Design of Mechanical Transmission Systems

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Week – 03

Lecture – 07

Lecture 05_ Automobile Gearbox: General Engine Operation and Transmission Types

So, very good morning. So, today's lecture we are going to discuss about automobile gearbox and you can see this is the learning outcomes. In the learning outcomes we will discuss about manual transmission mainly focusing only on the manual transmission. We are not going to discuss anything automatic transmission in this entire course work. Within that general engine operations and we will discuss about transmission types, the three transmission types and also a ray diagram which is another name called saw tooth diagram. Then gear ratio, what are the typical gear ratio available for the gears.

And you can see this is the typical gearbox, it is a manual transmission gearbox of course, this is actually a synchro mesh gearbox. So, before proceeding to the automobile gearbox, we will understand the difference between a machine tool and automobile gearbox aspect. So, what is the difference? So, maybe I will jot down here machine tool like this, machine tool GB gearbox we have, then this is the automobile gearbox. What is the basic difference between these two- automobile gearbox? The first point, the machine tool gearbox is fixed right, is a fixed stationary. So, this is fixed and stationary fine. How about in automobile gearbox is fixed, but mobile it has mobile ok, it has to move fixed, but mobile it should move yeah that is there that is one thing. So, any other information in machine tool gearbox, you can have how many speeds you want? There is no limitation about the speeds, there is no limitation about the gears ok, no limitation of no limit on number of gears talking about number of gears in the gearbox ok. But is it possible to have in automobile gearbox? No, it is a fixed you have a limitation. So, maximum you can go 7 plus 1, 7 is the forward FWD forward, the 1 is the reverse. How about the size? Size no limitation of size for machine tool right, no limitation on size, it is highly limited right, highly limited because you want to have a as smallest as possible. Another critical point, very very important point, the machine tool gearbox does not have any resistance, no resistance involvement, no resistance involvement in the machine tool gearbox. Whereas, you have resistance in automobile gearbox, existent of resistance ok. Normally, it called as a or called as a tractive effort, tractive, traction or tractive effort that is the term is called ok. So, obviously the automobile gearbox, automobile gearbox as small as possible ok. So, which is the big constraint, it is going to be big constraint, you have to make it, you want to have a speed also, you want to have a efficient and very effective at the same time, it should have a smaller size right. So, as you aware of that I said the automobile gearbox will undergoes a resistance right.

So, there are three different types of resistance, one is called air resistance. Remember, when you talk about air resistance, when you move on the road you will have air, you have to overcome the air, you have to overcome the air that is also need to be taken care of that. So, and another one is called gradient, gradient means when you move to the mountains what

happen that is also very resistance right. So, that is second one is gradient resistance, normally that is represent in terms of percentage, you will say percentage the gradient resistance 1%, 5%, 10%. The third is very important your rolling resistance assuming you have a coin right, you have ball, when you roll it on the floor what happen after sometime, it stops it automatically right without any effect, because it is a rolling friction. So, the vehicle has to overcome the air resistance, gradient resistance and rolling resistance. In fact, if you look at the corresponding R_a equal to rolling resistance is,

$$R_a = \frac{1}{2} C_d \rho V^2 A$$

Let me ask question, a C_d is nothing but your drag coefficient, ok. Then, ρ is the density of the air where and V is the vehicle velocity, ok. And A what do you think about A, yes projected area or else frontal area that is where it is very important, you have to have a very what you call is stream line aerodynamic right to minimize the air resistance. So, the frontal area or projected area that is very critical frontal area of vehicle that is clearly given. Thus, for the air resistance.

The second is a gradient resistance ok, when the vehicle moving on the slope the weight is coming to the picture and the angle usually the $\sin\theta$ ok. So, in terms of represent 5%, 10% or of the entire break power that is how usually measure.

$$R_g = W * \sin\theta$$

Normally W is called vehicle weight, vehicle weight sometime ok vehicle weight sometime is called GVW, can you tell me means is called gross vehicle weight. So, the total weight of the vehicle ok that is fine.

The other one is called rolling resistance right. Rolling resistance is,

$$R_f = \mu W$$

In fact, this is a rolling friction normally this value varies from 0.02 to 0.04 ok. Let me ask question of, which is the out of three resistance which one is the more higher value gradient ok. Let us see is it gradient or what let us see one by one ok. So, this is the total resistance called R_T,

$$R_T = R_a + R_g + R_f$$

So, as it said initially tractive effect the propelling thrust at the tire to the road interface to needed to overcome the road resistance right. Overcome resistance means the vehicle is on the road and you have to move right. If you want to move initially you need to overcome all these resistances that is why is called tractive effort usually measured with respect to kN ok. And interestingly if you look at the tractive effort this is given with respect to vehicle speed you can see the vehicle speed and the x axis then tractive effort is in the y axis ok. And look at as you move shifting the gears usually the low speed higher the torque right higher the effort the moment increase in the speed the effort of tractive will be reduced that is what is clearly mentioned you can see that the first gear shift second third fourth fifth and so on. As you move on to gear up the tractive effort is reduced ok. So, what is this area this area is called unobtainable energy here the energy is loses ok. I am sure you aware of that whenever you change the gear you have to press the clutch plate right press the clutch plate then change the

gear and engage. So, what is that mean when you press the clutch pedal even then the engine runs right engine runs. So, what happen that engine power is a loss right actually you are choking the engine then change the gear then after engage you release the engine. So, this is a loss of the power loss of fuel that is one thing is there ok. And interestingly this is the reference you can see that now I am giving you three different aspect this is a rolling distance as I said rolling distance $\mu * W$ right. So, μ is vary from 0.0 to 0.04. So, it is a constant this is the constant already you can see that, but how would this resistance air resistance R_a already the equation I have given which is your drag coefficient constant density constant frontal area constant which is variable your velocity square it is a velocity square. So, obviously what happen the curve will be supposed to be right parabolic. So, can you can you see that at the initial speed my tractive effort for air sense very less as increasing the speed what happen to my air sense will be higher right higher speed higher again tractive effort you can see that yeah that is the one thing is there. So, in fact this is actually the gradient you can see this is one in means is a 10% usually 10% you can see this is the tractive effort the gradient aspect you can see that what is happening is very high value the gradient one and it is a 20% ok one in five resistance is even higher. So, the gradient will be as we mentioned gradient is the highest tractive resistance among the three yeah ok. And now we will move on to the H curve performance the curve performance is given you can see that the exercise is given in the engine speed then we have a vehicle speed on the y axis multiple y axis you can see that and then you have a torque requirement here this is the torque requirement then the brake power this is your brake power and this is a specific fuel consumption ok and you can see this is the ray diagram for a eight speeds one two three four five six eight that is given. Now, interestingly this is your engine torque performance you can see that engine torque performance and this is your engine power for different speeds and this is your specific fuel consumption in automobile what happen we always focus on the specific fuel consumption because we want to have optimum fuel consumption ok.

So, look at this the moment if you go beyond two thousand rpm your fuel consumption is increases the moment you go less than less than 4500 rpm the fuel consumption again is higher whereas, for certain speed the fuel consumption is as low as possible ok. With that range we look at the torque performance as you aware of that we need a more torque because gradient is very critical when you go into the mountain area or slope or over beach passenger car it is fine what about the truck going to have a heavy load right. So, there a torque is very critical. So, you have to always choose the maximum torque the peak torque this is the peak torque ok that is a peak torque that is one thing the other thing is the power also is very critical right torque is critical the power also very critical ok when is the power is critical when you move on the plain road right. So, when you move on to the gradient aspect the torque is crucial. So, you have to make sure that the torque will be as high as possible when you move on to the plain road the power is important. So, if you look at the power. So, I cannot have a entire power at the same time I have to consider in the fuel consumption I can say my power maybe I can fix it up in this direction. When you have a maximum torque, your speed will be minimum right when you have maximum torque your speed is the minimum when you have a maximum power then your speed would be maximum speed N_{Max}. So, this is for engine application engine specification. So, this is engine specification. So, normally any vehicle right in automobile vehicle usually will mention the maximum torque and the maximum power for maximum torque it will have a low or lowest speed and maximum power is highest speed. So, in other way you have to operate your entire engine between this range ideally suppose to be that is a range you should

operate in if by operating that engine speed and engage in the gears for different vehicle speed remember that two different speed this is engine speed and this is the vehicle speed. So, then you can arrange you can obtain the speed of the vehicle you can see that this is called saw tooth because the shape is coming as a saw tooth aspect right. So, this has to be within this the range. So, this is the range. So, now we know why vehicle should operate between the two specific speeds one is high speed for maximum power low speed for maximum torque is it clear now.

So, now we will move on to the transmission as seen your videos you will see the sliding mesh manual transmission usually use a spur gear you have a constant mesh manual transmission will have a helical gear the third is called synchromesh manual transmission which will discuss in separate section and fourth is a epicycle gear box transmission ok. These are the four important things, but generally the vehicle will have a sliding mesh, constant mesh and the synchromesh. So, these are the most preferred arrangement ok. Now, we will let us talk about individually what is that about the constant mesh aspect a synchromesh aspect and sliding mesh aspect.

So, sliding mesh gear box the gears are missed by sliding the gears with the help of mechanism in order to obtain a different speed the help of mechanism which is already said gear selection mechanism that is a one it is simple and the oldest type of gear box mostly spur is used and disadvantage is the gear noise due to the type of gear obviously right very high noise that is what you are going to get. The difficult to obtain the smooth and quiet and quick change of gear without great skill of and judgment that means the driver should have a great maneuvering skills otherwise you will have a difficulty for smooth quiet and quick change of the things. Now we will move on to the constant mesh gear box. So, the main shaft pinion revolves freely on the bushes or needle bearings already I have mentioned that needle bearings ok and are all in constant engagement with the corresponding blade shaft wheels. When you talking about the wheels it is again it the gears it meaning to the gear also right.

The second thing is the gear operation is obtained by locking the respective gear to the main shaft by means of dock clutch. The quieter running helical gears and during the gear changing the noise and wear reduced by the simultaneous engagement of the all the dogs instead of only one pair of gear teeth as on the sliding mesh gear box yes. It is very smooth very smooth and quieter and in fact wear also reduced. The reason is it is a mostly helical gears when helical gear they will have a smooth engagement initially it will engage and the load is increasing gradually right that is what happen whereas, in the spur gear entire thing has to be engaged with this is the gradual engagement. So, that is the difference between a spur and helical.

In fact, so when we have a single helical gear is a disadvantage the reason is the helical will have a axial thrust component also right. So, with the single helical pinions the driving loads on the teeth cause an axial thrust which must be resisted by the thrust washer or shoulders or else corresponding axial thrust bearings otherwise that will give a imbalance. So, you need to have a when now use a helical gear I am talking about single helical gear you need to arrest or balance the axial force in the shaft by providing the corresponding rolling element bearing. Sometime this is a single one this is called single helical gear usually you can have a other type is called is a double helical sometime it is called herring bone. Herring bone means it is a fish when you look at the fish thus the bones will have a symmetric this is called herring bone type. The advantage is by having this kind of setup you can eliminate the other axial force you can eliminate axial force.

Now, I will bring back again the transmission aspect this is a engine from clutch the transmission you will have from there you go to drive shaft and the rear wheel. Now, you can look at again on the top view from the engine. So, you will have a one particular it is called engine speed up to clutch I will normally say that E engine speed from after reaching to the transmission to your differential this is called your N_g which is the gear speed. The other one is from the gear it moves to wheel rate the wheel speed W. So, E represent for engine G represent for gear which is for gear box and W represent for the wheel of automobile vehicles. Now, we will go three important aspects of thing the gear is for the gear box. So, you will have first is the i_g is a gear ratio i_g is the gear time is the ratio of the angular velocity of the input gear N_E to the angular velocity of the output gear N_G. So, it is also known as speed ratio of the gear time that is one important i_g. The second one is final drive ratio it is a after the gear box from to the wheel it is called final drive ratio. So, the differential unit of drive shaft is the ratio of the input velocity N_G to the output velocity of the N_W drive axle and drive wheels is called final drive ratio. So, you have two different ratios from the engine to gear box right from that is gear ratio from gear box to wheel is called a final drive ratio. There is one more term is called total drive ratio sometime is called overall ratio this is called i_t, i_o means overall both are same overall ratio right. You can see the overall drive ratio of a vehicle is the ratio between engine angular velocity to the drive axle and driving wheel angular velocity N_W is nothing but you know this is actually$i_g = N_E/N_G$ right drive by driven is not it. Then you have i_f it is a final drive which is again what happen N_G/N_W.

Now, I want to have i_t it is a total drive or i_o is over drive it is a product of both $\frac{N_E}{N_G} * \frac{N_G}{N_W}$. So, finally, you would expect that the total drive ratio is engine speed to your wheel speed is that right. So, these things are very important I will give you a few examples the gear ratio for passenger vehicle look at this the different cars you have starting from Audi, BMW, Cadillac, Fiat, Mercedes Benz, Nissan, Toyota all those things are there and you can see that the corresponding transmission manual automatic manual automatic depends. We look at the manual again for few things we look at always the first gear will have a higher ratio first gear has a higher ratio as we move on to the higher gear ratio the speed is reduced you can see that the narrow down 2.12, 1.43 and 1.03 and 0.84 and this is the final drive ratio and interesting look at a BMW 320i right is a 5 gears 4.23, 2.52, 1.66, 1.22 and 1. That means, the fifth gear is directly attached with the engine speed that is the clutch shaft. So, you can eliminate fifth gear by doing that that is advantage right that is information you can see that same for a BMW 520i again you can see that and again if you look at maybe I can see that Volvo S70 manual transmission this is a 3.07, 1.77 and 1.19 and so on. Now, we will move on to the for Indian vehicles you can see this is Ashok Leyland, Hindustan motors, Fiat, Maruti, Maruti gypsy, Tata indica, Hyundai Santro the gear box is given 5+1 mostly synchromesh all the other things are synchromesh. Look at this is a very high gradability 6.98 and 4.3, 2.65 and fourth is 1.6 and the fifth gear 1.1. So, eliminate fifth gear right directly connect the clutch input to the gear box output. Similarly, we are mostly India we try to adopt. So, that in India we always concern about the specific fuel consumption in that aspect we prefer to have a the top gear is 1:1 ratio because the fuel is very expensive you can see here HM, the Fiat 100 also similarly Maruti gypsy also you can see that whereas, indica as a slightly variant is less than 1 for a higher speed similarly, for a Hyundai Santro.

Now, I will talk about another couple of minutes very important look at this diagram this is a diagram for a saw tooth perfect right this is the first the figure a is for geometric progression figure a is called geometric progression which we discuss earlier and the figure b is for progressive is called progressive or logarithmic both are same logarithmic progression both ways look at the difference in geometric the ratio is the pressure constant for the all the speed 1, 2, 3, 4, 5, 6 what happen here 1.43, 1.4 all the same thing and this is a corresponding saw tooth profile saw tooth diagram saw tooth yeah. So, normally as I said we have to operate between the maximum speed to minimum speed that is why you have to construct your entire gear box this is your N_{Max} and this is your N_{Min} yeah this N_{Max} and N_{Min} look at this what happen. So, this is the way it is a first gear it is operating all the time whether I am operating first gear second gear third gear my engine speed has to be N_{Max} to N_{Min} that is always stretches whereas, look at this again this much energy is losing here the you know we are losing these things the moment a use logarithmic ratio of the where step ratio slightly variable you can see that the step ratio is not constant 1.65, 1.49, 1.36, 1.24 whereas, do you see is very smooth right if you look at this one this is very smooth and not much energy loss compared to your geometric progression and interestingly I fixed my N_{Max}, I fixed whereas, look at this what is the what is the observation see here my N_{Min} is reduced you can ask the one question. So, I have a N_{Min} is the higher speed for the first gear is it necessary all the time you want to bring down your minimum speed even if you operate higher speed of the engine no need right because I know as increasing the speed, I want gear shifting right I need to have higher speed of the vehicle. So, if I reduce it the range what happen to my power consumption will be reduced can you see the difference if you have a geometric you have to operate a constant N_{Max} and N_{Min} the range whereas, if you have a progressive or logarithmic you can reduce it the minimum speed right range for each gear by doing that you can save a fuel. So, that is the advantage I will stop now. Thank you.