you have any sensor here then sensor will stop your sparking or engine will be getting stopped but if you do not have sensor then it will be disastrous high temperature can introduce oxidation in lubricating oil contributing the formation of carbonious deposit oxidized oil more prone to deposit formation okay So, whenever you are running a engine, IC engine, especially IC engine, internal combustion engine or maybe gas turbine engine also later I will discuss.

So, all these engines, you must check lubricating oil properly. If lubricating oil lost its viscosity, you become more thicker, then you have to change it.

So, lubricating oil system, so normally you will have one piston here and crank is here and rotating. So, sorry this is not looking good I will draw properly this is also not proper now it can rotate smoothly inside. Now, what will happen for there will be one cylinder lubricating box cylindrical lubricant lubricating box okay so from there you have to inject your lubricating oil so specific arrangement for higher large engines for normal small engine it may not be there for heavy machinery large engine you may have extra lubricating oil system okay so lubricating oil service tank

So, engine cooling, what happens? You have crankcase, you have piston. Several times I told that this temperature can go more than 2800 degree centigrade or 2000 degree Kelvin. But your aluminium piston, if you are using aluminium, then piston melting temperature will be like 650 degree centigrade about. So, very low.

So, then what you have to do? You have to remove heat as soon as possible. So, for that you have piston liner will be here. Now, all around there will be one water jacket. Water in.

So, you take low temperature water. It will be circling all around cylinder. It will take lots of heat. Then it will be going out. Now you have seawater.

You can use seawater for cooling. But normally for corrosion issue you do not use directly seawater for engine cooling system. So for that what you do? You take seawater and you take another fresh water or low salt water. So this is low salt water.

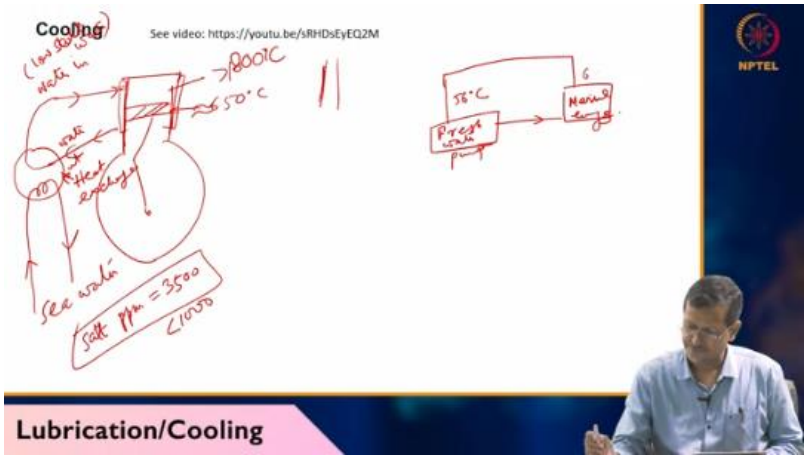
So low salt water how do you get? You filtrate or use you use desalination technique to reduce salt okay so the low salt water you take and that will be circulating continuously okay it will be circulating but you have to reduce heat somewhere okay so whenever you are reducing heat you take sea water this is heat exchanger So, seawater you are taking just for reducing temperature of fresh water. The fresh water you are circulating around your cylinder.

This is seawater. So, seawater cooled engine. Although seawater is not directly touching your cylinder, they will avoid because seawater is very much corrosive. Seawater is having salt. PPM is...

bus per million ppm 35000 not degree 35000 about ok but our drinking water ppm will be like less than 1000 ok but for your machinery application your ppm can be much lower also because you don't want salt corrosion or any deposition around this piston cylinder because whenever there is any metal surface If you have any debris or deposition, deposition means maybe mud or some other contaminant will be there. So, that will be reducing heat transfer rate. So, that is also not allowed. So, seawater directly if you are giving around cylinder.

So, that will be creating some deposition or some marine growth something around the cylinder. So, that will be reducing your heat transfer performance. So, that is why fresh water will be circulating all around and seawater will be helping fresh water to reduce temperature. Fine. So I have one picture here.

I'll draw. So marine engine, let's say marine engine and freshwater pump. Pump is here and it is going like this. so 56 degree centigrade for example 68 degree centigrade okay now I have one heat exchanger here heat exchanger means it will be It will be reducing heat from some fluid and it will be giving heat to some other fluid.

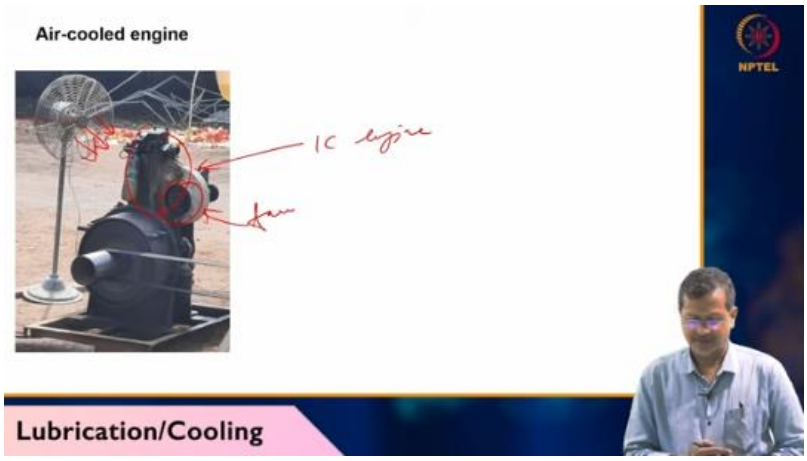


So, my marine engine is here. So, marine engine will be getting cooled because of this circulation of fresh water, but this heat is taken by seawater. So, seawater will be passing through this heat exchanger that will be reducing my fresh water temperature. This is simple line diagram. Any drawing you can do and you can explain how things are working.

That will be okay. So, air cooled engine. So, here that picture I have shown also before. So, this engine is not having any water jacket around. So, this is, there is IC engine actually.

And this air, air blast is given to engine. So, that will be reducing, that is reducing. There is also one fan. This is also fan. So, both fans trying to take heat from engine and it is reducing the temperature of the engine.

So, small engine may be possible using fan like automobile engines. Automobile engine air cooled actually. Motorcycle engine air cooled. Motorcycle engine you cannot put like big water tank. So, whenever you are driving the bike, so automatically air will be entering into the engine and it will be getting cooled.



But some other engines, bigger engines, they need water cooling or some other arrangement which will be reducing the system temperature. Thank you very much for today's lecture. Next day we will discuss about some mathematical calculation. Thank you.