MARINE ENGINEERING

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Lecture72

Gears

Good morning everybody. We have already started the power transmission system topic. So within power transmission system we have seen we have one propeller. Propeller is connected to a tail shaft. Tail shaft.

This is propeller. Propeller blades. These are actually blades. So if you can see the turbine lecture or pump lecture, there will be blade. Blade will be transferring energy from fluid or to the fluid.

And blades will be fixed on hub or boss. Then tail shaft will be passing through your stern tube. Then stern tube, there will be sealing arrangement, bearing arrangement. So stern tube, it will have seal. plus bearing because bearing will be holding the load but seal will not allow water or oil to pass through it.

Then this tail should be connected to several intermediate shaft. Then there will be one thrust shaft or thrust block. Okay, so thrust block will be taking thrust block Then there will be gear mechanism. Then there will be another shaft going to engine.

Again this shaft will not be hanging in the air. There will be certain bearing arrangement every time. Let us say this is one shaft. This is another shaft. So every time there will be some bearing arrangement.

This will be holding the shaft. in horizontal position if we do not have bearing then shaft will be sagging or it will have vibration and other issues shaft will have properly aligned so that there will be no vibration and there will be no extra load on bearings or other systems And when we are talking about gearing system, gearing normally it will be gear reducer. Why gear reducer? Engine speed normally like say 1000 rpm and blade speed let us say 100 rpm.

So, 1000 rpm engine speed, blade speed 100 rpm. So, you have to reduce the speed otherwise system will not work. Your propeller will be too high speed that at that high speed there will be cavitation and other issues. So, you do not run propeller at very high speed rather 100 to 100 speed will be optimal. and engine speed can be 100 to 2000 3000 rpm also possible so based on your engine speed you have to select your gear or gearbox then you have to reduce the speed then that uh it will be transferring power to shaft shaft will be connected to a thrust block thrust block will be taking all the axial loads

Then it will be passing through several bearings. There will be intermediate shaft. Then it will go to tail shaft. So tail shaft will be connected to your propeller. So propeller will be hanging actually to be creating one cantilever.

So when it is creating cantilever that means some bearing it should be passing through certain bearing. So bearing normally it will be sleeve bearing or muff bearing or journal type bearing. So ball bearing will not work because whenever a heavy load is there and very high speed is there. In that case, we do not use ball bearing or roller bearing. We use journal type bearing.

Journal bearing means like there will be no ball or anything like one hole is there and a shaft is here. This will be rotating inside. So, there will be no axial load holding capacity. It will be holding only the radial loads and it will allow rotational motion. Axial motion also possible.

So, the journal bearing or slip or muff bearing will be there here by tail shaft. So, that is that will be passing through strand tube. Strand tube will have sealing arrangement also. Sealing arrangement is required because your lubricating oil or lubricating system it will not allow water to enter into engine space or the lubricating oil or grease whatever you use for lubricating or reducing friction of the bearings. So, that should not go into water.

If it is going to water, then there will be pollution issue and Marple will have strict instruction not to pollute water. Now, we have discussed several items for the shaft design, key design and other designs. Now, we will see the gear part. So, gear in top left corner, you can see one picture, big gear is there and one small gear is there. Okay, so big one can be driving gear, one be driven gear.

So based on your requirement, you can make one driving, one driven. So for example, if I make this is driving, this is driven. So driving gear is having less number of teeth. Because diameter is lower. Okay.

So teeth is related to diameter. So if you are increasing diameter number of teeth will be increasing. And you cannot with diameter change you cannot change teeth shape and size. Because there is a big gear is having certain shape and size of teeth. And small gear is having different shape and size.

Then the teeth will not fit into the cavity of the other teeth. Okay. So one gear is having teeth like this. Another gear must have same shape and size teeth. Then it will be mating properly.

If it is having, let us say one is very small you are making, one is very big you are making. So, big will not enter into your smaller cavity area. So, that mating will not be proper. So, that is why the gear, when two gears are mating, their shape and size must be same. And one is driving gear and one is driven gear.

And diameter is related to your number of teeth. So, larger diameter means larger number of teeth. Again, small gear here in this picture, you can see small gear driving big gear. So, small gear rotation will be higher than big gear. How can you tell that?

Like 2 pi r if you can calculate or you can see one rotation of small gear, big gear will take maybe half rotation. So, several rotation of small gear will have limited or lower number of rotation on big gear. In opposite way, you can think also like big gear can be driving gear and small gear can be driven gear. So, whenever you need to reduce speed or increase speed, you can use gearing mechanism. There are some other mechanism also we will discuss.

So, gear is the rotating machine part having cut teeth or cogs which mesh with another tooth part in order to transmit torque. So, it is transmitting torque only. This is transmitting torque. torque or power or power okay so if you want to know more about gears then there will be lots of books available even NPTEL lectures also available available machine design one NPTEL lecture some NPTEL lecture like go pinup okay so go peanut npt lecture uh one professor he has recorded so you can look at that also for more details because in mechanical and other departments they need more detailed study in your case you have only few minutes to study on gear mechanism they will be doing how to cut gear

what are the different profiles and different small small angles how much angle should be there what will be how to reduce friction in designing material selection so in detail study they'll be doing but in our case we don't have that much of scope so we'll be going for limited study so that you can understand what is here how it is working how power is

getting reduced uh not power your speed is reduced but whenever you are transferring power from one gear to another gear your power is not changing okay because power equals t into omega So, here omega changing, omega means 2 n pi by 60, n means rpm, rpm of a gear or shaft. So, omega means radian, unit is radian, T is torque, P is power. okay so power will be fixed we are assuming this 100 efficient bearing so this power is fixed your torque is changing means your omega changing means torque will be changed okay store can omega can be changed but p is not changing normally these gears will have efficiency 98 99 okay so very high efficient gears also available and in normal calculation normally we ignore this losses in gear So, let us say number of teeth in T1, this is T2, number of teeth in gear 1 or small gear equals T1 and gear 2.

This is gear, I can say gear 1. This is gear 2 equals T2. So, gear ratio is T1 by T2. This is also speed ratio. Okay.

So, if you are changing number of teeth, your speed also will be changing. Okay. Now there are several types of gears. Okay. You may have seen spar gear.

Spar gear means this is spar gear. The shaft, two shafts are there. Okay. And gear placed here. You see this gear teeth are parallel to the shaft.

Okay. So my shaft is here. My gear is here. My shaft is here. Okay.

Gear teeth are parallel to the shaft. Okay. spar gear. And another is helical gear. In helical gear, what is happening?

Gear tooth or teeth. Teeth are not parallel to the shaft. This is helical. This is spar. So, two spar gear can meet, but one helical, one spar also can meet, but you will have different criteria for that.

And another is rack and pinion type mechanism. Rack and pinion type mechanism actually we are using for a wave energy converter. You may have seen this we have one rack and we have gear teeth actually here and I have one pinion. Pinion will also have teeth like this. If I move pinion up and down it will be touching the rack.

Rack means straight line gear. Infinity radius. So this is infinity radius. right infinite radius uh in infinite this is better term uh so when you wrote you move the rack up and down right will be rotating so that rotating rotation we use for our wave energy harvesting purpose okay so that is called rack and pinion mechanism rack and pinion rack and pinion mechanism another is meter gear meter gear is first you have to know the bevel gear bevel gear is like this shaft is here and teeth are like this okay so bevel gear if two bevel gears are mating actually your shaft angle will be changed if you see spur gear two shafts are parallel okay shafts are

shafts are parallel and teeth also parallel. But in helical gear shafts are parallel and teeth making angle with shaft axis. So, in bevel here shaft is here, but another shaft can be like this, intersecting shaft, And your teeth may or may not be parallel to the shaft axis. Warm gear.

Warm gear you see one gear is having longer teeth and another smaller teeth. This is called warm gear. Another internal gear. Internal gear is like this. Teeth will be here inside.

Inside there will be teeth. And you have gear here also. One gear can be rotating inside another gear. So that will be internal gear. and the screw gear okay so there are different types of gears are there the most common will be like spar gear bevel gear rack and pinion i am already using for my wave energy converter so there is these are different types of gear and they have different applications also for example my wave energy converter i have to use only rack and pinion now i cannot use spur gear similarly like whenever you have uh two shaft you are changing uh direction so in that case you have to use bevel gear spur gear will not work for example if you see truck if you see back side of truck

there will be like some mechanism like this okay then wheel is here wheel is here okay from backside if you see this one there is one gear system actually so this will be rotating continuously and wheel will be rotating wheel will be rotating okay so shaft are perpendicular to each other so in that case you can use bevel gear okay spur gear you cannot use so similarly curve wheels also will have bevel gear and In many cases, wherever required, you can use your gearing mechanism as per requirement. So, whenever you are

talking about gear, you should know a little bit gear nomenclature also. This is taken from Peter R. N. Child's book. So gear teeth I said specific shape will be there.

So you can see this one curve is there, another curve is here, another curve is here. So these are connected. This is flat. This is face width. This is called face.

Then it will be coming like left side and right side. This will be completely identical. Then there will be curve. Then it will be almost straight. Then curve.

Okay. So that other gears will be coming and it will be meeting like this. Okay. Exactly it will be fitting. Again it will be sliding up.

Okay. Then it will be having reduced friction and it will not be locking also. Like say if dimension is different. Let us say one gear is having this dimension or the teeth is here. It will be meeting properly.

But if it is very thin then it will not enter. Rather it will be locking here. It will give you higher friction. So shape and size must be same. Again opposite also must be happening.

For this one is having gap and this is your gear. It should not be too wide or too small. It will be exactly matching. So both gear teeth whenever you are designing one gear teeth just replicate for both the gears. That way you can make same teeth for both the gears.

But dimension can be different. When diameter is different, your number of teeth is different. You cannot make fraction of teeth. 2.5 teeth you cannot make. You have to make 2, 3, 4, 5, 6, 7, 8, 9.

So let us say 10 centimeter diameter, 20 centimeter diameter. So 20 centimeter diameter gear will have larger number of teeth. okay smaller diameter have lesser number of teeth your gear teeth size you're not changing when you're selecting two machine gear but let's say you are selecting two small small mini small like toys gears will be there so they'll have small gear their teeth also will be identical but small both cases okay so normally gear diameter when you say we say the pitch circle diameter center to this almost middle this diameter is called pitch cycle diameter gear diameter implies that one okay speed reduction gearbox so i said like your engine will speed higher propeller speed lower so you have to reduce the speed so how to reduce the speed you can see this right side picture i have copied from one website iqs directory so you can see this on big gear let's say one Then it is connected to 2, then 3, then 4.

Gears
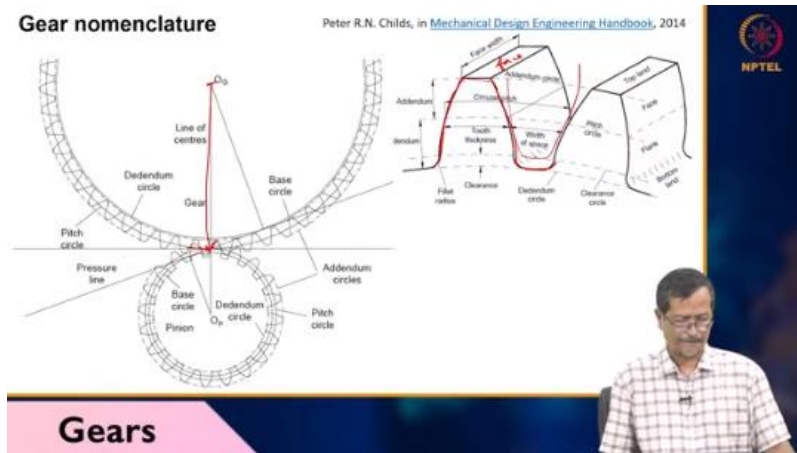
If I can draw in my, my one gear is here, big one. So, big one is connected to smaller one. This is smaller gear connected. So, small gear is connected to yellow color, that one, bigger one little bit. Then yellow color one is connected to another small one.

Then shaft is going. So this is incoming start driving. This is driven. I can make one. Here.

You can see the driving shaft is driving gear 1. Gear 1 giving rotation to gear 2. Gear 2 and 3 connected same shaft. So their rotational speed will be same. 2 and 3 on same shaft.

So rpm of gear 2 and gear 3 will be same. And gear 4 is connected to gear 3. okay so four will have different speed than three okay now you can see speed direction let's say gear one if it is clockwise so driving shaft is rotating clockwise means gear one will be rotating at clockwise direction okay so gear two will have different speed and rotational direction will also be changing okay so gear two it will be anti-clockwise Then gear 3 will have rotational direction anti-clockwise because it is directly connected, right? So, this is also anti-clockwise gear 3.

But 3 and 4, 3 driving 4, that means 4 direction again changed. So, 4 direction become clockwise. That means driving shaft direction and driven shaft direction become same. Now, how much speed we reduced? Can you calculate?

Let us say Z1, Z means number of teeth, number of teeth of teeth in gear 1, Z1 equals 26, Z2 teeth in gear 2, 43, just some guess value I am giving, Z3 So, now what is the gear ratio? This one gear ratio 26 by 43 and if input shaft rpm input shaft 1200. This is driving shaft RPM 1200, what will be the RPM for driven shaft? So, RPM of 2, 1200 into 26 by 43.

Now, second and third gear, second and third both are connected. So, same RPM, same direction. So, rpm for 3, 1200 into 26 by 43, same, there is no change. And direction also

same, rpm 4, 20 by 43, you can see this one, 20 by 43, 1200 into 26 by 43. okay so it is becoming 337.47 so this is my final rpm okay so initial shaft had rpm 1200 final shaft become 337 rpm okay so this way you can reduce your speed from engine let's say one engine is having 1200 rpm so you can get 337 that means if your propeller speed is 200 required so that means high then again you have to change your gear sizing

Number of teeth you have to change. Maybe 1 to 2 or 3 to 4. Some ratio you can change so that you can manage less than 200 rpm. So if you have one gear, some gear can be like this one smaller, this one bigger. Some cases I will have smaller gear connected to bigger gear.

Let's say 1, 2, 3, 4. So multiple gears I can connect and I can change my speed from 1 is to 100, 1 is to 100, any speed I can change. In my laboratory if you go, initially we use gear mechanism for changing speed for my wave energy converter. Then gear mechanism like automobile gear changing mechanism so that we can check our system performance in different wave height and period. Later when we got VFD, so we replace the gear mechanism, we are using variable frequency drive.

So variable frequency drive is changing my wave height and frequency for laboratory testing purpose. Okay, so that sort of modernization also happening. So later we will discuss how this VFD can help in your propeller speed changing. So belt and chain drive. So whenever you are transferring power from one shaft to another shaft,

so you can have certain mechanism let's say coupling you are giving so the same speed you are maintaining but in some cases you are not maintaining speed or shaft can be far away distant from each other for example one shaft is here another shaft is here then direct coupling will not work so in that case you have to use some gearing and other mechanism okay so one mechanism is there your cycle chain your wheel axis somewhere and your pedaling access somewhere in that case you are using chain drive okay you can remember that okay so in that case you are using chain drive for example you have big cycle okay and you have pedal here and this one will be larger one this one will be smaller one and your chain is connected like this right and whenever you are turning in this direction this will be tight side this is slack slack side means the loose side because slack side okay and chain this is chain bicycle chain this is chain okay and chain will be passing over once wheel wheel will have shape like this okay so bicycle chain and sprocket so chain will have lots of holes and this pins or this teeth will be entering in that hole okay so that way you are transferring power in that case no friction allowed no no sliding allowed not friction if

chain is sliding over this sprocket is not you are pedaling but it's sliding it's instead of driving the wheel so in that case chain will be going away from the wheel okay so in that case you are not transferring power So chain drive can be used for motorcycle and other also.

But very heavy and very high speed machinery normally we do not use chain. We have gear mechanism or other mechanism. This chain is very heavy. Heavy will have high momentum. So failure rate will be higher.

And lots of connections are there. Lots of connections means failure rate also will be higher. So another option is the belt drive. Belt drive also you may have seen like this. Two pulleys will be there.

And pulleys will be connected with softer material. This is called pulley. Sometimes there is a sheave. So pulley 1, pulley 2 and again if it is rotating in this direction this will be your tight side. Maybe this is driving.

This is driven. Belt. So this is tight side. This is slack side. okay so one shaft is there another shaft is there one pulley is here another pulley is here pulley will be connected to belt and when one shaft is rotating belt will be transferring power to another pulley pulley will be connected to shaft another shaft will be rotating so that way belt and pulley drive will be working so one is flat belt drive flat belt drive means it is just flat cotton sort of belt and the v belt drive v belt means

The belt will not be completely flat. If I see cross section of belt it will be like this for flat belt. But V belt is like this. So V belt and your this pulley shape also will be like this. Okay.

So multiple V belt will be used. Multiple V Okay, belts. In flat belt, normally one belt will be used. For V belt, multiple belts will be used.

Okay, so V belt will have more power transferring capability. More power transfer. Okay, so lower power transfer. And some sliding or slipping also allowed in this case. And in this case you can see this driving pulley and driven pulley both are same direction.

If one driving is clockwise driven pulley also in the same direction clockwise direction. But in gear drive you have seen the direction changes. So, difference between V belt chain and gear belt chain and gear drive. So, belt drive slippage may be occurring large center distance like say belt one belt is here. So, center distance is large.
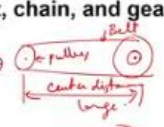
So, this center distance distance large. Speed reduction up to 1 is to 10. Okay, a pulley and belt are main component. This is pulley, this is belt. Okay, efficiency very low and material normally elastomeric softer material will be used.

Chain drive, so chain drive you are using already in your cycle bike, right. So, in chain drive also you have two sprocket and you have chain. Speed reduction once you change and chain this is not pain chain element like sprocket chain this is a basic element efficiency is very high 98 percent metals like stainless steel titanium nickel plated alloys that can be used for chain drive systems and for gear drive you have seen two gear will be meeting each other center distance is very low okay and gear ratio can be like 1 is to 40 very high speed reduction or speed increasing possible using your gear drive So main drive, gear element actually, efficiency can be very high.

They are saying up to 100%. 100% not possible anyway, but they say 99%. Material can be steel, bronze, cast iron, powder metal. For toys, you have plastic gear also available. Thank you very much for this lecture.

I will start next topic on bearings and seals. Thank you.