Spur and Helical Gear Cutting
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Lecture – 36
Gear Hobbing - II

Welcome viewers to the 16th lecture of the series Spur and Helical Gear Cutting. So, in the last lecture, we were discussing about the uniqueness of the locations of the gearboxes in case of hobbing machine.

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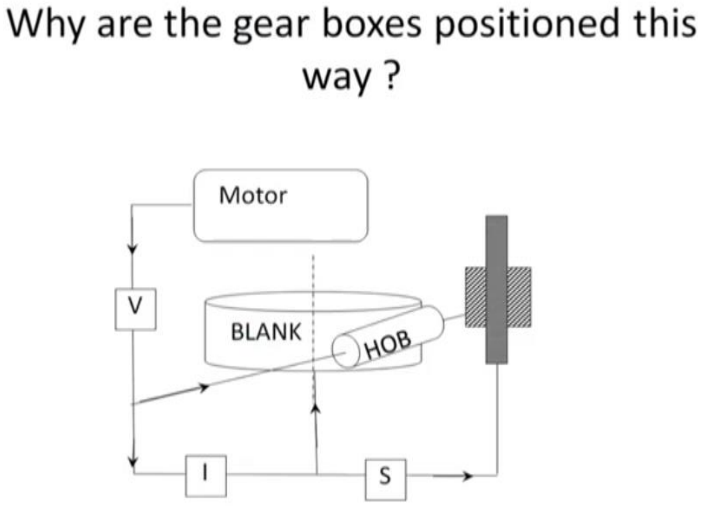

And if you look at this, this was the accepted position. And this was the change position and we noticed that the location of I in this particular position unfortunately is going to change the hob RPM and that would result in a different cutting speed. And that is going against our basic resolution that one gearbox should affect only what it is intended to and nothing else. Change in speed should be controlled by the change in U_v, change in speed.

So, this is not acceptable. Let us take up any other positions which might be acceptable. What if we keep V here and I here? In this case, is V changed? Yes, it is going to change the hob RPM and it is exactly meant to do so. From the motor, we get some RPM and from that particular RPM, we are changing it to some other RPM and providing it to the hob. So, V is serving its purpose.

But the problem is, as V is lying in the loop now between hob and blank, a change in V is definitely going to bring about a change in the RPM ratio of the hob and blank which means that you are going to start cutting a different number of teeth. Something you never intentionally wanted to do. So, V cannot be placed here because it starts interfering with the indexing or selecting the number of teeth for cutting.

Another one, what about this? Can we have this sort of a location? V is in the correct position because the change in V changes the RPM of the hob. But, if I instead of this location has been shifted here, does it cause any problem? It is still in the loop between the hob, if I pass between the hob and the blank. And therefore, there is absolutely no problem it can control the number of teeth to be cut.

However, we see that it is also in the line between the blank and the vertical movement of the hob. This is a threaded element, a screw rotating inside a nut and configured in such a way that if the screw rotates and does not translate and if the nut does not rotate but translates only. Due to the rotation of the screw, the nut will suffer a translational motion and accordingly the hob will have its vertical longitudinal feed.

So, unfortunately, this particular longitudinal feed is going to be affected, if we put I here because it is defined as millimeters of hob movement per rotation of the blank. So, here we find, once I is placed here and it is changed. Definitely it will change the number of teeth to be cut, the purpose it is supposed to serve but it is also going to change the number of millimeters per workpiece revolution.

Because it is simply going to change the number of millimeters you are moving with respect to the blank rotation. Therefore, this is also not affected. Why? Because it does change the number of teeth correctly but it also affects the feed which it is not so supposed to carry out? So, this is also not accepted.

What about this one? If we place S here, it does control the number of millimeters of movement that means, longitudinal movement of the hob with respect to rotation of the blank. That is in one rotation of the blank. How much is the job or the hob coming down? So, it does control it, because it is in that particular line. With respect to the blank rotation, you can change those numbers of millimeters you are bringing it by up or down.

Unfortunately, it is now also in the loop between the hob and the blank and therefore, it will start affecting number of teeth being cut which is not at all acceptable. Therefore, this is also not a correct configuration.

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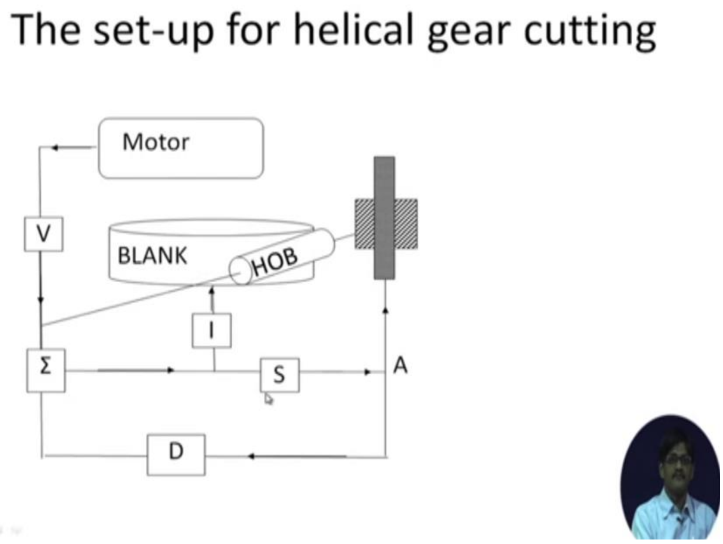

Now, we will introduce in brief, in very simple language, the setup for helical gear cutting. What is helical gear cutting? For this let us have a quick look.

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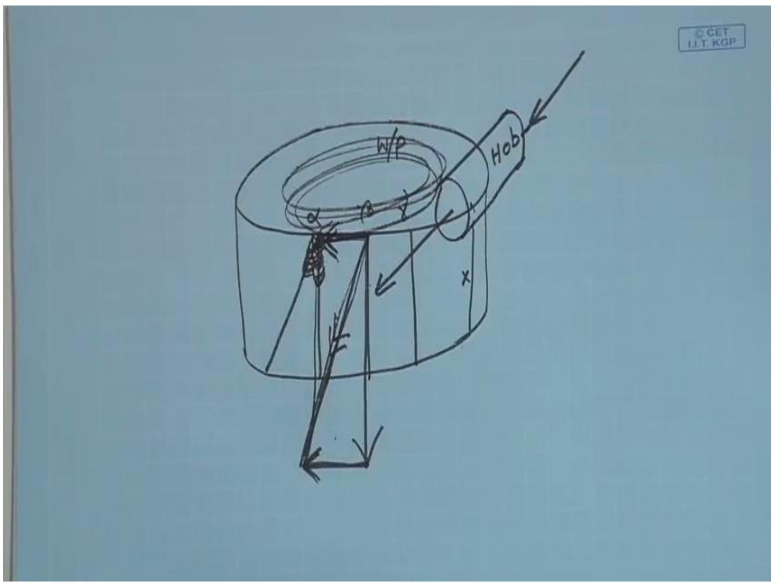

First of all, on this particular figure. If I have a blank on which if I have matched the rotational ratio of the hob with the workpiece, if this rotational ratio is matched, when say the meridional plane x comes under the hob, it gives a cut. So, this way each and every, say let us call these meridians, alpha, beta, gamma, x. All these are going to get cuts which are going to be vertically downwards exactly.

Just because they are synchronized, they are matched; they are exactly given the rotational ratio that they are supposed to have. So, cuts take place this way. But in case of, helical cutting, we want the cuts to take place this way. So, metal cutting scientists thought this way, I am moving down in this manner, I want to move down in this manner when I am cutting helical threads.

So, it basically boils down to the addition of a velocity vector during cutting action. How do I provide this velocity vector? Can I provide it by making the hob move this way, but in that case, it will lose contact. So, this velocity vector can be provided by rotation of the work piece. The work piece can rotate and therefore provide this velocity. So, an additional velocity will be obtained by rotating the work piece.

So that, the final resultant vector lies in the direction of the desired helix angle. This is the basic idea. How do I rotate the work piece? Now, here I can point out one thing which you have to know think about. I will say, the work piece is already rotating. So, how come you are going to think of rotating the work piece? By virtue of this rotation only it is having synchronization with the rotation of the hob.

So, this means we are basically talking of an extra rotation. What is this extra rotation? That means in addition to the rotation of the work piece in order to synchronize with the rotating hob, I put some additional rotation. How much will be this additional rotation? This additional rotation will be such that one complete extra rotation will be carried out by the time the hob moves by one lead of the helix angle thread.

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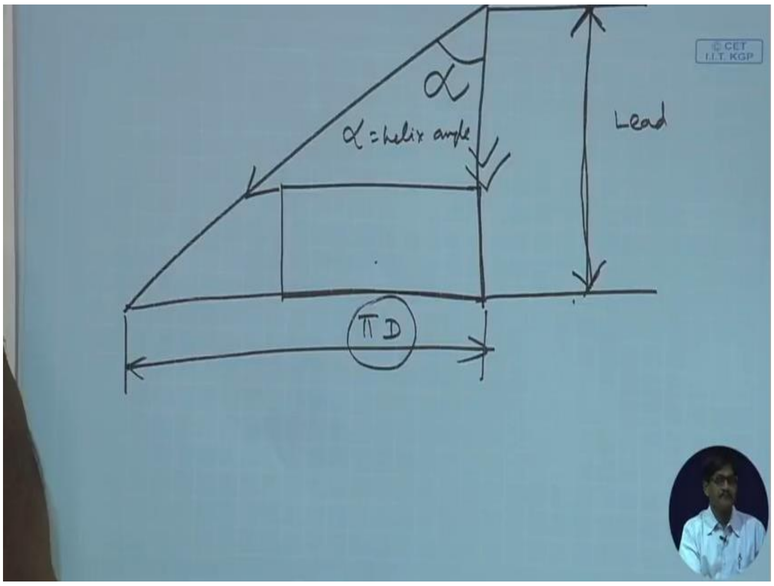

Let us have a look at it on the figure. This is our work piece and therefore, if we unfold the full work piece this comes out to be πD circumference. Now, that the helix should be such that, this is equal to lead of the helix and this we know as ∝. The helix angle and therefore, helix angle is $\tan^{-1}\frac{\pi D}{L}$. So, ∝ equal to helix angle, so, we have to find out how much is this motion downwards?

This is the feed motion. I want to move this way, if I can move exactly πD amount that means, if I can rotate once, by the time I am carrying out the lead motion then my job is done. So, in order to move by D, how many times does the job have to rotate by? It has to rotate by one time only. One time single rotation which is extra to the more rotational motion it is already having.

So, for this one rotation we will ensure that lead amount of motion will take place for the worm. The worm when it is being fed down, it will execute exactly lead amount of motion by the time, the work piece rotates once. So, work piece rotates once, lead of the helix is this much, that means, cutter moves by this or that amount.

And, therefore, this helix angle will be established. So, having understood this let us start doing some calculations, by the way. Now, if we look at the figure, in order to make this possible, that means in order to make this extra rotational addition possible, we are incorporating another separate line.

What is the separate line? Since power has come up to this point after which it enters a vertical screw by the rotation of which this nut is moving downwards. There itself, I have tapped the power here and I have passed it through a gearbox and added up the result of that gearbox with the input coming directly from the motor.

So, this is feedback, this is called the lead change gears and changing the lead with this that means different helix angles will be cut with the help of this and this is this sign of summation. These 2 rotations will be added here. Now, how do you add rotations? The mechanism which does it? It is referred to as a differential mechanism.

So, this represents a differential mechanism. From the differential mechanism the output ultimately passes through to the blank rotation and basically and this **(15:08)** also already existing though. So, these 2 inputs are added together and given to the work piece, so that it undergoes some additional motion.

We will see how this works. So, we are now accepting that we have 1, 2, 3, 4 gear boxes. And a differential mechanism for adding these 2 inputs.

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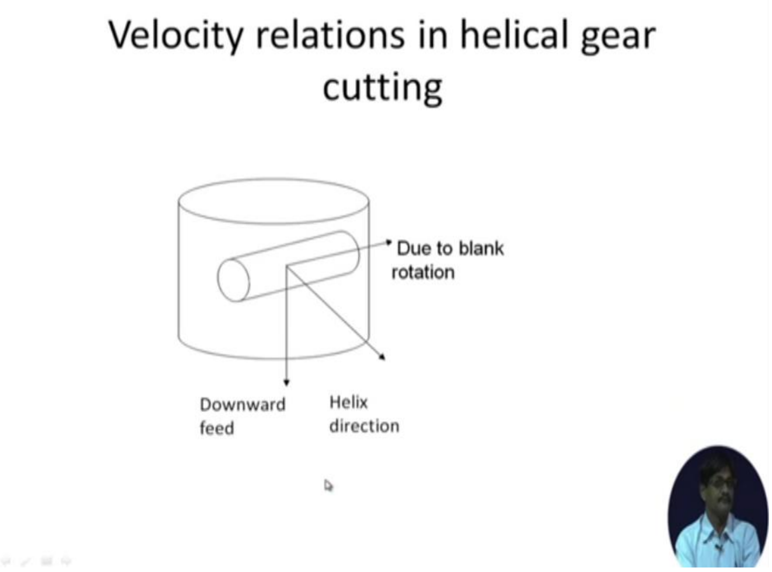

This is the velocity relation which we have already discussed. That means, the hob has downward motion and the blank will be given extra rotation because of which they will be tangential motion, the resultant of both the velocities will give rise to the helix direction.

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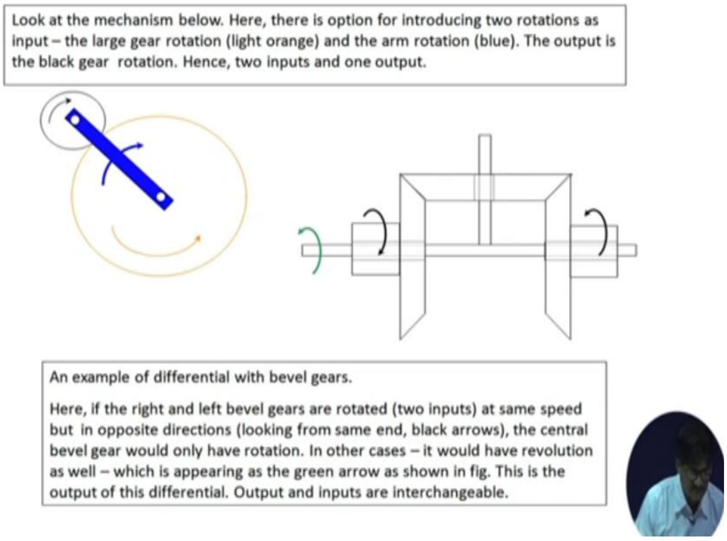

Now, a word about differentials. What is a differential? Differential can be the sun, planet mechanism, where I am having this large orange coloured gear which is having its own rotation, it is rotating. Who is it connected to? Is connected to another gear in mesh and these 2 are pinned, they are having pin connection with an arm, this blue arm. So, I can rotate the blue arm also, which I have shown by a blue curved arrow.

So, I can rotate the orange gear. Let us have a look again at the figure. I can rotate the orange gear, I can rotate the arm and due to these 2 inputs, the output of the black gear will be defined. And therefore, two inputs are considered here and there is one single output, rotation of this particular gear. This is a differential called sun and planet mechanism.

And here we have another differential called the bevel gear differential. Let us see, what is the scheme of operation? This is one bevel gear which is getting input from one source. This is another bevel gear which is getting its input from another source. Maybe ultimately, they are drawing power from the same motor, but they are coming through different paths having different rates of rotation.

So, these 2 bevel gears are rotating at different rotations per minute. What will happen if they have equal rotational value but opposite in direction? That means one is rotating clockwise, one is rotating counter clockwise. What will happen to this gear in contact with them? In that case, this gear will remain in position and just rotate about its axis. Because this is rotating say 80 RPM, clockwise 80 RPM counter clockwise.

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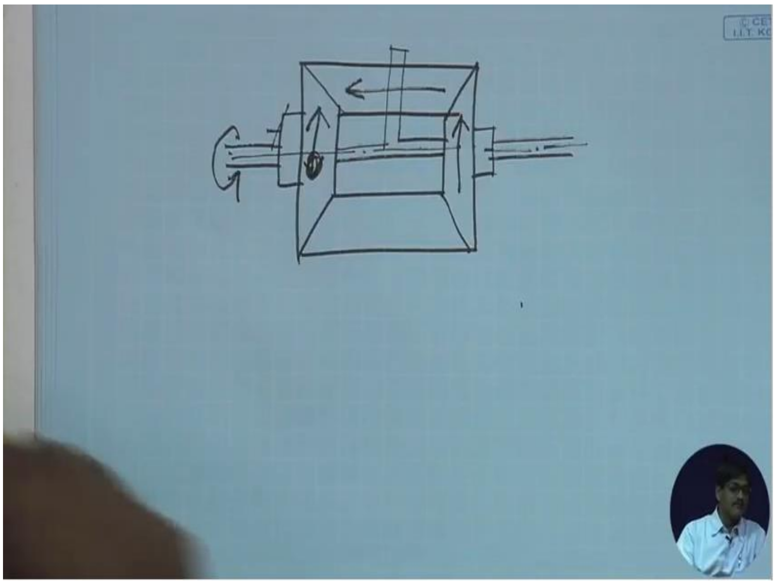

So, this will remain in position and rotate, because let us draw a figure. This is the figure. I have 1 here at this place. So, I am rotating this one this way. I am rotating this one this way and therefore this gear will be rotating this way. If these are equal in magnitude, it will simply remain in position and rotate. But suppose I had rotated this one in this direction. What would have happened? Same rotation both of them in the same direction.

In that case, this would have been driven round and round and round this way physically. And we would have noticed a rotation in this final resultant shaft because both of them are moving this way. And therefore, this gear is going to move this way now, and therefore this shaft would have rotated and this would have moved this way like that.

So, by addition of these 2 input rotations I can get a final output rotation here. So, having understood this we can move on to our final discussion about gear hobbing setup.

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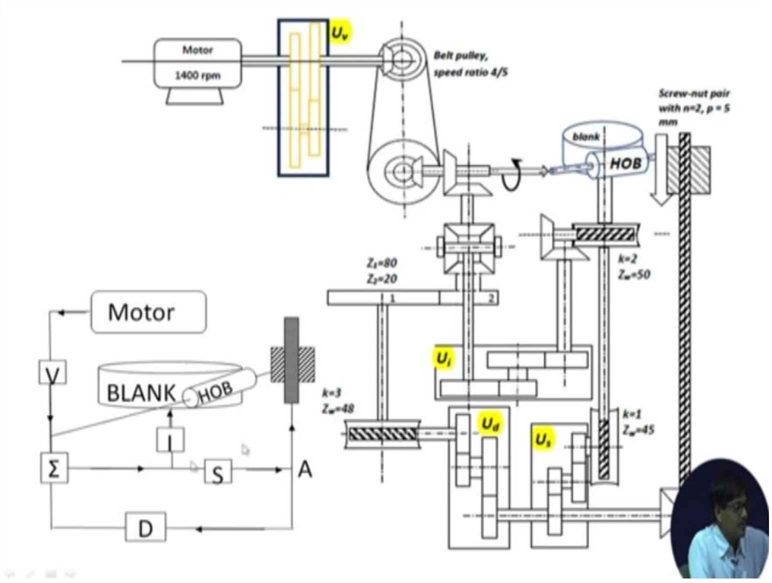

This is a gear hobbing setup. Now, how is it different from this one that we have studied just now? This one is a schematic diagram, where the details are not provided. But ultimately when we are discussing about gear hobbing, everything has to be considered. So, let us see what are the things that we are supposed to consider here? First of all, as we discussed, the motor power source, from the single power source.

First of all, let us look at the gear boxes. First gear box that we should come across is V. Yes, U_V is there, with yellow colour. After that there is a bifurcation here. What happens at that bifurcation? One side goes directly to the hob and the other side goes to the differential mechanism.

Let us track them down, yes one side is going to the hob and the other side is going to the differential mechanism that is good. What is happening to this hob it is connected to the work piece and they rotate together and this differential mechanism gets one input from the motor which is basically this one.

It has another input coming from the lead change gears. So, the first input is this and the second input is through these two gears, 1 and 2, not this gear shaft in between inside. What is this particular gear shaft then? This gear shaft must be containing the output.

Where is the output going in this schematic figure? The output is supposed to go to this particular index gearbox. Wait a minute, this index gearbox should have been here. We will be definitely matching and finding out whether we have by chance put the wrong figure. So, in that case, from here we are supposed to get the index gearbox. Yes, it should have been here. Shall I quickly make this change?

Let me see how fast I can do it. I think this should suffice. I cannot remove this small line, how does it matter. So, this is the configuration which is correct. So, let us read once again, the motor, U_v that is speed gearbox. So, there is the bifurcation here. One side goes to the hob. One side is going to the differential. Next, from the differential gets another input. This one, it must be from the lead change gears.

Yes, it is from the lead change gears. Differential has an output which is going to index gearbox. From the index gearbox, there is a bifurcation. Yes, from here it goes to the work piece and it also goes to U_s bifurcation. Here there is the bifurcation. After this bifurcation, it reaches the blank on this side, it reaches U_s on this side and from U_s it is supposed to come out bifurcation is there.

Yes, there is a bifurcation. One goes to U_d. And the other one goes to the screw. So, this figure is correct, it matches with this one figure. Now, let us see what we are supposed to do here? We are supposed to first determine, we have first of all tested it and found out that everything has been correctly configured as regards the locations of the gearboxes.

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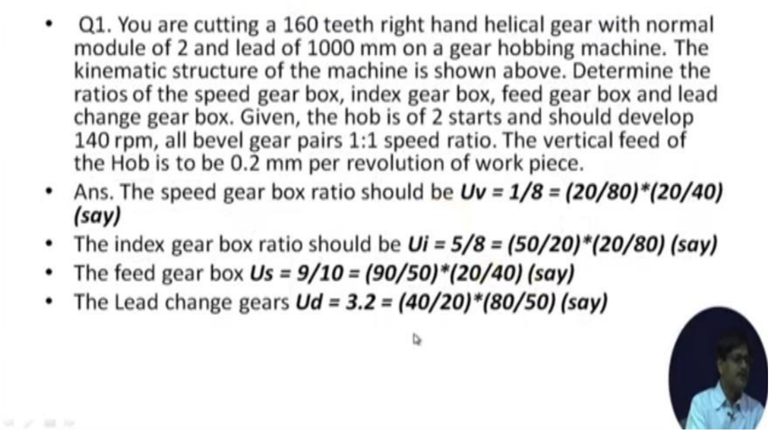

And next, let us take a numerical problem. You are cutting a 160 teeth right hand helical gear with normal module of 2 and a lead of 1000 millimeters on a gear hobbing machine. Determine the ratios of the speed gearbox, index gearbox, feed gearbox and lead change gearboxes given the hob is of 2 starts and should develop 140 RPM.

All bevel gear pairs are 1:1 speed ratio. The vertical feed of the hob is to be 0.2 millimeters per revolution of the work piece. Answers are provided, answers are U_v should be $\frac{1}{8}$, index gearbox U_i should be $\frac{5}{8}$, the feed gearbox should be $\frac{9}{10}$, and the lead change gearbox U_d should be 3.2. So, once the answers are given, the figure is given, you already have prior knowledge of working out this sort of a problem on gear shaper.

I expect that you will be able to solve this problem fully yourselves from the figure that I have given you just ahead of this one. So, in this lecture I am not formally solving it. I will take up the solution the next day. In the meantime, I would suggest that try to solve the problem yourself, because how to solve this sort of problems from previous practice.

Let us have a quick look. Here for example, is there any mechanism which is not known to us? How it operates? We have belt pulley, bevel gear etc. The differential is something which is at present not known to us. I would suggest that when you are solving for the initial part of the problem, consider that you are not cutting a helical gear. By the way, have I provided the helix angle? I have not provided the helix angle.

Can you guess how you can find out the helix angle? You can find out the helix angle from the value of the lead. We know the helix angle = $\tan^{-1}\frac{\pi D}{L}$. By the way, you do not yet know how to work with the differential? In the differential I can suggest that when you are finding out the initial values, consider the output RPM of the lead change gears to be 0.

And that way, you can first set the values of V, I and S that means U_v, U_i and U_s can first found out by considering the output of the lead change gears to be 0 RPM and then we will find out the final value of D. So, with this we come to the end of the 16th lecture. Thank you very much.