Design of Mechanical Transmission Systems

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Week – 04

Lecture – 10

Lecture 10_Automobile Gearbox: Basic Transmission Types and Kinematic Diagram

So, good morning to all. So, we will continue the problem. In fact, in this problem what we have done so far, we have done the ray diagram aspect right, for each speed using a tyre formula, find out the tyre radius with that we try to find out the gear ratio, final drive ratio, overall ratio from the overall ratio to we moved vehicle speed right from the vehicle speed we have completed the ray diagram. So, general operation we discussed has been types also we have discussed ray diagram also we have completed and today's lecture, we are going to focus about a kinematic diagram and also number of teeth in each gear calculation those are the things we are going to discuss in today's lecture. In fact, just wanted to give recap, the basic transmission types right single stage, double stage and multi stage. If you look at a single stage, the input is one shaft, this is the input is one shaft then you will have output the next shaft that is a two arrangement, only two shafts are involved whereas, if it is two stage, this is your input shaft from there the transmission goes to your output shaft or you can say lay shaft intermediate shaft is called lay shaft right.

From there the transmission goes to through the output shaft. So, this is called two stage gear box. In fact, this is the one we are going to use extensively in automobile transmission. The configuration looks similar to your reverted gear train, your input will come in this direction, then you will have a lay shaft from here to lay shaft, then you will have a output shaft. So, the input and output are in the straight line. So, that it will make more compact right. So, this is the reverted gear train arrangement the same reverted gear arrangement, we do it or we imply in the manual transmission as a two stage. And this is the three stage in the three stage what happen, you will have a one input shaft right, you will get a two output shafts, this is the one you can see that this is one output another one this is another output. So, if this kind of arrangement is a special arrangement anything beyond the three shafts or different directions normally called as a multistage.

And it is interestingly, this is the real manual transmission gear box you could see here this is taken from it is display in our machine design building at the entrance you could see that when now you see it you can go and see this gear box look at where is the input starts come this is your inputs you can see that this is the input and this will have reduction straight away. And this is your lay shaft, from the lay shaft transmission goes to the output shaft this is your output shaft. So, this is the arrangement, this is your lay shaft and please pay attention closely right, this is sliding mesh again this is sliding mesh spur gear if you look at the teeth arrangement, which one is the first gear it is second third and fourth the larger the one is the first gear right you could see this is the first gear, second gear and this is your third gear and this one more is joint is given, that is usually used for fourth gear, that is information and also observe there is one which you have to observe, we are not showing any the reverse gear it is not visible here that is we will ignore it. And what is the other information you get from this figure, look at the first gear second gear third and fourth what is that you are observing? The size is changing right, I am not talking about the gear size I am talking about your face width can you see that can you observe it, the face width is larger then the next you will address another face width then as you move on to the higher speed the face width is keep reducing. Remember the first point, our gear box is to be as small as possible it should be optimized and the weight should be also as low as possible right.

We could have straight away same face width, that is fine but as shifting the gear from first to second what happened to your torque requirement, higher the torque lower the speed so we have that success will be more the success will be more okay straight away we can have fix this face width to the all the gears as we move on to the higher speed your torque reduce when you torque reduce what happened the stress will be reduced. So in that case do we need the same face width, no need, okay so you can reduce it so by doing that you are making the gear weight even further down, right that is that is you have to be considerate during the design aspects. And as I said from the engine straight away we reduce the speed reduction, you can see that from there we vary that and interestingly this is taken from Maruti Suzuki the same arrangements slightly different okay you will see that this is the first, second, and this is first arrangement from the engine right okay and third fourth and fifth at the end, this is output shaft this is your output shaft they make reduction either do it at the beginning if the arrangement is possible or else you can do at the end also, okay which one is better at the beginning is better or the end is better beginning is better because by doing that I do not need to have another shaft it will make even more bigger size if you do it at the beginning itself my size is even more compact okay.

So now we will do the kinematic diagram okay so for the ratios are given we have not considered what is the gear type but in the problem clearly mentioned is constant mesh gear box, okay this is constant mesh gear box yeah so when you say constant mesh gear

box you can choose you have freedom to choose whether you want to have a spur gear or you can choose the helical gear both you can use it okay so it is a constant type the mesh type is constant mesh gear box GB so gear type we have not considered so far we can assume it now itself, we can assume as a spur we can have both helical and spur we will assume as a spur okay, then when you say spur the profile would be full depth, involute profile that is the profile right usually we use involute profile what about pressure angle standard pressure angle, we will get pressure angle φ usually 20° right you can have 20° so it is not given but we choose as a 20° okay that is the one thing so this is the information we have taken at the moment, spur full depth involute, and the pressure angle 20° that is okay the another information I would like to emphasize about these things okay this is the constant mesh is fine how are we going to arrange the gear box, can we arrange the speed from right to left or left to right either way is fine either way fine you can do either way but after doing that you have to check the dynamics of the rotating masses, that is very critical so the first you would expect the shaft from clutch input, right the clutch input is coming from the clutch yeah, is there an information the gear ratio saying that the gear ratio is coming one, did you say anything one no right so there is no then there is no connection input and output as a one joint is there okay, so I will have a one gear right this is my input shaft coming from the input shaft from here it reduced okay it will reduce to at least by mostly half of the size will be reduced so yeah I am just this is my lay shaft so what is this is the lay shaft right and this is the output okay, so how are you going to do that kinematic diagram, where is going to be the speed we want to have a the first speed yes it has five gears five plus one we are going for the five gears so still one more information, we have not discussed we have not discussed we have not taken consider the gear selection mechanism right because this is constant mesh right so in between you need to have gear selection mechanism, dock clutch that is also will be part of that and that should be common because you do not want to too many gear selection dock clutch you need to have a as minimum as possible by doing that again you reducing the further the size and the mass of the gear box okay.

So I will do from here yeah I will make it from right to left assuming that the center distance is constant right, the center distance between these two right the lay shaft and output shaft is must be constant, the center distance okay this is the gear one this is gear one, so that is the one then I will have a next higher speed, so one okay then I will have a another speed so this is the gear one and this is the gear two and this is the gear three okay then one more higher speed suppose to be face width should be I am taking, we are not considering face width at the moment we are just for understanding purpose we are doing that okay then we will have a fifth gear.

So, this is happen okay, so from here what I have done, I have taken this is my dock clutch arrangement for the dock aspect okay usually the dock clutch arrangement will come at this shaft output shaft let me finish this one and then I have taken this is my first

gear what I have done I have taken this is my dock clutch arrangement for the dock aspect okay usually the dock clutch arrangement will come at the this shaft output shaft let me finish this one okay. So, this is the first gear that I have taken this is my first gear and this is the first gear yes so you could see that this is my first speed first gear, second gear, third gear, fourth gear and fifth gear so we are not showing any reverse thing only focusing about the the first forward thing okay so and we have this is the output shift is clearly given where are we going to place the the dock clutch right we need to have a common one okay so usually we can have one common one between first and second gear that is a notation just fine okay when you have you have to give the enough space for between those those sliding aspect then the next as is an adjacent gear it should be closer the reason is the selection mechanism will come into here only right it would not be so this is the one between first and second and this will be third and fourth why I am emphasizing this also will fix your length of the shaft right the face width and the spacing between the gears are directly right fixing the length of the shaft, this length of shaft also need to be as small as possible so that we are make it a gear box as a compact okay that is the one thing is there so I have done this one and finally we can have a one more right a probably this is common, right so this the fifth gear can be even more closer to the fourth gear and you can have one gear selection mechanism right that would be in this in this position, yeah, so this is the kinematic diagram.

This is the way the kinematic diagram need to be arranged for the manual transmission much simpler not as complex as a machine tool gearbox, because your speeds are seven, right five here in generally it will go seven or eight plus one forward thing right so as we discussed can we have the numbers also we can odd and even numbers gear numbers we can have one, right one two, three, four, five, six, seven, eight, nine, ten, eleven and twelve okay this is your twelve, this would be twelve, okay yeah another question is which is the drive gear which is a driven gear what are the drive gears? Which is driven gears are? They are systematically come in machine tool gear box right it is always we take it as a the odd ones are drive givers evens are driven gears but here is not the case the transmission occurs from the clutch input to lay shaft, this is the one right then from here the motion goes to your output shaft okay it goes from here, okay, so in that case your gears four, six, eight, ten, and twelve are drive gears right, yeah gear number one also drive okay but when you say as a gearbox we consider only this the first five gears okay, that is yeah that is coming from the engine from engine to we reduce straight away by certain ratio then from here how we are distributing the speed, vehicle speed right the in that case would you consider the first one to or just the rest of the gears yes absolutely yes till then because this would be the input gear two would be the input for the your entire gear box things okay in fact what happened for torque for the lay shaft is it constant or variable torque. A torque will be reduced I mean since you reduce the speed the torque will be higher but will be constant torque on the lay shaft but in outputs of the torque will be variable torque so that information you should aware of that right, so

when we do the module calculation this information will use and find out which way to solve the problem to find out the required a module for the given gearbox okay and this is the kinematic diagram for the Maruti Dzire gearbox, yeah. So I think, this is a as a gear type there is one more way you can as a represent as a line diagram, okay as a represent a line diagram let me ask one more question this is a constant mesh what happen if you have gear box which is sliding mesh, what is the arrangement you see, the previously I have shown the picture also right I have shown the picture so there will be one only one gear will be mesh other gears will have a displaced will be a part of the face width of the given gear box okay obviously the length of the shaft will be higher if you choose spur gear with the sliding mesh so if you choose a constant mesh irrespective of the helical gear or synchromesh mesh, okay the shaft length will be reduced ,right if you simply representing just wanted to show as a line diagram, gearbox line diagram okay, so this is the line diagram for the Maruti Dzire gearbox okay, keeping the center distance constant, yeah that is it so this should be okay, so you will have the mechanism here this another one yeah, you can see that the first, second, third, fourth and fifth yeah one information I would like to give this is the input shaft from the clutch and this is the lay shaft and this is your output shaft for the transmission aspect. You can see here, input shaft is directly coming from the engine, but we don't know what is the ratio, by default we reduce half of the speed. Then the gear ratio would be 2 right by usually by default it will be variable again. Gear reduction is 2 from the clutch input shaft. So, this is the gear reduction to the counter gear in the lay shaft. But that information is not given to us right. It is not given to in the problem. If it is not given usually we wanted to make it half of the speed. So, reduce the we have a gear ratio as a 2. So, we are now we have completed the kinematic diagram for the gear box.

The next stage or next step would be to find out the gear ratio, find out the gear ratio between the all the gears. Let me ask question right which is the smallest gear here? This is the one right this is the 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 which is the smallest gear here please tell me 1 that is already coming from the engine. So, leave that if ignoring 1 and 2 the rest of the gears right 3. 3 or 12 also good good observation it could be 3 or 12. So, my question is in gears, would you prefer to have a drive gears design aspect? or a driven gear design aspect? Yes, when I say drive gears and driven gears from drive gear the force is transmitted power is transmitted, in the driven gears the power is taken. So, which is create a more stress the drive or driven drive. So, you have to focus on the drive aspect not the driven things right, when you think about the gears calculation your focus would be based on the drive that is the one which is causing the stress to the other gear by contacting by meshing. So, if you look at I would look at 4, 6, 8, 10, and 12 with that 12 will be will be the smallest gear right G_{12} smallest gear. So, this is the one which is causing the stress to the other gear.

Yes, that is the thing. Now, can we move on to the calculation. So, second part we are doing number of teeth calculations, each gear is given by the number in GB (gearbox) .So, you know first I am talking about Z_2 , $\frac{Z_2}{Z_1} = 2$ that is given as a 2 we have taken as a assumed as a 2 that is fine. Now, we will go for the first gear what is the first gear ratio.So, first gear ratio your I_{g1}, the I_{g1}should be 3.545, that we would expect from

$$I_{g1} = \frac{Z_2}{Z_1} \times \frac{Z_{11}}{Z_{12}} = 3.545$$

So, this is the difference you see from the regular machine tool gear box to automobile gear box this is the gear ratio first gear ratio. Similarly,

$$I_{g2} = \frac{Z_2}{Z_1} \times \frac{Z_9}{Z_{10}} = 1.904$$

$$I_{g3} = \frac{Z_2}{Z_1} \times \frac{Z_7}{Z_8} = 1.233$$

$$I_{g4} = \frac{Z_2}{Z_1} \times \frac{Z_5}{Z_6} = 0.911$$

$$I_{g5} = \frac{Z_2}{Z_1} \times \frac{Z_3}{Z_4} = 0.7256$$

these are the values, these are the gear ratio correspondingly. So, now we need to find start to find out the number of teeth yeah. So, number of teeth so for first gear right your, I will rewrite again

$$I_{g1} = \frac{Z_2}{Z_1} \times \frac{Z_{11}}{Z_{12}} = 3.545$$

yeah, but we know that $\frac{Z_2}{Z_1} = 2$ that is clearly taken. So, which is the unknown to us both Z_{11}, $Z_{12}$is unknown. So, somewhere we have to start assuming minimum number of teeth for gear number G_{12}. So, what we could do always G_{12} should be greater than 17 because the you know this to avoid is it undercut or interference right, to avoid undercut the minimum number of should be greater than 17 ok. We will assume as a let assume because I already have done the calculation. So, I will G_{12} I will assume as a 18 number of teeth ok, now we need to sort it out $\frac{Z_{11}}{Z_{12}}$ ok yeah. So, already I know this 2 when you substitute, then I want to know the ratio between $\frac{Z_{11}}{Z_{12}}$. So, if I done that I will be it will be 1.7725 and assume that Z_{12} is the 18 when I do substitute that 1. So, the Z_{11}, I would expect 31.905 approximately you can take it as a 32 approximately you take it as a Z_{11} = 32 ok. Using center distance, remember refer your kinematic diagram center distance the

number of teeth Z_1 plus Z_2 must be equivalent to Z_{11} plus Z_{12} based on the center distance.

$$Z_1 + Z_2 = Z_{11} + Z_{12}$$

So, one more information I would like to share here. Here in this problem there is no concern about the center distance right. You can what are the center distance based on calculation you can free to choose it. However, some place you will get a problem your center distance fixed. So, for that we have to do the calculation right. So, I will give that kind of problem in the assignments ok. So, now can we solve this problem please yeah. So, I know Z_2 by everything I need to bring it everything with respect to Z_1 ok. So, a Z_2 should be 2 times Z_1 that is there right

$$Z_1 + 2Z_1 = Z_{11} + Z_{12}$$

$$Z_1 + 2Z_1 = 32 + 18$$

$$Z_1 = 17$$

$$Z_2 = 34$$

$$17 + 34 = 32 + 18$$

$$51 \neq 50$$

Z_1 plus 2 times Z_1 equal to Z_{11} plus Z_{12} which already I have already done. So, we know the values which are what is that 32 right 32 plus 18 which is coming 50. So, tell me what is the value you are getting for a Z_1 what is the value you are getting, what is the value you are getting how much 17 ok right Z_1 is a 17. Then Z_2 would be it will be 34 right 2 times right 34. So, we got 17 and 34 and then already we know other which is other Z_{11} equal to 32 and Z_{12} equal to 18 we got it. So, this is one thing we have finished it. Now, we move on to the gear ratio ok is it my question is this solving, my question is the number of teeth are matching look at this is 32 plus 18 is a 50 right is a 50 ok whereas, I got 17 and 34 is it correct? no it is not correct right. So, this is a 51 is coming. So, 51 cannot be equal to 50 then what is the step we are going to do that yeah what is that we want to do. What is that we can do? I am sorry. Yes that same assumption ok we got Z_{12} is 18 that is clear that is yeah that is assumed yeah true ok.

Now, I am just wanted to find out another way also in the gear ratio what is the Z_{11} is coming we got it Z_{11} let me go back here. So, this is what we got here right this is 31.9 ok we got 32 here then Z_{11} is 32 and Z_{12} 18 that is coming here. Is it exactly 17 = Z_1 that is a question what is that value 16.67. So, that is a problem right 16.67 is coming and we made it as a 17 thing yeah. So, that is not the correct, that is not the correct one ok instead of 18 what happen? Let me ask question another question if this is 32 this is 32 ok what

happen if I make it as a round of even though 31.9 if I make it as a 31.9. R 33 is it possible yes yeah any other answer yeah which one is it possible. Then I should I make 33 Z_{11} if I take 33 right if I make Z_{11} as a 33 what happen my Z_{12} remain same right Z_{12} remain same as a 18 right then what happen my Z_1 yeah 17, Z_1 will be 17, Z_2 would be 34.

So, now do the summation I will take the summation of this summation right give me 51 the similar summation if you do the 51. So, that satisfy right. So, if you assuming right Z_{11} as a 33 not assuming rounding off to 33 you would expect a Z_{12} be as a 18 and Z_1 = 17 and Z_2 corresponding with 34. So, by center distance aspect we are matching the number of teeth right number of machine teeth we have matched. Now we will move on to gear ratio 2 your,

$$I_{g2} = \frac{Z_2}{Z_1} \times \frac{Z_9}{Z_{10}} = 1.904$$

but already we know Z_2 and Z_1 are already known to us their values are known to us. So, we have to do the same thing. So, the 17 and the 54 that already known to us. So, we need to focus only above the Z_9 and Z_{10} yeah right. So, same way your Z_2 let me write rewrite

$$Z_1 + Z_2 = Z_9 + Z_{10}$$

you have to use the center distance equation by center distance method right.So, if you solve it I am not going to detail I am going to write it. I will say it will going to give the answer. So, Z_9 should be 26 and Z_{10} = 25 right 25 and 26 it should be coming as a 51 it should be satisfying 51 correct and gear ratio 3. For gear ratio third gear ratio

$$I_{g3} = \frac{Z_2}{Z_1} \times \frac{Z_7}{Z_8} = 1.233$$

So, already is known to you only you have to find out Z_7 or Z_8 as usual using a center distance method. So, this is the same way you have to use the center distance method as usual using a center distance method

$$Z_1 + Z_2 = Z_7 + Z_8$$

right and you know the ratio also $\frac{Z_7}{Z_8}$ ratio also 0.6165, you know that by solving it you would expect your Z_7 teeth 19 and Z_8 is a 32.

So, please work it on you will get this answer. So, even if it is adding this one that give me number of teeth as a 51, total number of teeth using center distance method gear ratio for fourth gear is equal to 0.4

$$I_{g4} = \frac{Z_2}{Z_1} \times \frac{Z_5}{Z_6} = 0.911$$

$$\frac{Z_5}{Z_6} = 0.4555 \qquad (a)$$

$$Z_5 + Z_6 = 51 \qquad (b)$$

So, when you substitute this (a) and (b) as you did in the previous things. I would expect Z_6 should be 35 and Z_5 is 16. So, this is the number of teeth you would expect for gear ratio number 4, this is done. Now, we will move on to gear ratio number 5. So, this is the number of teeth you would expect

$$I_{g5} = \frac{Z_2}{Z_1} \times \frac{Z_3}{Z_4} = 0.7256$$

using same as your center distance method try to find out the number of teeth

$$\frac{Z_3}{Z_4} = 0.3628$$

Finally, you would expect Z_3 = 14 and Z_4 = 37. So, that is the summation 51 comes. Let me write individually Z_1 = 17, Z_2 = 34, Z_3 = 14, Z_4 = 37, Z_5 = 16, Z_6 =35. Now, Z_7 =19 corresponding Z_8 = 32, Z_9 = 26, Z_{10} = 25 and Z_{11} = 33 and Z_{12} = 18. I think we got all the values. So, what are you see these are the drive gears number of these again 2 except 2 I think 4, 6, 8, 10, 12 are drive gears whereas, reserve driven gears. You might ask question. So, we have chosen number of teeth 17 and above, but you got number of teeth on the driven gears 14, 16 is it good? Does it causing a problem design problem right.

So, just think about that. So, we will continue next lecture for the module calculation aspect. Thank you.