Gear and Gear Unit Design: Theory and Practice
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Lecture – 44
Machine Tools Speed Change Gear Unit – III

We are continuing with module 8 which is internal epicyclic and other special gearing. And this is lecture 44, where I shall a continue with machine tools speed change gear unit and this is the third part of it.

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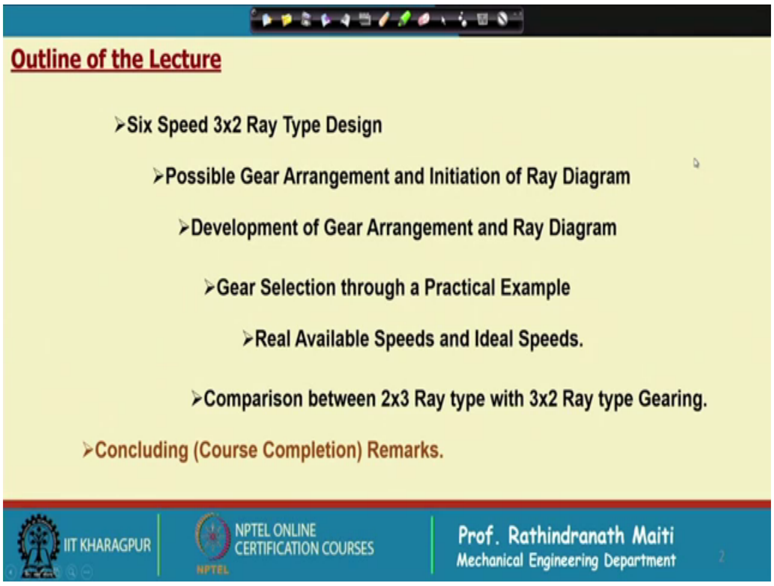

Now, in this lecture first we will discuss about 6 speed 3 into 2 ray type design earlier in last lecture we did 2 into 3 ray type design. So, here we shall consider a problem on 3 into 2 ray type design.

Next, possible gear arrangement and initiation of ray diagram then development of gear arrangement and ray diagram and gear selection through a practical example, real available speeds, and ideal speeds, and comparison between 2 into 3 ray type and 3 into 2 ray type gearing. This means that we will in the practical example will be same as it was in 2 into 3 ray type and then finally, we shall compare merits and demerits and this is the last lecture. So, there will be a controlling part.

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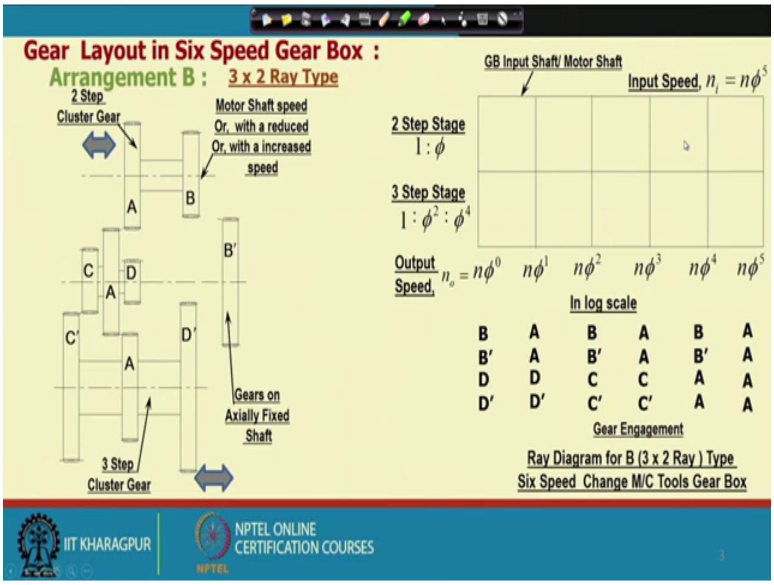

Now, if we consider the 3 into 2 ray type essentially this will have 3 stage reduction in the last step ; that means, in this case if you look into this gear unit that is in the bottom of that. So, this is as you find here this is totally 3 steps are there.

Now, what is if we a look into this figure what is there? That this is the in the fixed axis there are 4 gears and in this 2 gear sets, where we change the gears and top there are 2 gears and bottom there are 3 gears.

Now, what will be the ratios the common ratio is 5, but what we find in 3 step stage here, we find this is we have taken one into phi square is to one is to phi square is to phi to the power 4 and 2 step stage ; that means, in this stage 1 is to phi. So, definitely this ray diagram will be different although we will get the same speed in GP series.

So, what we need to do after knowing that this minimum speed and maximum speed or maybe initial speed and the final speed, then we will take the 6 steps 6 speeds. So, for whether it is 3 into 2 ray type or it is 2 into 3 ray type these will be same.

The ideal speed will be same and then we will develop this ray diagram.

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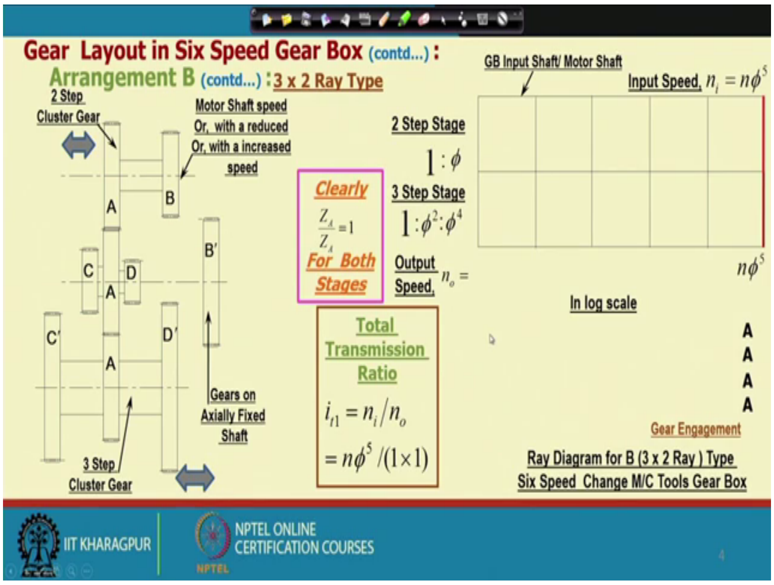

Now, first we shall consider the maximum speed. So, for maximum speed connection what we need to do here total ratio is in I into sorry input speed divided by output speed input speed is the motor speed and this is this ratio is we can have the same if you if you look into here the input and output, this is our input and here this is output.

And here the transmission ratio one is to one this means that in the development of ray diagram, we try to engage the gear a and a in this stage here these are of equal size a means these are of equal size and then we also for that we will get this is the ray diagram here and next we get.

So, this the, this is the gear engagement what we have shown, that this gear was here that has been shifted. So, this is the engagement it has a engaged here ok. And next again in other step so, we are getting this one ratio here right. Now next again we will engage a and a look at this a is being engaged with a and we get this ray diagram here and as well as in this step also the ratio is one. So, we have engaged this series of gears and we have got this one.

Clearly Z A by Z A A is equal to one; that means, these gears are of equal size.

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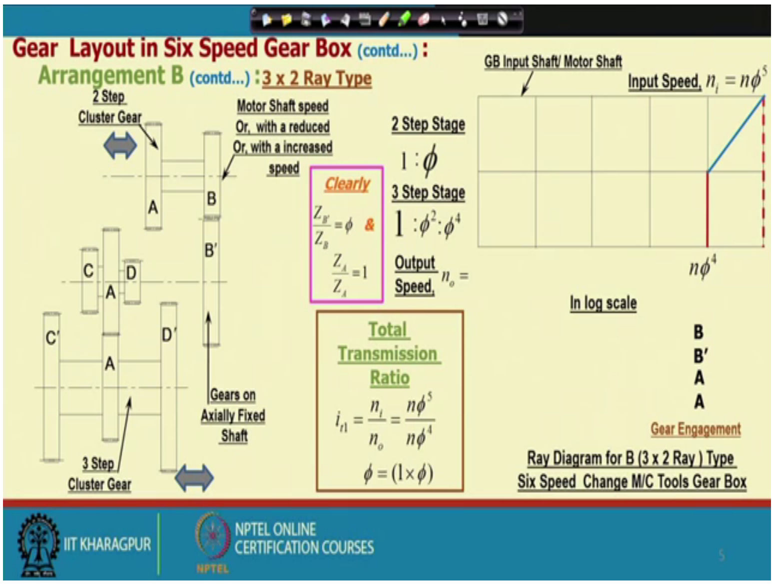

Next, we will consider the next speed n phi to the power 4 ok. In that case first we find out what is the transmission ratio, now input is n phi to the power 5 whereas, output is n phi to the power 4. So, reduction ratio must be phi reduction ratio is phi; that means, we have to use in 2 step gears we have to get that one, because this phi is available in the 2 step gears.

Now, what we do we engage first of all that only with this in second stage phi it will do. So, definitely in the 3 step stage we will engage one is to one. So, a is engaged with a. So, ray diagram we will directly go from bottom to top then, what we will do?

So, this is the gear engagement we have engaged this one and next we choose B B dash to get this one because A A engaged we get 1. So, we will now you engage this one to get B B dash. So, B is engaged and we are getting this one these 2 we have used in 3 step stage one and 2 step stage the common ratio and we have got this ray diagram ok.

So, this part is also completed and clearly here Z B dash by Z B we have to make is equal to phi and Z A by Z A 1, it was already there next we will consider n phi to the power cube.

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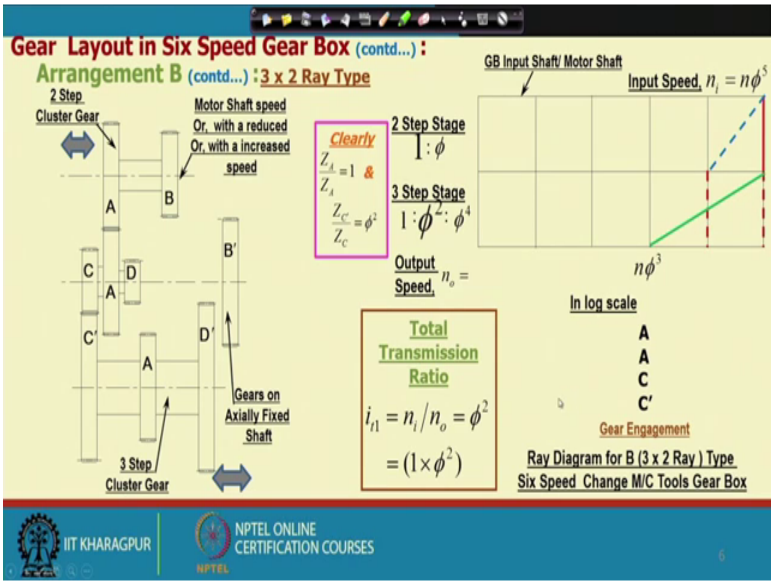

In this case again we calculate the transmission ratio the input remains same that is the motor speed, in this case we have considered. So, n phi to the power phi and output is that n 0 n phi to the power cube.

So, we get this transmission ratio phi square which the combination is possible in 3 step stage it is phi square and it is 2 step stage 1. So, in to get this phi square in 3 step stage we will go for the next gear set C C dash clearly this is there. So, we are now gear engagement will be like this C C dash and this is the gear engagement, we have be engaged the gear there and next A A and we have engaged the gear in the 2 step stage also and the ray diagram by green line from this bottom to it has the middle it has the inclined line green inclined line is the ray diagram.

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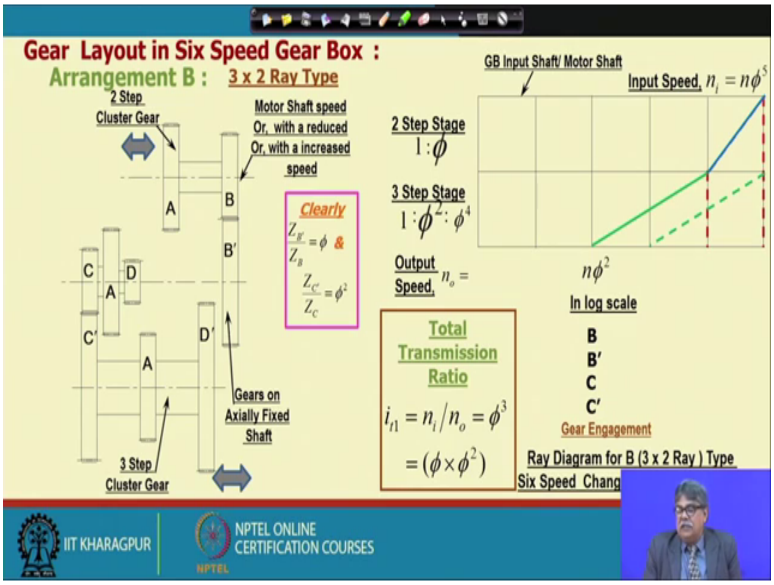

Next we shall consider n phi to the power i square.

Now, first of all we will find out the transmission ratio in this case we get phi cube, but if we look into these 2; that means, here 2 step stage 3 step stage know here the phi Q is there. So, what is to be done only possibility is that we have to engage phi square in 3 step stage and phi into 2 step stage.

So, we are now we are trying to get the phi square how it is possible we are that is Z C by Z C already we have seen the earlier step. So, we will engage this one first CC dash and we have engaged this gear here at the 3 step stage. Next we will go for we have got the ray diagram here and next we shall go for BB dash to get this phi and that is given by this ray diagram.

Already it was developed earlier. So, this is BB dash we have engaged. So, we have arrived here ok.

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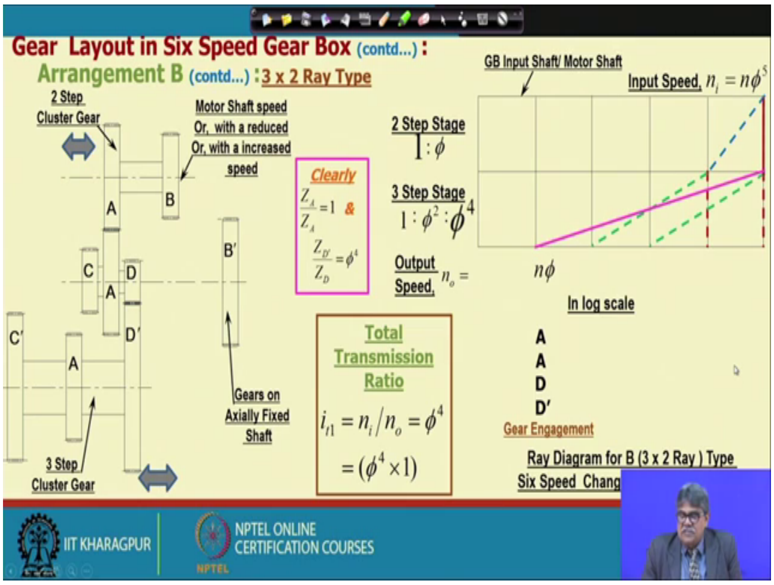

Now, we shall go for next the lower speed that is n phi and that total transmission ratio in this case we get phi to the power 4. And looking into 3 step stage they are directly phi to the power 4 is available. So, we shall engage that one and in 2 step stage we shall engage one is to one.

Next, clearly what we find Z D dash by Z D is equal to phi to the power 4 and Z A by Z A is equal to 1 these 2 we will engage this is 1 and this is phi to the power 4 and whatever the gear engagement first of all we in 3 step stage we will engage DD dash.

So, DD DD dash is engaged and in 2 step stage we will engage A A. So, A A is engaged and we get this speed also.

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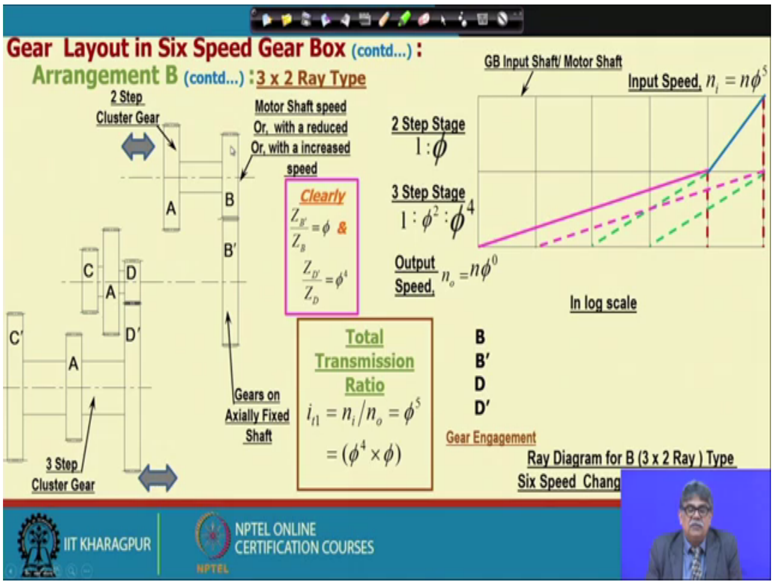

Next, the last speed that is the lowest speed which is phi to get this the transmission ratio is phi to the power 5. And this combination is possible in 3 step stage using phi to the power 4 and in 2 step stage using phi, clearly Z D dash by Z D is equal to phi to the power 4 we have to engage that 1 in 3 step stage and in 2 step stage we have to engage Z B dash by Z B, which is phi.

So, gear engagement in 3 step stage we will engage D D dash. So, D D D dash is engaged and next we will engage in 2 step stage B B dash and we have engaged that one.

So, in that way we have got the last or the lowest speed the in the ray diagram we have connected this pink line and this was already, it was there BB dash line it was there. So, this is the full ray diagram of for this 3 into 2 ray type here again I would like to mention that when it is written like this 3 into 2 or 2 into 3 we have to keep in mind that 3 is 3 step stage usually in the last stage why usually it will be in the last stage so, at the bottom and the motor with the first step. So, in the on the thirst shaft 3 step stage will be at the bottom and 2 step stage will be in the top if it is 2 into 3 then 2 will be at the bottom 3 will be in the top, that we have to keep in mind.

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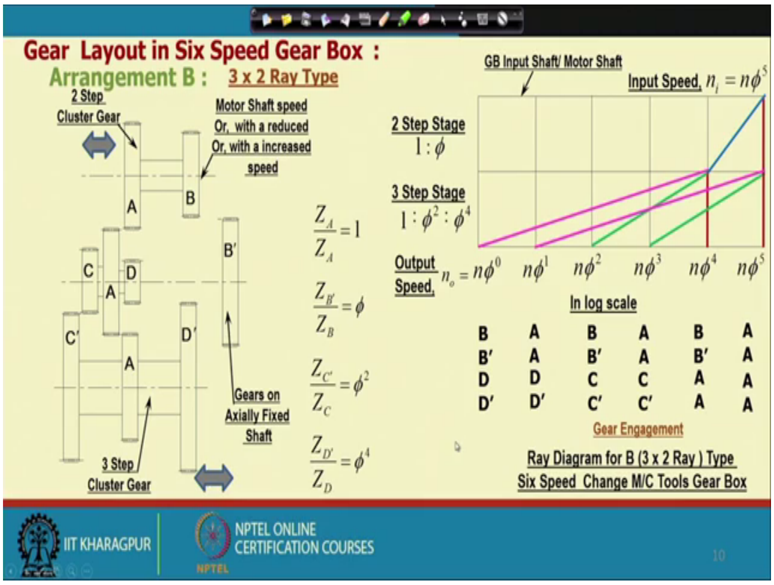

And now what we have got that already we have developed we have seen how the gears are engaged and what we find that by engaging A and A that is into 2 step stage or in 3 step stage we get the ratio 1, engaging Z B and Z B dash we get the common ratio phi, engaging Z C and Z C dash we get phi square and Z D dash and Z D we get phi to the power 4.

Now we have to find out the, what should be the possible tooth number for such gear units so, that we will find within it with using the same problem practical problem.

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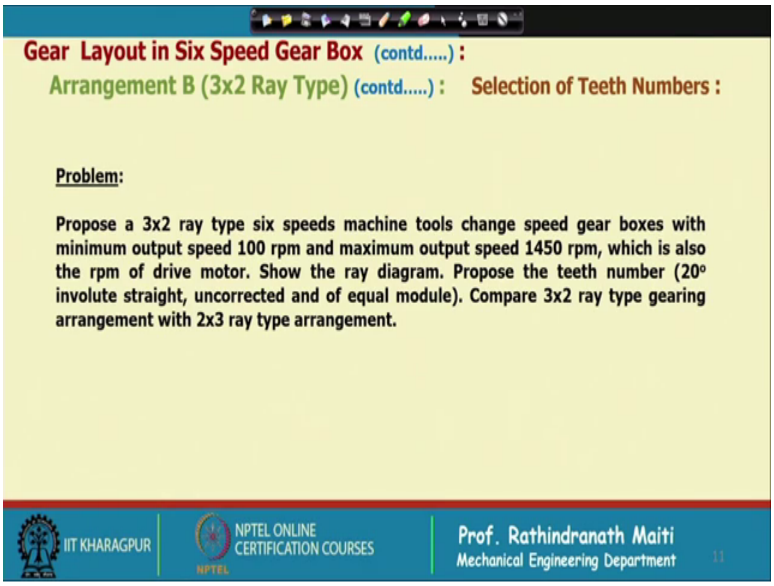

What we did for 2 into 3 ray type now the problem is that propose a 3 into 2 ray type 6 speeds machine tools change speed gearbox with minimum output speed 100 rpm and maximum output speed 1450 rpm. So, this means that we have to get 100 speed the minimum and maximum speed 1450 and this is in this case what we have considered that a this is the motor speed 1450 is the motor speed, but that may not be we can have some other speed or may be the same speed and it is not the motor speed it is from other gearbox another shaft it is coming.

So, the ray diagram so, we have to show the ray diagram in 3 into 2 ray type and proposed the teeth numbers and teeth must be 20 degree involute straight uncorrected and of equal module ; that means, for the for changing the gears replacement with other gears. So, what we do we take the same module and then we shall compare 3 into 2 ray type gearing arrangement with 2 into 3 ray type arrangements.

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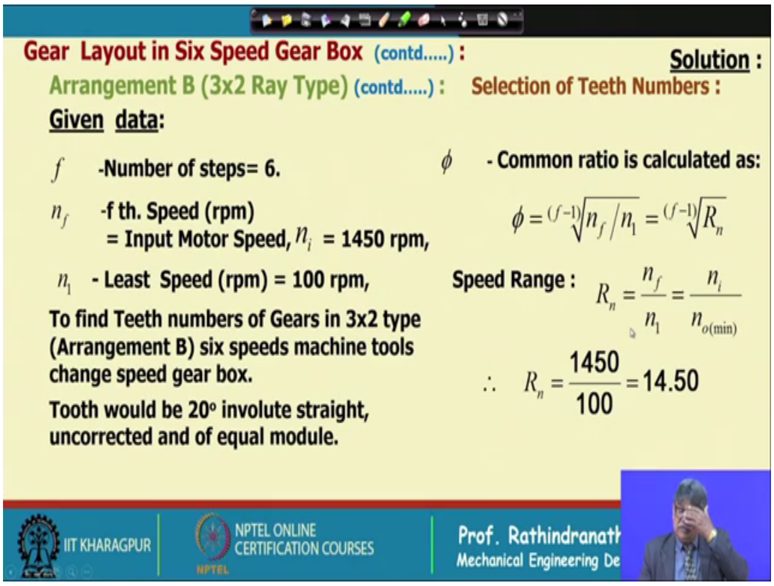

Now, what are the given data number of state steps is 6 it is mentioned and if it is speed rpm input motor speed n i is equal to 1450 rpm that is input rpm and list speed or rpm that which is called n 1. So, that is 100 rpm to find teeth number of gears in 3 into 2 type, which is we have mentioned as arrangement B 6 speeds machine tools change speed gearbox.

This we have to find the tooth would be 20 degree involute already we have mentioned, it should be straight tooth uncorrupted and off equal model. Now the common ratio we will calculate. Now the common ratio is either f th or in this case the final speed the maximum speed, that is called speed range.

So, that to the power number of step minus 1 not to the power that is under root of f minus 1 that would give is the common ratio. Now here the R n can be calculated this value the 1450 divided by 100 which is 14.50.

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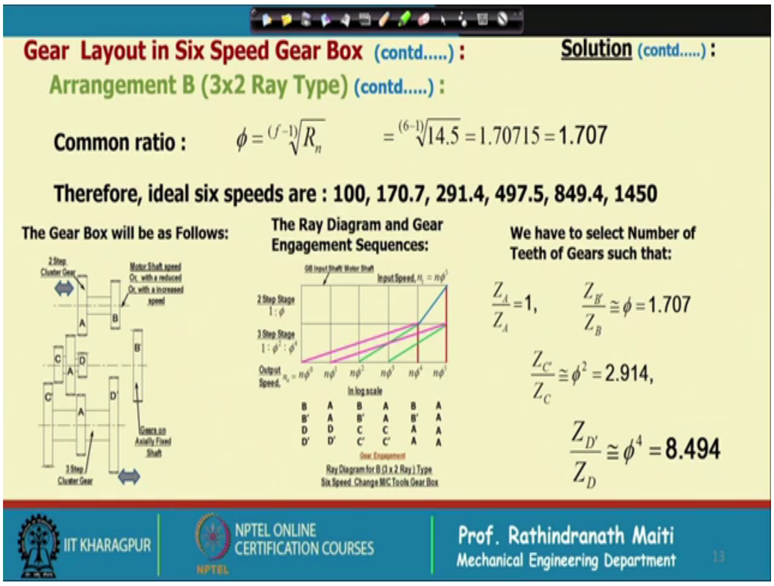

So, clearly the phi we will be calculated as 14.5 root 5, which gives us 1.70715 we can consider this is 1.707. So, this we want, but as the gear again cannot be of fraction teeth number.

There will be some deviation, but a design should be such that it is it should be as close as possible to the GP series. Now getting this we get the speed minimum is 100 the next speed is 170.7, next 291.5, next 497.5, next 849.5 and finally, 1450.

Now, while we use the gears in that case first of all 14 15 will 14 15 because this is motor speed and that is being transmitted 2 1 is to 1 gear, but other when in most of the cases will be very close to that even if the small smallest 100 it may not be hundred it is something different.

So, after choosing the gears we have to start from the maximum speed that I will show. Now this is the typical 3 into 2 ray type gear box already we have seen this one and here the this bottom step is the 3 step stage, there what we find in the on the cluster bottom cluster we find that 3 gears are there, and middle one which is the fixed shaft which is not moving axially this is having 4 gears firmly mounted on the shaft. Here the CAD it is apparently on a cluster, if maybe on a cluster or maybe separately mounted on their whereas, at the, this input shaft and the final output shaft you will find these are on a cluster.

Now, we shall try to find out the teeth numbers. So, this is the ray diagram which already we have developed, we have to select number of teeth of gears such that Z E by Z A; that means, this A gears of the same teeth number. So, the ratio is equal to 1 and Z B dash by Z B is equal to 1.707, that what the ratio we have found and Z C dash by Z C is equal to phi square is equal to 2.914 and Z D dash by Z D is equal to phi to the power 4, which is 8.4 9 4.

Now look at this 8.4 9 4 already what we have found earlier in a single stage this is not permitted, in machine tool design and this problem I have taken intentionally to show that this one is very high and with that also finally, we will have.

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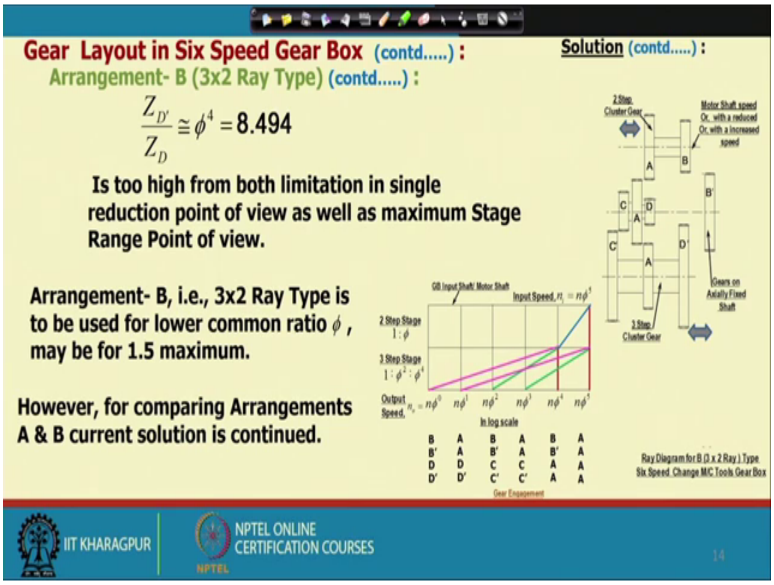

Now, this Z D dash by Z D phi to the power 4 it is too high from both limitation in single reduction point of view, because usually this is not more than 6 is allowed. As well as maximum stage range point of view what we have seen earlier. So, practically at this stage we should discard the design itself. And also there is a message that 3 into 2 ray type probably suitable will be suitable only for, if the phi is less in this case phi is 1.7 it should be less than that probably if it is even below 1.5, 1.2, 1.4 for that type of common ratio better we can go for 3 into 2 type gearboxes, but in arrangement ray 3 into 2 ray type is to be used for lower common ratio phi may be for 1.5 maximum I have written here.

So, you can you can examine in that case phi to the power 5 4 will be less than much less than 8.494 and it will be within the limit. However, for comparing the arrangements A and B current solution is continued this means that this problem has been taken that in such cases we will be tempted to go for arrangement a only and here I am after selecting the gears we will see what are the disadvantage going for that ratio 1.707 with 3 into 2 ray type.

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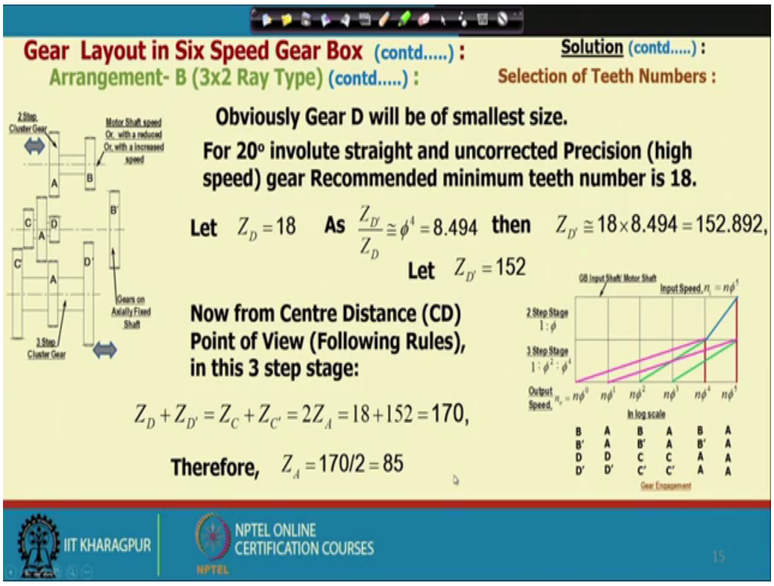

Now; obviously, gear D as this is DD dash is having the maximum ratio gear D we will have the smallest size and in this case as the ratio is very high. So, we shall go to a value as close as the minimum number of teeth and in case of 20 degree in involute state and corrected precision gears it is 17.

So, we shall go for 18 we will go for 18 it could be taken at 17 as well we are considering it is 18. So, if Z D dash is 18 then sorry Z D is 18 then Z D dash multiplying with the ratio for that gear it is coming 152.892. Now this could be taken as 153, because it is it very close to 153 from this transmission ratio point of view we would go for 153, but remember the summation of Z D plus Z D dash should be even number.

So, that we can divided by 2 to get the teeth number of A so, in that case we will consider Z D dash is equal to 152 not 153 and that surely there will be a deviation will be more. Now from this center distance point of view then Z D plus Z D dash must be equal to Z C plus Z C dash and that must be equal to 2 A plus Z A plus Z A that is twice Z A. So, that number is 170 and we get that Z A directly is 85.

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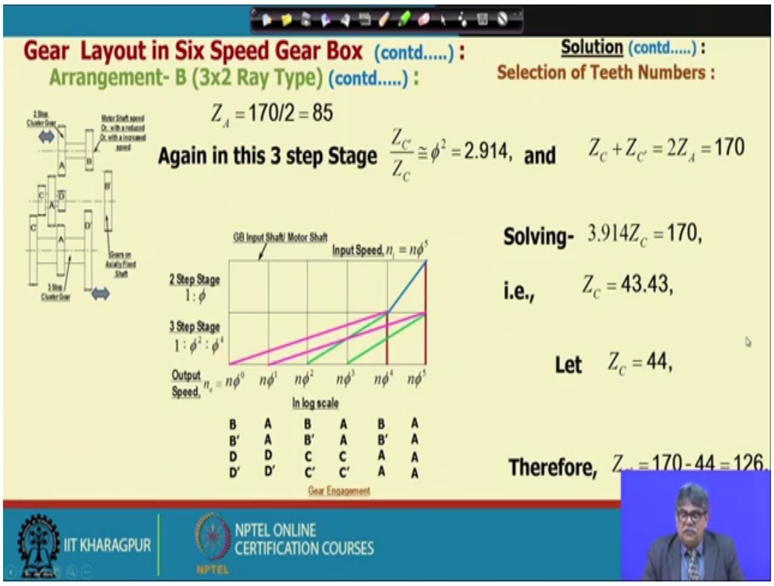

Next after selecting that Z A is equal to 85 we will try to find out the teeth number of Z C that is teeth number Z C and Z C dash for which the ratio is phi square and from there we find that Z C is 43.43 A 4 3.

So, we can go for either 43 or maybe we can go for 44 in this case we have taken 44 and Z C dash therefore, is 126.

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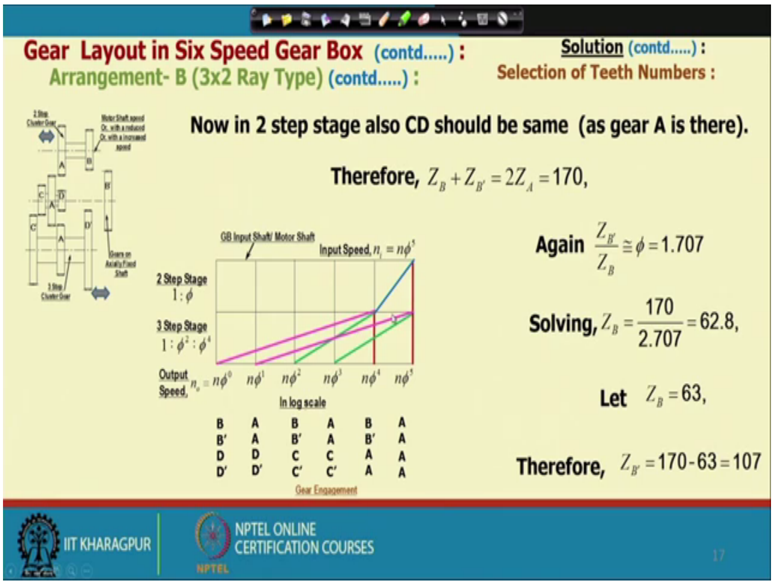

Now, in 2 step stage also C D should be same as gear A is there. So, therefore, Z B plus Z B dash that also is equal to 170 and again Z B dash by Z B which is equivalent to phi is 1.707, solving Z bay B we get it is 62.8, and we consider that Z B is equal to 63 and therefore, Z B dash is equal to 107.

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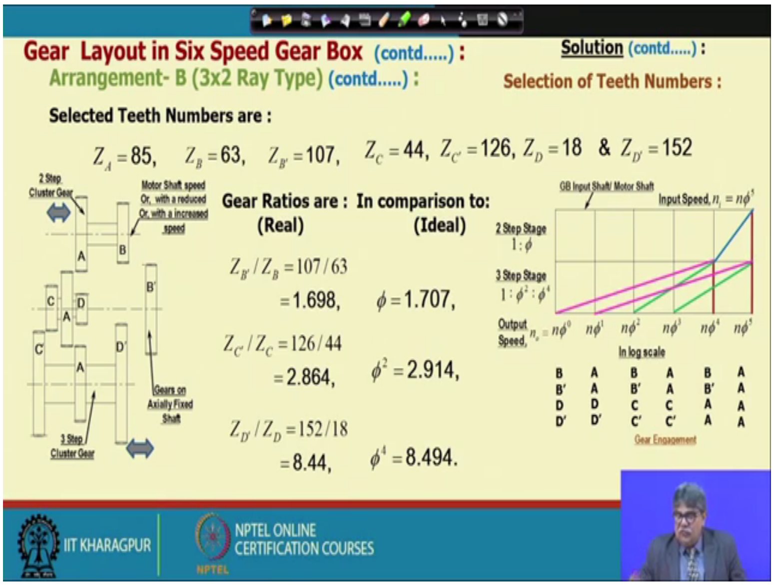

Now, we have selected all the teeth numbers. So, what we find Z A is equal to 85, ZB is equal to 63, Z B dash is equal to 107, Z C is equal to 44, Z C dash is equal to 126, Z D is equal to 18 and Z D dash is equal to 152. And the gear ratios the real gear ratios are 1.698 2.6 8 sorry 2.864 and 8.44.

In comparison to the ideal 1, where this is phi is equal to 1.707. So, there is some deviation and here it is 12. 8 6 4 we have got 2.9 1 4 and here in this case 8.44 and we have got 8.494 hm. And we should also know that if when the speed is high then this division is a little more that effect will be less whereas, if the speed is less the effect will be high. So, in that way we can go for another series of gear and we can find that these will be more close to the realistic value.

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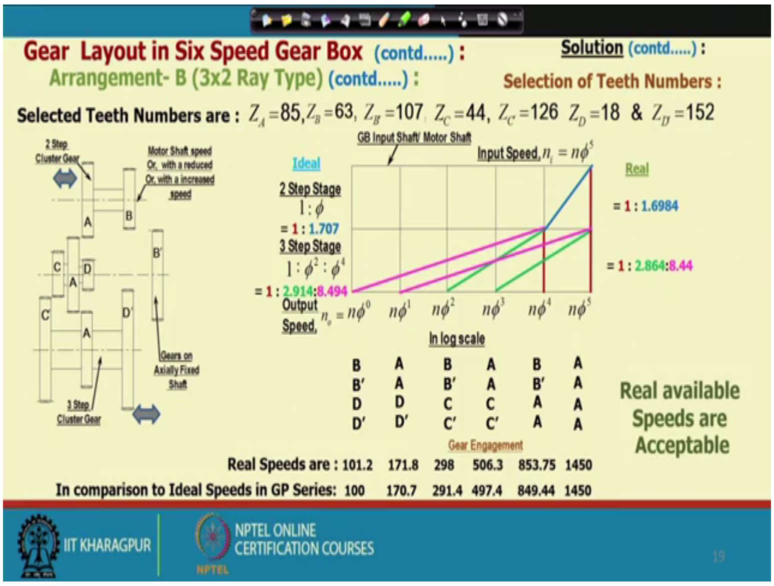

However, with this what we find that. So, this is the gear arrangement what we have shown here and realistic it could be like this ideal it is like this, but realistic we have got these 2 values, and with that real speeds we have got 101.2, 171.8, 298, 506.3, 853.7 6 and this is 1415 motor speed.

I suggest here that instead of maturing this value although it has been calculated, when we are calculating this value we should consider direct gear ratio and from there we should get these values. Now this if you compare with the actual series what we have taken that what we find that maximum speed of course, 1450 the next speed a was 849 close to 850 and we have got close to 854, this deviation is not much. Next we wanted to have 497.4, but we have got 5 0 6 3 elevation a little bit more and next to that we wanted to have 291.4, but the speed is achieved is 298, next the which is the common ratio multiplied by the minimum 170.7 and we have got 171. 8.

Very close and the lowest one instead of 100 we have got 101.2. Now these values the speed values are really acceptable, we can go for some other gear and spend maybe we can take teeth number as low at 16 also which slight modification or without modification and in that case 16 or 17 and we can find that this ratio may be close to that. And perhaps there some optimization technique can be developed by which we can find which one will give the level value, but there is a little scope because the smallest gear we have to take very close to 17 in case of 20 degree teeth. In case of course, if you go for 30 degree pressure angle there we can take the teeth number much less.

Now, if we compare these 2 Gear box.

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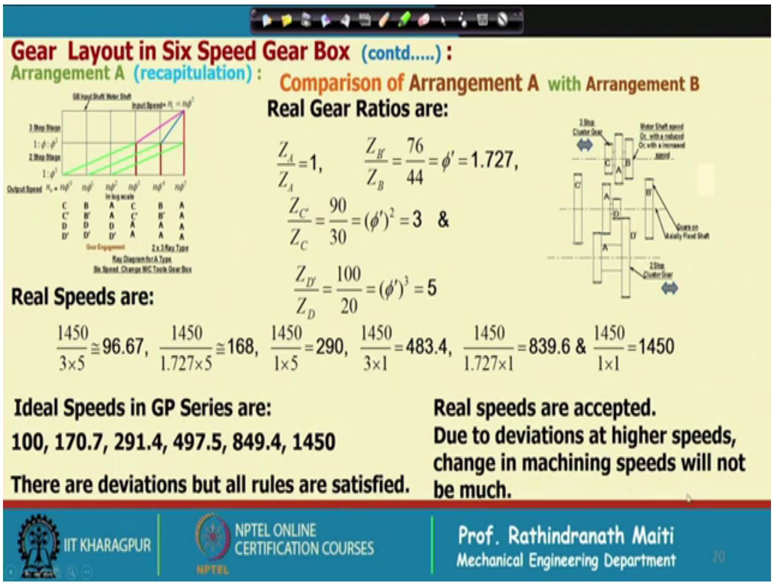

First of all we will see that what we did in case of arrangement A, this is recapitulation there the ratio was 1.7 to 7 and from there we got the speed ratio 96.6 5 and then 1 sorry 294 82 and 4 839.6, 1450, if this is 168 in comparison to the realistic value 100 and it is 70.7 to 91.4, 497, 849, and 1450, these are also very close.

So, by both gearing arrangement it says the speed is constants we have got more or less same deviation hm. So, both are acceptable from speed point of view, but let us look the other things.

Real speeds are acceptable due to deviations at higher speeds change in machining speeds will not be much.

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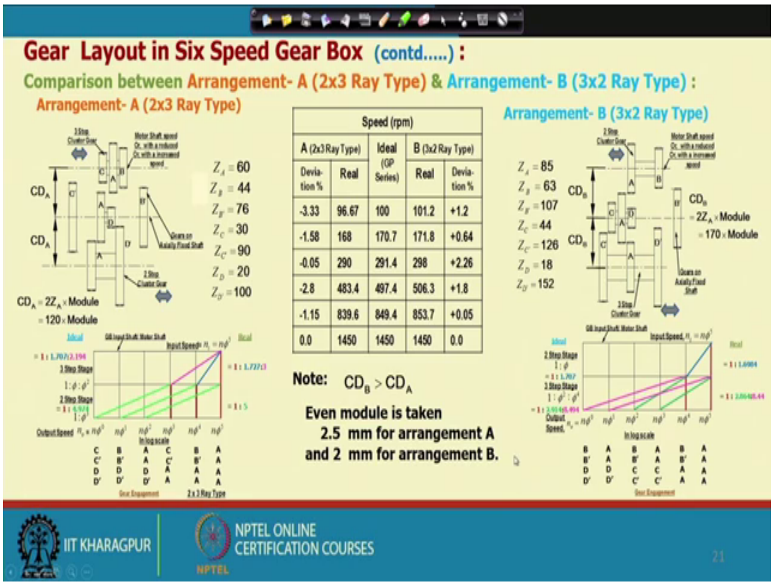

Now, we shall compare these 2. So, we have 2 into 3 ray type the gearbox arrangement is this and this is the ray diagram, and if we consider the arrangement B 3 into 2 ray type for that the ray diagram is this you can you can see these what are the differences are there.

And this teeth number selected in this for this gear box these are the teeth numbers here these are the teeth numbers. Now then if we judge the deviation from the speed this is the ideal speed and here the real speed for 2 into 3 ray type here 3 into 2 ray type this is a little higher side for.

So, this deviation is all plus this deviation is all minus and what we find in this case maximum de deviation is 3.3 3 in this case maximum deviation is 2.26. So, maybe the B is better than from the speed deviation point of view, but if we look into the center distance this center distance the 120 into module here it is 170 into module and in that way even if you take the this case say 2.5, 2.5 is generally used for this gear it is very common either 2 or 2.5 is used, let us consider that we have taken 2.5. So, in this case the center distance will be totally 240 plus 6 300 and in this case it will be much higher.

Even if we reduce this to 2 module still the center distance will be more. So, in that considerations definitely this gear box will arrangement A 2 into 3 ray type will be better in that way. And also I would like to mention that in this case as this last stage that is D by D dash in arrangement B is very high, we should this can this arrangement A, but speed wise it was better than A.

Now, this is the end of the lecture series as well as the end of the course and I think that you have been benefited out of this course. By no means this, has made you an expert on gear design, but if you keep all this basic design in the background, then whatever problem you face which is more difficult in gear designing, definitely this will help you to find a way how the gear can be designed. Of course, we should read more and more on gears.

Thank you.