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Course
On
Spur and Helical Gear Cutting

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Lecture 06: Numerical Problem Milling Of Helical Gears

Welcome viewers to the sixth lecture of the series spur and helical gear cutting.

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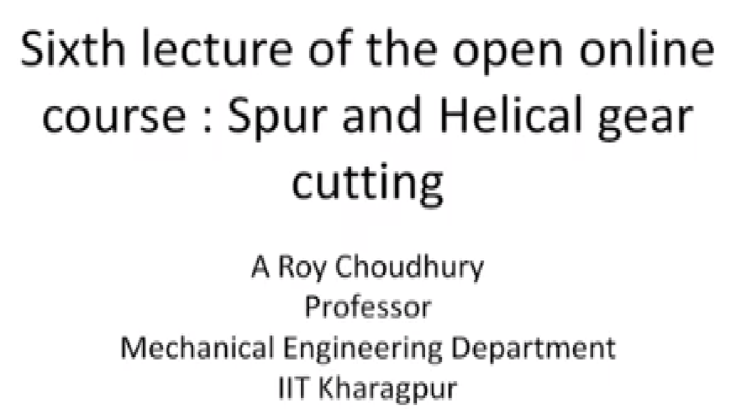

So last time when we met we were discussing our question.

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A student is developing a set-up in which he intends to rotate a fan at 8640 rpm from a motor rotating at 1440 rpm. He has the following gears with him. Which are the ones that he should employ in a gear box which has only two shafts with centre distance of 120 mm?

Spur Gears of module 2	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Nos of teeth	80	40	30	90	60	60	100

This was that a student is developing a setup in which he intends to create a fan at 8640 rpm from a motor rotating at 1440 rpm is the following gears with him which are the ones that should employ in a gear box which has only two shafts with center distance of 120 millimeters okay, 120 millimeter Center distance, okay. So we discussed a possible configuration.

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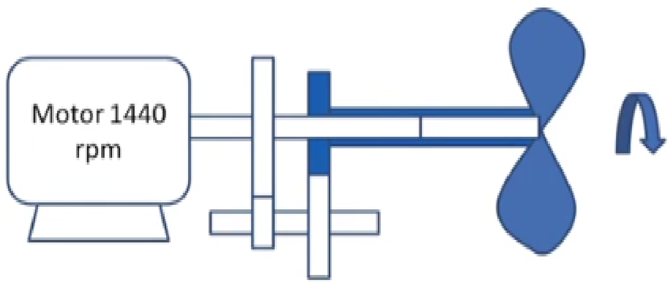

In which the motor is rotating here and there are two gears which are reducing a increasing the RPM in this ugly shaft these two gears are sharing the RPM and this is finally giving it to another gear which is loosely fitted on this shaft and connect it to the fan so that ultimately the fan rotates at the required rpm, what sort of increase is there so if you divide the initial rpm sorry if you divide the rpm.

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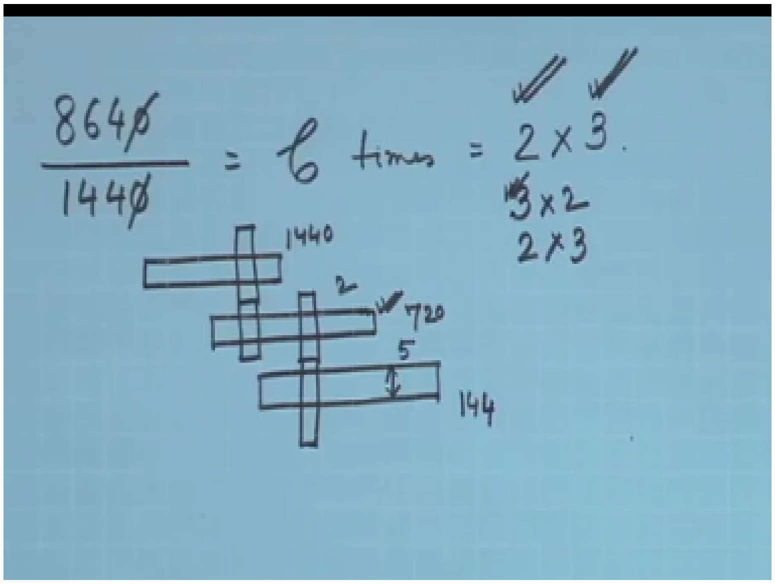

And let us work it out on the piece of paper 8640 rpm by 1440 rpm I think off and I if you calculate you will find 6 x 4, 24. 6 times increase of rpm is required and as shown in the figure it has been the it has been provided that we should try to achieve it in two steps, now this is 2 x 3 so let us have a multiplication of the RPM 2 times and then the multiplication in three times but should we first do three and then two or then two and then three.

Or does it does it really matter if I am doing two first and three next etc generally what happens is if you have three shafts if you had three shafts okay here also basically we are having three shafts if you have say the general case of three shafts and say you are bringing down the RPM okay the rule is generally, do the first reduction okay as a smaller ratio and then do the next reduction that means if you have to get say if you are working at 1440 rpm and from there if you have to reach say how much.

Let us divide this by10 so this becomes 144 rpm if it is to be reached so it is 2 x 5, so it is better to have five reduction here of course five reduction is extremely difficult in one stage hypothetically let us say if you want to reduce the speed by a factor of 5 here and by a factor of 2 here it is good because the intermediate shaft will be rotating at a high rpm in that case 8 sorry 720 rpm less is the RPM more is the torque.

And therefore more is the diameter of the shaft in order to which standard that torque that is the problem because you would have to spend more money for making the shaft because it will be more robust in size had you had five reduction five time reduction here the RPM would have been less than 720 and you would have had to employ a much larger diameter shaft in order to withstand the torque which would have appeared here so the rule in sliding clusters is that, have smaller reductions first and larger reductions as close as possible to the final stage.

In this case however we are making the RPM higher and higher, so initially we are rotating a smaller RPMs and then we are going for higher rpm. So higher rpm less is the torque and therefore we let us have this one first okay, let us have this one first so that when we are in the shaft number two we are having a much higher rpm it has to withstand less torque. And therefore let us have a reduction of three first and then a reduction of two if you now go back to the problem and look at the let us look at the computer screen and look at the values can we have look at the computer screen please.

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A student is developing a set-up in which he intends to rotate a fan at 8640 rpm from a motor rotating at 1440 rpm. He has the following gears with him. Which are the ones that he should employ in a gear box which has only two shafts with centre distance of 120 mm?

Spur Gears of module 2	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Nos of teeth	80	40	30	90	60	60	100

So if you look at the values of the spur gears number of numbers of teeth available in that case spur gear of module 2 is provided and let us see whether they have a number of teeth which is 1 is to 3 yes 30 and 90 but will they fit in 120 millimeters Center distance, okay.

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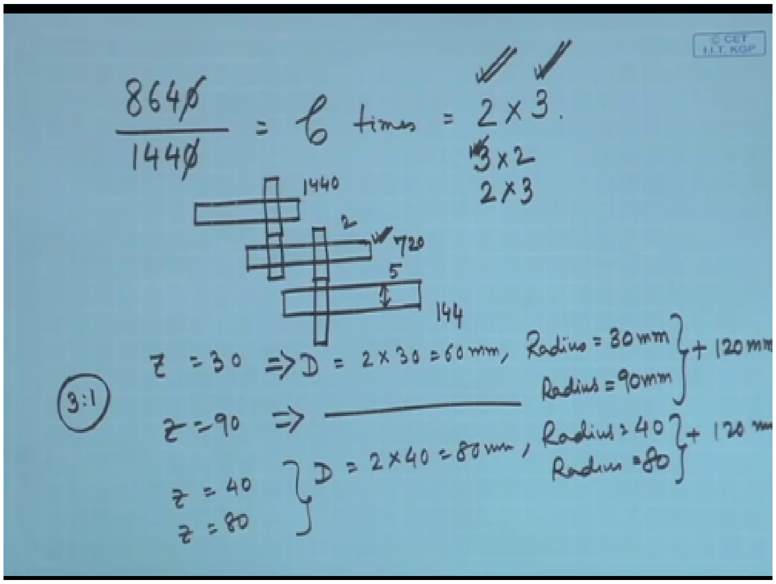

Their diameters are so z = 30 diameter equal to 2 x 30 = 60 millimeters and radius = 30 millimeters and Z = 90 naturally we can pass all these we can say radius will be equal to naturally three times of this, how much is that? It will be 90 millimeters this one when added together will give us 120 millimeters Center distance so this is quite satisfactory we can use 30 teeth gear with 90 teeth and achieve 1:3, 3:1 speed increase.

And therefore we can also use Z = 40 and z = 80 where combined they will give radii of you know this diameter will be equal to 2 x 40 = 80 millimeters therefore radius will be equal to 40 millimeters and this lower radii mean radius of the larger one nothing will be 80 and therefore this will be adding upto 120 millimeters Center distance that is also this can be used so we will use 30 and 90 gear and we will use 40 and 80 here and that way the RPM will be you know increased to six times its previous value, so let us have a look at the figure once again.

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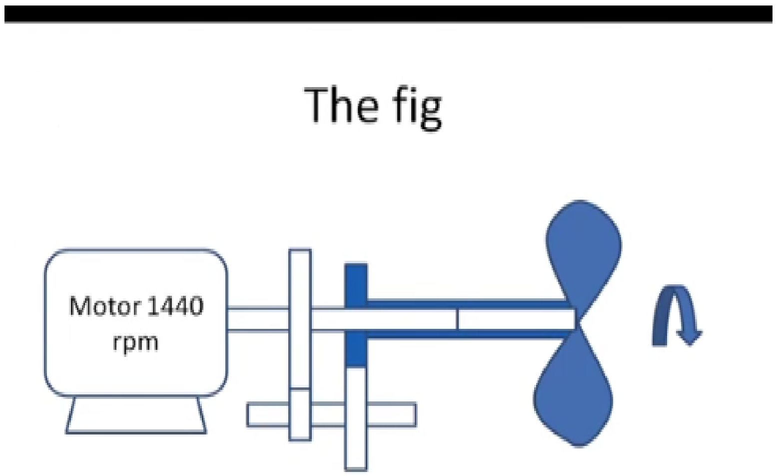

This one will be 90 teeth, 30 teeth, 40 teeth sorry 80 teeth, 40 teeth and therefore the fan will be rotating on the required speed, okay.

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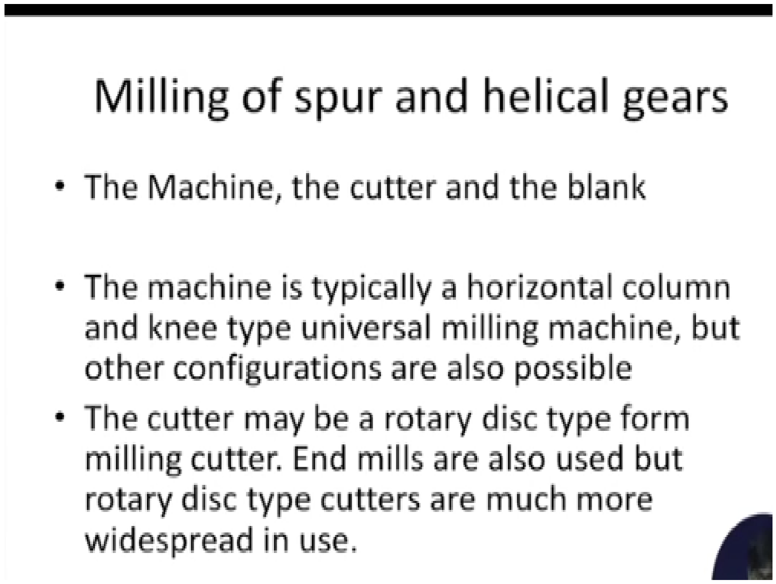

So after this I had another problem which we will discuss later on let us formally start the sixth lecture the question which we have left bind I will definitely provide the discussion and answer to you in subsequent lectures, milling of spur and helical gears so what do we do in case of milling of spur and helical gears first of all we have a milling machine we carry out milling operation and there is a specific type of cutter or other cutters and we take a blank which is generally a disc shape it I mean a cylinder with a certain amount of thickness which is equal to the width of the gear.

And we cut away certain portions from this blank so that the teeth remain but the material which is there on the tooth spaces that is removed and only the teeth remain so cutting off of some material is required, if you have a look at this particular figure this is how it is done.

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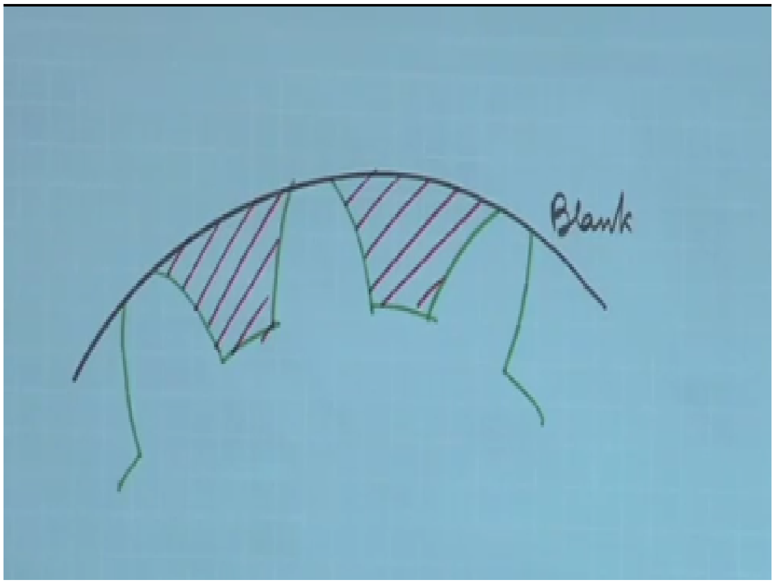

This is the original blank okay this is the blank which means the material from which we are going to cut out some extra material so that only that which is required remains what is required these are the teeth which are required, this is what is required. So there is some material which is not required which is it can be quickly identified as this part this has to be removed and it is on the milling machine that we do the removal of these you know tooth space material. So if this has to be done what do we have as a machine as the cutter etc, etc. Let us go through them one by one.

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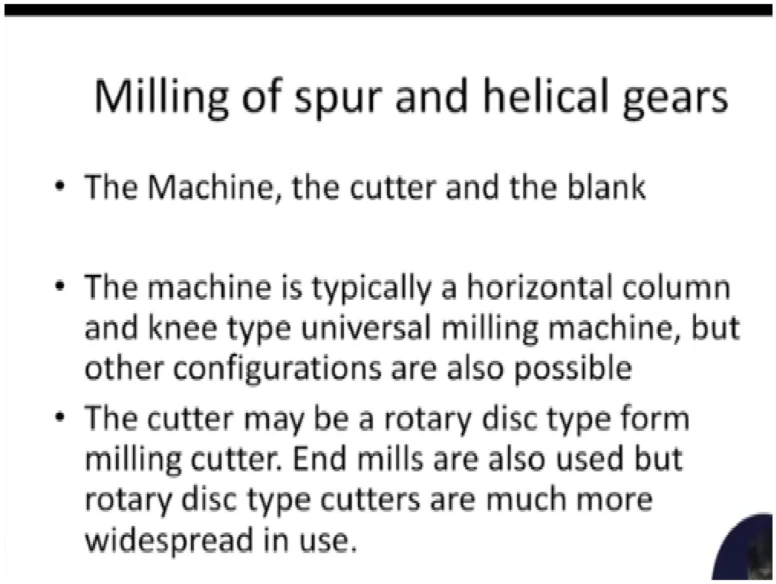

First of all the machine is typically a horizontal column any type Universal milling machine but other configurations are also possible, there are many other configurations like fixed bed type okay then vertical milling machine omniversal milling machine so many other but the one that we have identified here this will serve its purpose quite well for both spur gears and helical gears okay, so let us move through them one by one. Horizontal milling machine horizontal milling machine means whether cutters axis cutter rotational axis is horizontal okay.

So this identifies basically the configuration of the cutter in space its axis of rotation is horizontal okay will the vertical milling machine do, yes you can set it up that way but this one this combination of all these you know specifications that is definitely one to serve the purpose, column and knee type column and knee type is basically referring to the structure of the milling machine where there is an upright or vertical column which supports the table on which you are putting the job.

And that also contains the vertical screw which can be you know utilized to make the cutter a table move up and down let us have a quick look at that.

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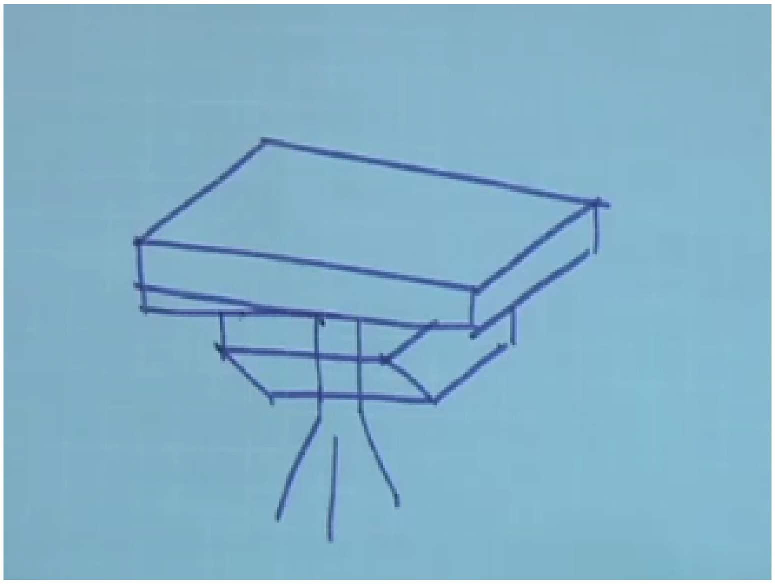

This is your table sorry this is your table and you will have a column sort of thing so let us draw it this way and here you will have a device to you know house all the mechanisms so not a very good depiction let me draw it a fresh.

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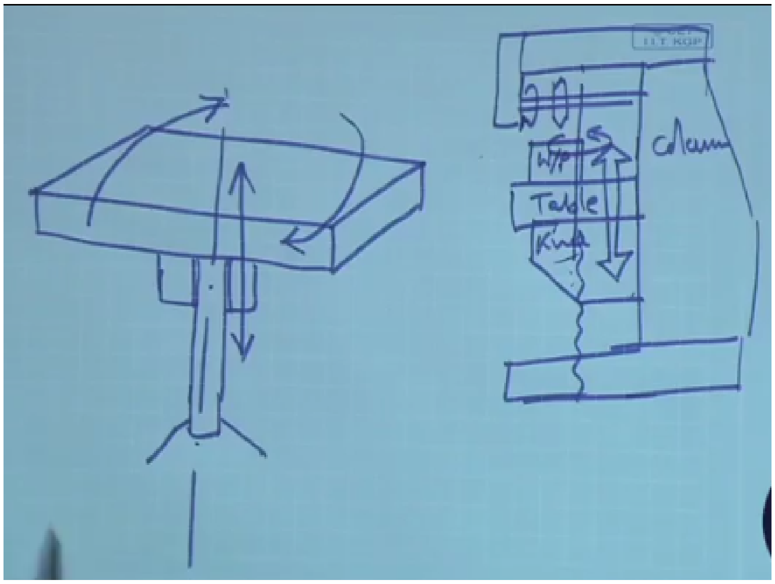

Table and there is one vertical screw provision for a vertical screw okay and this vertical screw is supported here and this one a there is a provision to have a nut here which makes the table move up and down, okay. So this whole thing then seen from the side looks like this table and screw and it can move on the milling machine up and down but what is the column that we are talking about this is the column okay.

So sorry this is the column this is the table and this is called the knee and the cutter can be supported on a shaft Colin Arbor this is the cutter and you have the milling machine, cutter is rotating by the rotation of this particular shaft and you can put your job here your work piece if you want to move the work piece down this vertical screw can operate and the whole thing can come down and this column.

And me type structure allows the operator to interact with the machine very easily it is an open type of structure you want to move the job up move this up want to move the job down move this down you can move it longitudinally in a horizontal plane you can move it transverse on a horizontal plane this is extremely accessible so for manually operating machines this column and me type configuration is extremely easy to operate, so for a machine this is the case and what about Universal machine. For universal machines our rotation about the vertical axis is possible you can rotate the table about the vertical axis this is the vertical axis the table can be rotated this way this is extremely useful for cutting of helical gears okay.

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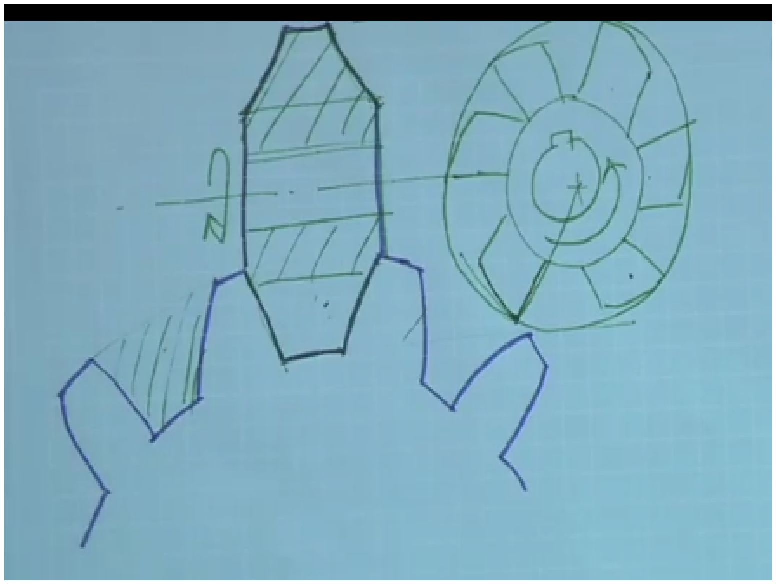

Now the cutter, how does the cutter look like? The cutter looks like I want to cut off this portion so the cutter exactly conforms to this particular shape rather let us use a different color this is the cutter so it looks like this in what way this is its axis of rotation okay it might not move right up to this portion because there will be teeth like this why have I given no section line here actually here also there will be no section line.

Because they you may be cutting only the body portion or the teeth how do the teeth look like, so this is one view of it the teeth would be looking like this okay. So this is the basic body on that these would be the teeth, sorry no space decorator okay fine so this is the cutter it rotates this way and removes material, so this is one view and this is the other view so from the side it looks like this I mean from the end it looks like this.

It rotates this way and from the other side it looks like this it rotates this way it has a hole inside and there is one key whole key way, what is the advantage of this cutter? It is doing a just a copying okay copying a form which is already made on it this is exactly conforming to the gap which is to be cut here somebody has already done it for you this sort of complex in volume profile has been you know machined on it when it has been made.

On the other side you can see the teeth here what is this one it is slightly moving away from the circle along an Archimedean spiral to provide clearance and the rake angle can be say 90 degrees so on this side we have the rate angle and on this side we have the clearance angle, okay. An

Archimedean spiral ensures that the clearance angle be more or less remain constant if it is logarithm spiral it will be absolutely you know regained the clearance angle.

Anyway so this one will be rotating and here it will be rotating this way and removing all this material, so once this has been done it is removed this one is rotated so that the next material to be removed this part this one comes here and again the cutter is used to you know pass through while rotating and remove this particular material, this is what is done in case of milling you have the job this way the cutter goes through cuts the material you rotate the job cutter comes cuts the material you again rotate the job like that. So it simply cut rotate cut rotate cut rotate like that, this process of rotation is called indexing.

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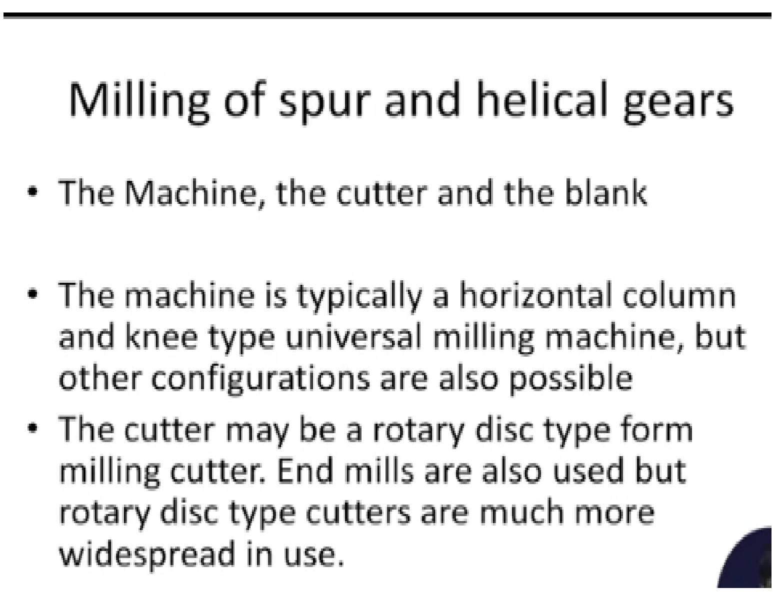

So let us have a quick look at other aspects of the cutter the machine and other attachments. so this sort of cutter is known as route rotary disc type form milling cutter it rotates it is shaped like a disc and it has a form imparted on it which it will be reproducing on the blank in order to form the gear, however N milling cutters are also possible the N milling cutter you know will be cutting this way let me draw a figure to show you.

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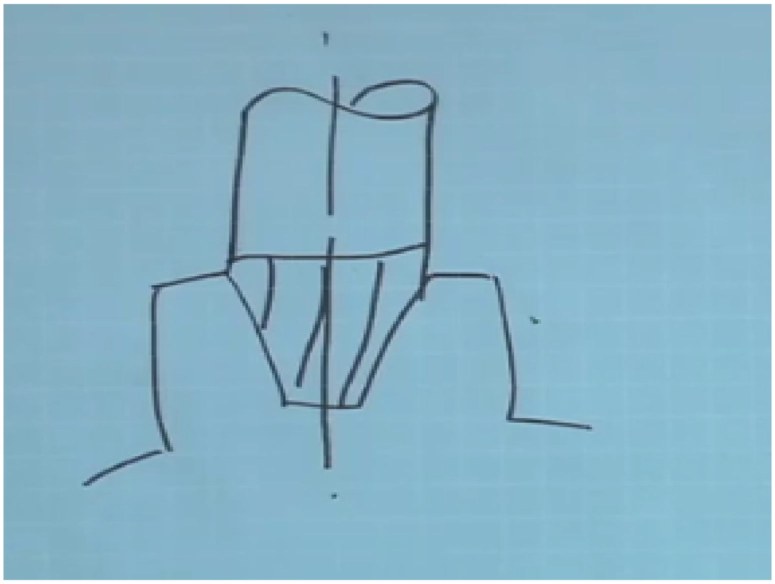

Have a look please this is the N milling cutter okay, it rotates this way and removes material it is not as popular as the other configuration of rotary disc type form milling cutter okay.

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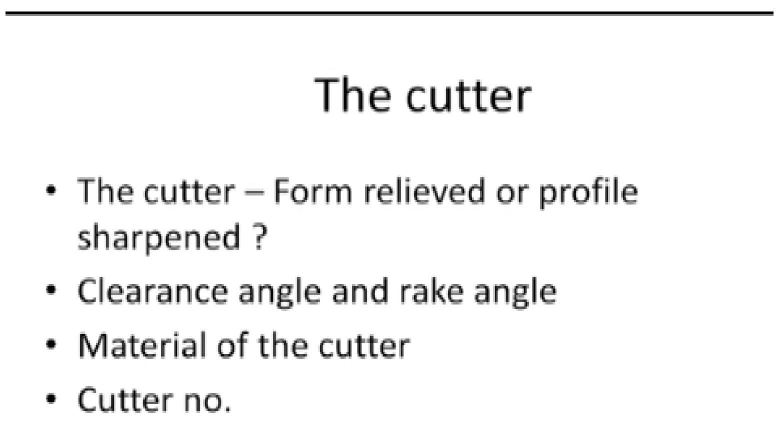

Now so we have discussed almost everything about the cutter it is as we discussed it is a foam milling cutter so it is it falls under the category of form relieved cutters where the sharpening is done on the rake surface never on the clearance surface because the clearing surface is having a definite form it cannot be disturbed and what you call it the material cutter has not been discussed it can be made of high speed steel it can be made of carbides etc. Cutter number we will take up a little later.

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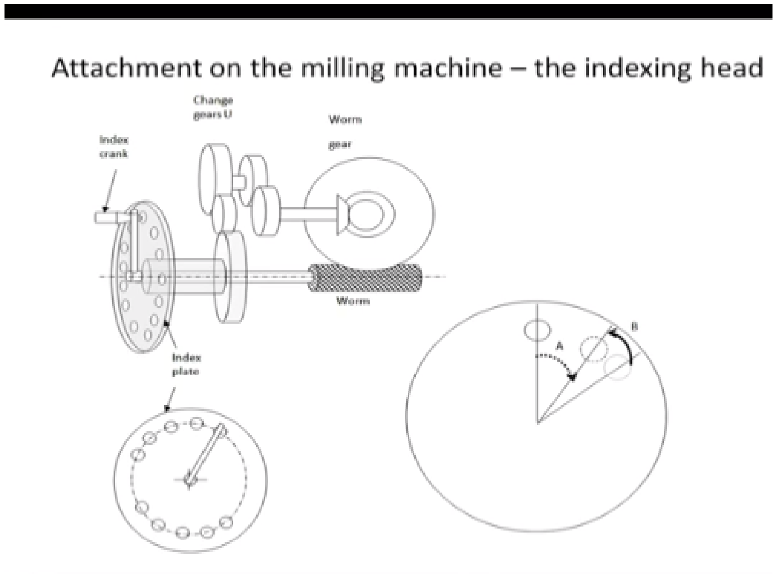

Now about an attachment which is extremely essential for the milling operation to be carried out okay, please look at this particular figure we will come to this figure a little later, first let me try to explain on this you know hand drawn figure why this attachment is required.

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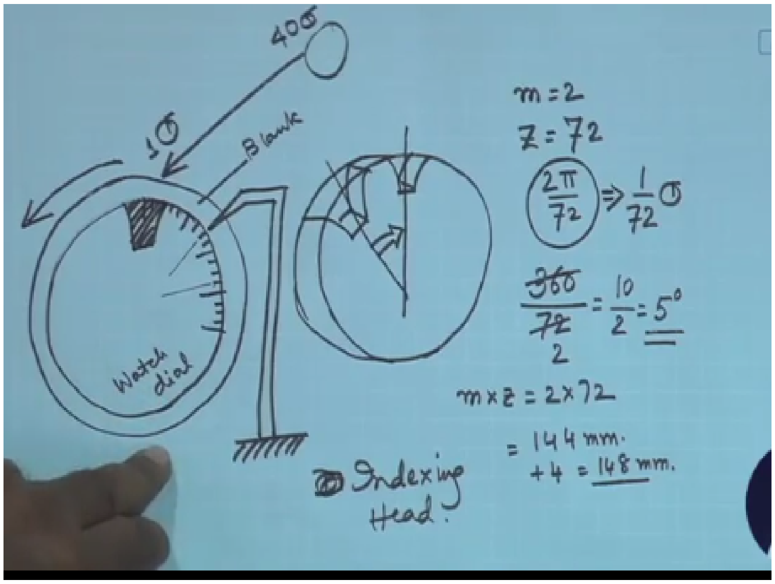

If you look at this particular gear okay if I have to remove this material in order to create teeth in that case after this has been cut I have to give it a rotation of this much and here I have to give a rotation up till this point, how do I give that? So let us do some calculations to find out how much is this rotation is supposed to me, so once again let us take some specifications say module equal to two numbers of teeth equal to say 72 okay.

In that case the rotation should move the gear by an angle 2Π/72 this is the angle to be rotated through, basically it corresponds to one by these many radians equal to it corresponds to 1/70 second of a rotation, so how do I do that? Well the easiest thing would be let us have some sort of a dial maid suppose you go to the you know nearby watch shop watch repair and watch new watch selling and ask them, do you have the dial of a watch, okay available as a piece of paper?

They will say yes but what do you want to do with that well you have your own plans you buy it okay and you paste it on the blank. So this is your blank and this is your watch dial you have pasted it and then you have a marker or a small marking needle and you put it on some fixed object once one tooth has been cut this tooth has been cut that is very good what do you do you have to cut 72 teeth.

So in order to 72 teeth you understand 360 is one rotation divided by 72 mean show much, 36 goes into 72 how many times twice so 36, 72 they cancel out you have 10 above and I have 2 in the denominator so that you have 5 degrees. So for each tooth to be cut a 5 degree rotation is required between two cuts, you cut one tooth then you rotate it by 5 degrees you can be able to cut another tooth this is the basic idea.

Just 5 degrees you might be asking yourself but mind you the diameter of the job is M x Z = 2 x 72 and that makes it 144 millimeters on top of that add 4 millimeters for the outer diameter and it is really 148 millimeters outer diameter quite large, okay about this much this much diameter, so on that five degrees rotation would be a substantial amount of circumferential movement and therefore fighting which is no problem you start from here you will be counting okay.

1degree 2 degree 3 degree 4 degree 5degree if these are you know representing degree so from here to here rotation would be given. So you will say that's it I solved the whole problem of milling just have a bomb or dial like this fixed up loosen the bolts which are holding it in place for cutting move by 5 degrees on that watch dial and clamp it once again and cut there is one problem, life will not always be so smooth it might end up in a you know very difficult head to handle fraction.

And secondly whenever you are moving like this without one here without anything okay it is difficult to control the manual errors that you will always be you know always be making because you will be making eye estimations you will be making parallax error due to eye estimations you might be so might be going for backlash error all these things errors are there this is very difficult to handle these things.

But if you have a mechanism of you know reducing this error you will be in a much better position so what we do is we have a device which can rotate this I can rotate this blank but from a source where a huge amount of rotation will be giving rise to this one rotation of this blank, so I will have more control if you asked me to move by one degree which is difficult or say 0.5 degree which is difficult.

Instead on that initial rotating object okay high rotation rotational handle or crank I will give 20 rotations so that those 20 rotations will correspond to may be half a rotation here, so if you want to move very small divisions small angular distances I will actually convert it from a large angular distance where my percentage errors will be much less, suppose I am always making an error of half a degree everywhere or say not half a degree, half a degree is quite high say one minute one degree equal to 60 minute equal to 16 to 60 seconds.

So suppose I am always making an error of 1 minute if you make an error of 1 minute here it gets directly transmitted to the job but if you have a rotational device which is here and it is having say 40 rotations of this is giving one rotation here one minute error will be reduced by a factor of 40 when you come to the actual job so such a device is called an indexing head which converts a large amount of rotation to a very small amount of rotation by gears. Once again so we will end this lecture by having a quick look at such an indexing head.

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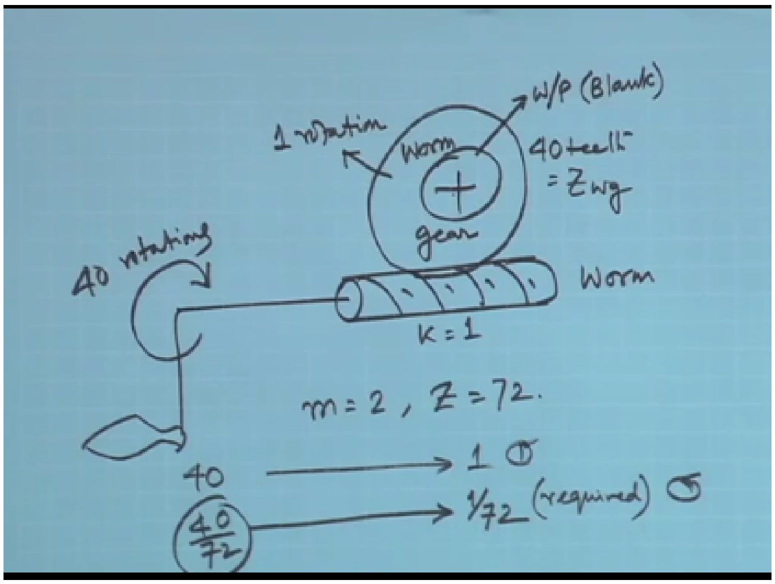

The indexing head basically consists of this is the main working part of it, this is a warm now you are quite conversant with the worm and the worm gear can be here up can be here to the side etc let us draw it up it has a worm gear connected to it worm gear what is worm gear doing, this one has say 40 teeth and this one is say K= 1, so if I give 40 rotations here this is going to give me one rotation only.

So if M = 2 and Z= 72 okay I have 40 rotations giving rise to one rotation, I have 1/70 second of rotation which is required this is required on the work piece and I am hanging above piece here itself work piece means the blank on which you are cutting gears on the same shaft as that of the worm, it rotates with the worm the work piece. So 1/70 seconds of a rotation is required this is a symbol of rotations 1/ 70 seconds of a rotation is required, 1/ 72 here.

In order to cut the next tooth, so this will be obtained by 140,1/ 72 40/72. 40/ 72 rotations you give to the worm and warm here by this particular handle and you immediately have the job rotating by 1/72 rotations, okay. So with this we stop here next step we will take up the details of milling to finish spur gear milling and after that use of differential indexing is called simple indexing, we will take up differential indexing and after that we will take up cutting of helical gears, thank you very much, thank you.