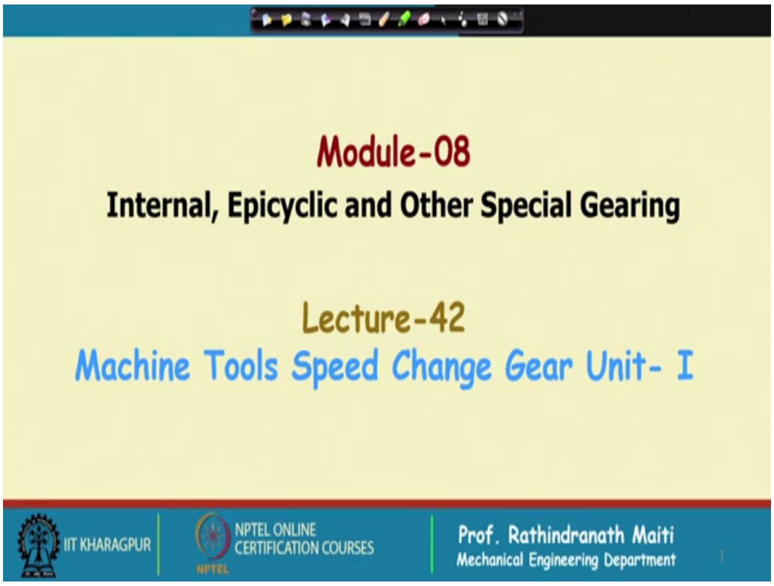
Gear and Gear Unit Design: Theory and Practice
Prof. Rathindranath Maiti
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 42
Machine Tools Speed Change Gear Unit – I

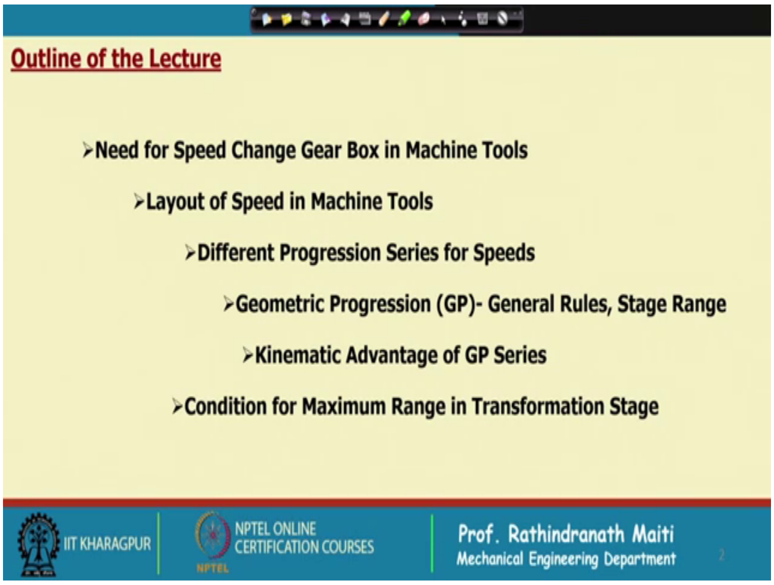
Internal epicyclic and other special gears modulate 8.

(Refer Slide Time: 00:17)



And, today's lecture is a really a special gear, which is Machine Tools Speed Change Gear Unit and this is the first lecture on that topic.

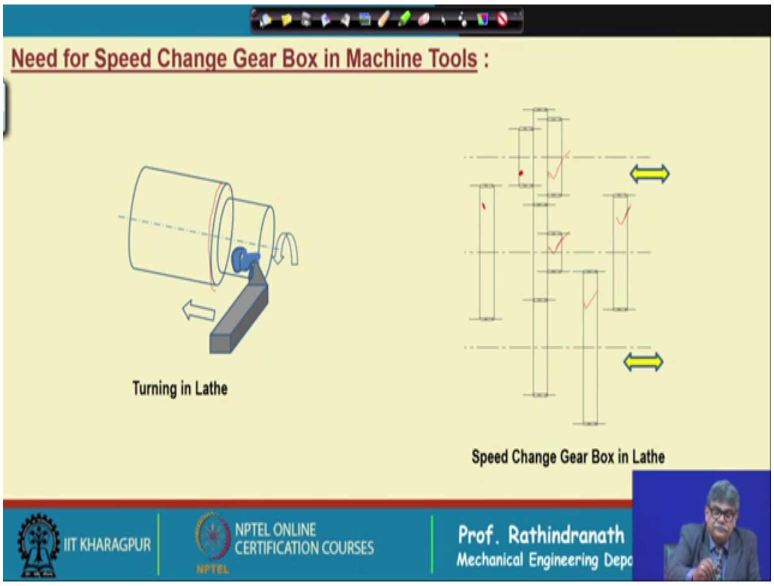
(Refer Slide Time: 00:37)



Now, in this lecture, I shall cover need for speeds change gear box in machine tools, layout of speed in machine tools, different progression series for speeds.

Geometric proposition GP General Rules and Stage Range, then Kinematic Advantage of GP Series, and finally, Condition for Maximum Range in Transformation Stage.

(Refer Slide Time: 01:10)



Now, first I shall discussed, why we need speed change in machine tool gearbox? Let us consider a circular bar, which is being machined in a lathe this is the turning process and tool is engaged here. If we consider the first the diameter was the left hand side what was the diameter was there.

So, first diameter it was it this big ok. And we have reduced this one again this might be second cut or I think. Now lathe this spindle that rotates at a certain speed and if we consider the velocity at the teeth of the tool that is the cutting velocity. That definitely for the same speed we will reduce, when the diameter reduces.

Now it is been found that for a particular material with a particular type of tool, that this speed should be should have an optimum value for which the surface will be the best finished. This of course, changes a depends on other factors also, but speed here is one factor.

This means that, when the in this turning process? When the diameter is being reduced it is if it is reduced then we can go for higher speed , but diameter is changing in infinitely; that means, first it is the highest diameter then again it is reduced again it is like that. So, each and every point if you would like to increase the speed that is possible it is not that it is not possible we can use that set of control and that set of mechanism. So, that speed is increases keeping the cutting velocity always equal , but if this will be expensive and go all the control and everything will be also the maintenance cost running cost operating cost everything will be higher.

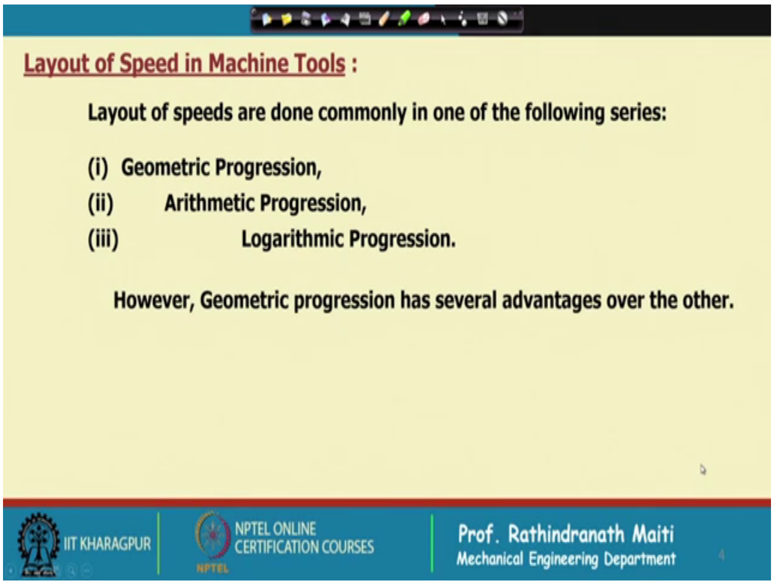
Now, it has been seen that for a diameter range we can keep the same speed and we get the average of that, but the very close to the best finish this means that say for example, we can give the rpm 50 for the diameter may be 63 to 55 millimeter say. This means that if the spindle is driven by a motor and a gearbox where we can change the speed or some means it is not necessarily gearbox it might be the bell drive also.

We can change the speed then looking into the diameter we can change the speed before cutting process start; that means, suppose if we have taken a 200 millimeter diawar and we have to reduce it up to 100 or maybe different steps are there, then possibly we will we may need 3 4 5 different speed to have the best finish of that. So, for that we need a some sort of gearbox.

Now, here it is shown that this is a speed change gearbox in length we shall discuss later that how this gearbox is designed? So, here what it is seen there are 3 shafts usually this intermediate shafts it will it is kept fixed; that means, gear on that are positionally fixed whereas, these are the cluster gears this can move this way and that way also this can move this way and that way. Say, if at this moment as you see that all these 3 gears on 3 shafts of equal size they are engaged, this means that if this shaft is connected to motor and this shaft is connected to lathe spindle then this is this will give the same speed.

But, as we if we change this next gear or this gear this means, if we engage this with this or this with this then we will have a different speed and again in this stage we can engage with this and in that way we can have totally 6 speed out of this gearbox. We shall discuss about this gearbox later as shown here, this and these gears that those can be shifted and in that way this gearbox is designed.

(Refer Slide Time: 07:20)



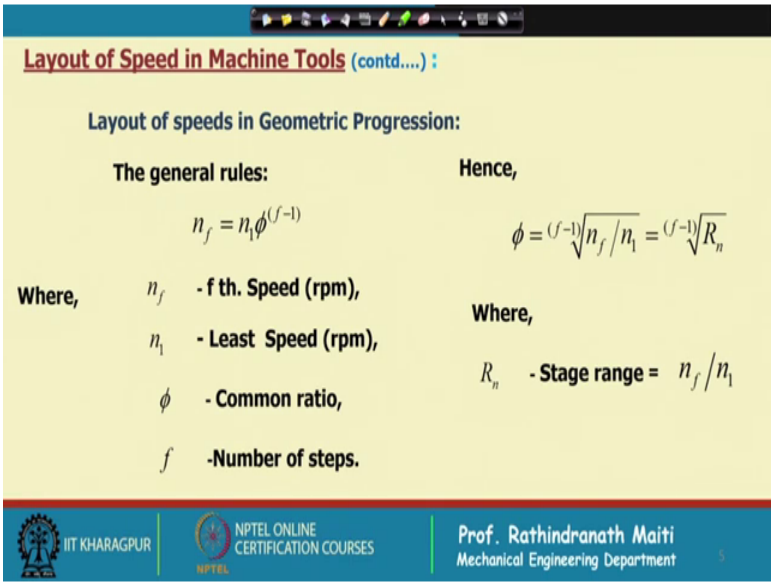
Now layout of speeds are done commonly in one of the following series, it might be geometric progression, it might be arithmetic progression, and it might be logarithmic progressioN.

Depending on what is the purpose, but it has been found that geometric progression gives better results say for example, if we take a bar of 200 millimeter and that will be made a stiff sets or spindle which may have minimum diameter 50 and maximum diameter say 180 and there will be few steps. And it is found if the speed are varied in geometric progression that is again in the steps then, that will be best utilized for the better surface finish of that sort of operation. So, in geometrics progression is widely used.

Now, what is the advantage of geometric progression, arithmetic progression, or logarithmic progressions, and where in which machine what is used these are basically taught in do into the machine tool designs. In this case we shall consider only how to design a speed change gearbox and we are considering only geometric progression and tool. So, that what might be the speeds and what are the restriction there? What are the limitations there? And from there how we can design a gearbox? It might be 6 steps gearbox, it might be 8, or it might be even less.

So, we with the help of an example and geometric progression series I will show you how the gearbox are designed, design means basic design what are the teeth numbers etcetera, etcetera.

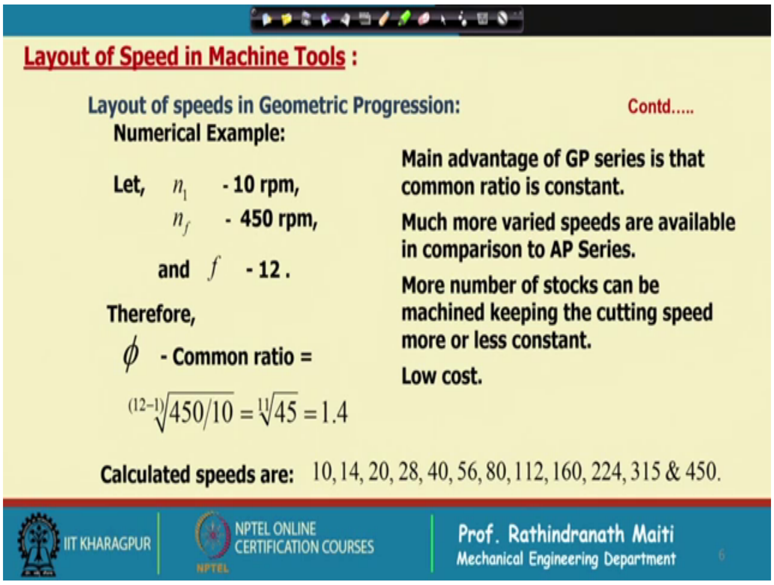
(Refer Slide Time: 09:30)



Now, first of all layout of speeds in geometric progression. The general rules are say in f at f stage the speed will be n one speed at a particular range then phi minus f minus 1, where n f is the fifth ff speed and n 1 is the least speed phi is the common ratio in geometric progression and f is the number of steps.

Hence, the common ratio can be found out from this formula, this way. And now this a fifth speed by the least speed that is called that is designated as R n where R n is the stage range ; that means, this may be 2 stage, but total stage range each R n.

(Refer Slide Time: 10:45)



Now, let us consider and numerical example n 1 is 10 rpm, and final speed we would like to have 450 rpm, 10 rpm say for a lathe it is very slow speed, but if the diameter is very large we need to go for such a slow speed just for your information. Now that speed from 10 to 450 we would like to go in 12 steps.

So, therefore, common ratio phi will be 12 minus 1 sorry 450 divided by 10 root under root 12 minus 1; that means, under root 11 45, which is 1.4 this is a if we know this is very close to root 2 and it is a good number.

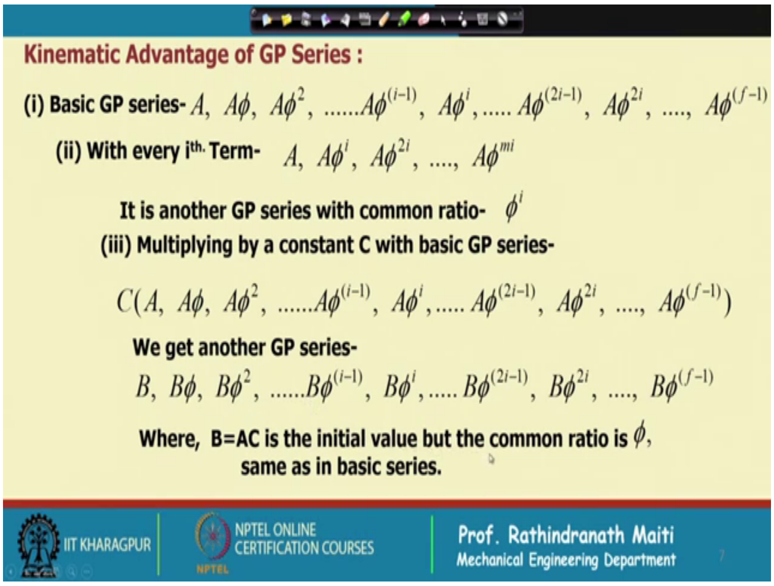
And in that way we can calculate, if you just go by the formula that any n f speed is equal to n 1 into phi to the power f minus 1, we will get this 12 speed 10, 14, 20, 28, 40, 56, 80, 112, 160, 224, 315, 450. As you can see these are increasing in such a way and it is found, if we finish a circular bar with such a from such a the from a diameter where we need 10 rpm.

Then we come down to 450 rpm if we by in that process if you change the speed 10 next when the diameter is slightly reduced 14, then next when it is reduced the 20 28 like that will get more or less same cutting speed at the tooth teeth. So, this is the preferred series. Now the question is that maybe 10; we are getting at the beginning is it possible the gears should be such that we will get 14, 20, 28, 40, 56 in all value what we have calculated here answer is no, it is not possible that we can get. Because this teeth are of whole number and ratio of that may not match that alpha alpha square alpha q all cannot be matched, that is the that we should learn and we should try to make the gearbox as close as possible to get this speed as close as possible.

We will see that. Now main advantage of GP series is that common ratio is constant much more varied speeds are available in comparison to arithmetic progression series more number of stocks can be machined keeping the cutting speed more or less constant, and this is also found that this can be designed with low score.

So, unless there is a special purpose we normally we would follow the geometric progression nor the logarithmic progression; Now the arithmetic progression series.

(Refer Slide Time: 14:37)

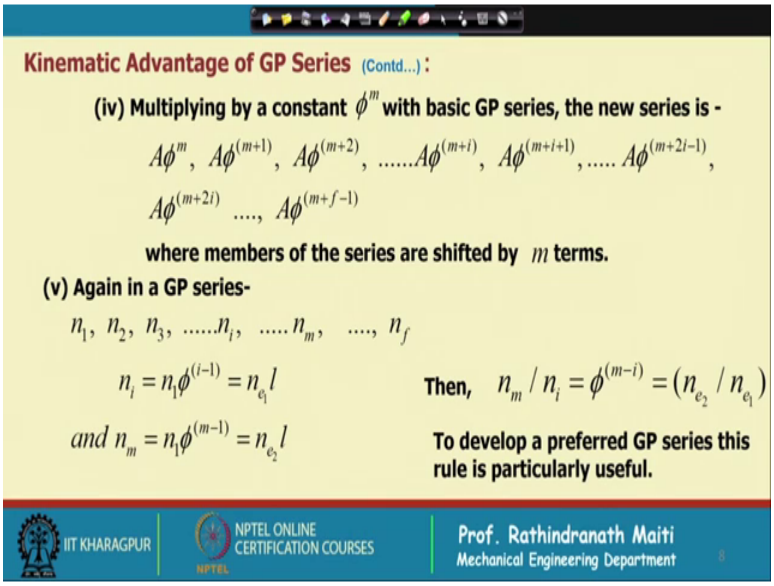


Now, another things that what are the kinematic advantage of this GP series that also I am discussing, because in the gearbox you will find just simply suppose there is a 6 steps gearbox, just adding another stiff they are that is from motor to input to that gearbox; we can get another series.

So, that is quite interesting. Now basic GP series as we have taken A into A alpha A alpha square, etcetera, etcetera A is the initial, then with every i th term a alpha to the power i alpha to the power 2 I, etcetera, etcetera, this is also another GP series; that means, suppose if we can a speed increaser or decreaser and there will be step jump like this and we will get this a new series, it is another GP series with common ratio phi to the power I multiplying by a constant C with basic GP series, that we will get another new GP series that we have multiplied by A C this is simply suppose that we have increased the motor speed or decrease this motor speed, at the minimum was 10 we have made it 15 then we will get this new rpm, but keeping this ratio same.

But it is a new series of the speeds. So, that is again regenerated by BB B 5 B phi square etcetera.

(Refer Slide Time: 16:27)

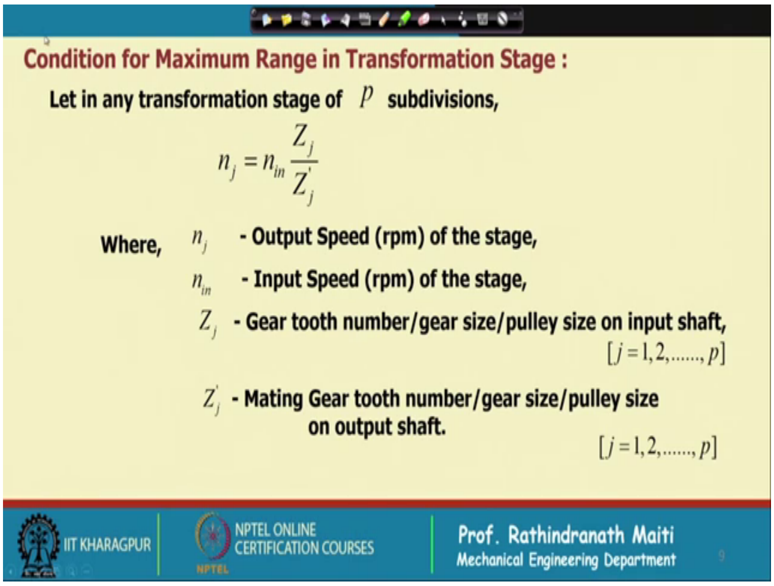


Multiplying by a common constant phi to the power m with basic GP series the new series will become A phi to the power m A 5 m plus 1 and last 1 m plus f minus 1, but this is again another series. Again in A GP series n 1 n 2 n 3 n I n m n f, which is n I is equal to n 1 into phi 1 minus 1 I minus 1. Similarly n m can be expressed is n 1 phi m minus 1 that is n e 2 into l that is l is a common factor is coming and with that we will get n e 2 by n y is equal to phi m minus 1 to develop a preferred GP series this rule is particularly useful we can we can have another GP series.

Now, these are at this instant it is very very difficult to grasp that these are all possible if we have a standard sorry we have already designed to gearbox is 6 6 steps or maybe tool step in this case. And then we adding the externally some other gear ratio or increasing or decreasing the speed of the motor or the prime over, we can get another different series.

So, this means that, suppose if we need to machine say a bar 400 to 50 millimeter in 1 this smallest diameter there then if we take another one say which is 100 to say 25 possibly, we can use the same machine with maybe another set of gears and that can be used. So, that is the advantage of GP series.

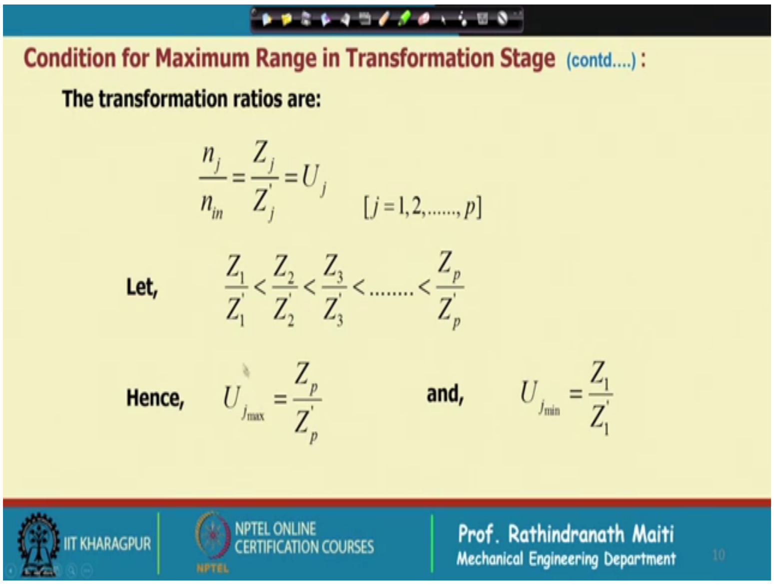
(Refer Slide Time: 18:36)



This 2; I have shown this in with respect to understand that what is the what we need to consider in designing a gearbox and machine tools? Let in an in an transformation stage of peace have divisions ; that means, n j is equal to n in that is the input rpm into Z j by Z j by sorry Z prime j. This means that here we what we would like to express that n j is the output speed of that stage at a particular stage and n in is the inputs speed of that stage and Z j is a gear tooth number gear size pulley size or input shafts. Say that might be j is equal to 1 2 3 up to P and Z S mating gear tooth numbers gear size that also vary from this to this, this means that by this ratio simple the gear ratio Z j by Z dash j or we can consider the Z 1 by Z 2.

Then, we can have another speed that a output speed. Now this ratio if we change the output speed we will change keeping the inputs puts speed is constant.

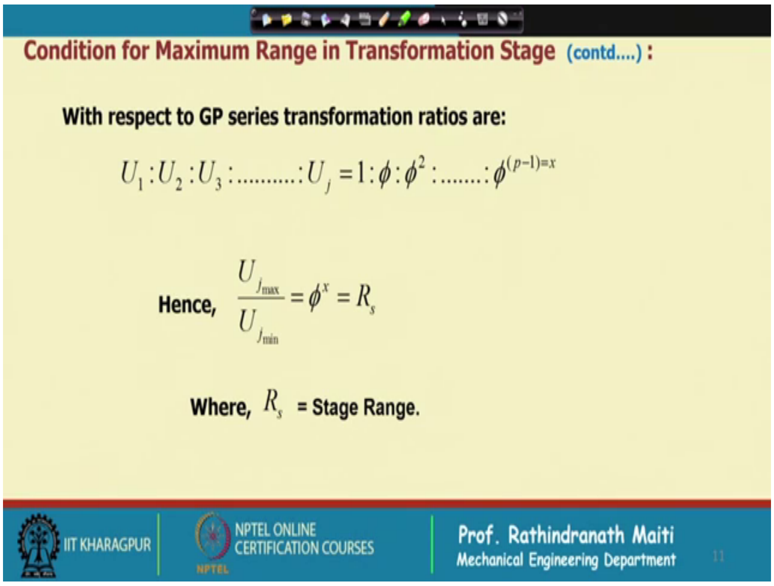
(Refer Slide Time: 20:08)



Now, this is called this is defined as U j and here as we find Z 1 Z dash Z 1 dash Z 2 by Z 2 dash is equal to Z 3 by Z 3 dash this is all as you see that to get the different speeds we need to use the different sets of gears and with that we find that we will get different speed that is shown here now hence U j max is the Z p by Z j p ok. So, that is the maximum transformation U j max. So, U j max is U j mean if Z 1 by Z 1 dash Z 1 dash.

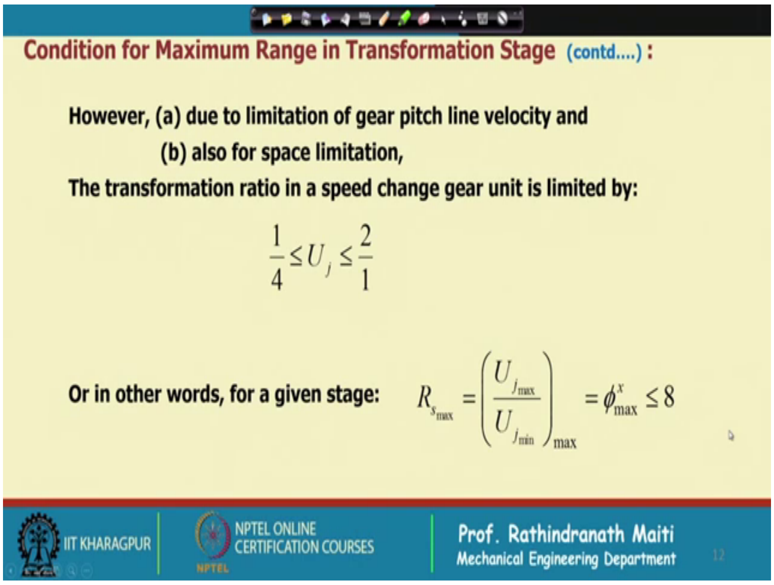
So, this is what we will calculated in this range analysis this is the minimum and this is the maximum and there should have in a gearbox this should have again some limitations.

(Refer Slide Time: 21:15)



And if we put U one U 2 U 3 up to U j we will find 1 phi phi square etcetera, etcetera, we will get it and U j max by U j mean is equal to phi to the power x this is P 1 minus is equal to x. So, phi x is equal to R S. So, this R is it is called stage range ok. Now this stage range again it will be limited.

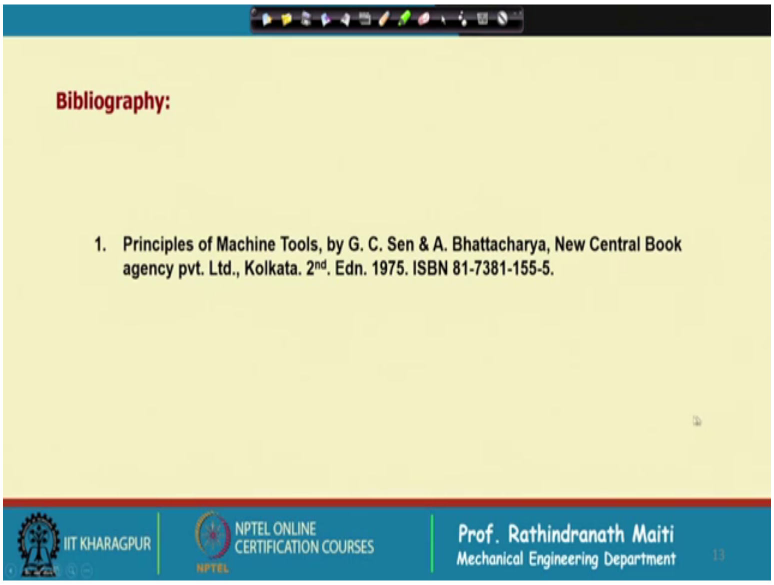
(Refer Slide Time: 22:00)



Now, due to limitations of gear pitch line velocity and also for space limitations, the task transformation ratio in a speed change gear unit is limited by 1 by 4 U j sorry 1 by 4 should be less than equal to U j should be less than equal to 2 by 1; that means, if we look into this equation.

That one side it is 1 by 4 a U j should be greater than that or equal to that and it should be less than 2 by 1; that means, totally in that case from minimum to maximum is 8. So, that sort of limitations is there which is shown here; that means, for a given stage R S max U j max by U j mean is equal to phi x max and which is less than equal to 8.

(Refer Slide Time: 23:08)



So, this we need to follow for designing the gearbox, when we come to a practical problem then I will show how these rules are followed. Now this means that in this lecture what we have learned we have first of all considered that why we need the speed change, then we have shown that how what are the different series that are followed for the speed change, and it is found that GP series is the best and in the GP series how to find out the different ratios? And then while we are selecting the steps and stages, then what should be the bare range a stage range.

Now this is any machine tools book machine tool design books can be followed, but this is a special mention that this is a machine tools by G C Sen and Bhattacharya of New Central Book agency Kolkata this is the old book, but that is a very good book where you can get you can learn more about this machine tools gear box design.

Thank you.