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Course
On
Spur and Helical Gear Cutting
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Lecture 09:
Helical Gear Cutting on Milling Machine

Welcome viewers to the ninth lecture of the course spur and helical gear cutting.

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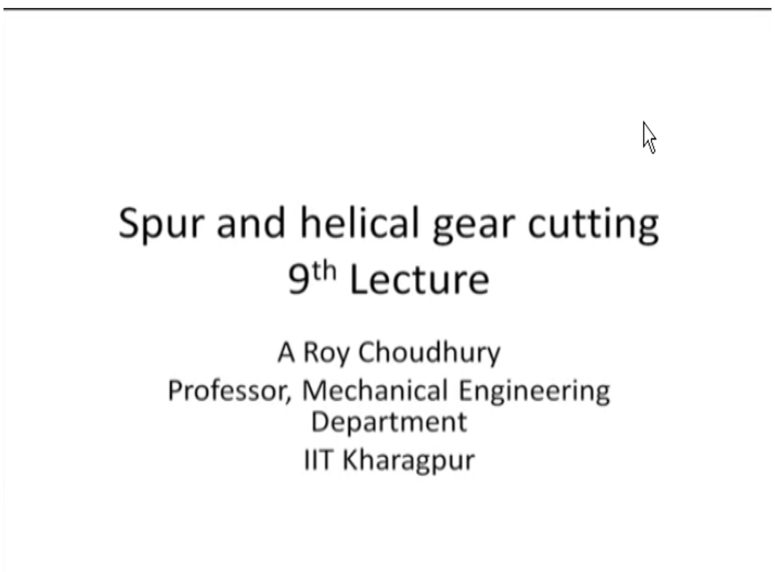

So today we will continue our discussion on differential indexing for gear cutting and continue with further for helical gear cutting.

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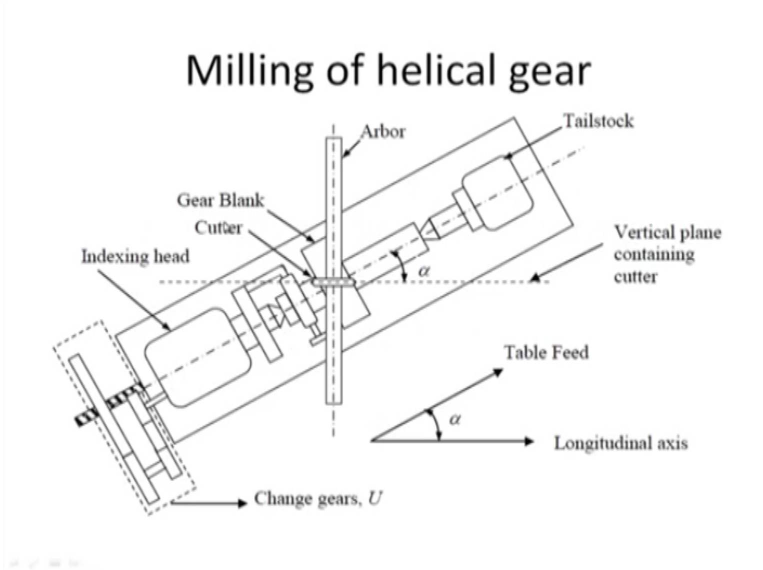

So to start with by the way we have finished most of the discussion on differential indexing so let us start with helical gear cutting on the milling machine what do we have here we are seeing the milling machine from the top the milling machine table you have already seen this one in the previous lecture and let me quickly identify the various parts which are present here.

For example this is the gear blank it's basically a disc that means cylinder shape and job with a short height and it's rotational axis is this one, this one is the rotational axis of this gear blank where is the cutter the cutter happens to be this one and the rotational axis of the cutter is here so the rotational axis of the cutter and the rotational axis of the work piece they are inclined to each other at a particular angle.

There is an angle existing between the two this angle is α the helix angle okay this is the indexing head you are already conversant with the working of the indexing head and we are utilizing this indexing head for our purpose of helical gear cutting okay in what way first of all it is providing the support on one side of the gear blank the other side is supported by a tail stock the work piece may be held on a mandrel and this is the you know the dog which drives the mandrill and therefore if the indexing head suffers rotation the work piece is going to rotate what's the in how is the indexing head set up you can see at the bottom.

There is this lead screw of the machine table sticking out okay it can be seen from the top now this dotted line is showing a, a gearbox it's called change gears you okay so it's taking its input from the lead screw okay for the time being we will look at it this way it's taking its input from the lead screw and through a set of change gears the power is ultimately coming to the index plate okay the index rate has not been drawn here.

But the index plate is here index plate is getting rotated so if we lock the index crank with the index place the index crank is also going to rotate and this rotation will ultimately be transfer to the warm and then to the warm gear and then on to the work piece so if the lead screw rotate rotates if the lead screw rotates these change gears will pass on this location changed rotation of course to the index plate then on to the index crime which is locked with the index plate and then to the warm to the warm gear and ultimately to the work piece.

So now we have connection between the rotation of the work piece on one side and the longitudinal motion of the work piece okay this is the longitudinal motion and the rotational motion they are connected up why are we connecting it up because last day as we discussed whenever if you if you have a look at this piece of paper.

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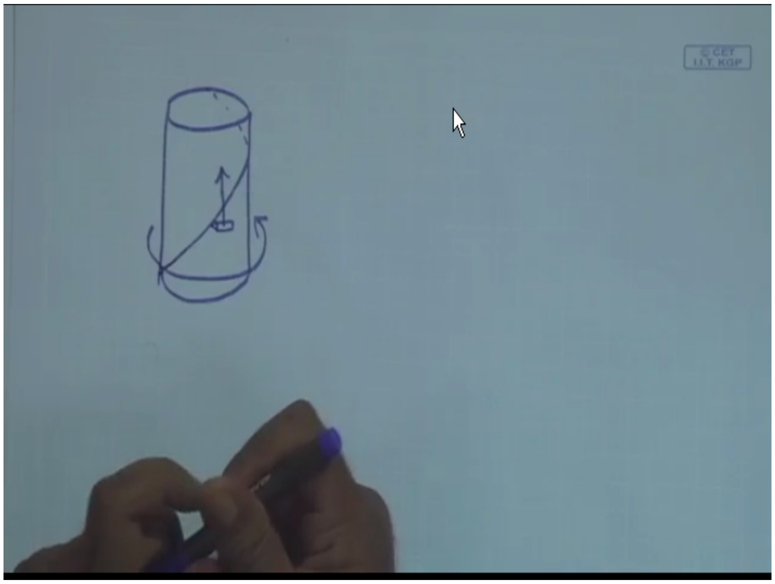

If we have a particular you know cylinder on that by some means if we are tracing a line okay this line will be executing a helix I mean the tracer will be executing a helical line if you have circular motion of this disk combined with straight line motion of this say pencil if they are you know proportionally moving that means if this is moving a certain number of units this moves by a proportional number of units and this particular proportionality is maintained.

Even though this might be slowing down I mean the rotation or translation might be slowing down if they are proportional to each other this will be describing a helix this is the principle we are using for cutting out the helix in case of helical gear cutting so if we come back to this figure we have rotational motion of the blank connected up with translational motion of the blank and we know that in one rotation a helix lines up a helix lines up by the lead for multiple start threads okay.

Let's comeback to this one and let's have a quick look here so let us draw a larger figure so in a gear you have multiple starts definitely because you had so many teeth so these are the helices and they are belonging to different you know helices they are multiple star how many starts there this particular threaded element has if you are cutting 73 teeth it's having 73 starts okay so each of these are individual helices and therefore say if you name this one as number one this lines up this way and just imagine what distance it's going to climb up sorry.

We have run out of space let's take this one this seems to be more obedient to our needs fine that's it so it is comeback to the same position and this is equal to we are just within reach this is equal to the lead the climb up in one rotation so if this be the climb up we have to ensure that the tool I mean the cutter moves this much longitudinally while the cutter suffers one rotation by sorry while the work piece oppose one rotation.

So that's it that is how we are going to move so first of all the thing that we have to do is calculate the lead how much is the lead for our particular, particulate job particularly gear to be cut so let's have a look at that so this is understood okay job connected through change gears to the lead screw so that longitudinal motion and rotational motion of the job they are connected together love degrees also discuss one point why have a implying the job at a particular angle in about a vertical axis.

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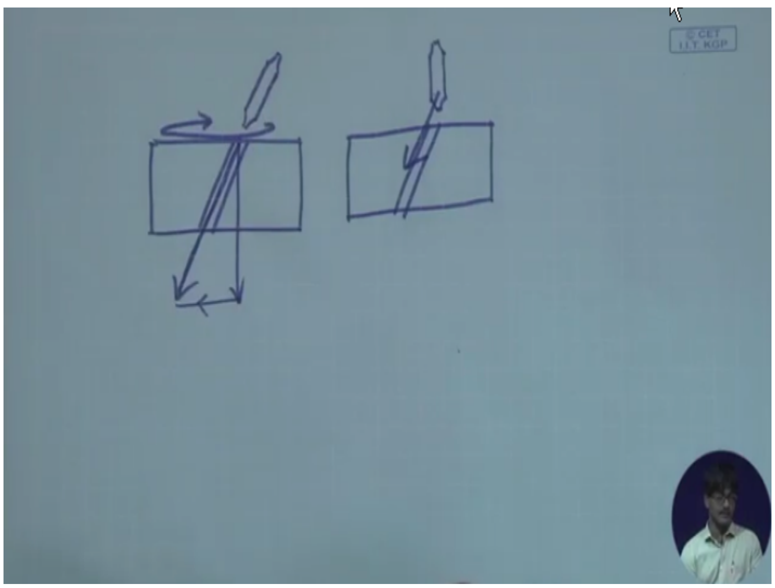

This is because once we have understood that the cut is taking place along an inclined line if you kindly have a look once again once we have understood that even though this is the job the cut is going to take place this way so the cutters which is once again that same cutter that we have used for spur gear milling that same cutter has to pass this way now okay we have ensured the motion to be in this direction by the coming combination of rotational motion okay combination of rotational motion and straight-line motion.

That's what we have already ensured that the motion is going to be this way so you have to orient the job I sorry orient the cutter physically in this direction otherwise otherwise you will be you will not have a cutting action but you have a slapping action what sort of that is the in that case had you not oriented it this would have been the case cutter would have hit the job on its side so it's a sort of slapping action it won't have cut at all okay it would have cut and brushed and you know the whole thing would have been spoiled.

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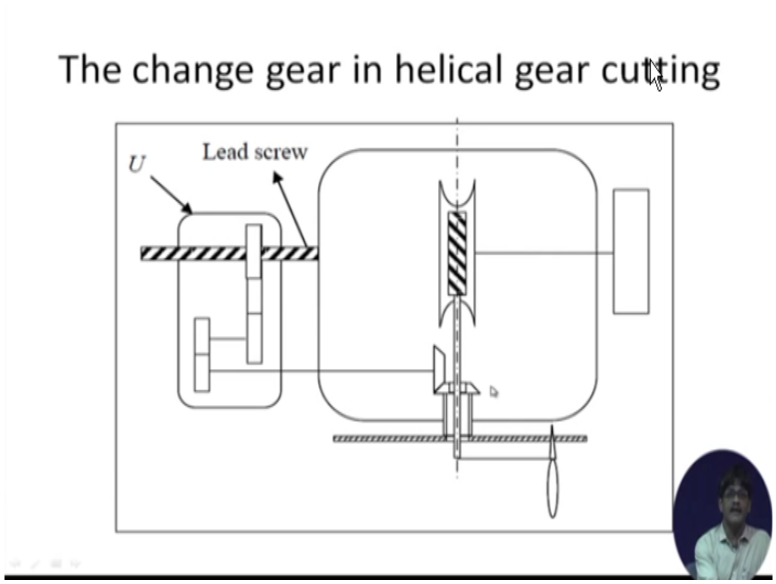

This trying to move this way just imagine so orientation of the cutter so that it follows through, through the cut is very important and that's what we are doing by rotating the table about a vertical axis so now for the calculations now those who have had problems in understanding what we mean by locking of the index plates with the index crank is a quick view, view at that this is our job this is our Roman worm gear and this is our index plate.

And this is our index crank right from the lead screw if you follow up lead screw gearbox connected with connected with the index plate through these two level gears and you climb up to the index plate the index plate is rotating due to the rotation of the delete screw now, now you have locked the index crank with the index plate so that it then takes place rotates then index crank is rotate and the worm will rotate and the worm gear will rotate one job will rotate okay so this is the connection seen in two dimensions I hope it will be now easy for you to follow.

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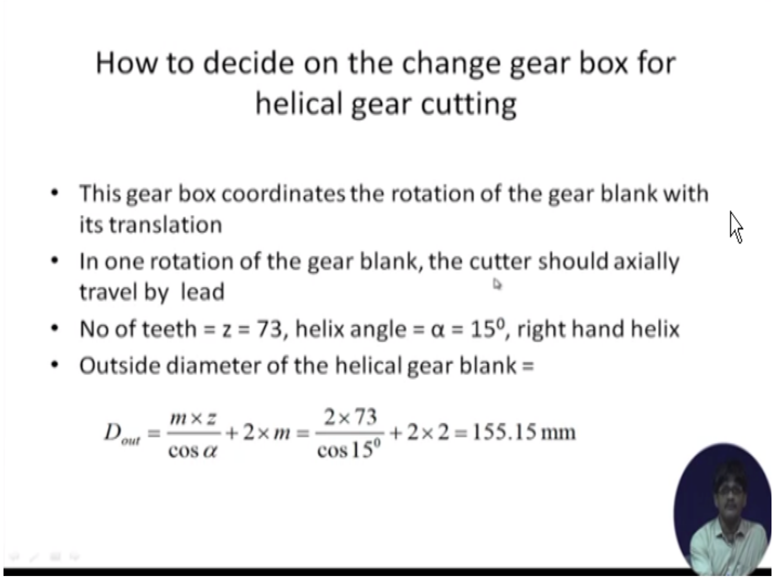

Now for the calculations what are the calculations how to decide the change via box for the helical gear cutting first of all the this gear box coordinates the location of the clear black that it's translation is already we have already discussed it at length in one rotation of the gear blank the cutter should actually travel by lead is also accepted we have already gone through this number of feet being equal to print 73 helix angle being equal to α equal to 15 degrees right and helix okay.

We will come back to right and helix for the for this calculation it is not that important outside diameter of the gear blank is being found out now why suddenly we are finding on the outside diameter this is because the operator has to choose the correct gear blank science so that you know so that the, the gear is correctly made if you if you make a mistake in the outside diameter it is with respect to the outside diameter.

That you are going to apply depth of cut so if the outside damage is not correct everything will be affected so outside diameter has to be found out very carefully and as we have calculated previously it is equal to M into Z divided by cos α you come up to the pitch diameter plus 2 module you go up to the outside diameter so it's coming out to be 155.5 mm.

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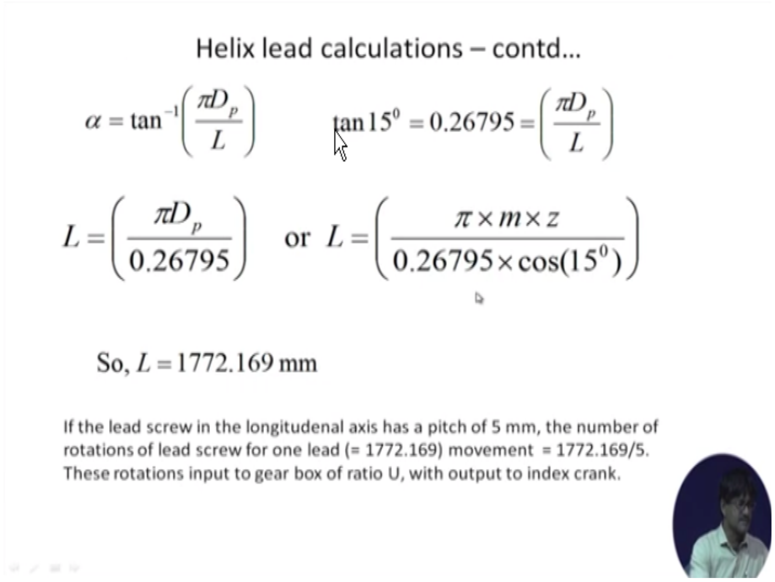

Next we understand that α the helix angle is equal to tan inverse D_P/ L let's have a quick look at this okay if we come back to our page this is it this is the you know direction of teeth so if you unfold this helix and get a triangle okay you are unfolding it sorry I should have drawn it from here let me let me choose a fresh piece of paper so that there is no misunderstanding okay.

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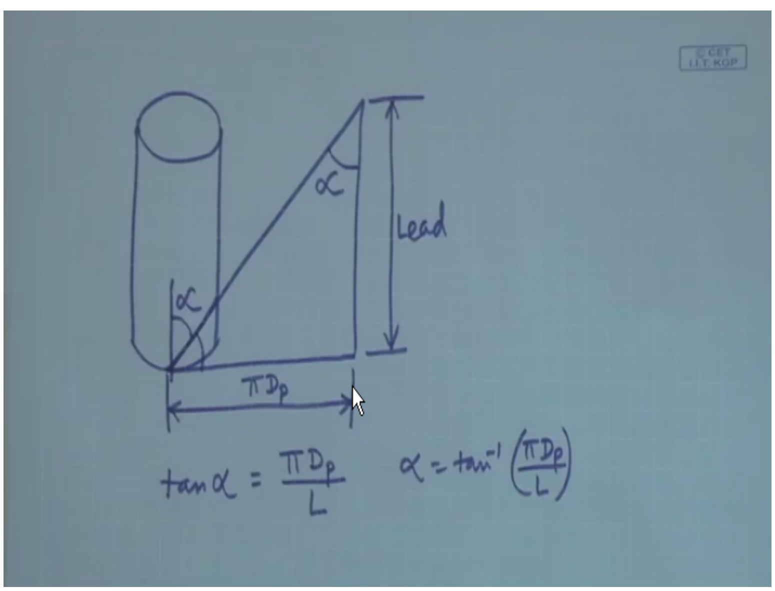

This is your cylinder this is your helix and you unfold it so that you get a triangle what's this triangle having is having this side equal to π*D_P that means the circumference of the pitch circle okay circumference of the pitch circle it rides up by the lead in one rotation so this must be equal to lead and what's the you know what's the helix angle incase of as we discussed before this angle is the helix angle for screw threads this is the helix angle α for sometimes in some literature is called β.

This is the angle for helix angle for gear teeth if that be so tanα we can write tan α is equal to π/D_P divided by L which means α is equal to tan inverse $\pi D_P/L$ that's it so once we have established that let us come back to this so that's what we have written out here this is the relation which defines α now do we know this side and that side yes $\tan 15^0$ okay it's just a you know other way of writing it $\tan 15^0$ is known to us so I simply calculated and written it down here.

Now do I know D_P yes I know D_P D_p is equal to M into that by cos α so I can write that down also so that I can calculate L so that way L becomes defined so I have taken L to the other side upstairs I mean to the numerator so L is equal to this goes down point two six seven etc and πD_P so D_P I replaced by $m*z / \cos 15^0$ and therefore I have found L to be 1772.169 mm just imagine a small year of 155 outside diameter it's having a lead more than one meter almost two meters 1772 meters.

So lead has been found out once we find out the lead let's see what's written in the small print is the lead screw in the longitudinal axis has a pitch of five millimeters oh this is important this says that okay we plan to get a longitudinal motion of 1772.169 millimeters in the same time that we rotate the job once so how can I achieve how many rotations of the lead screw would be required to get 1772.169 millimeters naturally divide this distance by the pitch of the lead screw.

And we will get the number of rotations that is what which has instead here see the number of if you read this one the number of rotations of lead screw for one lead movement lead being one seven, seven to eight etc so that is equal to 1772.169 divided by the pitch of the lead screw now what's the pitch of the lead screw equal to that we are providing you if the lead screw in the longitudinal axis has a pitch of five millimeters.

So we get this as the number of rotations of the lead screw that's good these rotations are input to gearbox ratio you with output to index screen if you follow that the lead through was giving up its rotation as input to the gearbox so this rotation is input to the gearbox so let's see what happens so this rotation is input to the gear box.

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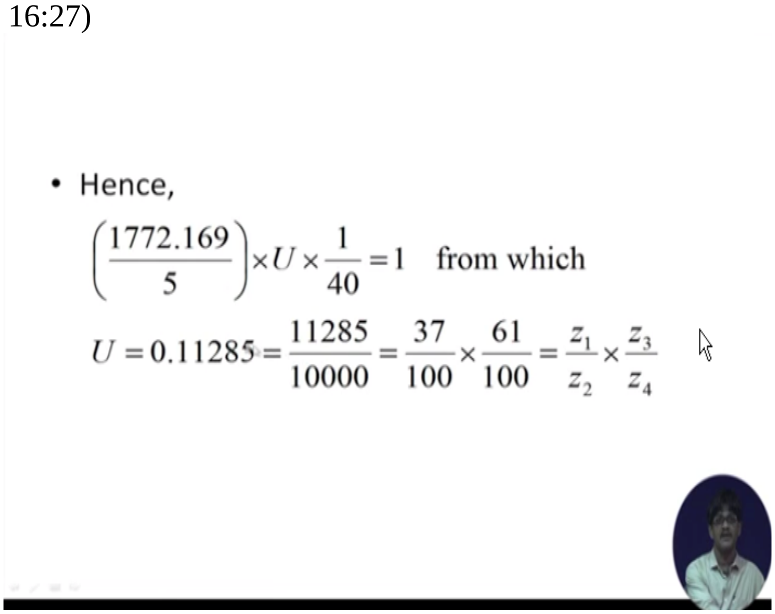

So multiplied by u gives you the output from the gearbox that enters the index plate index crank and goes to the warm worm here where it suffers a reduction due to warm and warm gear rotation of one by 40 and this is given to the work piece so if this must be equal to one so I hope this is you in fully agree with this and therefore from here we can get you to be.11285 and I have divided it into two fractions where I am getting the numbers of teeth of those gears wheels which can form this particular gear ratio so leading from the lead screw to the you know index plate I can have read one by read 2 into 3 by Z 4 to be equal to this one okay so this way I can calculate the gear ratio for helical milling and you know set it set up the machine so that a helix is cut.

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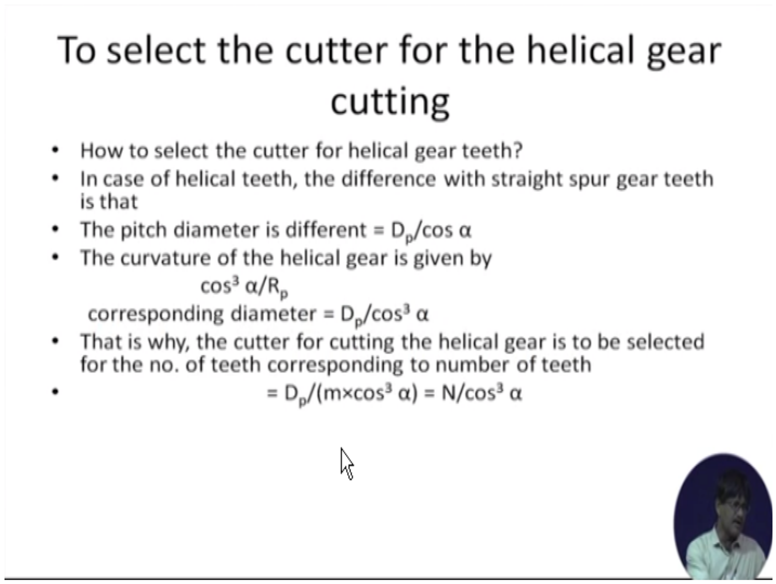

However this is not all for helical gear cutting in helical gear cutting selecting the cutter is a head why because the same cutter as used in case of spur years won't do what do we exactly mean by that being that suppose you are using the same cutter as used in spur gear cutting if you are using the same cutter then something must be the same for the two years yes the value πm must be the same for the two years.

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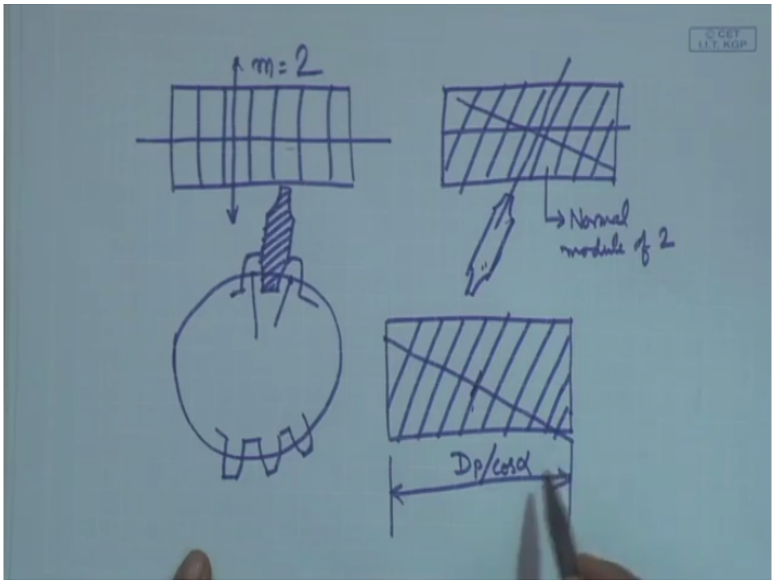

However for the for a helical gears it does not occur in the same plane as that of the spur gears let's see what we mean by that if you have a look here in case of spur gears this is the direction in which the teeth align okay and on the on the other view if you look at this the theta this way so this is basically okay sorry this is basically the cutter the cutter is a you know physically defined piece and therefore it gets defined by this particular gap and as we have studied previously this gap is equal to this particular distance not the angle sorry.

This particular distance is equal to π*m, π* so the cutter is having inside it this particular information and this information is you know connected up with the direction perpendicular to the axis this is the axis it's it's imprinted perpendicular to axis however if you are using the same cutter in that case if these be the teeth direction okay the same cutter is used this way and that information of the cutter the same information is imprinted normal to the teeth.

That means normal to the teeth you can say that the distance will be π* from this point to this point so that is why we say that this helical gear has a normal module of 2 so here the module is 2 for the spur gear module is 2 this is the module cutter number this is the cutter with module equal to 2 the same cutter used here defines the normal model of the helical gear okay so we say that the normal module of the helical gear is 2 that's fine.

So in this direction the distances between the teeth will be different if you cut it along this direction having understood this thing now comes the question how do we choose the number of the cutter for this if you look at the helical gear these are the teeth already we know that this diameter is equal to D_P by cosα where D_P is the pitch diameter of the corresponding spur gear that means same module as the normal module of the helical gear and same number of teeth.

So that is divided by cos α and that that will be get the pitch diameter of the helical gear now if you cut it this way since we are doing all the cutting perpendicular to this direction okay the direction of the teeth if you are doing the cutting this way essentially you are working on you know if you take a section of a cylinder at an inclined plane you are essentially developing a and ellipse okay in this ellipse at this point okay there is a question of major axis and minor axis the minor axis is definitely D_P by cos α so if we draw now another figure.

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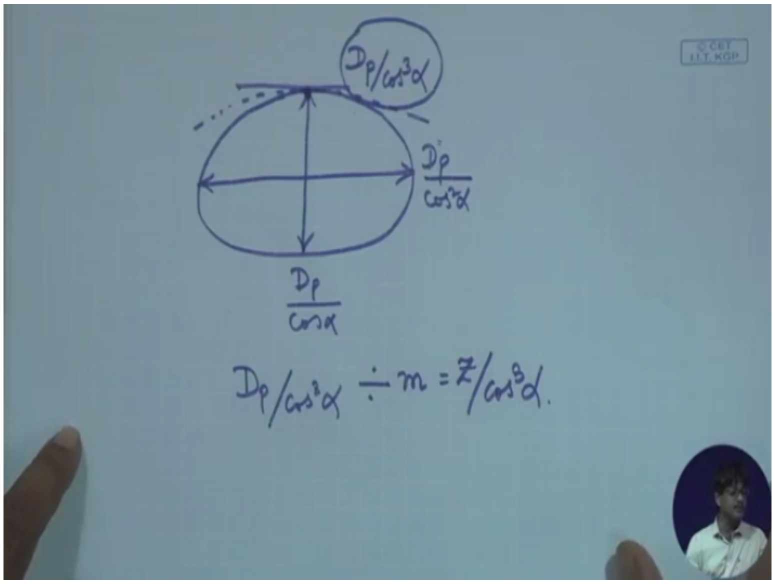

This is what it looks like now this one is twice be equal to D_P by cos α this one if you consult the figure you will find it will be equal to D_P by cos square α and we have to find out at this point what is the curvature what is the radius of curvature of the gear that radius of curvature will have a corresponding diameter okay radius of curvature double of that diameter of curvature that diameter will be able to accommodate a certain number of teeth that number of teeth will define the particular cutter number that you have to choose.

Now what do we mean by this as we discussed before milling cutters gear milling cutters they have a particular number associated with them corresponding to the number of teeth that they can handle this thing we have discussed in detail previously so let's see at this point what happens is the curvature is diameter of curvature is D_P by cos cube α now how do I get that I can

I can easily differentiate the X equation of the ellipse here and find out the double derivative and from the double derivative I can find out the curvature naturally here the you know the first derivative will give you.

Because it is reaching a maximum point but the second derivative won't be the second derivative can be found out and it will lead to this particular you know diameter I am NOT working this out I will try to provide you with supplements which will be available as attachments with this particular study and you can open it up and study it yourselves in many cases as much as possible I will try to provide you with figures videos etc which will make this thing much more clear so D_P by cos cube α this is now understood to be the effective diameter of the year.

And this particular point because it defines the curvature here so if D_P by cos cube α is the effective diameter the number of effective teeth will be diameter divided by number of T sorry divided by the module because M into Z is equal to diameter so this thing divided by the module will give us the effective diameter so D_P by M is nothing but equal to number of teeth so Z Y cos cube α so if you have a certain number of teeth divided by the cube of the course of the helix angle and you will get the number of teeth which you have to refer to for the selection of the cutter okay.

Because the cut is taking place and is at an inclined angle and therefore the profile of the teeth there's a slightly changing because they are getting defined at a different you know curved surface circular sorry a different curvature okay this curvature defines the diameter this defines a particular number of feet so with this idea in mind we will solve some numerical problems which will make this thing clear.

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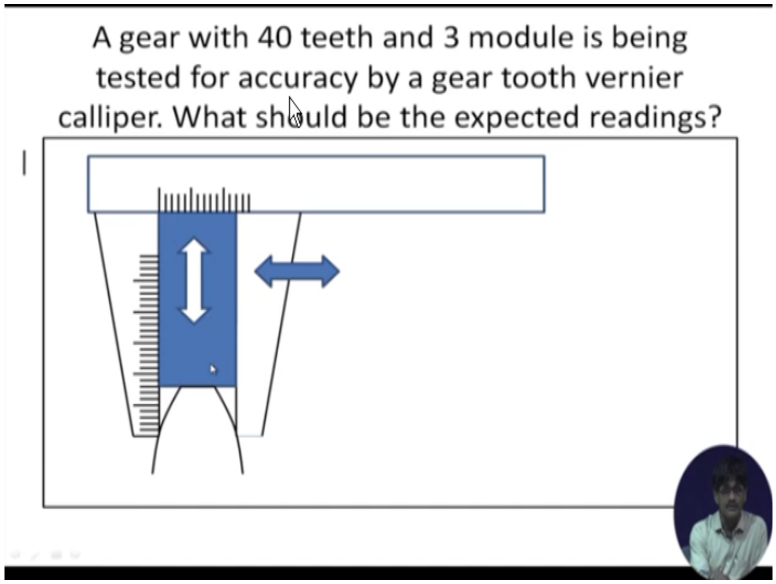

So this is what I have written down here all the things that we have discussed this, this we will come back if we need to and therefore we are coming to the N but we will have five minutes of discussion which I want to utilize for you know discussing certain aspects of helical name for example let us take a particular case suppose and to take a particular numerical example suppose you are having 73 teeth you are having 15 degrees just now I think we have solved this problem.

So I will take this opportunity unity to introduce one gear measuring method I mean testing of gear teeth whether it's made well or not by discussing about the gear tooth fernier caliper we had slightly you know refer to this in our previous lectures but not solve any particular numerical problem so we can do it now itself what is the gear tooth vernier caliper the gear tooth vernier caliper as shown has, has two calipers connected up into one that means this particular caliper jaws and move and accommodate different dimensions between these two jaws at this moment.

It is measuring this particular distance this is a gear tooth okay corresponding to these two jaws there is another you know moving slide okay moving in between which can be moved out or moved in to measure precisely this particular distance and therefore if we know a particular point on the gear where these two distances can be calculated we can open up these jaws to the you know the lateral dimension and expect the other dimension to be recorded in the vertical scale so we will quickly do the calculations and touch the gear to tooth in whatever you know whatever place it accommodates that particular distance and read off the vertical scale reading and compare it with the calculated value.

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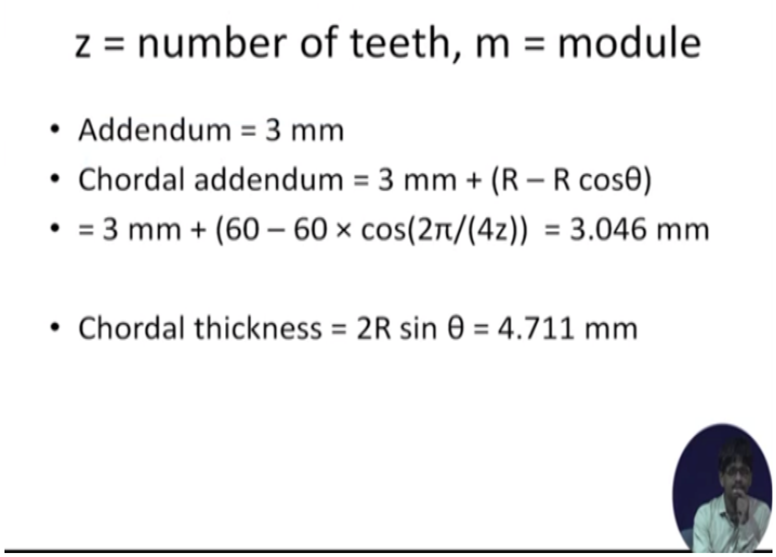

To see how well this is how accurately this has been made okay so let us have a quick look at the calculations for example suppose if you if you look at the figure.

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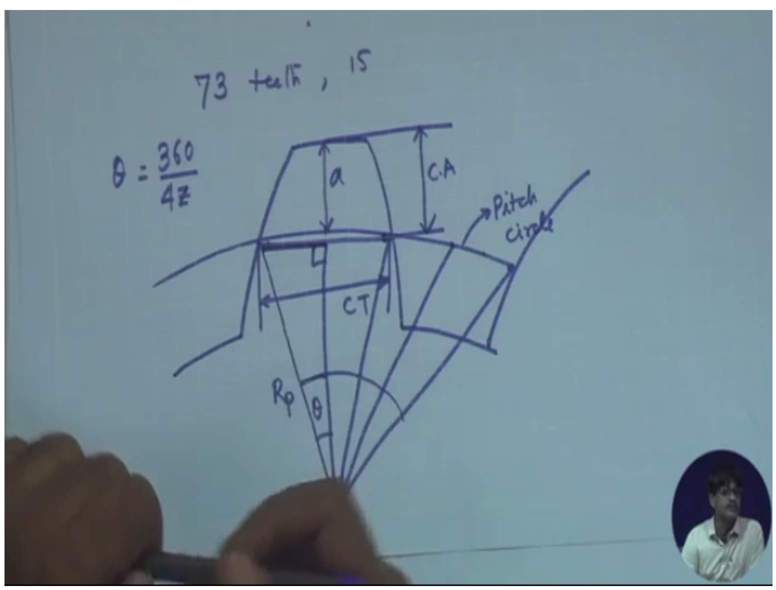

Suppose I am having a gear tooth this is one gear tooth and suppose I say that if this is the pitch diameter I say this is pitch circle pitch circle on the pitch circle if I take this distance we can call it choral addendum sorry if Chodel thickness and this distance we can call it choral addendum this is choral thickness now we can make exact calculations for these two values in what we choral addendum is very simple it is simply equal to the addendum so we call it e plus the small distance what is the small distance.

If we have this one as the pitch radius sorry just a moment yeah if you have this much this much as a pitch radius and if you join this distance this being a perpendicular we can say that this angle theta has a definite value in what way theta is equal to we have this one previously theta is equal to 360divided by 4z 360 is the whole if you divided by Z you get up till this point you get up to this point you divide it into four parts one two three and four okay and therefore this is 360 by 4 z once you know z you can find out theta so theta is known R_p can be found out from module and number of teeth and therefore this triangle is completely solvable.

So that we can find out this distance how much will this be this is equal to R_P coursesorry R_p sine-theta so this one is twice R_P sine theta and this one is module plus R minus R cos theta okay once we are equipped with these two values we can employ the method of gear tooth vernier caliper let's have a quick look at the calculations now okay the calculations say that Z is equal to number of teeth and M is equal to module so let module be equal to three millimeters I am sorry I have forgotten to write it down here module is equal to three millimeters and number of teeth is equal to say 20.

So if number of teeth is equal to 20 and modulus three millimeters addendum is equal to module so addendum is equal to3 so Cordell addendum must be equal to just a moment L we have to decide upon the number of teeth by back calculation have I mentioned the dimensions in the previous case yes a gear with 40 teeth and three modules okay I am sorry I missed this one.

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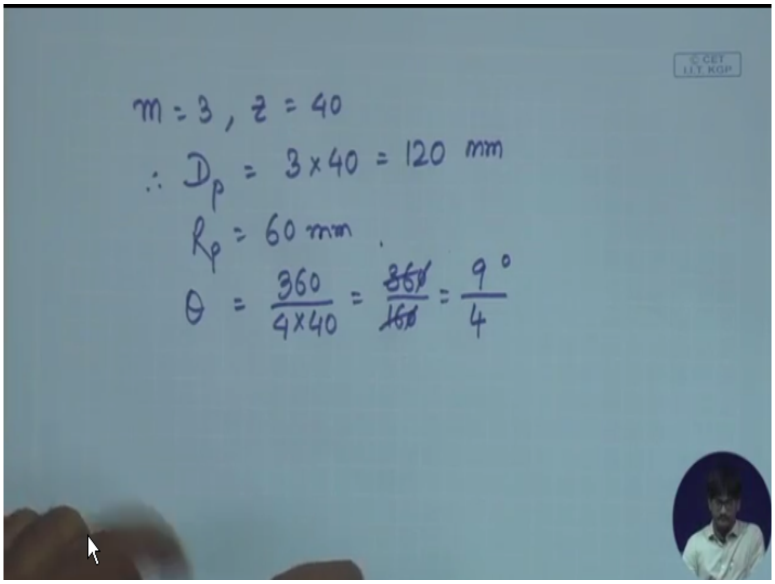

So if there are 40 teeth we can write that module equal to three Z is equal to 40 therefore D_P is equal to 3 into 40 how much is that 120millimeters and therefore RP is equal to60 millimeters we know RP 60 millimeters and we also know theta equal to 360 by 4 into number of teeth so 360 by 1 6000 cancels we have 9 by 4 9 by 4 degrees ok so once the angle is known we can easily find out and what we have done is we have found out addendum this way addendum is equal to sorry not have enough choral addendum, choral addendum is equal to addendum plus R - R cos theta so 60 - 60 into 2π by 4 Z and it is coming to be 3.046 mm.

And what is the choral thickness coral thickness is coming out to be twice R sine theta which means it will be 2 into 60 into sine nine by four degrees and it's coming to 4.711 so if you open up the molecule it if you open up this one to 4.711 and put it on the gear tooth and, and make this slide move away by just the amount which is you know automatically the tooth tip will be pushing it back outwards and it will register a particular distance along this particular scale.

This should be very close if not exactly 3.046 if it is away from 3.046 all these terms which are there one of them will be at fault so we can go directly to the manufacturing either if theta is not correct there was some problem with the indexing if R is not correct there is some problem with the adoption of either the depth of cut or the outside diameters o as it is made up of r and cos theta at least one of them have been at fault so with this we come to the end of the ninth lecture in the tenth lecture we will have discussion about a number of numerical problems on all the subjects that we have covered up till now thank you very much.