Gear and Gear Unit Design: Theory and Practice
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Lecture – 41
Reverted Gearing and Differential Gearing

We are continuing with internal epicyclic and other special gearing. And today's lecture is on a really special gearing, which is called reverted gearing and also I shall discuss about the conventional differential gearing and later I will show how riveted gearing also can be used as differential gearing.

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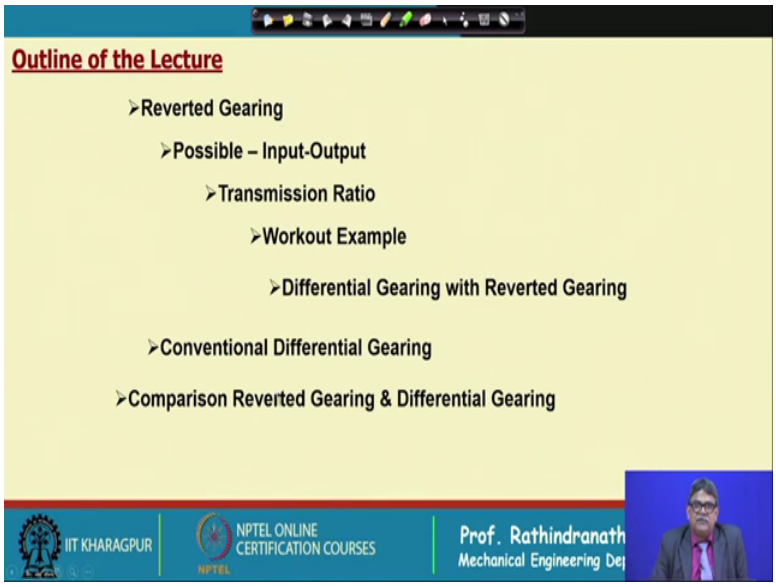

In this lecture I shall cover first I shall discuss about riveted gearing, then possible input output in reverted gearing, then transmission ratio next and workout example to estimate the transmission ratio of reverted gearing and as well as the possible direction of rotation.

Differential gearing with reverted gearing that I will also discuss. Next I will come to conventional differential gearing, which is used in automobiles comparison of riveted gearing and differential gearing.

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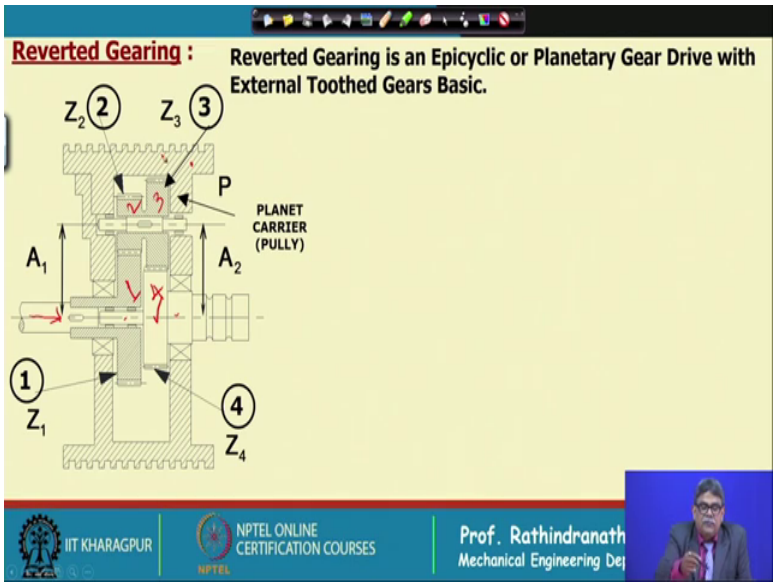

Now, what is riveted gearing, if we look into this figure, then in this figure first of all this we looks something like a drum for build drive this is a not flat belt, but the other belt drive with groove is there.

Now, inside there is a gearing arrangement what we look. First of all this is gear 1 this gear 1 connected to a shaft this is gear 1 and it is connected to a shaft and it is mounted from 1 side and then it is machine with a planetary gear of teeth number Z 2 and with the Z 2 integral is Z 3 which is having higher teeth number. Then finally, Z 3 is connected to Z 4, this is 3, this is 2, and this is 4 and as you see that this shaft is mounted with bearings inside the gearing, but; however, the bearing arrangement may be different we can say that this is on a fixed frame this bearing arrangement with fixed frame and may be with the rotating drum also as shown here.

This means that this gear can be rotated from this side this gear can be rotated from this side separately independently and these 2 will be output I will I will come to that and in this case input is the this drum. Now it is an epicyclic or planetary gear drive with external toothed gears.

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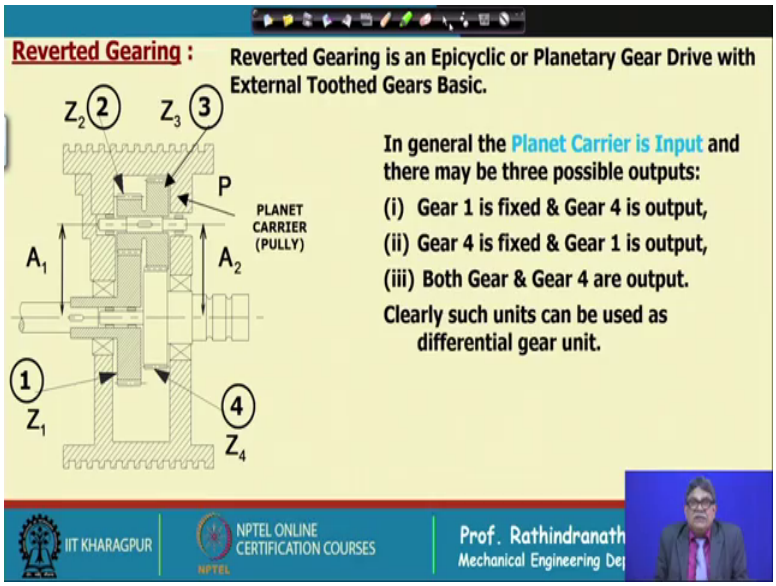

And in general the planet carrier is input and there may be 3 possible outputs first 1 is gear 1 ; that means, this I have already shown which is gear 1 it is marked by Z 1 1 that will be affixed and gear 4 is output, where input is the planet carrier come the pulley, because the planet carrier is directly mounted on the pulley.

Next gear 4 is fixed and gear 1 is output and third 1 both gear 1 and 4 are output both gear 1 and 4 are output. So, here it will be gear 1 gear 1 and gear 4 both are output clearly such units can be used as differential gear unit this means that, if we give the planet carrier input and take the output from both 1 and 4 that will rotate at the same speed of the pulley because everything will be in the coupling action, but if we hold one say 4 is fully held or partially held then gear 1 will rotate with some reductions.

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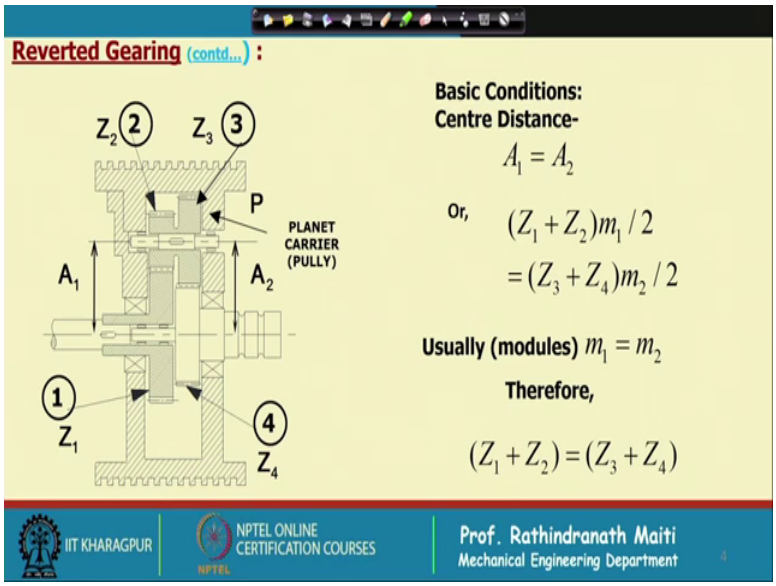

Now, basic conditions is that center distance from here to here and here to here as the planets are on this is integral on the same shaft. So, and input output is coaxial this centered distance must be equal or we can write Z 1 plus Z 2, that is the teeth number of gear or pinion 1 and planet pinion 2 2 multiplied by module of that section must be equal to Z 3 plus Z 4 into module of 2 divided by 2 we can eliminate 2 also, 2 is 4 we have put it as we have considered center distance.

Usually this modules m 1 and m 2 their same and it is equal to m you can you can consider therefore, the condition to be satisfied Z 1 plus Z 2 is equal to Z 3 plus Z 4, that is clear from the figure. It is not essential that module should be same, because if we would like to optimize this gearbox maybe size point of view it might be better if we take m 1 not equal to m 2, but usually if we make the m 1, module m 1 is equal to m 2 then the it will be cost effective and arrangement will be easy.

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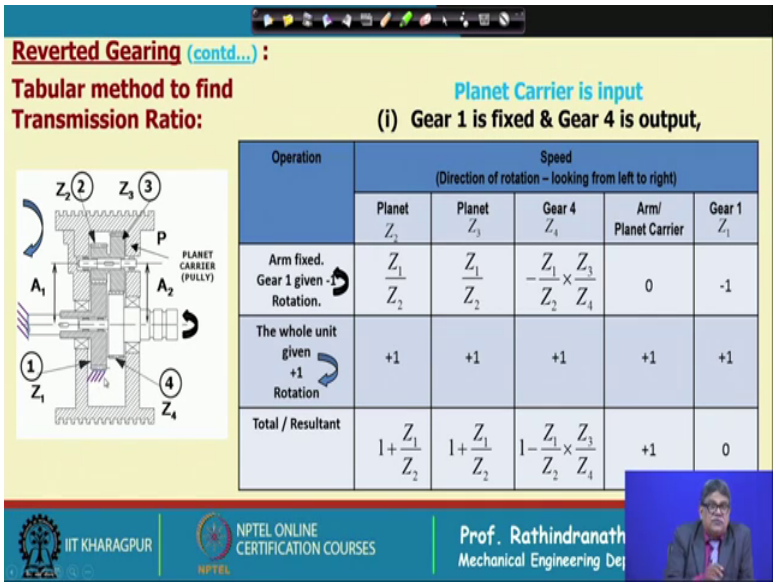

Now, how to find out their transmission ratio first we shall consider the first case which is gear 1 is fixed and gear 4 is output. In this case as you see this gear 1 that will remain fixed and input will be the planet carrier or the pulley and output will be 4.

Now to find out the transmission ratio in tabular method what we do arm fixed; that means, pulley is fixed and gear 1 is given minus 1 rotation minus 1 in this case, it is looking from that side or along the axis, it is rotating in the anti clockwise directions and looking from right hand it is rotating in the clockwise direction this is minus 1 rotation.

So, if it rotates the shaft that is the pinion rotates 1 revolution in that case planet Z 2 will rotate by Z 1 by Z 2 if Z 1 is more than 0, it usually it is like that then it will have more revolution more than 1 and the direction will be opposite. So, we will consider plus sign for that and the adjacent Z 3 integral Z 3 must be we will be equal to so, it is Z 1 by Z 2 and gear 4 will rotate in the opposite directions and it is it is a simple gear ratio of compound gear train that is Z 1 by Z 2 into Z 3 by Z 4.

And the planet carrier no motion 0 we have kept it fixed and gear 1 minus 1 as we have given this rotation. Now what we do the whole unit given plus 1 rotation this means that we take the whole unit along with the pulley planet everything we rotate by one revolution, that is in the opposite directions that is looking from left it is clockwise looking from right it is anti-clockwise direction it is plus 1.

So, we can add the plus 1 as per the concept of or the principle of epicyclic gearing on planetary gearing we add plus 1 to everyone. This direction is shown here and then the total resultant will become the planet Z 2 1 plus Z 1 by Z 2 planet Z 3 also the same and the gear 4 will be 1 minus Z 1 by Z 2 into Z 3 by Z 4 whereas, Arm planet carrier is the plus 1 and the gear 1 becomes 0 as we have given the 1 revolution in the opposite direction to the first rotation given to pinion 1 pinion or gear 1. So, with this table remember this value 1 minus Z 1 by Z 2 into Z 3 by Z 4.

So, this is the output and input is 1 for this pulley is rotating we if it rotates 1 revolution, then the output gear will rotate 1 minus Z 1 by by Z 2 into Z by Z 4. Therefore, you can see this we have shown on the figure that 1 is fixed and the output direction is also shown what might be the direction possible? However, we need to know the sign from the ratios.

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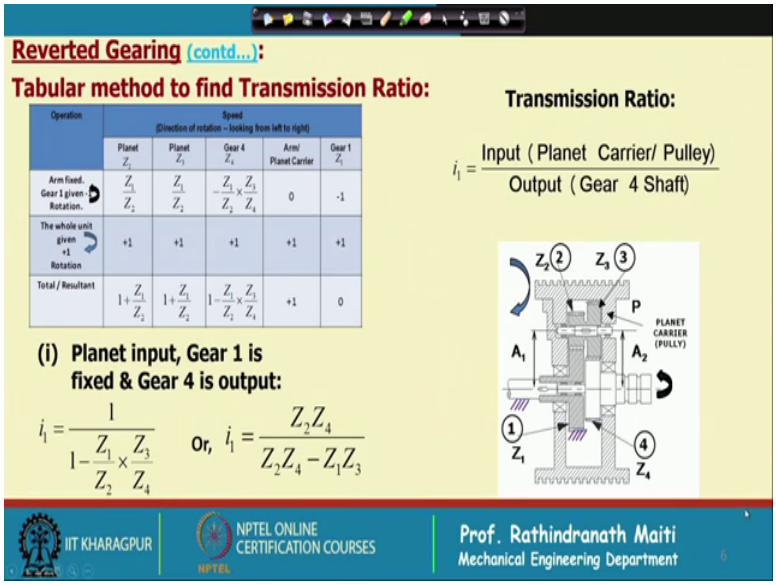

Now, again I have shown in the table, now the transmission ratio is input planet carrier pulley divided by output gear 4 shaft the rotation of that might be speed of that if it is talk it will be vice versa.

Now, this if we substitute that input planet carrier pulley is rotating at 1 revolution, it has rotated 1 revolution and output is 1 minus Z 1 by Z 2 into Z 3 by Z 4 and if we equate we find I 1 the transmission ratio arrangement 1 is Z 2 by Z 4 divided by Z 2 into Z 4 minus Z 1 into Z 3.

So, type one we get this one we should remember this formula or it is not difficult to find out also and here it is shown that what will be the arrangement.

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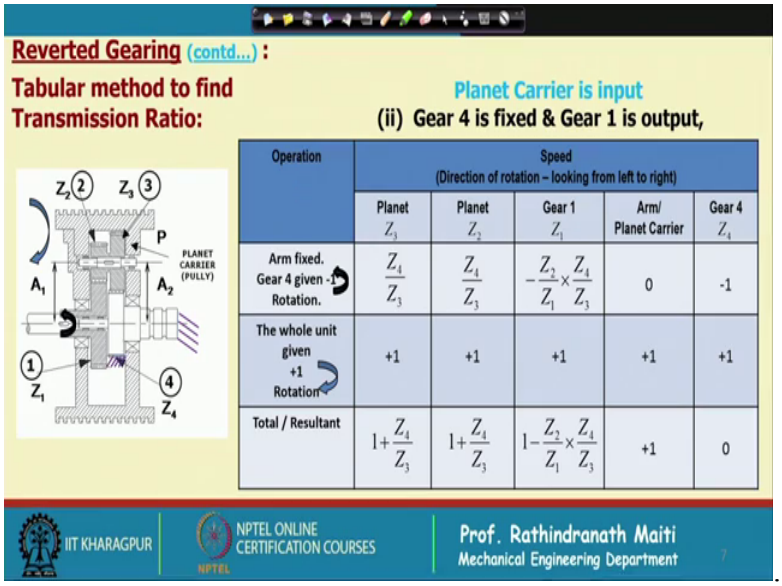

Now, if we consider the case 2 in that case we have considered gear 4 is fixed and gear 1 is output, where input remains the same the planet carrier.

Now, in the same way Arm fixed and gear 1 is given minus 1 rotation that is the clockwise from right hand side looking toward the axis. So, Z 3 rotate by Z 4 by Z 3. So, depending on which one is bigger Z 3 may rotate a less than 1 revolution or more than 1 revolution we will come to this ratio later, planet Z 2 which is integral that will rotate in Z 4 by Z 3 gear 1 will rotate again the gearing ratio, the Z 4 by Z 3 into Z 2 by Z 1 minus sign will come it will be opposite to the direction given to the 4 sorry the same direction given to the 4 and Arm and planet carrier is 0 and gear 4 is minus 1 which we have given.

Now, whole unit is given plus 1 revolution that is in anti-clockwise direction from the right hand side through the axis. So, we simply add the plus 1 to all in the same way as we did earlier. And we get that planet 3 will have rotation 1 plus Z 4 by Z 3 and planet Z 2 will have 1 plus Z 4 by Z 3 whereas, gear 1 we will have gear or pinion whatever you call it, 1 minus Z 2 by Z 1 into Z 4 by Z 3 arm planet carrier is plus 1 and gear 4 is 0.

And if we look that this is the input this is the output and this gear has been kept fixed. So, we have seen the possible to output and about the possible 3, input output as I told that whole unit if it is rotated then as the planet carrier is here then this will simply rotate these 2 gears as a coupling action and there will be 1 revolution output in both the shaft.

Unless one is held due to some reason, now in normal case we can break it and we can hold it for some specific purpose, but if you would like to use for differential as a differential gear unit gear unit of this unit. In that case 1 will not be held, but when it is turning. So, if it is in the inside it will have it will need more torque to rotate.

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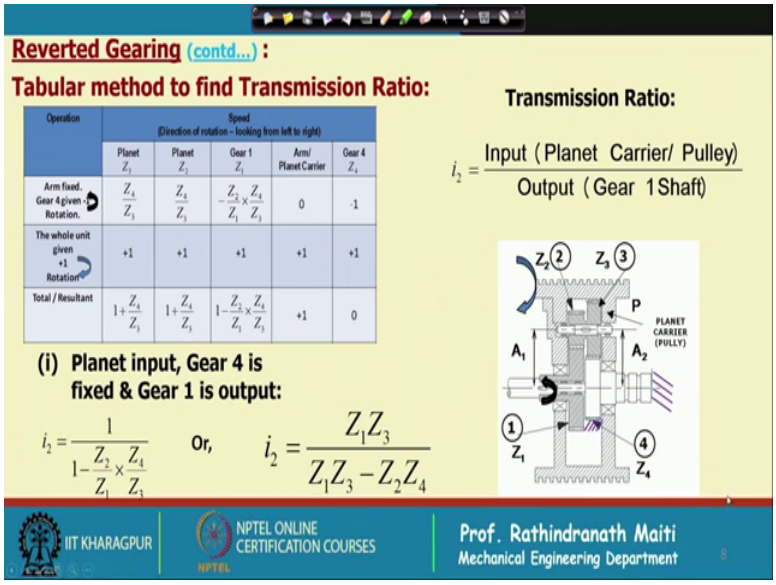

So, it will almost remain stationary the other one will rotate and we will get the differential action and the transmission ratio of this 4 type 2 same as input and output will make this ratio and it becomes i 2 is 1 by 1 minus Z 2 by Z 1 into Z 3 Z 4 by Z 3 or in simplifying i 2 is equal to Z 1 Z 3 d divided by Z 1 minus Z Z 1 Z 3 in minus Z 2 Z 4.

One thing is clear if we look this differencing other case it was it was different it was Z 2 into Z 3 minus Z 1 into Z 4 or vice versa. This will be definitely the to maximize these the bottom 1 or what is the in the denominator that should be as less as possible that should be as less as possible, here I have shown that what is the arrangement in this case what type 2.

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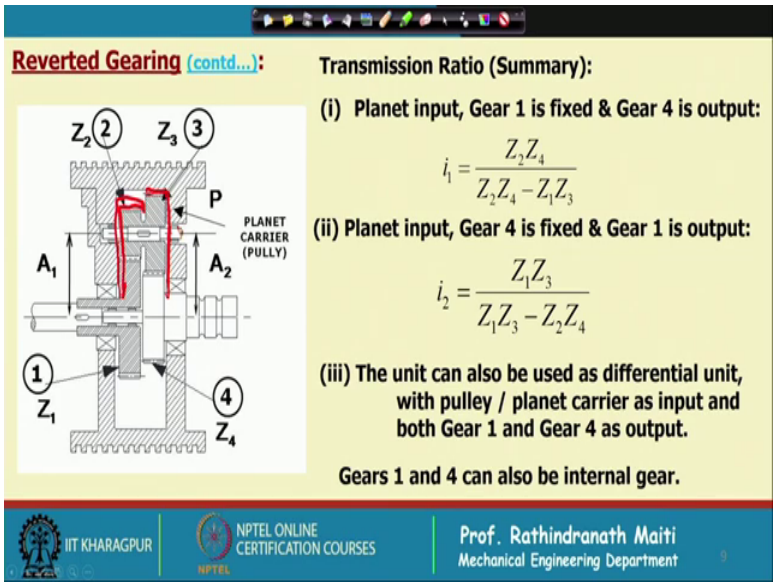

Now, if we take if you compare this type 1 and type 2 then there transmission ratio are as follows the first 1 is having Z 2 into Z 4 minus Z 1 into Z 3 and second case Z 1 Z 3 minus Z 2 Z 4. As I told that if denominator is if it is as less as possible then transmission ratio will be high. And this gives us also a clue that Z 1 Z 3 Z 2 Z 4 they are to be very close with very small teeth difference.

So, here I have written that the unit can also be used as differential unit which I have described gear 1 and gear 4 can also be internal gears, this means that if we would like to take internal gears then possible arrangement is that say this will be this will go like this and meet here and this 1 will go like this and will meet here.

Obviously, the casing will be different. So, it is possible that we can make it also internal gear, but; obviously, physically if you see this it is going through this planet carrier. So, it is not an easy task to make it, but if it can be done in some way it is also possible.

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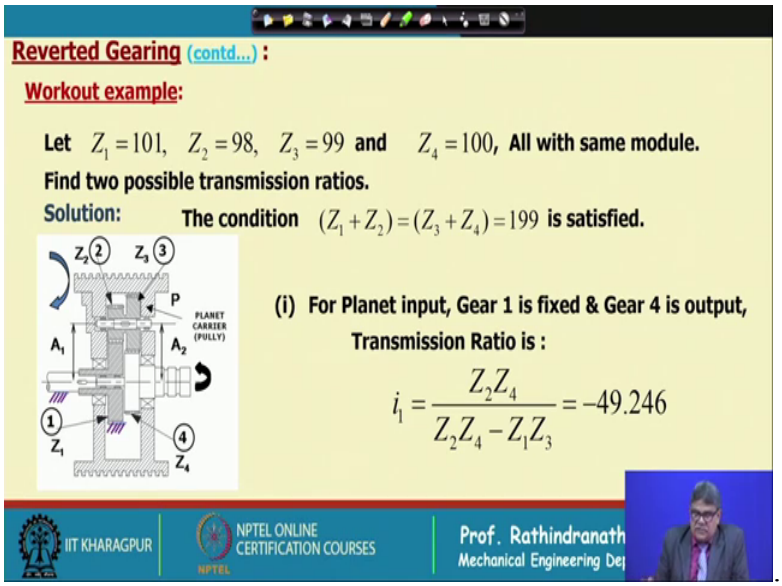

Now, we shall take an workout example we have taken the teeth number of pinion 1 is 101 then planet pinion or planet 2 is 98 as you find the difference is 3 only in this case and Z 3 we have taken 99 and Z 4 we have taken 100.

So, basically 98 99 100 101 this 4 teeth number we have taken. And always same module we have taken the same module to understand that how it is happening there we have taken the same module.

So, this question is that we have to find 2 possible transmission ratios. Now here Z 1 plus Z 2 is equal to Z 3 plus Z 4 1 99 is satisfied; that means, physically it is possible. So, for planet input; that means, input as this pulley gear 1 is fixed and gear 4 is output transmission ratio is as we have derived Z 2 Z 4 divided by Z 2 Z 4 minus Z 1 into Z 3.

If we substitute these values teeth numbers and equate we find the transmission ratio is minus 49.246. This means it will rotate in the opposite directions of the pulley minus sign. So, this direction is shown here.

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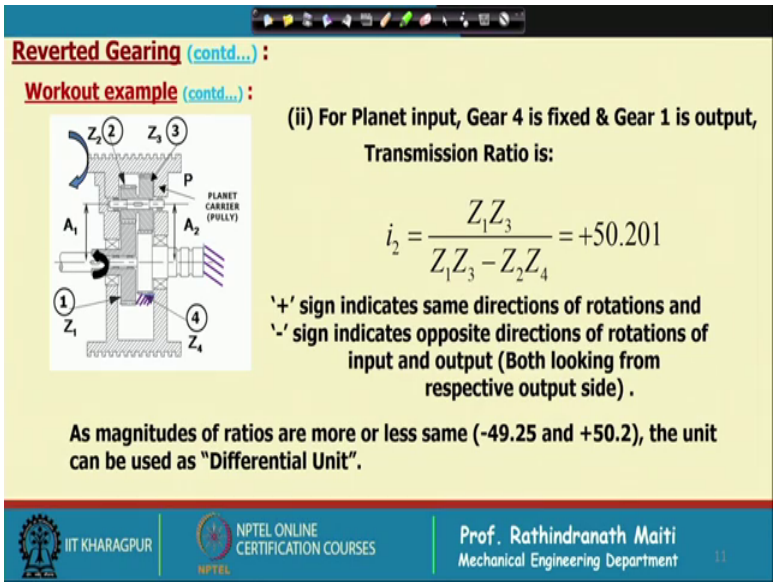

Now if you go to we calculate for other one that is type 2 gear 4 is fixed gear 1 is output, that we get substituting the values we get the transmission ratio 50.201 plus sign indicates same direction of rotations and minus sign indicates opposite direction of rotation of input and output both looking from respective output side.

So, this is the 2 ratios we have got and these 2 ratios has magnitude wise it is very close 1 is 49.25 another is 50.2.

This means that if 1 is held other will rotate at 50 times less speed. So, if we would use that as a differential unit then this gear unit will not only be the act as a differential unit as well as it will also act as an reduction unit and ratio as they are ratios are less.

So, even if this can be used as a automobile and as well I would say that instead of fully we can use a helical gear there and it could be driven by a helical pinion, which is coming from the main gearbox of automobile alternatively it might also be a bevel gear and the bevel output will be there I mean pinion will be there from the speed change gear box of the automobile. So, we have seen this can be used as differential unit also I have discussed that how the riveted gearing can be used as differential unit.

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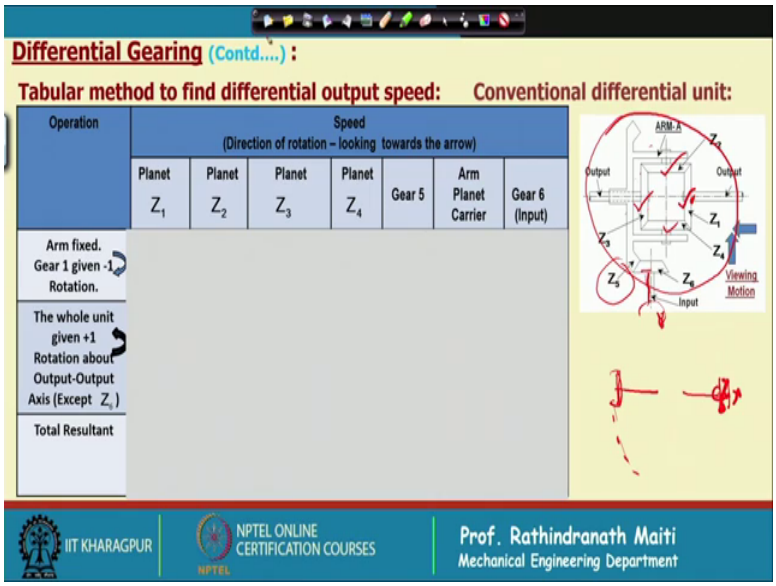

Now, let us come to the conventional differential gear unit in conventional differential gear unit, which is used in automobile we will find that from the train speed gearbox in automobile the power is coming to the differential unit through this shaft. Then there is a bevel pinion usually you will find this is a spiral bevel gear and by the spiral bevel opinion, that this is the tail shaft and then there is a gear and this is the differential unit. With this gear with the bevel gear there is a arm on which there are 4 bevel pinions are there, looking into sketch at least there will be Z 2 is equal to Z 4 and Z 1 is equal to Z 3 we have the pinion Z 1 Z 2 Z 3 and Z 4.

They are machine with each other and Z 2 and Z 4 is mounted on the arm ; that means, the whole of this Z 2 and Z 4 will rotate along with this bevel gear, which is Z 5 whereas, the half set which is going to the wheel one is connected with Z 1 another is connected to Z 3 these 2 wheels are going this sorry the shafts are going to half shafts are going to the 2 wheels, which it is driving. Now what happens when we keep the steering straight, then with the rotation of this pinion say it is roating rotating in this clockwise directions.

Then this whole unit the 2 wheels will remain more or less same torque this whole unit will rotate like this along with these 2 shafts, these are acting as a coupling these 2 are acting as a coupling. So, this will rotate this one and both the wheel rotate at the same speed.

Now, let us consider we are taking a turning in that case suppose we are taking a turning like this is one wheel and this is another wheel and this is a 1 half shaft this is another half shaft and suppose we are taking the turning like this. Then definitely to rotate this wheel at is very small space, because this will try to rotate about this axis whereas, this is rotating with the centre somewhere close to this may be centre of this wheel or very close to this somewhere here.

Then definitely this wheel need much more torque, because this whole wheel instead of rolling it is trying to rotate about it is point. So, what will happen as there is a less torque this will try start rotating keeping this one fixed; that means, this mechanism is helping to keep this almost fixed and with the help of this one, it is rotating in the opposite directions sorry it is rotating at the faster speed. Now we have to find out what will be the transmission ratio if this is fixed; obviously, when it is rotating when the steering is straight this is rotating simply rotating at the same speed.

Now, we will verify this. Now let us consider to find out the transmission ratio when one is fixed we will first of all we will consider that arm is fixed; that means, the arm a which is written; that means, Z 5 bevel gear is fixed and the gear 1 right hand side gear 1 is given minus 1, minus 1 is anti-clockwise direction of rotation looking from that side 2 arrows are given there we are viewing from that side. So, it is rotating in the anti-clockwise directions; that means, like this it is rotating like this ok.

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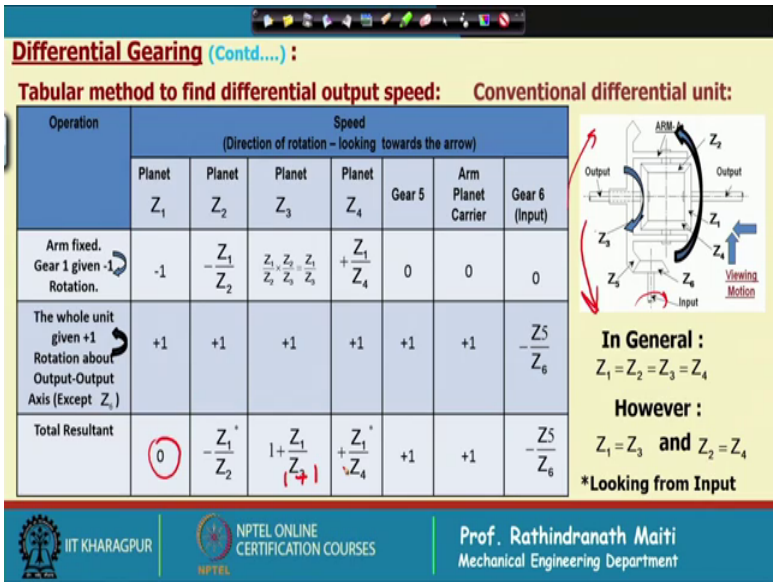

So, now what we are doing? So, if it is rotating in this directions minus directions ; that means, this is this then this must be rotating like this anti clockwise direction looking from this side.

So, this is again ro rotating in the in this directions in this direction looking from this side. So, this means that this is rotating like this is rotating like this is rotating like this. So, Z 3 Z 2 is rotating in this direction and Z 3 is rotating the opposite directions of this one of Z 1 looking from the same side. So, plus sign has come. And Z 4 we will rotate in the again with this ratio this is looking from this side, but ignore the Z 2 and Z 4 we are not considering our concern is Z 1 and Z 3 gear 5 is stopped.

So, there by the arm is also having 0 velocity and gear 6 input is also stopped. Now what we do we give now whole unit plus 1 revolution, in opposite directions from this from the same direction of view. Then simply what will happen we can give plus 1 plus 1 plus 1, but again I would like to mention Z 4 and Z 2 having this plus has no meaning, because this is not about their axis this is about the axis of the half sites.

However, when we are rotating this one then we will find this we have given clockwise; that means, we have given the clockwise rotation from this side. So, if we rotate like this. So, this is rotating clockwise. So, this must be rotating in these directions which is again the minus 1 from the convention what we have taken.

Now, finally, what we find that planet 1 has become 0 planet 2 again this is the same value this plus 1 is not being added, because it is in the same other plane whereas, this Z 3 is back becoming 1 plus Z 1 by Z 3 planet 4 is again in the other plane gear 5 is now rotating 1 and arm carrier, that is also rotating at 1 speed, but interestingly what we find that in case Z 1 is equal to Z 2 is equal to Z 3 and Z 4 even if it is not that it is Z 1 will be equal to Z 3, this means that these become 1 plus 1 2 whereas, this is 0 and this becomes 1 plus 1 2 in the directions, it might be that it depends on what direction this is rotating if it is rotating the opposite direction this will go in one directions, if you rotating in this direction this will go in other directions ok.

So, depending on these directions this will rotate either in this direction or in these directions. In this case what we have considered this minus sign we have considered for in this case clockwise. So, we truly rotate like this. So, these we will become like this. So, it will it will it will it will come like this it will be in this directions it will rotate if it

is rotating the opposite direction then it will go the other directions. So, that is the basic function of differential gear unit.

Now what we find in this case if this is 0 then this is becoming 2 twice the speed of this one, what the normal speed was there at twice speed it will try to rotate.

If we compare now with reverted gearing reverted gearing where if it is stopped and if it is other is allowed to rotate that hey there will be huge reduction it is the problem we have taken for which it is 39 to 40.

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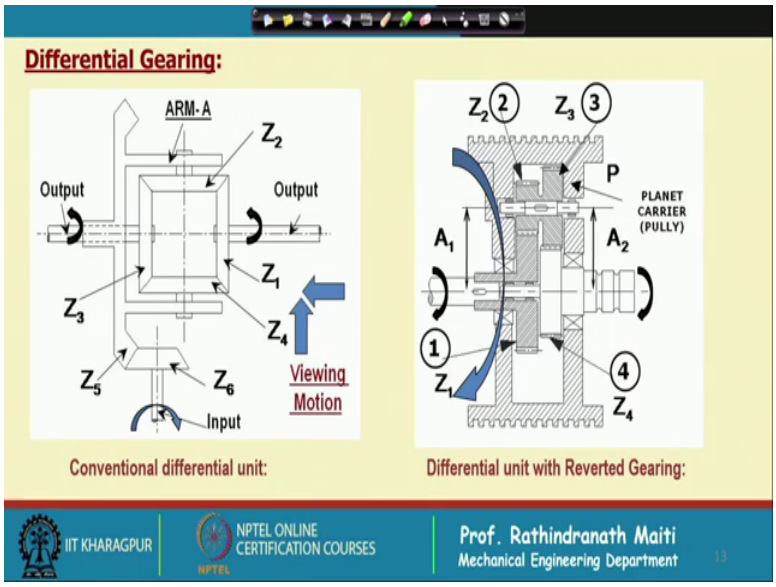

So, I we have explained how this differential gear unit is working and as well we have seen that how the riveted gearing reverted gearing is also can be used as the differential unit. However, in conventional differential unit the transmission ratio is not very high I mean the reduction ratio overall this is simply by Z 5 by Z 6 maybe 5 6 only and while the 1 is kept fixed the other 1 will rotate the, that as this is the speed ratio here.

Whereas in this case in case of reverted gearing will get huge reduction and the speed of in comparison to other to I mean Z 4 to Z 1 there is not much difference.

So, thank you and in this lecture what we have discussed that we have first of all we have considered a special very special epicyclic gearing with external tooth that is riveted gearing and we have shown that this also can be used as a differential unit and later part we have shown, that how a conventional differential unit works and then we have

compared how both can be used as a differential unit. However, from the reduction point of view that a reverted gearing is having much more transmission ratio, but it will be definitely expensive the and then the other one. So, these are not commonly used, but there is applications also such a gearing.