Design of Mechanical Transmission Systems

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Week – 02

Lecture - 04

Machine tool gearbox: Kinematic diagram Construction

So, very good morning to all. So, today's lecture we are going to continue with the machine tool gear box. In the last lectures, we have discussed about the construction of ray diagram and also we have started doing a problem. So, in this problem we have only done the ray diagram aspect. Today we are going to discuss the construction of a kinematic diagram. I am sure you are aware of that, the kinematic diagram is helps to place the respective gears based on the ray diagram, such way that to get the desired output for each changes in the gear box selection, that is a purpose to have a kinematic diagram. I am sure you would remember, this is the problem we have been doing, we have completed so far for the ray diagram aspect. Now, we will discuss for the kinematic diagram. So, we have complete the ray diagram here you can see that and we need to construct the second part kinematic diagram and the later part discussing about for a number of teeth for each gear in the gear box.

I am sure this is the structural formula is given 2(1)3(2)2(6) is the structure given formula. And this is the ray diagram we have constructed in the last lectures and 31.5 is the your minimum speed and 1410 is your maximum speed of course, start from here you must be aware of that the motor speed is 1500 rpm, which is not shown here we are only focusing about the ray diagram aspects. So, as you aware of that the given structural formula, I will rewrite again 2(1) then 3(2) what else we have 2(6) right this is the given structural formula. And you know structural formula is give information about the stages, right and also the speeds aspect there is one more information the kinematic diagram indicate about the number of gears, will indicate about the number of gears.

For first stage, the first stage is 2 of 1, it talk about one input speed and two output speed right and also the distance between the two output speed within the bracket that already know the another information is, it shows you need two gears in the first stage. In second stage, this is your first stage and 3(2) is a second stage and 2(6) is a third stage, second stage the formula 3(2) which shows you need a 3 gears. On third stage is 2(6) is not it indicate about you have a 3(1) and 3(2). So, you have 6 input speed and each input speed

will give you 2 output speed and 2 output should be placed 6 steps are apart, right that was the information. Now, another information you needed 2 gears, I think in the last lecture itself, we have mentioned number of gears the total number of gears you would need for 3 stage gear box is 14 the total number of gears the total number of gears is number of gears is 14 for this gear box GB means gear box.Let me ask one more question before discussing about the construction of kinematic diagram, I want to give information about the size and speed, if the gear size is big what happen to speed what about the speed, I am talking about relatively and you have small size gear you have small size gear. So, if the big size gear obviously, the speed would be low or small right, we are talking about big and small. So, low speed, so if the big size gear is small. Now, small size means high speed, so the size also very important. So, this is the clue we are going to use it in the construction of kinematic diagram.

And one more thing is, so this is the 3 stage already know that the number of shafts you need for this gear box is 4 shafts 4 spindles, the number of shaft means the spindles also I can say that the number of shafts in gear box or machine tool gear box we say spindle speed spindle right is 4. And one more information in terms of speed, so the speed of the gear box is 4. In ray diagram we use vertical lines, right vertical lines for indicating the shaft here this is for the ray diagram vertical lines, here in kinematic diagram we are not going to vertical line, but we would use the discontinual lines in horizontal direction for indicating a shafts in kinematic diagram. Now, move on to the kinematic diagram construction stage 1, you can see here, this is I want to take some information from stage 2. What is stage 1 consist of the stage 1 consist of the this shaft 1, this is your input shaft 1 we can say that shaft 1 shaft 1 is the input shaft 2 and shaft 3 and shaft 4 this is the 4 shaft.

So, my input is 1 speed output speed would be 2 speed is not it that is your formula that is your formula. Let us see, so my input speed should come from the motor this is from your motor and this is your desired output. What are the output speed here from the ray diagram you always you have to use a ray diagram to construct the kinematic diagram. Tell me what is that output speed you are expecting here I would expect G and F. So, what is the speed is gives for G - 500 RPM what about F - 350 RPM, in relatively can we say your F is a bigger gear because the speed is low, right, it is a relative term, it is a big gear it should be size will be big and obviously, G is a high speed the size would be smaller small just for understanding. So, usually what we do to represent schematically, we will have a kind of this kind of information it is a relative though. So, one is smaller another one is bigger. So, what is this is this is bigger for the low speed gear speed and this is for the high speed aspect this is the way, we are going to use it, during the construction of kinematic diagram. So, now, we know it is very clear stage one. So, we will go for the kinematic diagram actual, this is the shaft one spindle one, spindle two, spindle three and spindle four. So, normally we will have line like this to show right that is indicate above the shaft. So, how many output you are expert here gear box will have one output speed. So, what we going

to do we will show this is the one as output this is coming as a output here this is the will do this.

So, input the motor will be will have a motor here this is your motor and you know that the structural formula is given two of one, right and already we are discussed in the previous slide we needed two gears one big gear, one small gear, right one big gear which is representing 350 rpm my F, another small gear which is representing high speed G 500 speed rpm. So, they always together remember in machine tool by default the gear type is sliding. So, when you say sliding you always use a stick for moving the gear selection during the gear selection, a stick or a gear selector will be there. So, that you have to slide it is not automatic transmission right or it is not a not only automatic or constant mesh or synchronous mesh, this is sliding mesh. So, you always you have to move gear shift through shift and to get the desired speed.

So, in that case. So, these are the coming from this first stage. So, one is always mesh, what I did one is always meshing the other one if I want I have a another speed right what I should I should slide when you want to slide I should move to the another gear. So, they have to place based on the phase width phase width or thickness of the gear this is called phase width this you know this is the phase width this is the phase width. So, that much distance you should leave as a gap with the little clearance. So, that when you shift from this engagement between these two to the next engagement and please understand that. So, you always the drive gears are movable, the driven gears are fixed. That means these gears are fixed, they would not move, they will fixed into the spindle two. So, this is what is now on the current mesh, what is the speed you would expect 500 rpm because of bigger size to smaller size, the moment you shift this one, it will engage these two engage when these two engage what happen to the speed will be 355. So, because smaller gear to bigger gear. So, the transmission right please understand that the spindle should keep same centre distance between two shaft between two spindle the centre distance must be constant of course, it can be same center kept for other stages also or you can have different, but as long as the number of shafts are placed one spindle should maintain the same centre distance to the previous stage, that you have to follow. Now, it is right we have done the for the first stage aspect.

Now, we will go back to the stage two right this is your first stage this is your first stage and this is your second stage and this is your third stage. So, what happen to the second stage, what is the sectional formula 3(2) is the name 3(2). So, you have three of two you need a three gears that means one input will give three different speeds let us check for G, I have G, I have taken the G that will be the input to the my second stage we get a two speed G, I have G and F are both are two input speeds. What are the output speed I would expect for G, leave the G I will go for F, for F I would expect C, D and E and E right this what happen, if you look at the C it is 125 rpm I will put in bracket for easy to understand then if I do for D is 250 rpm and E 500 rpm. So, you have to have a three different size one

is bigger, medium and smaller because this is the second stage right. So, this for the smallest speed right, this is the next medium speed and next highest speed like this we can have it is a relative for understanding, right it is a relative as per we do. So, like we did for F similarly G also will have same thing right G also will have a same thing G would be I can straight away will go for the speed G would be 180, 355 and 710, right 180, 355 and 710. So, three speeds you would expect right.

So, this is already we know we have fixed for the stage one now we are moving to stage two. So, we need a three gears the all three gears in drive should be together right. So, one you can have a little smaller size and another one you can keep it in the right side. So, you can interchange it does not matter. So, one more thing understand that again dynamics also will involve, but our focus is not about dynamics about understand about the design. The placing gear also very critical based on the dynamic analysis rotation balancing the mass rotation mass aside that is also there. So, that is also will place a crucial place in kinematic diagram. However, we restrict only to understand how to place the gears that is how we are going to focus. So, now, we have three gears. So, how we need again three gears at least we will make one is measuring this one is measuring.

So, currently it is measuring will give me what is the speed I will get I will get maximum highest speed, right maximum highest speed highest speed. Then if I move this direction I can have this mesh will give you lowest speed again if I shift the gear to engage these two I would expect the medium speed in between right. So, already we are gave the three range for F. So, does G also right as aware of that these gears are fixed only the drive gears are movable. So, this is your arrangement for stage two kinematic diagram. So, this is your arrangement for stage two kinematic diagram. So, now, go for the stage three we discussed about stage one and stage two stage three what is the formula stage three 2(6), that is for one input speed you would expect two output speed. So, now, we have how many inputs we have C right we have E, D is there and C also there. So, we will taken the three actually in fact, in fact, you have in between also one two three four five six these are six input speed and each input speed should give you two output speed for example, C will give me two speeds right right two supposed to be. So, that is A and this is B. So, A would be 31.5 rpm and B is 250 rpm. So, which is indicate about again high speed and low speed that is it right. So, when you want to have a high speed the gear should be as small as possible, small this is for high speed aspect ok. And if you B would be for a bigger size ok. Obviously, you will have a low speed. So, same concept we are going to follow for this third stage also right. So, this is constructed for the stage one and stage two. Now, so one big gear one small gear that is what supposed to be happen right you can see that one big one small ok. Now, I need to have a one mesh, here the other one is this will give me the highest rpm and if I move the gear shift to this way, I will get the my minimum speed 31.5 rpm ok. So, in fact these two are fixed anything you put as into mark which indicate they are fixed gear they are not movable they are always fixed to the spindle

corresponding spindle fine. So, now, we have completed we have completed ok, but still we can ask question it is ok we have constructed two gears on the first stage three gears second stage and the another two gear second stage, but I still I do not understand how do I achieve 31.5 rpm. So, that is the fair question still I do not know how to achieve 500 rpm. So, what are the gears engaging if I want to get 31.5 rpm right. So, if in fact, so this is complete one again we will go back here this is fine. So, here so what I am going to do for our own understanding right all the driving gears will have a odd number all the driven gears will have a even number. So, I am going to say this is 1,2,3,4,5,6,7,8,9,10,11,12,13, and 14 ok. Remember all odd gears are drive gears, all the even gears are driven gears ok. So, which is for easy understanding.

So, let me ask a question I want to achieve 31.5 rpm how do I do that what are the gears need to be engaged. You can refer your ray diagram and also refer kinematic diagram, can you tell me what is the way to do that if I want to have a 31.5 rpm right look how do I do that. So, may be let me I will try. So, I am giving you gear number 3 if the gear 3 and 4 engage I will get the lowest speed am I right then. So, that is it. So, my question is. So, the when the three and four are missing you will get one speed the same speed will rotate in the all the gears in the shaft two right this is shaft one shaft two and shaft three right and the shaft four is the other things because all the gears are placing the same shaft right the five and six should have the same speed ok. Now, what is the next meshing 9 -10 can you say 9 -10 ok. So, that is a meshing. So, 3 - 4 meshing, 9 - 10 meshing, I want to have the lowest speed 31.5 rpm the next one would be13 - 14. So, this should give me 31.5 rpm.

So, can you check your ray diagram whether this is correct if you look follow the ray diagram right. Now, are you able to understand why ray diagram, kinematic diagram very important the ray diagram will talk about the speed flow, the kinematic diagram talk about the gear mesh engagement right, the power transmission both are there ok. Let me ask another question how do I get 125 rpm. So, it is much easier when I say 31.5 rpm because I have chosen the small speed. So, I can go for the all the bigger gears and engage that is easier now I am asking intermediate speed 125 rpm.

So, what are the gears missing to get one twenty five rpm right what are the gears can you tell me you can refer your ray diagram and by looking at the kinematic diagram, you can tell about which gears should mesh to get the 125 rpm, may be I would say start with the 3 - 4 ok. Then would you expect 9 -10 or 7 – 8, 7 – 8 ok. So, that is first stage,3 – 4 right, what are the speed is as a 4 gear will have a same speed for a gear number 7 ok because they are in the fixed in the same shaft spindle shaft, now 8 ok. So, what is the next one 13 - 14 excellent. So, now, ok may be I will ask one more question how do I get 1410 rpm. So, last thing I want to get thousand four hundred ten rpm. So, can I have answer for that if I want to have a 1410 rpm maximum speed, because already we know that thirty one point five it is a lowest speed we have taken the 125 rpm as a intermediate one now I want to choose that the maximum speed. So, what are the gears must be engage to get maximum

speed 1 -2 ok excellent. So, will go slowly little one to gear one and two should mesh then from here, it should be 7 - 8 the because of the 8 gear is the highest speed, 7 - 8excellent then 11 – 12 can you see that. So, in the last I mean someone answer you need a twenty gears, you do not need, though we have twelve gears by having additional two gears, we are able to achieve all twelve speeds right that is possible due to your progression, right progressive gears right that array that one thing that is a very critical aspect and with the help of ray diagram and kinematic diagram we are able to achieve it ok.

So, now the next thing what we are going to focus the number of teeth aspect ok. So, number of teeth we need to understand each gears we need to find out for each gear of course, we are going to use two ways you can approach generally as the beginning of the lecture, I said we will use the center distance right. So, assuming that for gear between 1 and 3, 2 and 4, 5 and 7, 9 they should have a same center distance otherwise not possible ok. Similarly, if you look at 6, 8, 10, 11, 13, 12, and 14, they should maintain the center distance right. So, there may be center distance different does not matter, but within when the meshing they have to maintain among the gears having same center distance then only the size can be maintained the speed ratio can be maintained ok, that is what we are going to do in next class finding out the number of teeth ok. Thank you. .