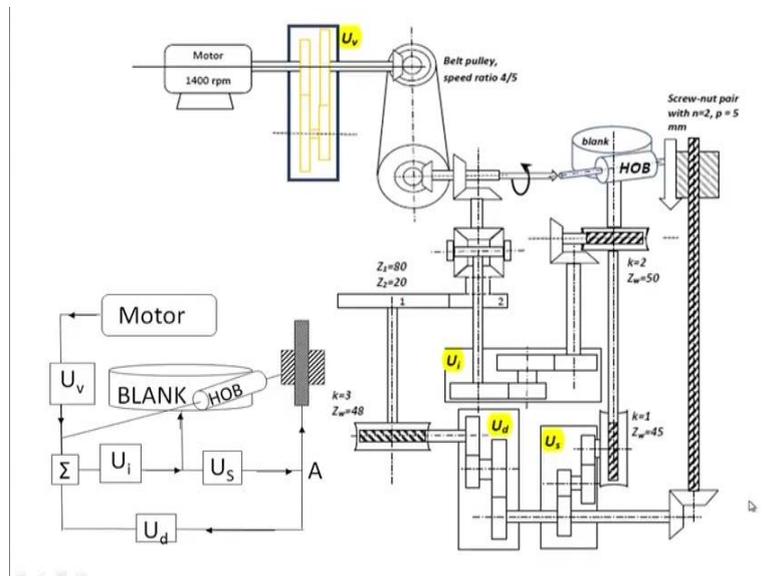


**Spur and Helical Gear Cutting**  
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**Lecture – 37**  
**Gear Hobbing - III**

Welcome viewers to the 17th lecture of the open online course Spur and Helical Gear Cutting. So, last day when we stopped at the end of the 16th lecture, we were dealing with the calculations of the gearbox ratios for the gear hobbing machine in connection with the solution of a numerical problem.

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So, let us move right away to the problem. This was the figure that we were dealing with. These were the positions of the gearboxes which we have checked against this figure. And they all have matched and we have 4 gearboxes to solve. The speed gearbox  $U_v$ , the feed gearbox  $U_s$ . The index gearbox  $U_i$  and the lead change gearbox or differential gearbox  $U_d$ .

So, just to pick up the threads, this is the workpiece, this is the hob, this is the motor, this is the flow of power is being shown to the different mechanical elements. This is the differential which is adding up 2 inputs to produce one single output. The differential is shown here as a summation symbol. It is adding up the input from  $U_d$ , the lead change gearbox and the input from the motor side.

And the addition is being passed through  $U_i$  and finally being given to the blank. It is also passed downstream through the regular other main mechanical elements. So, this was the setup, we have already had a look at it.

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Numerical problem in Gearbox calculations in Hobbing

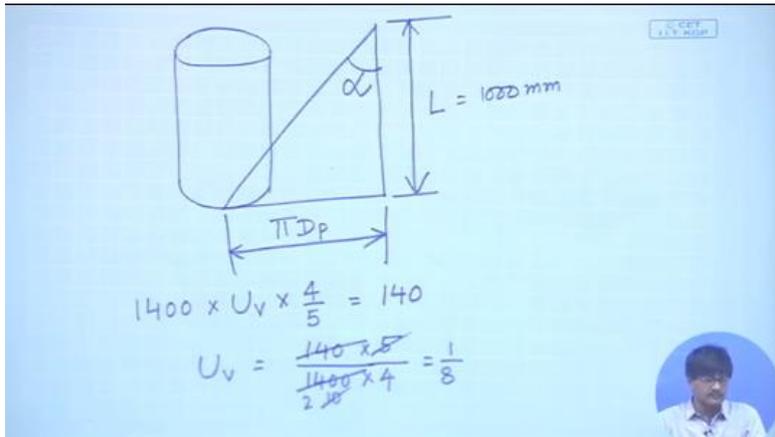
Q1. You are cutting a 160 teeth right hand helical gear with normal module of 2 and lead of 1000 mm on a gear hobbing machine. The kinematic structure of the machine is shown above. Determine the ratios of the speed gear box, index gear box, feed gear box and lead change gear box. Given, the hob is of 2 starts and should develop 140 rpm, all bevel gear pairs 1:1 speed ratio. The vertical feed of the Hob is to be 0.2 mm per revolution of work piece.

- Ans. The speed gear box ratio should be  $U_v = 1/8 = (20/80) * (20/40)$  (say)
- The index gear box ratio should be  $U_i = 5/8 = (50/20) * (20/80)$  (say)
- The feed gear box  $U_s = 9/10 = (90/50) * (20/40)$  (say)
- The Lead change gears  $U_d = 3.2 = (40/20) * (80/50)$  (say)



Now, the next one the problem. You are cutting a 160 teeth right hand helical gear with normal module of 2 and lead of 1000 millimetres on a gear hobbing machine. So, what is the information that we have? 160 teeth. Normal module is 2 and lead is 1000 millimetres. So, if you look at this figure, it looks like this.

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$140 \times U_v \times \frac{4}{5} = 140$

$U_v = \frac{140 \times 5}{1400 \times 4} = \frac{1}{8}$



If you unroll one tooth, this is the lead equal to 1000 millimetres. This is the circumference equal to  $\pi D_p$ . Here it will be equal to  $M$  normal module into  $Z$ , number of teeth divided by  $\cos \alpha$  is the helix angle. So coming back we have further into the question, determine the ratios of the speed gearbox, index gearbox, speed gearbox and the lead change gearbox. That is good.

Given, the hob is of 2 starts and should develop 140 RPM, all bevel gear pairs 1:1 speed ratio etcetera. So let us take up  $U_v$ . Once, we are discussing about the value of  $U_v$ , let us take a quick peek back at the figure. So we have the motor 1400 RPM. This will be multiplied directly with the  $U_v$  which has to be found out. This is multiplied by, here it passes through a bevel gear pair and we know that that speed ratio is one is to one so we do not need not bother about it.

After that comes a belt pulley with speed ratio of 4:5. So, we will take it as output RPM by input RPM.?

$$1400 \times U_v \times \frac{4}{5} = 140$$

Let us find out what  $U_v$  comes out to be.  $U_v$  comes out to be:

$$U_v = \frac{140 \times 5}{1400 \times 4} = \frac{1}{8}$$

$U_v$  is equal to  $\frac{1}{8}$ .

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#### Gear Box Calculations

- $1400 \times U_v \times \frac{4}{5} = 140$   
So  $U_v = 1/8$
- $U_i \rightarrow$  Start from 1 rotation of hob
- $1 \times \text{Diff} \times U_i \times \frac{2}{50} = (2/160)$
- Differential ratio is 1/2 when considering power flow from hob to Job via  $U_i$ . Gear 2 from  $U_d$  is considered stationary.
- Hence  $U_i = (50/2) \times (2/1) \times (2/160) = 5/8$



Next, so  $U_v$  is matching. I have also included in the PPT, the solution. So, if you by chance miss anything in the lecture. You can always refer to a PDF of the lectures which we will be uploaded and you can be abreast of the solution. Index gearbox ratio, let us find out the index gearbox ratio and for that, once again we move on to this one.

Where is the index gearbox? Here it is. So, index gearbox ratio, if we remember it determines the number of teeth to be cut. In order to do that it determines the speed ratio of the blank and the hob. What is the speed ratio of the blank and the hob? If we consider them to be once again

worm and worm gear pair. In that case, we have ended there their speed ratio should be  $\frac{K}{Z}$ , where K is the number of starts on the hob and Z is the number of teeth to be cut.

So, here the number of teeth to be cut is 160 and the number of starts on the hob is equal to 2. So the speed ratio should be:

$$\frac{2}{160} = \frac{1}{80}$$

So, let us see how  $U_i$  is managing that. So, if you look at this figure from the schematic view. First of all we can say that if the hob is rotating, in that case for every rotation of the hob, we go all this way and ultimately land up on the blank.

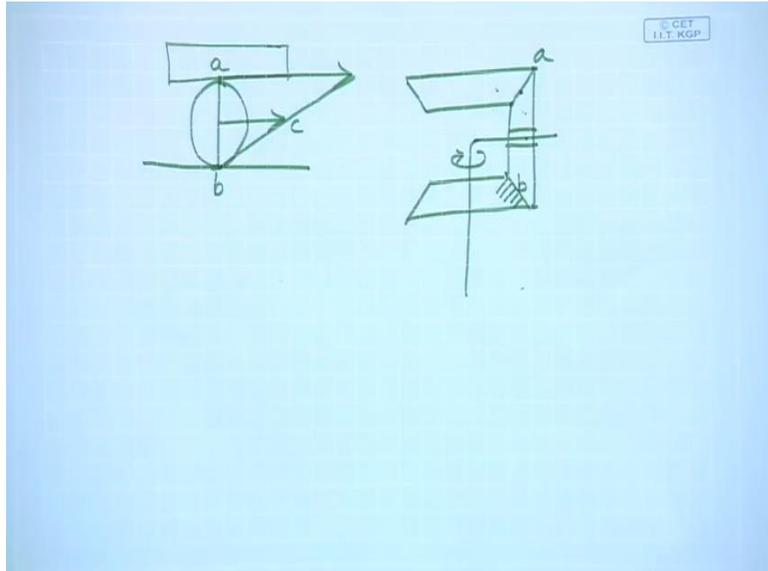
The blank should be having a speed of  $\frac{1}{80}$  RPM. Just one more sentence regarding the schematic view. So, we will be passing through Hob RPM 1 RPM and then we pass through this differential. And we have to decide what sort of influence this differential will have on the RPM.

Next we pass through  $U_i$  and after that we go on to the black. So, let us look at the figure once again hob RPM. So if the hob is rotating once, this one rotates 1:1 and we arrive at the differential, this is the differential. Now, what happens in the differential? Suppose I am rotating this particular gear, in that case, for the time being we consider that the input from the lead change gears  $U_d$ .

This input is locked, 0 RPM, it is not moving. So, we understand that the gear marked, 2 the bevel gear connected with gear 2, it is having 0 RPM, it is fixed in space. If it is fixed, it does not rotate in that case, this one will be rotating and imparting some rotation on to these two. These two and how will they rotate? They will be rotating at half the RPM of this one. Why is it so? Because, if you look at this.

They will have a relation of this type roughly. Remember how heavy pieces of stone they were moved up during the time pyramids and other things were built, they were moved up on logs. So, this particular velocity is going to impart half its velocity at this point. This velocity rather here this velocity is going to be half this one.

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If you have something, a steady member on that there is a rotating member and this tangential velocity is shared with another member they will have a velocity relation of this type. This centre point will have half the velocity of this one and the same thing is happening here. This one, as we discussed, is not moving. It is fixed, on that this wheel is rotating and this one is having same tangential velocity this way outside the paper. The case which is existing here.

So, a corresponds to a, b corresponds to b and c corresponds to c. This rotation, if you have an arm, this rotation. So this rotation is going to be half of this one. Once we accept that, then we understand there is a going to be a ratio of half multiplied with the input rotation coming from the hob. Now, this can also be derived by one equation called a Willekes equation. We can have a look at that when we have some spare time from these lectures.

So, once we have a ratio of half introduced, we have hob rotation, multiplied by half coming to this particular rotation, multiplied by  $U_i, \frac{K}{Z} = \frac{2}{50}$  equal to  $\frac{1}{80}$ . Let us see the calculations now.

$$1 \times \text{Diff.} \times U_i \times \frac{2}{50} = \frac{2}{160} = \frac{1}{80}$$

and differential ratio is being taken as half.

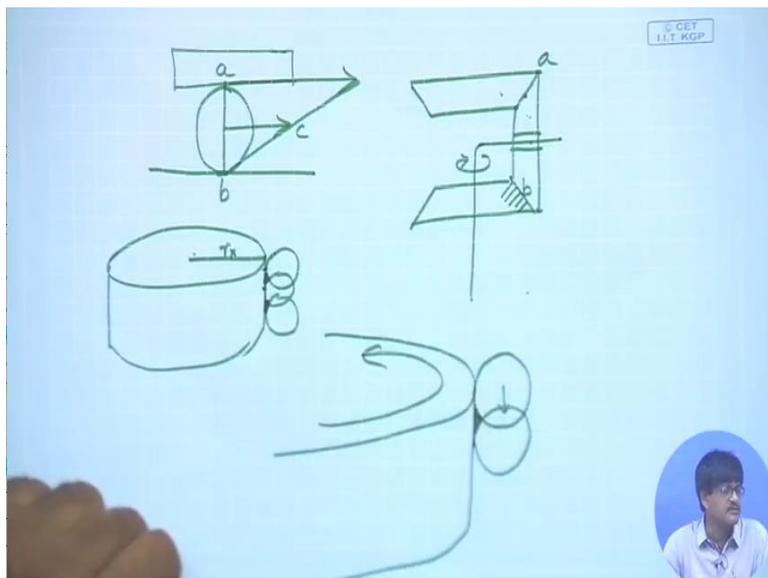
$$U_i = \frac{50}{2} \times \frac{2}{1} \times \frac{2}{160} = \frac{5}{8}$$

So,  $U_i$  comes out to be  $\frac{5}{8}$  as per our calculations.

So,  $U_i$  has been solved.  $U_v$  has been solved already. And therefore, we move on the feed gearbox. We will determine how feed gearboxes decided? Let us see, where feed gearbox is situated? The feed gearbox is situated here and the feed gearbox we can notice is here, how is the feed gearbox influencing the operation of the machine?

We say that is the hob is moving down too fast. In that case, it creates a problem that the surface which is left, it is going to be too rough. Let me draw a figure and show you.

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If this is the blank and this be the idealized position of the hob. There is only a point to point contact. So, after every rotation, say, this particular meridional position, this radial position we call as  $r_x$ . So it is going to come back to  $r_x$  after every rotation. One rotation it is here, second rotation, it is here, third rotation is here. So, it leaves behind these small scallops of material.

How does it look like in a blown up figure? It looks like this. This is one position, so, this is going on rotating and this is descending. So it will reach this position say after one full rotation of the work piece rotates and will leave behind this part uncut and therefore, this is going to define a roughness on the profile.

So, if that happens we would like to set a particular feed which will give us acceptable roughness. If we want an acceptable roughness, in that case, let us see what has been designated in the problem. The vertical feed of the hob is to be 0.2 millimetres per revolution of workpiece.

So, that is now understood that per revolution, if the workpiece rotates once. The hob has to come down by 0.2 millimetres by that particular time. Let us go back here and let us see how this is implemented. First of all, how is the hob coming down? Well, just as it is rotating, it is also attached to this nut. This nut is attached to the hob so that if the nut goes down, the hob goes down as well.

So, who is making the nut move down this particular screw vertical screw which can be seen here this is rotating and it is bringing the nut further and further down. Now, if the nut is really moving down. Why does not it rotate with the screw? Because the screw is restricted from translation and the nut is restricted from rotation.

And so, therefore if this screw rotates, we have the nut moving down. How much does it move down? It is supposed to move down by 0.2 millimetres by the time the workpiece rotates once.

We say that I will start with one rotation of the blank move down through all the mechanisms and finally arrive at this nut and I will assign that particular value which I derive equal to 0.2. So in that case, what do we have to do? If you look at the schematic diagram, we have to move through this channel. Blank rotation,  $U_s$  and then finally the lead screw and then the nut and just this particular part will help us in defining  $U_s$ .

So blank rotation is 1, so we move right down. So we are moving down. Why didn't we take this bifurcation? Because it has nothing to do with the vertical motion. Vertical motion is defined right down to this position we come across a worm and worm gear. And therefore, we have 1 rotation, multiplied by  $\frac{K}{Z}$  which means  $\frac{1}{45}$ . So 1 rotation of blank multiplied by  $\frac{1}{45}$  multiplied by  $U_s$ , out we come here into 1:1 must be equal to the number of rotations of this leads group.

And per rotation it moves by, screw nut pair they have  $n = 2$ ,  $p = 5$  which means a number of starts = 2 and pitch = 5 which means per rotation it moves by 10 millimetres. Lead is equal to number of starts and multiplied by the pitch  $p$ .  $L = np$ . Per rotation it moves by  $L$ . So, the rotation of the screw will be multiplied by  $L$  to give us the final movement of the nut, which is equal to 0.2.

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$$1 \times \frac{1}{45} \times U_s \times 10 = 0.2$$

lead of screw-nut pair = 10 mm (m x p)

$$\Rightarrow U_s = \frac{0.2}{10} \times 45 = 0.9$$

Let us write it down here 1 rotation of the workpiece multiplied by  $\frac{1}{45}$  which is this worm and worm gear pair multiplied by  $U_s$  because we are now moving through  $U_s$ , multiplied by  $L$  lead of the lead screw nut pair equal to 10 millimetres which is really equal the number of starts into pitch.  $L = np$ .

$$1 \times \frac{1}{45} \times U_s \times 10 = 0.2$$

$$U_s = \frac{0.2}{10} \times 45 = 0.9$$

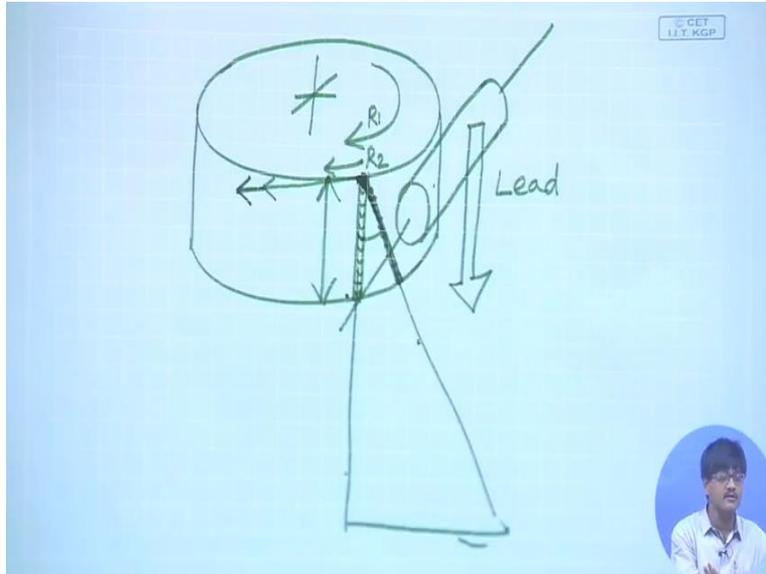
$U_s = 0.9$ . Therefore, we arrive at the answer of  $U_v$ ,  $U_i$  and  $U_s$ . Last of all we have the lead change gears. Let us look at the lead change gears.

So, for that, once again the figure. Where are the lead change gears? The lead change gears are  $U_s$ , coming here if you follow me from the point it is a bifurcation. On one side, we are serving the screw, on the other side we are serving the lead change gears. Normally when you are cutting spur gears, they do not take part in the cutting action.

But now they are going to rotate and they are going to get added up to the RPM which is imparted by virtue of hob rotation from the other input side. 2 inputs getting added up and forming the final rotation of the blank. Now, the question is how much should I rotate the blank by this particular input. From the other side of the input we have already calculated the amount of rotation which has to be given to the blank and accordingly we have decided upon the value of  $U_i$ .

But from this side an additional amount of rotation will be provided, which will take care of the fact that helical cut will be imparted. So, for that, I will just once again come back to the figure that we had discussed the last day.

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This being the job, we can avoid all sorts of very complex, complicated calculations by this particular statement that whatever be the rotation ratio of the workpiece and the cutter. This is the cutter, the hob, whatever their rotational ratio that is creating synchronization.

That means, if 1 cut takes place and another cut is going to take place later on and along this particular line, when the hob is going down. Exactly 1 cut is going to take place this way. This is accepted. Over and above that, if I suddenly add yet another rotation, so this was rotation 1,  $R_1$  and this is  $R_2$ . If I add an extra rotation, in that case what will happen is? This will get staggered, either to this side or to that side depending upon this extra rotation.

If I add this extra rotation so that it adds up this will move faster. And therefore, this will be lagging behind. Let us see this one once again. This is moving at a particular rate, so that it is synchronized. Now, if this body moves a little extra amount, therefore what will happen is this particular part which was to get cut? It comes here. It does not get cut and therefore, there will be a cut out this time.

The body is getting ahead. So, the cut is falling to some place which is lagging behind. So, the cut will take place this way. How do we calculate? How to make this cut at the particular angle

that we want? For this we say that whatever is the initial rotation that has been taken care of by the other side of the movement.

But this particular input will be such that, by the time I get from this point to this point, I will be rotating the job 1 extra turn. So, this is coming down, there is no problem with this. This is coming down and due to the first rotation this is exactly coming down along this line. So, if I rotate a bit of extra amount so that by the time, it has moved down by the lead. This extra rotation is exactly 1 rotation.

I will find that it will have these lines along the helix angle. So, our relation will be, if this one goes down by the lead amount, lead of the helix, which is given to 1000 by the time the hob moves down by a 1000 millimetres an extra rotation will be provided. You might say but this is not going all around by  $\pi D$ , no. But if you not consider this way this relation will be maintained. This will be 1000 and this will be  $\pi D$ .

Because, we have related them this way. By the time a lead amount of movement takes place, this is only the width of the gear. This is not lead. This might be hardly say how much 1 inch? That means 25 millimetres, 30 millimetres like that and the lead is 1000 millimetres. So, we are relating them this way. By the time you go down 1000 millimeters, the full rotation is achieved. So, by the time you go down by the width of the gear a certain amount will be achieved but they will be in the same ratio.

Therefore, this helix angle will be maintained. So, let us see how this relation is maintained. By the time the hob goes down by lead, extra rotation takes place by one full rotation. So, with this in mind, let us look at the schematic figure now. So, we will say that, I will achieve 1000 millimetres that is lead amount of motion in this particular nut. For that I will have a certain number of rotations of this screw.

With these many rotations I enter  $U_a$ , that means the lead change gears and from the lead change gears I go to the differential. I calculate whatever ratio differential offers me when the other output is off and this input is on. And I pass through  $U_i$  once again and the rotations that the blank should have for this case is 1 rotation. So, coming to the actual figure with details.

Here, if you look at this one, this goes down by lead which is 1000. How many rotations of the screws should take place for those 1000 millimetres vertical movement? Definitely 1000 divided by 10 millimetres. So, we can say that the workpiece lead by the machine lead which is very popularly used workpiece lead 1000 divided by the machine lead, which means the screw which is belonging to the machine, it has its lead as 10.

So,  $\frac{1000}{10}$  must be the number of rotations of this lead screw. That is good  $\frac{1000}{10}$  is 100 rotations so 100 rotations per minute. It is now input to the do not stop here this is not stopping here. This shaft goes right through to  $U_d$ . So 100 rotations multiplied by  $U_d$  and then comes a worm and worm gear, so it is  $\frac{3}{48}$ . This enters  $\frac{Z_1}{Z_2} = \frac{80}{20}$ .

And we arrive at the doors of the differential. How will the differential act here? Here, the other side is now locked. The other side does not rotate. While the other side is locked, this one rotates and once again a ratio of half will be multiplied. So when this ratio of half is multiplied, we have multiplied by half, so enter  $U_i$  once again. Now from the other side of the differential, so multiplied by  $U_i$ ,  $1:1, \frac{2}{50}$ , equal to 1 rotation of the blank.

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$$\frac{1000}{10} \times U_d \times \frac{3}{48} \times \frac{80}{20} \times \frac{1}{2} \times U_i \times \frac{2}{50} = 1$$

$\downarrow$  Workpc lead / Machine lead     
  $\downarrow$  Worm / Worm gear     
  $\downarrow$   $\Sigma$

$$U_d = \frac{200}{100} \times \frac{1}{U_i} = \frac{2}{U_i} = \frac{2 \times 8}{85} = \frac{16}{5} = 3\frac{1}{5} = 3.2$$

Let us write it down as per this relation:

$$\frac{1000}{10} \left( \frac{\text{work pc lead}}{\text{machine lead}} \right) \times U_d \times \frac{3}{48} (\text{worm} - \text{worm gear}) \times \frac{80}{20} (\text{spur gear pair}) \times \frac{1}{2} (\Sigma) \times U_i \times \frac{2}{50} = 1$$

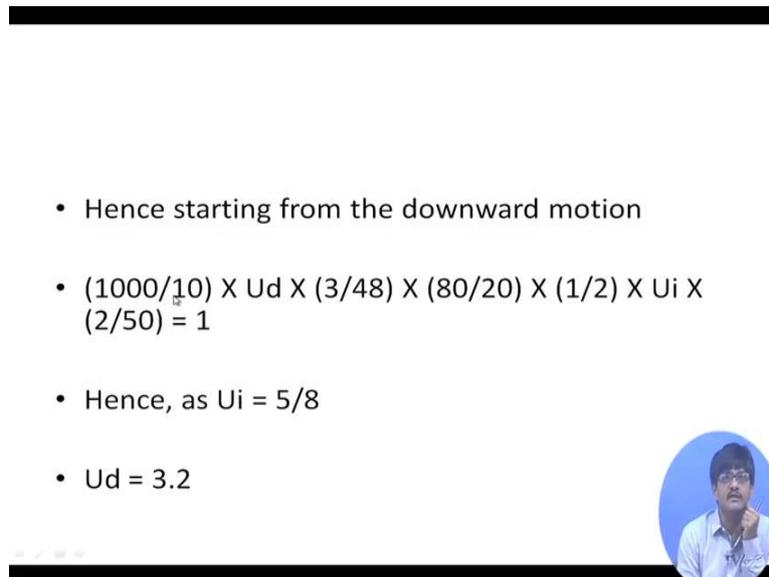
So, let us have a solution of  $U_d$  in this manner.

$$U_d = \frac{200}{100} \times \frac{1}{U_i} = \frac{2}{U_i}$$

$U_i = \frac{5}{8}$ . So,

$$U_d = \frac{200}{100} \times \frac{1}{U_i} = \frac{2}{U_i} = \frac{2 \times 8}{5} = \frac{16}{5} = 3\frac{1}{5} = 3.2$$

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- Hence starting from the downward motion
- $(1000/10) \times U_d \times (3/48) \times (80/20) \times (1/2) \times U_i \times (2/50) = 1$
- Hence, as  $U_i = 5/8$
- $U_d = 3.2$



So, this way we find out the ratio of  $U_d$  and come to the end of the numerical example and therefore, we will continue the discussion on, our vertical gear hobbing in the next lecture. Thank you very much.