**Design of Mechanical Transmission Systems**

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**Week – 05**

**Lecture – 14**

Lecture 14_Automobile Gearbox: Shaft Design, Lubrication Selection and Method

Good morning, welcome back to today's lecture and we have been learn many things as move on into lectures. So we have discuss various aspect operation, transmission types, ray diagram, kinematic diagram, teeth calculation, gear failures, gear material selection and we have done the module calculation as well. Now we are going to discuss about the sharp design, its overall sharp design aspect and if time permits we will discuss about lubrication selection as well. And this is the problem, so if you look we can do the tick lot of tick, done the gear type ray diagram, kinematic diagram, suitable material for main for gears, we have done that, but we have not done for the main and lay shaft aspect this is yet to be done carried out bearing selection also need to be done, lubrication also need to be done and heat losses and gear box casing. So, these parts need to be covered in forthcoming lectures. The purpose of the shaft is the shaft transmit rotary motion one end to another, they can transmit rotary motion sideways by arrangement of gears pulleys belt sprocket and chains.

Loading can be different, the shaft generally subjected to combine loading they can have a torque, bending loads, and axial loads also. So all loads could fluctuate in shaft so shafts are designed using a concept of fatigue aspect which is the dynamic failure aspect we have to do the shaft design. Look at this, this is the typical transmission system you can see various shafts right this is represent what shaft, it is a cam shaft, this is your cam shaft you can see the various shafts and this would be your crank shaft right this is for crank shaft this is you can see that this is this is spline, spline shaft for from clutch to gear box input right. And you have this another shaft it is the lay shaft right finally, you will have a main output shaft.

Look at this in the transmission itself you are having so many shafts of course, one is missing is a reverse gear shaft the smaller one which is not showing in the picture. Even though the diagram shows the uniform diameter in actual application the diameter will be very different. You can see this is your typical, what is it crank shaft right, you can see the crank shaft and wherever you see the holes right you can see this is very shiny which is for the journal bearing aspect. So the lubricant will fall through that one and try to minimize the friction where that is one thing. This is your cam shaft right you can see the cam shaft.

So these are the lobes to operate valves for a fuel aspects inlet valve and outlet valve. In between you may have these are called journal bearing ok journal bearing this is the shaft and you have a ring. So that is why this is called journals usually they are the one will subject to very high wear rate wear and friction. So normally this type of portion where contact happens right those will have a higher hardness compared to in between this non contact area right even including the lobe also. So even though you shaft have wherever you have a journal bearing aspect that would be higher hardness ok compared to the rest of the parts in the shaft and this is taken from advanced vehicle technology by Haines Isler you can see this is a 5+1 double stage gearbox.

Double stage means input and output will be riveted gear aspect. So this is your reduction right this is your reduction and this is your shaft coming from your clutch this is the clutch and this is your lay shaft, you can see that the lay shaft is clearly given from there you will go it goes to main output shaft ok. So when you observe this diagram what do you think of it ok look at do not you think your lay shaft is much bulkier if look at this the lay shaft is much bulkier compared to your main output shaft because that is the one you take the entire power and transmit to the main output shaft, that is one aspect and also another question do you see the gear, I am sorry do you see the shaft diameter is uniform for the lay shaft and the shaft diameter is you can see that no right, it is a variable right if you have uniform shaft what happen uniform diameter of the shaft then the shaft dia is very heavy and mass also you know is going to be add which you do not want to right. So where out the load at that that portion alone you can maintain the diameter the remaining portion you can minimize it by doing that you are optimizing the shaft diameter at the load acting positions such a way that the volume and weight will be reduced ok and actually this is the synchromesh arrangement look at that so anything indicate in this symbol which is for the bearing aspect these are the bearing which are supporting the gear that arrangement you can see that and interestingly if you look at the lay shaft, the lay shaft kind of this is the bearing you can see that there is a nice taper roller bearing at the end right here also you can see the nice taper roller bearing is there so that means is like kind of simple supported beam arrangement usually the lay shaft is simple supported beam arrangement whereas if you look at your the main output shaft it would be like a overhanging it will be like a overhanging this here is it is a fixed somewhere in this position is fixed as you move on to the from left right to left there is no support right only the bearings are there right there is no support source it is kind of over hogging a beam or cantilever you can say that so that is the arrangement you will have ok. Let me ask one more question so what the loading aspect do you find any difference between the lay shaft as well as the main output shaft is it question is clear the loading aspect just think about as move on I will give explanation ok.

So you can see this is the shaft configuration automatic transmission the input shaft coming from your clutch then main output shaft the single arrangement ok and this is the counter shaft and of course you could see here this is the input shaft and output shaft sorry another input shaft and this is actually your lay shaft, it is all steps ok these are we will have a steps then we will move on to the shaft material generally material property must be such that the deflection must be as small as possible if you have a too much deflection that is not good so the misalignment will happen ok. So you have to careful by selecting the material deflection must be small so generally we will use for high young's modulus material and a particularly steel is a good choice normally you can go for a ANSI 1020 to 1050 called as a low carbon steel they have high strength and usually high young's modulus with the small deflection what do you what do you mean by ANSI what do you think of it ANSI just standard right what is that then we have other material ANSI what is ANSI what is ANSI 1340 to 50, 3140 to 50 so on 4000 series you can say that 5000 series and 8000 series which are alloy steels for highest strength purposes, if you have a operating corrosion environment then you have to use the stainless steel to minimize the corrosion effect right and you have to use a carburized grade carburized means you are strengthening the material by inducing carbon content right. So again the ANSI 1020, 4320, 4820, 8620 will be useful ok if the shaft is to be used as a journal, remember one of the shaft array I have seen wherever you have polished one with the hole that is will be will have a rubbing action against your shaft is there you have a ring also in a race so that will be rotating and make a contact so obviously wherever you have interaction is prone to wear so that is the reason when now we have a journal bearing arrangement we need to give higher hardness, now you know that that portion alone why we are giving a carburized grades right for higher hardness purpose. If properties only some of the above materials usually I will give the table C 10 which is taken from the Robert Norton right you can see this is taken from the machine design by Robert Norton you can see the all the material combination ASI or SI both are same depends on the condition rolled right hard rolled or cold rolled or quench and tempered keep on moves, you can see here. Then element on shafts ok so usually you will have bearings right the rolling element bearing and journal bearing steps on the shafts accommodate element such as bearings, sprockets, gears and pulleys, keys, snap rings, and cross pins to secure elements on the shaft to transmit the torque or prevent things from moving axially. So you have a shaft, remember when you have a constant mesh usually you need to fix the bearing first on top of that you will fix the gear right so by doing that you have to make sure that the contact between the shaft and bearing is be secured if it is not secured they may move axially either left to the right side that is not good so ok so they in that to avoid that you will have a circlip usually we say in bearings keys and snap rings should be provided to prevent any axial movement.

So as I said earlier the diameter may not be uniform so it will be keep changing so when you keep changing it will be step down right when you have step down you will have sharp corners that is not advisable, the sharp corners will act as a stress riser or stress concentration, so you have to take care of those things while designing the shaft diameter. So grooves or snap rings holes for keys and cross pins causes stress concentration so while designing we must consider this aspect stress concentration factor I am sure you would have studied your undergraduate course $K_s$, $K_f$ right those factors will come into the picture. Shaft stresses ok so you will have a main three important stresses normal stresses from bending aspect then you have shear stresses from bending then shear stress due to rotation torsion and you will get axial stress due to axial loads ok. Let me ask a question, if you have spur gear what type of load the shaft would experience sorry, bending and stress ok suppose if I give you instead of spur gear you are getting helical gear what do you expect you will have axial load also because the helical will have another load component which axial component that would act on the shaft so you have to be careful depends on the what type of gear you are going to use it, then based on the gear get the loads the different loads talking about bending and right the torsion as well as axial loads. Since the shafts have a high length to diameter ratio the stresses from the bending is negligible that is what we are going to do that when compared to shear stress from the torsion obviously the shear stress will be more crucial than your bending and bending loads you can this is standard equation

$$\sigma_a = K_f \frac{M_a R}{I}$$

$$\sigma_m = K_{fm} \frac{M_m R}{I}$$

$\sigma_m$ I just wanted to inform you what is $\sigma_a$ and $\sigma_m$ this is the main stress $\sigma_m$ is the main stress and $\sigma_a$ is the what yes amplitude right so that is the thing so this is a shaft is subject to fatigue load so you always think about with respect to sigma a and sigma m right $M_a$ is the alternating moment, $M_m$ is the mean moment, $R$ is the distance of the outer most fiber which we know that and if the $K_f$ and $K_{fm}$ are your stress concentration factors please refer for more details Robert Norton a machine design book they have all the information.

Similarly for torsion the standard equation right, τ equal to $K_{fs}$ into $T_a$ $R$ by j

$$\tau_a = K_{fs} \frac{T_a R}{J}$$

$$\tau_m = K_{fms} \frac{T_m R}{J}$$

$T_a$ is your alternating torque $R$ is the radius you know that radius of shaft and this is your alternating right shear stress and $J$ is the polar moment of inertia so that is you should know that and similarly for the mean shear stress you will have a $T_m$ the same thing you are only replacing with the corresponding torque and stress concentration based on the your the alternating as well as the mean aspect and this is for axial loads is very simple equation force by area corresponding your stress concentration factor these are the equation

$$\sigma_{axial} = K_{fm}\frac{F}{A}$$

and of course, since the this is what you call it dynamic load right dynamic failures you have to follow the equation remember this is where we are talking about your mean stress and this is the alternating stress and what do you $S_y$ means yield strength right S y is the yield strength $S_e$ means endurance strength right sometime you may have $S_f$ also what do you mean by $S_f$ fatigue strength fatigue strength ok and question is yield strength only for steels because your S-N curve will have a sharp knee remember this is S-N curve right and this is your number of cycles assuming that this is your stresses so anything will have a sharp knee right there you talk about your endurance strength aspect right this is for steels usually this is applicable only steels, for non steels, other than steels ok, the curve would be like this I am sure you would know these things your stress and your number of cycles so there we cannot find out exactly where is it so in that case you go for a fatigue strength so here the fatigue $S_f$ will come into the picture here $S_e$ will come into the picture this is major difference between steel and non steel material ok. Generally which one use preferred to use it is a Goodman equation or modified Goodman equation or Soderberg equation for the shaft design, it is depends on the material right whether is a what is the material say right no that is a steel is the material, I am talking about with respect to ductile material or brittle material based on that those things again will change. So, this again we need to brush your failure theories yeah so sorry, we are going to have a develop equivalent alternating a mean stress which is a $\sigma_m$ and $\sigma_a$ both we need today then using fatigue criteria either Goodman line or ellipse, depending on the type of the loading and type of material the shaft diameter will change ok and general consideration shaft design you can see that always the shaft should be as short as possible that is one thing you need to do that shaft arrangement should be simply supported beam rather than the cantilever beam then the stability will be much better stability would be much better. Allow sharp have a better stiffness by mass ratio and a higher natural frequency than the solid one, ok, hollow sharp is always better because you reducing the mass by reducing the mass what happen your natural frequency you can increase it.

So, have you heard about natural frequency when you operate shaft matching the natural frequency what do you expect resonance. So, you do not want to operate your shaft dia closer to the resonance. So, better to have hollow shaft will would be preferable keep stress riser I am talking about stress concentration away from the larger bending moment regions to and to minimize their effect with the providing generous radii and reliefs generous radii mean instead of having a step like this will have sharp corner better to remove gradually like this by doing that you are avoid stress concentration ok. Lower carbon steel may be preferred metal, since it is a higher stiffness which already I have mentioned that general general consideration of again continue deflection gear should not exceeding 0.127 mm it is a general thumb rule and relate to show between the gear axis should less than 0.03°. If you have a bearings when you say sleeve it is indicate about the journal bearings the sharp deflection across the bearing length should be less than the oil film thickness ok what do you mean by oil film thickness do you know how does the journal bearing operates how does the journal bearing operates any idea.

So, you have a shaft right assuming this is the shaft right then, there is a ring also will come into picture this is the thing by rotation right due to squeezing action the film will develop the pressure and lift the entire rod that is called nothing but hydrodynamic effect right. So, what I am saying the shaft deflection across the bearing should be lesser than the oil film if the deflection more than the oil film what happen you would not have a hydrodynamic effect. So, that is the information you know you have to pay attention when the part of the shaft used as a journal bearing. If non self aligning rolling element bearings are used then the shaft should be you can have little more allowance 0.04° non alignment means non aligning.

So, bearings there are so many bearings are there self aligning bearings deep groove ball bearing depends on the generally bearings for axial load, but we may have sorry I make a pardon generally bearings for radial loads application aspect if you have axial load then you have to take care of that. So, when now you have axial load, then the alignment will change to take care of that you can have a self aligning ball bearing, magnetic bearings and the deep groove ball bearing those things can be used such a way that it will give a little more fluctuation for to have a higher slope 0.04° . The first natural frequency shaft should be at least three times higher than highest forcing frequency expected in service obviously, this is to avoid any resonance right now you know that why we wanted to forcing to better to choose the hollow shaft than the solid shaft. So, this is the standard equation you can see that this is for the steel this is for the steel and this is for non steel. I am sure you know $M_a$ means moment alternating moment the corresponding torque and this is again similarly, for you can see this is $M_a$ for alternating and the corresponding mean thing you can see here.

$$\left(N_f \frac{\sigma_a}{S_e}\right)^2 + \left(N_f \frac{\tau_m}{S_y}\right)^2 = 1$$

$$d^3 = \left(\frac{32N_f}{\pi}\left(\sqrt{\left(K_f \frac{M_a}{S_e}\right)^2 + \frac{3}{4}\left(K_{fsm} \frac{T_m}{S_y}\right)^2}\right)\right) \; for\ steels$$

$$d^3 = \left(\frac{32N_f}{\pi}\left(\sqrt{\left(K_f \frac{M_a}{S_f}\right)^2 + \frac{3}{4}\left(K_{fsm} \frac{T_m}{S_y}\right)^2}\right)\right) \; for\ Non-steels$$

$N_f$ is nothing, but your factor of safety, $N_f$ is the for the shaft aspect factor of safety and interestingly look at $S_e$ is given endurance limit strength is given for the steels whereas, $S_f$ is given for the non steels these are the two equation it is given a torque constant and the bending is fully reversed. So, where do you expect torque constant and bending is fully reversed where do you expect right my question is where do you expect assuming that this is coming from the my input shaft, this is I am talking about right from there I will take the lay shaft this is my lay shaft moves on. So, the reduction will happen here the reduction is happen here remember I am talking about the lay shaft. So, what happen to the torque in lay shaft torque is constant right, how about your bending how about bending is it fully reversed or not? It is fully reversed right you are making the contact right after that you leaving. So, that means it is a maximum and 0.

So, right again going back it is a fully reversed fully reversed it is a fully reversed. So, this is for fully reversed remember I think you should know this, we heard about these things what is this arrangement what you call this arrangement and this is 0. So, what is this arrangement there is one more arrangement will come, there are three things fatigue load aspect right. So, this is which is the fully reversed here, second one right what about fluctuation there is a fluctuation somewhere else will go like this right. So, these are three arrangements.

So, do you expect gear is a fluctuated load no it would not be fluctuated right. So, it should be maximum to right. So, check all those things aspect, you would have studied Design of Machine Elements. Let me ask one more question now we know torque is constant and bending is changing, another question what I want to know this is your first gear assuming that the smallest pulley, this is the biggest one the largest one I am taking two example from the lay shaft aspect from the lay shaft aspect. So, torque is constant what happened to the stresses here what happens stresses this is your pressure right which way the load will act that is another question assuming this is my gear profile right this is my gear profile. So, if you do that normally you will have in this way right this is your resultant $F_n$ right this is your pressure angle if you divide you will have a two components one is tangential $F_t$ will come into the picture, the another one will come into $F_r$ will come into the picture, your tangential load is there and radial load also both together will have resultant load.

So, when you do the shaft calculation you have to split diameter into two components one is vertical component and horizontal component right I think this is the way you should have do the diameter calculation. So, what you have to do you take the $F_t$ alone $F_t$ will be horizontal. So, that is one thing will be there I am just for indicating alone then this one will be radial right similar way you will have one $F_t$ and one radial. So, what we have to do? So, whenever you do the calculation you take the particular gear right you take the particular gear and apply the load and try to find out what is the diameter and move on to the next where torque is constant, but $F_t$ will change right the $F_t$ keep changing $F_t$ and $F_r$ changing again that position for that particular gear you have to find out what will be the moments right then moment try to find the diameter. So, this is the way you have approach first do the split the shaft into vertical and horizontal and each gear right do the calculation and try to find out the moment then do the square root of I am sure that you know that then find out the corresponding diameter based on the constant torque and fully reverse bending thing.

I am just giving you concept because it will take lot of time to do the solve the problem. Now I am giving another information fluctuating bending and fluctuating torque it is a mean bending, mean torque usually we will use one message to find combined equal alternating mean stresses and use the modified Goodman line equation. My question is what type of loads would the main output shaft experience is torque is constant or variable? Torque is variable. So, variable means fluctuating right it is fluctuating that is one thing we got already from last shaft we know what is the happening to the bending also right the same thing would reflect to the corresponding the contact reaction forces. So, then obviously the main output shaft is subjected to fluctuating torque and fluctuating bending right.

So, again we have to calculate for the main output shaft individual diameter using this equation.

$$d^3 = \left( \frac{32N_f}{\pi} \left( \sqrt{\frac{\left(K_f M_a\right)^2 + \frac{3}{4}\left(K_{fsm} T_a\right)^2}{S_f}} \right) + \left( \sqrt{\frac{\left(K_{fm} M_m\right)^2 + \frac{3}{4}\left(K_{fsm} T_m\right)^2}{S_{ut}}} \right) \right)$$

This is equation valid this is ASME equation right is valid only for the fluctuating torque and fluctuating bending. The previous equation is valid for a constant torque and fully reverse a thing right. So, again you can you could see here M a you have to find out from your beam shear diagram and bending moment diagram similarly the other information and this $K_f$, $K_{fsm}$ all are related to your stress concentration factor please refer machine design book by Robert Norton is given the complete information.

Now, the standard size for the solid shaft, now you got the shaft diameter based on the calculation and if you get up to 25 mm ok even if you get a fraction, you can have increment of 0.5, if the diameter falls between 25 to 50 you can choose 1 mm increment and so on for 100 to 200 or 5 mm you can do that ok. Let me ask one more question we have done the model calculation we have done the standard diameter for the shaft. So, where is the check to whether our procedure is correct or not how will you check whatever we done the so far calculation how will we check is there any method to check whether whatever we done so far is correct or not there should be a way right yes or so yeah factor of that we are giving factor of safety right the all calculation we have chosen the remember pitting says for module calculation we given the $S_H^2$ =1.5, 2, 2.5, 3 we have done that similarly we have taken the frame factor ψ right a sectional support ψ different values and we got the relationship also that is finding the values the question is whatever we got the values or whatever we got answer or correct or not how will we check what is the way to check ok or how they are let within the frame within the design constant within the design limit ok.

So another way is deflection what we do we check with the deflection one is shaft deflection, if the meet they are correct if not we have to vary. So, this is given diametral pitch nothing but your reciprocal of module diametral pitch is usually used in US system whereas, in rest of the countries other than the US will use the module calculation ok it simply says number of teeth per inch that is called diametral pitch yeah. So, if you look at this the spur gear when diametral pitch less than 4 the deflection can have a higher then as you move on to the more teeth then the deflection reduced to 0.125, 0.05 ok. So, these are the one aspect deflection aspect from the shaft deflections and another one is rigidity aspect also you are going to select the bearing and going to fix it right from there what is the slope right. So, depends on the bearing you select the slope should be within this limit if not again you have to redesign your entire gearbox. So, there are tap head roller bearings, cylindrical roller bearing, deep groove, spherical, self-aligning, and uncrowned spur gears. So, within that, this is the self-annealing and spherical will take a more slope which can be adjustable that is most preferred. So, normally whenever you have a helical single helical or Herringbone, this type of bearings are much useful right yeah. Very importantly length of the shaft calculation is just for guidelines the distance between the gear and gear wall you should give a 10 mm the distance between the two adjacent gear you can give the 5 mm remember I gave I have shown the gear box right very close the gear box from the taken from machine design section you have seen it right.

So, there are the very close we have to maintain it. So, that the length can be reduced and of course, for bearing support usually will take a 30 mm, the bearing support means we talk about end of the shafts where you have to give the bearings right that will have a 30 mm and normally for dog clutch and synchronous arrangement right, we will give a 50 mm. So, that is of course, this are this is enough I am just one point I am missing your face width that is also will add up into your shaft calculation. If you have first gear the face width will be higher, second gear will be reduced and again when you go for a higher fifth and a sixth, right they will slightly increase those three need to calculate that is also will come into the picture right all together they will give you a length of the shaft right. Now, we will move on to the lubrication ok why would we need a lubrication first patient that is come into picture right yeah yes where and there ok.

See this is standard equation right this is your μ equal to F by W F by W is given

$$\mu = \frac{F_{max}}{W} = \frac{1}{2\sqrt{\frac{\tau_b}{\tau_i} - 1}}$$

ok I will give you simple example. I have a box which has the load W right resting on a one surface. When I try to move in the direction so the resistance will offer to me prevent this things. So, this is F tangential thing and this is the one which is this is the normal load W this is the reaction load R which is also W right μ equal to F by W is given that is the one thing is there. So, another scenario what I am going to do that same weight I am giving same weight inside I am having a small lubricant right. So, the same block is there let me ask in this condition what about my tangential force to move the block will be higher than the dry condition or lesser, lesser that is correct.

So, I am giving just this is just may be take it as a oil may be coconut oil fine. So, this is the F right and again you should know that my W is remain constant according to the definition coefficient of friction equal to μ equal to F by W, W remain constant ok. But just now we know that this μ oil right is lesser than the μ dry we can say that right $\mu_d$ we can say that ok. So, that can be possible if your tangential force reduced because the W remain constant is not it. So, why the tangential force is reduced that is the question I know simply by putting the lubricant it will improve the object to move easily right that is there, but question is how the lubricant influencing frictional force that is the question right.

So, just think about it we know this is the standard equation right. So, what happen your frictional force, have you heard of a shear stress even the fluid shearing between the as a layer you will have shear force the shear force directly proportional to the velocity grain

$$\tau \propto \left(\frac{\partial u}{\partial y}\right)$$

$$\tau = \eta \left(\frac{\partial u}{\partial y}\right)$$

remember very fascinating your μ is called coefficient of friction that is assistance offered by the body right this η is nothing, but coefficient of viscosity that resistance offered by the fluid can you see that relationship now right, the same but the phases are different right one we called as a coefficient of friction the other one is called as a coefficient of viscosity ok. Then you may ask question then what is the relationship can I write shear force equal to my tangential force by area you can do that right that is what happening. So, the you can replace τ by F by area anyway constant right assuming that. So, if replace it you will get everything with the based on the shear strength this is what happening.

In fact interestingly this is the equation, you can see that this is the coefficient of friction and this is the shear strength of the bulk material and i indicate about the lubricant film interfacial length ok. So, that is the ratio that is the ratio. So, higher the you can see that higher the shear strength of the lubricant what happened your coefficient of friction what happened, can you see the relationship now right my question is if shear strength of the film and shear strength of the base material equal what happened to your coefficient of friction, coefficient of friction will be very high as you keep on reducing when I reducing what happened right when you reduce this value right shear strength the lower the shear strength of the lubricant your coefficient of friction will be the lower this is the concept. So, the viscosity how the viscosity and the lower ways shear strength are related based on that your coefficient of friction also will be reduced this is the important thing please understand that and right. So, at then the lubricants you can have a different lubricants application based on engine oil, gear oils, turbine oils, hydraulic oils, metal working oils, in that again cutting oils, forming oil, then rust preventive that is also there then usually the base the lubricant we consider base oil which is mineral byproducts then base oil polymerize usually will have a polymerize as synthesis if it is a synthetic oil additives, that is the one will enhance the performance ok.

So, we will have a natural additives you can have synthetic additives and more importantly gear lubrication I wanted to talk about the purpose of gear lubricant is you need to understand above the what is the function is going to be provide, then properties of lubricant we need to understand, you need to understand what lubrication regime is going to be operate and selection of lubrication that is also important and what is the way you have to apply the lubricant when you say apply the lubricant whether you want to use the splash \method or bath method or using nozzle and spray the lubricant. So, that is also very important thing and how much volume of lubricant also required for the gear box right. So, the function of the lubricant is first reduce the friction, it should remove the heat in the contact and it should able to clean the lubricant- Detergency which is additive aspect and also it is reduce the noise by giving the dampening effect, it should provide the leakage aspect more importantly it should prevent wear aspect right. So, these are the main function of lubricant and of course, this is the kinematic viscosity yes. So, the viscosity is the important property for the lubricant ok.

So, I think remember I said earlier also depends on the speed depends on the speed if you have a high speed gear box you should go for the low viscous ok. And if you have low low speed then you can go for higher viscous higher the viscous the cost of the lubricant expensive ok. The reason is if you choose the higher viscous lubricant for higher speed application when you speed means. So, assuming gear is there you have taken the very thick coil if gear is rotating the thick coil for a few minutes what happen the shearing between the lubricant will give a internal heating right, internal heating will in turn reduce increase the heat the moment heat is increases what happen to your viscosity reduces when the viscosity reduces it is go back to lower level right. So, why do want to anyway by if you operate with gear higher speed automatically due to the internal friction it will reduce the viscosity. So, rather a spending or using high viscous lubricant better to use the low viscous lubricant. So, that is the reason. So, low viscous oil used for high speeds high pressure low temperature whereas, high viscous oil used for low speed, higher pressure, higher temperature. So, this what is standard equation

$$\vartheta_{4.0} = \frac{7000}{\sqrt{V}}$$

you should used to find out what is the required lubricant ok. So, this $\eta_{40}$ is a kinematic viscosity of oil centistokes at 40°C is 7000 by square root of V, V is the mean pitch velocity ok.

Remember you have so many gears how will you find out you can take the average pitch velocity of the shaft and try to find out and substitute you will get the V right. In fact, so again as velocity increases look at this as pitch velocity increases your viscosity decreases remember that is a thumb rule basic thumb rule. So, higher the velocity lower viscosity lubricants are preferred and if these are the thing. So, once you find out the viscosity and operating temperature excuse me once you find viscosity right and you know what is the operating temperature based on that you can select the lubricant what is you needed. So, normally we use for ISO VG grade, ISO is a internal standard organization VG means viscosity gradient.

So, it start from 46, 68, 100, 150, 200 so on depends on the operating temperature bulk temperature you have to select the lubricant. I think I will stop now. So, we will continue next class. Thank you.