Production Technology: Theory and Practice

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Lecture – 25
Lab-02

Hello and welcome to the course on manufacturing technology theory and practice. Now I would like to describe how a bevel and a spur gear can be fabricated in the lab. I will show you some slides so that you could understand in a better way when you will go to the lab. This will be the introduction to the fabrication of the bevel and the spur gears and then in the laboratory we will show you how these gears are fabricated.

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If you see here this is making a spur or a bevel gear, this section first describes the procedure to make a bevel gear followed by the description of making a spur gear. you can see the 3 dimensional or the pictorial view of bevel gear. This bevel gear has to be fabricated in the milling machine and turning machine together so let us see the steps.

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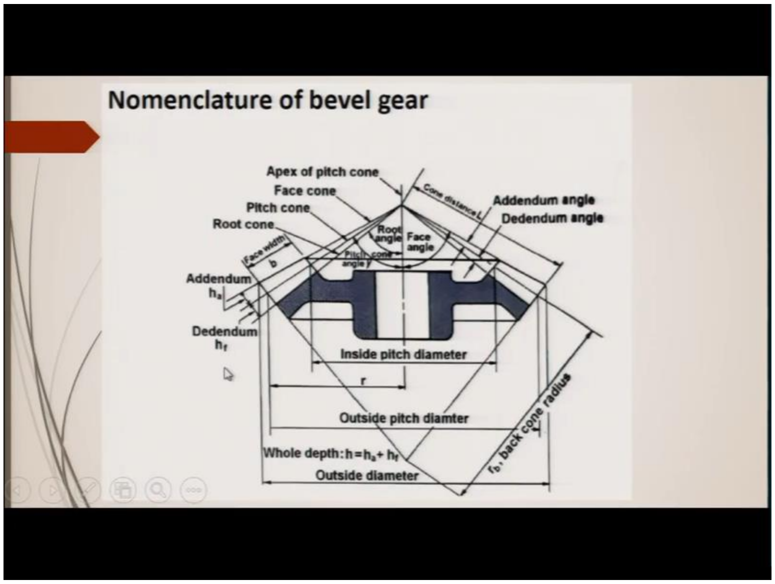

First of all, we have to have the nomenclature of the bevel gear in the drawing. In this drawing this is the 2 dimensional, this is the actual drawing of this. This is hatched, these are the teeth of the bevel gear. This is the center line and with respect to the center line this is the radius. This point is the point along the pitch circle this is called the pitch cone this is the cone.

And here in the spur from here to the radius this is the center line. from one tooth to another tooth this is the pitch circle lines this is called in case of bevel gear this is called the pitch cone and the other 2 lines one is called the face cone and another is called the root cone.

So, this is the root cone, this is the face cone and for this tooth similarly, this is the face cone and this is the root cone. Therefore, from this point to this point this is the outside diameter and the pitch diameter will be from this point to this point and this is the half of it. So, this is the radius, half of this pitch diameter, this outside pitch this is called somehow in case of bevel gear is called outside pitch diameter.

Now from this line, that is the pitch circle of one tooth up to this distance is called the back cone radius. Now here you can see the 2 angles, one angle is the angle between this lines that is for the as I said this face cone and between the pitch circles here. This angle is called addendum angle and between the pitch circle and this line which is the root cone this angle is called dedendum angle.

Addendum and Dedendum principle you might be knowing from your B.Tech first, second year level. Now from this point where these lines, because these are cone, these lines meet from this point to this point to the extreme end point of the bevel gear. This is called the cone distance which is L. Apex cone apex of the cone pitch of the cone is here. And similar to the Addendum and Dedendum angle we have the Addendum and this is called a Dedendum.

The angle is Addendum angle, this angle is Dedendum angle. This height is the call the Addendum, this height is called a Dedendum. Now inside pitch diameter is here and this is the outside pitch diameter from here to here is the outside pitch diameter, from here to here it is the inside pitch diameter. Now there are 2 more angles, one is the face angle between the axis and the line which we call as the face cone.

This line you see and this axis is the face angle and this is the pitch cone angle, this is the route angle pitch cone angle is between the pitch line or the pitch center and the center line. Now the root angle is between the root cone and the axis of the bevel gear this is the root angle here. So, we have the root angle, we have the face angle and the pitch cone angle. Additionally, there is a face width.

These are all the parameters or the nomenclature of a bevel gear that we should be knowing because according to these nomenclatures we will have the parameters calculated or given some of the parameters have to be calculated and some of the parameters will be given.

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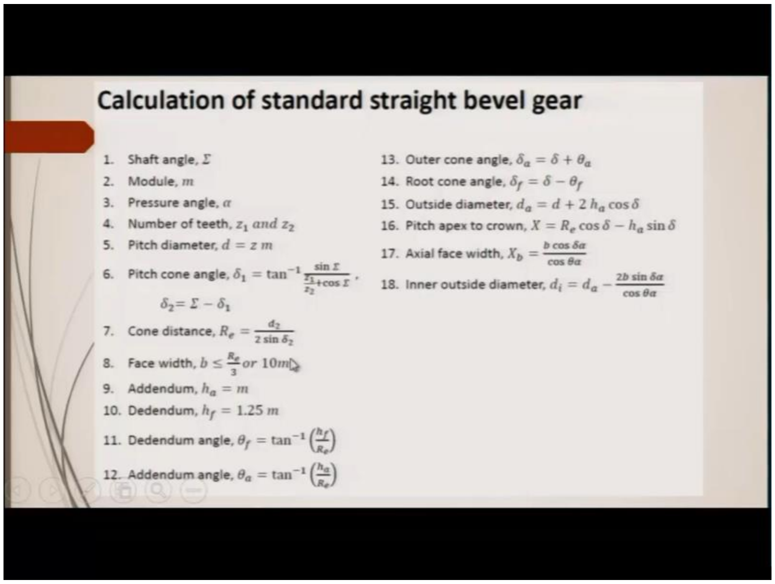

The calculations of a standard straight bevel gear these are the following. Now you can see that this shaft angle. The shaft angle is the angle at which the 2 shafts input and the output shaft 2 shafts are located. In case of bevel gear for example the another shaft which will be in touch with this or in coupled with this gear this shaft has to be at an angle of 90^0 with the axis of this gear.

These are the 2 shafts on this, there is a bevel gear on this shaft there is a bevel gear and those bevel gears are mating for transmitting the power from one shaft to another shaft. The bevel gears are normally used for transmitting the power from one shaft to another shaft which is at a 90^0 angle whereas spur gears that you have seen earlier, are used to transmit the power between the parallel shafts.

And the bevel gear is between the perpendicular shafts. Therefore, the shaft angle will be 90^0 module will be given by us; what is that module that we need depending on that we will give this value m; pressure angle also we will be giving which is α number of teeth it is our choice Z_1 and Z_2 depending on what is the transmission ratio you would like to have, you can have the number of teeth.

Because as I said that the transmission ratio is the number of teeth is in the input gear and output gear. It says Z_1 and the Z_1 pitch diameter we have shown to you this is that and this pitch diameter is equal to $(Z \times m)$ meaning that what is the number of teeth that we have selected multiplied by the module that we have decided. This is a product of these two parameters Z and m that will give you the pitch diameter.

Now the pitch cone angle is given by $\delta_1 = \tan^{-1}\left[\dfrac{\sin\Sigma}{\dfrac{Z_1}{Z_2}+\cos\Sigma}\right]$. This is a formula that can be derived from the geometry of the bevel gear, I am not going to derive it now. This is derived and can be found in any kind of a handbook. This is how we can find out what is the pitch cone angle.

These parameters have to be calculated because according to the pitch cone angle you have to place the shaft otherwise the bevel gear will not be produced correctly. Pitch cone angle for one it is this and for the meeting one it will be shaft angle minus this because this the concept of the pitch cone angle, cone distance is $R_e = \dfrac{d_2}{2\sin\delta_2}$ δ_2 is here for the another gear and d_2 is for the pitch diameter of the output shaft.

d_1 is the input shaft and d_2 is the output shaft. Face width *b* is less than $\left(\dfrac{R_e}{3}\right)$ or it is taken as the 10 times the module. R_e is the cone distance either less than 1 / 3 of this cone distance is the face width or it is the 10 times the module is normally the face width. Why it is 10 times of module? This is taken from the design point of view.

And the manufacturing point of view in the sense that how these gears are working if the module is such then width has to be at least 10 times the module that is what the concept. This is what experimentally or in practice when the bevel gears work this is from the practical experience. We can say in one word, Addendum is module and the Dedendum is 1.25 module.

Now depending on how this bevel gear will be working, in which conditions it will be working how much torque it will transmit, depending on that we actually select the module because if it is a very high kind of a torque that is to be transmitted then the module has to be bigger because the teeth have to be fatter. This is how the Addendum of the module is decided and this is calculated by the module.

And when you are finding out the Dedendum this is the Dedendum here h_f is normally 1.25 times the module or 1.25 times the module that you have selected. Now that Dedendum angle this is given by $\theta_f = \tan^{-1}\left(\frac{h_f}{R_e}\right)$ h_f is that the Dedendum and R_e is given here, which is cone distance. R_e can be found out from the diameter of the pitch diameter of the second gear, output gear.

And the pitch cone angle of the second gear is the shaft angle minus this pitch cone angle. Now the Dedendum angle and Addendum angle you can find out by this way. Dedendum angle is when you are dividing this by the Dedendum and obviously for Addendum angle you are dividing the Addendum by the R_e.

R_e in both cases have to be the same; this R_e is given, I mean calculated already as a cone distance. Outer cone angle is $\delta_a = \delta + \theta_a$ $\delta - \theta_f$ will be this that is the root cone angle. So, these are already in θ_f Addendum angle Dedendum angle these are already calculated, δ is calculated, pitch cone angle so you can find out what is the outer cone angle, what is the root cone angle, and therefore outside diameter you can find out.

Because the δ is known, h_a is known, d is known. d means d_1 and d_2 so these are the 2 diameters. Now pitch apex to crown this is X you can find out from the drawing this is here cone distance and the pitch apex is the apex of the cone, apex is here . This is given by using the simple geometry and width you can find out outside diameter will be this, again, by this formula you can simply find out. Now let us see So, knowing some of the parameters, the remaining parameters can be calculated.

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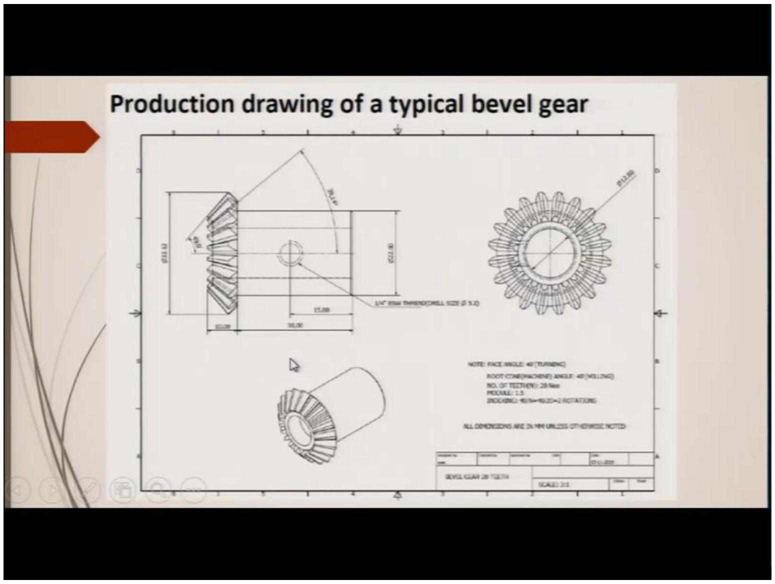

We can now find out how this can be manufactured. This is the production drawing of a typical bevel gear, you can see the production drawing here. The drawing that you are familiar with that all the parameters have to be there; this is the side view and this is the pictorial view of that. Here this is the engineering drawing with all the dimensions, this is the title block. This is the final drawing that has been made with all the parameters.

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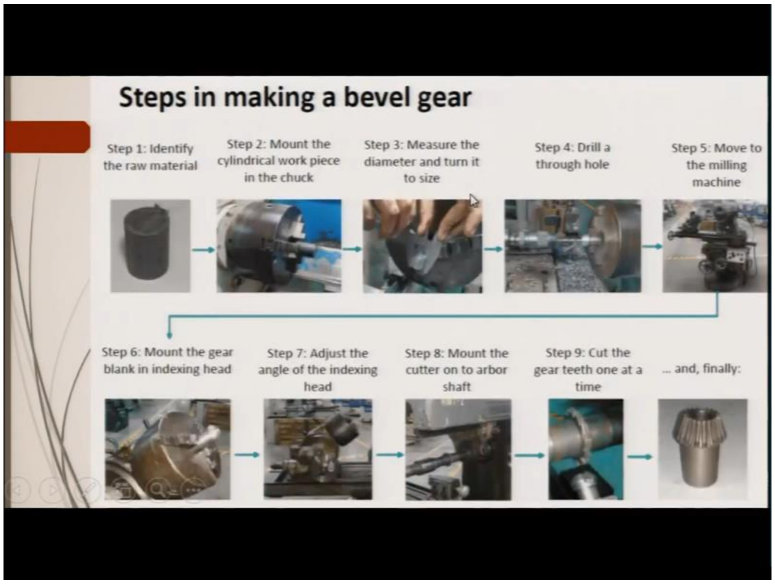

Now how to make that bevel here? First step is to identify the raw material. The raw material out of which you are actually going to make the bevel gear can be a mild steel cylindrical piece, it may be a steel piece or the material that you desire. Now the step 2 is to mount the cylindrical workpiece in the chuck. Since it is a cylindrical workpiece, normally we mount it on the self centered chuck where the center of that workpiece will be co axial with the center of the spindle.

Therefore, it is a 3 jaw chuck you can see that 3 jaw chuck, it is mounted on the 3 jaw chuck and it is self-centering, if you rotate from here, if you move one of the jaws all the other 2 jaws will be moved this we will show you in the lab. You can see this measures the diameter and turn it to the size. Now the size is given to you this is the external diameter, this is the internal diameter, all these sizes all these dimensions will be given to you.

Accordingly, you measure and then turn it to the size so that accordingly the diameter can be turned. Step 4 is to drill a through hole because we have a through hole here as you can see this through hole here inside this one or this is shown by the dotted line. So, drill a through hole, again the drilling hole as you can see that this can also be done in the turning lathe.

For that you have the headstock here where you are mounting the workpiece through a 3 jaw chuck. And in the tailstock on the opposite side of the machine tool you have the tailstock where you can mount the drill that you will see in the lab and that drill will not be rotated like in the drilling machine, that will be rigidly fixed in the tailstock and the tailstock can be moved towards the rotating job which is in the headstock of the machine.

And the through hole can be made then. Step 5 is to move to the milling machine because this completes the operation in the turning. You can see from the drawing that the job will have a section where it will have the conical part. So, this is for cutting the bevel teeth and this also has been made in the turning lathe after this the milling process will start.

Milling process will start on that blank which has already been made in the turning lathe to cut the bevel gears teeth. Mount the gear blank in the indexing head this is the part of the indexing head, this is the 3-jaw chuck and the entire 3-jaw chuck is mounted on the indexing head, you can see this indexing head here, now the indexing head is used for indexing the subsequent teeth that means after cutting one tooth how you are going to rotate the blank, so that the blank could be ready for cutting the next tooth.

In that case we have to know all those calculations, all those angles and number of teeth that you are cutting. You can see the gear the blank is mounted in the indexing head now this is the indexing head adjusts the angle of the indexing head because this will be the same as the angle that has been calculated here, this angle. Without that you cannot cut the bevel gear.

So, you are adjusting the head angle, mount the cutter on the arbor of the shaft. This is the horizontal milling machine that is used for cutting the bevel gear and here is the cutter. How to select the cutter is a standard one. You will see in the lab that there is a rack, on the rack there are different kinds of milling cutters and in each of the milling cutters there is a leveling that particular milling cutter can be used for cutting these many to these many teeth.

Let us say from 30 to 60 teeth or from 60 to 80. There is another gear, for example. I am telling you because you will see that in the rack there are many, many different kinds of gears and each of these gears is identified to make the particular number of teeth and that depends on the profile. So, depending on that number of teeth you have a profile and that profile will be conformed to that particular milling cutter.

And you have to select that particular milling cutter for cutting those many teeth. This milling cutter will have a central hole and at the center also along with the hole it will have a keyhole. Using that keyhole and the center hole this milling cutter is mounted on the arbor of the horizontal milling cutter horizontal milling machine and this attachment he will be shown here in the lab.

And you will be shown how this milling cutter can be mounted on the arbor. This you can see in the closed view that this is the cutter which is mounted on the arbor and this is the workpiece that has been made in the lathe machine and here in this inclined surface which is according to the angle which is set here this angle is according to the calculation that we have done, I have shown it to you. And then one by one, one tooth after another tooth, the gear is cut and finally what you get is this. These steps in details can be seen here.

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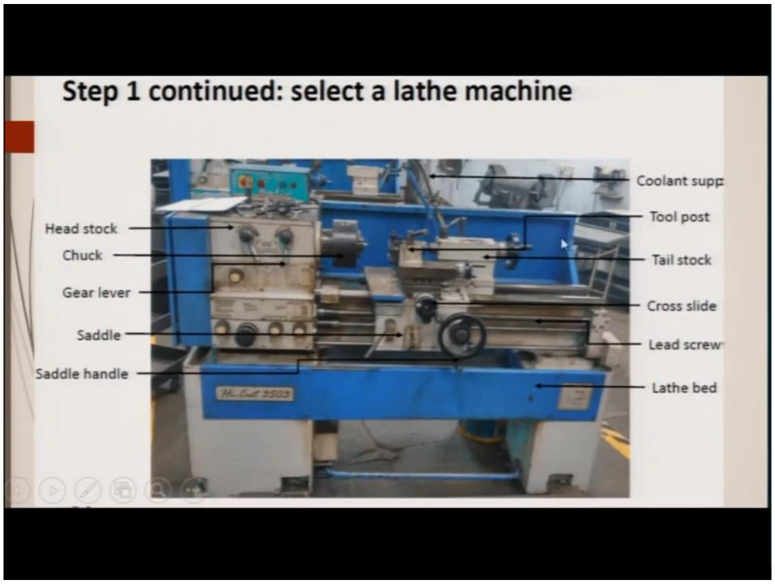

Select a lathe machine, so here are the details of the lathe machine here we have the tool post for example where the tool is there tailstock is here as I showed it to you, here is the headstock inside that we have the gearbox this is the chuck in this case it is 3-jaw chuck, the gear levers are here, here is one, here is another. With this we can change the number of RPM of the rotation of the spindle that means inside this headstock, there is a gear train.

And you will see the gear train, we will open the box for you and then depending on the number of teeth of the input and output gears and intermediate gear you will get different kinds of RPM. Those different RPM can be obtained by moving these gears one or the other one. The saddle is here this is the saddle which will move along with the tool post, along the bed of the machine tool, that is the lathe here so this is the lathe bed.

And this is the lead screw here you can see the lead screw and this is the cross slide cross slide means that if you rotate this handle the slide will be moving perpendicular to the axis of the spindle or axis of the workpiece, tailstock I have already told you that in the tailstock you can have the drill mounted or the centers mounted for supporting the long cylindrical jobs on the center holes, here we have the coolant supply.

Depending on the type of the operation that is being performed you need to have the coolant supplied and coolant will be supplied to the machining zone between the tool and the workpiece because a lot of temperature is produced due to the friction between the chip and the rake face of the tool or the already machined workpiece and the flank face and so on

So, those surfaces of the tool particularly have to be cooled down, why I say for the tool particularly because tool surface have to be protected otherwise the tool geometry will be lost, when you are putting the fluid it will come to the workpiece as well in the machining zone. So, the workpiece also will be cooled down because otherwise the workpiece becomes very hot as well. There could be some kind of thermal deformation of the workpiece; so for all those purposes, the certain type of coolant is supplied, so that the tool as well as the workpiece remain cool.

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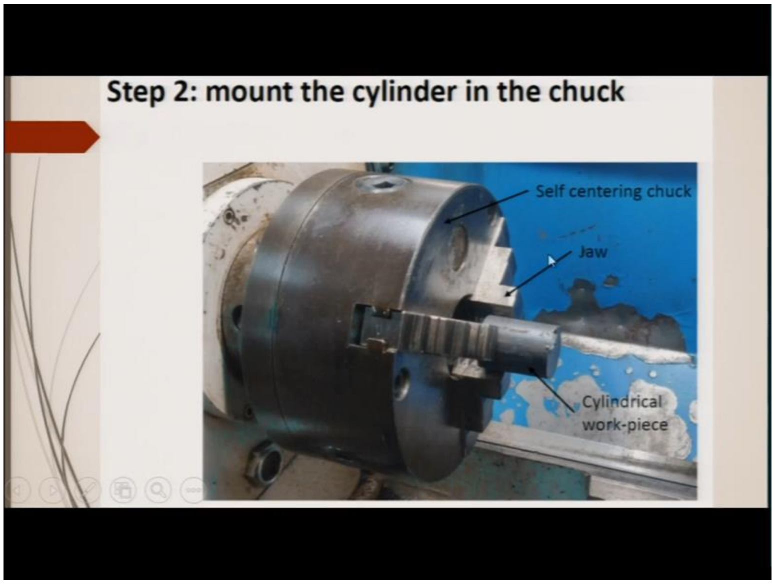

Now after that a cylindrical job will be mounted on the 3-jaw chuck here. The 3-jaw chuck is in the closed view, we can see that this is the workpiece, the value will be added to the workpiece meaning that you will have the proper surface made then the conical head has to be made so that the gear can be cut because right now it is the turning lathe, it is the lathe machine on which the work is going on.

But ultimately, we have to cut the bevel gear and bevel gear will be cut on the milling machine. Here we will see that this is a self-centering chuck as I said that is the 3-jaw chuck, these are the jaws this is one jaw, second one and this is the third one and this is the cylindrical workpiece which is mounted here. So, all the 3 jaws will be simultaneously moved coaxially and the part will be mounted on this, so that the axis of this cylindrical workpiece will be co axial

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With the axis of the spindle of the machine this is important because otherwise if you are machining without having the 2 axis coaxial then the machining will not be appropriate it will be either tapered or out of roundness.

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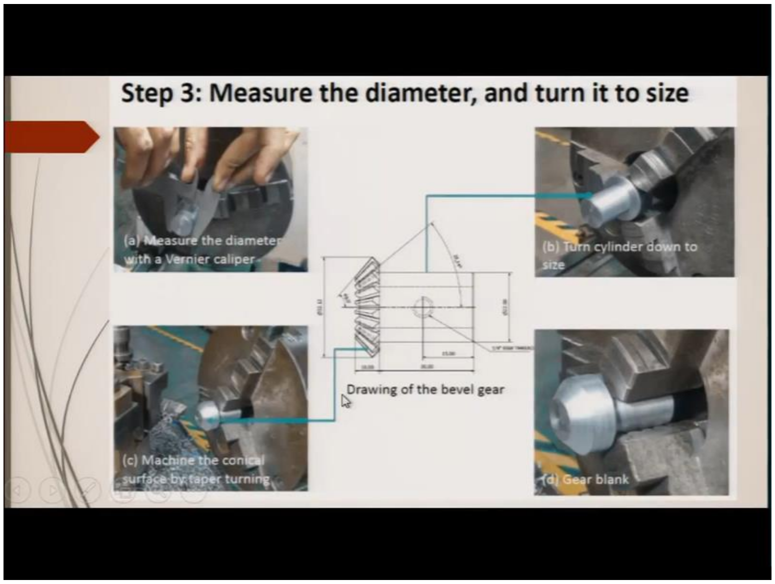

After measuring the diameter, turn it to the size, measure it with the vernier caliper because it will give you the more precision for of the measurement. Here the processes that are being performed here are given here; turn the cylinder down to the size. This outer diameter of the body of the shank is being turned here as you can see that and this is held in the head that has already been machined, this head will be cylindrical head.

Now the tapere turning will be done here. Therefore, it is cylindrical part as such and this is held here in the 3-jack chuck and this other part will be turned, that means the length of the part will be turned, third step is machine the conical surface by taper turning. So, this surface where the teeth will be cut has to be produced; this is the surface, and the whole gear blank is made here as you can see that this is the tapered turning, this is the cylindrical surface, this is the cylindrical surface.

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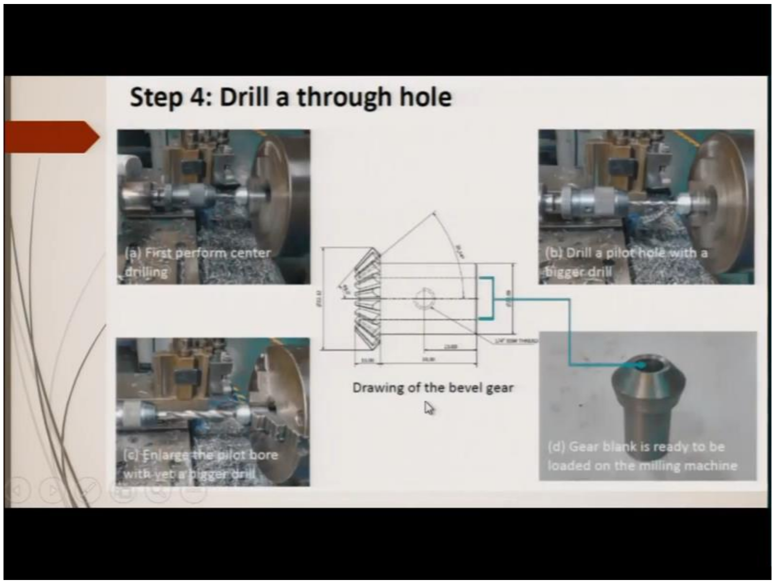

Now the next step is to perform the center drilling first; center drilling is required to make the centers on both sides so that the drill can be penetrated properly. So, before drilling the hole, the center drills have to be used to make the center drills perform the center drilling then drill a pilot hole with a bigger drill. Some diameter of the pilot drill has to be selected so that initial hole can be drilled then you take a larger diameter of the drill.

And enlarge the pilot hole, so pilot bore or the pilot hole has been made with the diameter of the drill less than which is required for the internal hole, I mean to say this hole of this diameter. Here we will take a diameter of the same size, so that the final hole can be made. Here the diameter is less than the diameter here then the final diameter is selected, final diameter of the drill is selected and the hole is drilled; gear blank is ready to be loaded in the milling machine.

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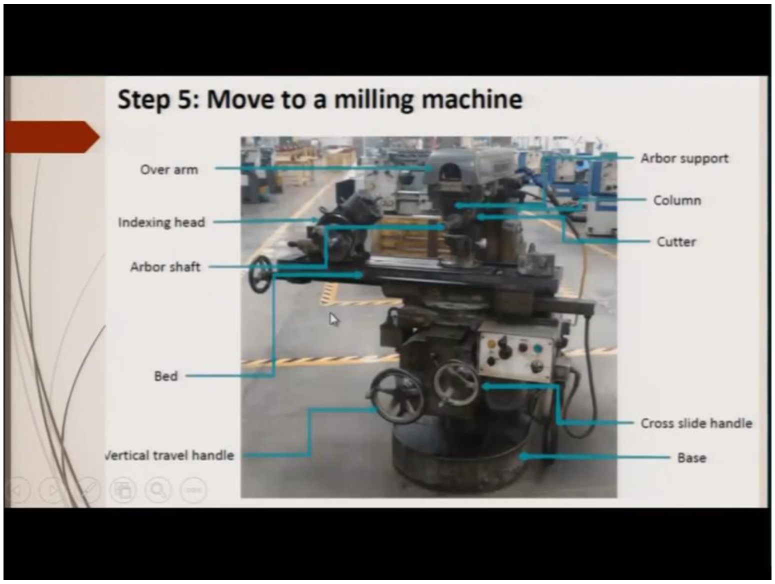

Now we will go to the milling machine; here is the milling machine where that part will be loaded and then the gear will be cut. This is called the over arm here, on this the spindle is located, is hanging here as it is and this is the arbor on which the milling cutter will be mounted; this is the arbor support if you can see here, this is supporting the arbor and this is the entire column s shown here; this is the column this is the cutter.

Indexing head, as I showed it to you, and on the indexing head you have the 3-jaw chuck on which the part will be mounted this is the arbor as I said this arbor shaft, this is the milling machine bed this is the bed and here we have the cross slide handle that means if you rotate this the and the cross slide will be moving. It will be moved along this side.

And on this slide way the slide will be moving perpendicular in this axial distance and this is the base on which the entire milling machine is located; vertical travel is here. With this you can have the movement in this direction. And with this rotation of this handle, the table will be moving in the direction perpendicular to the vertical direction.

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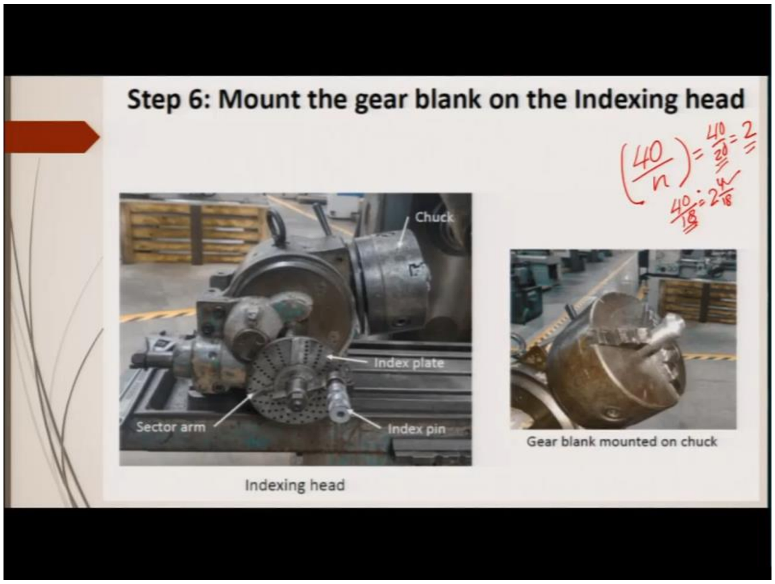

Now the gear blank is mounted on the indexing head; this is the indexing head as I said and this is the 3-jaw chuck; now the indexing head and the gear blank are mounted on the chuck. You know why indexing head is required, as I said that this is required to rotate the blank from the position of one tooth to the another one. Now, this is very simple how it actually can be done.

And the formula is 40 divided by n this is the formula, why it is so, because inside this indexing head we have a worm and worm wheel. And I told you that worm and worm wheel has a transmission ratio of 1 is to 40. So, that is what we have used and *n* is the number of teeth that we have to cut. Here we have the worm and worm wheel, worm wheel rotating, so the worm wheel will rotate the spindle along with the workpiece, suppose we have 20 teeth.

So, it will be 40 / 20 which is 2 that is 2 rounds; if we rotate the index head two complete rounds then it will give you the actual pitch for cutting the 20 teeth; suppose you had to cut 18 teeth. So, it will be 40 / 18. Now, you can see that this is 2 complete rotations and then 4 rotations out of 18 holes, that is how we actually make it, for cutting 18 teeth formula is for 40 / n so 40 / 18 which is 2 complete rotations, i.e. 36.

40 / 18 meaning that if we have an indexing plate where the peripheral number of the holes are 18 so after moving 2 complete rotation you move 4 of the smaller holes 1, 2, 3, 4 where it will be 18 holes total in the periphery. That is how the calculation is made; it is simple and you quickly

make a calculation that is (*40 / n*) how many times the indexing plate has to be rotated and how many fractions of rotation has to be given after that. So that will be the indexing for the teeth from for moving from one position to another position of the teeth. This is the gear blank mounted on the chuck.

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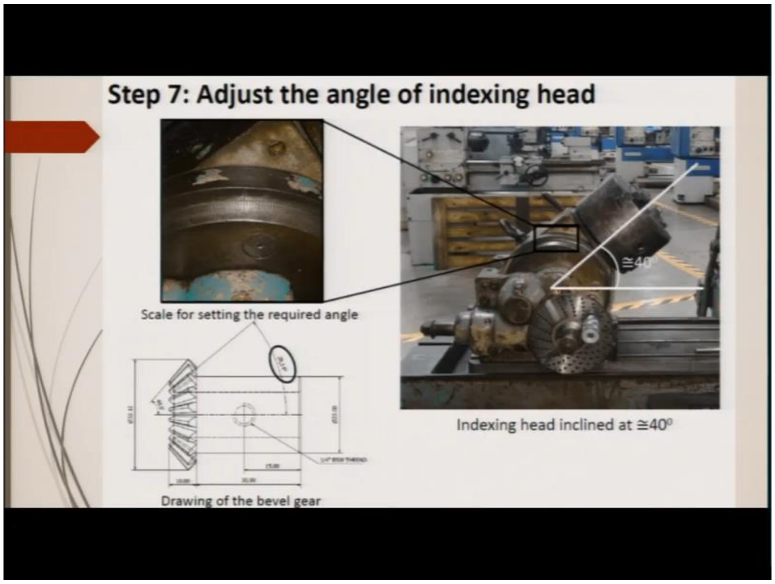

Here adjust the angle of the indexing head as we said that this angle has to be adjusted with respect to the horizontal and you can see a graduated plate here that will tell you what is that angle and that angle we have already calculated according to this angle the indexing head angle indexing head has to be adjusted with respect to the horizontal. Let us say it is about 40^0 we have calculated I think it was 39 point something, so about 40^0.

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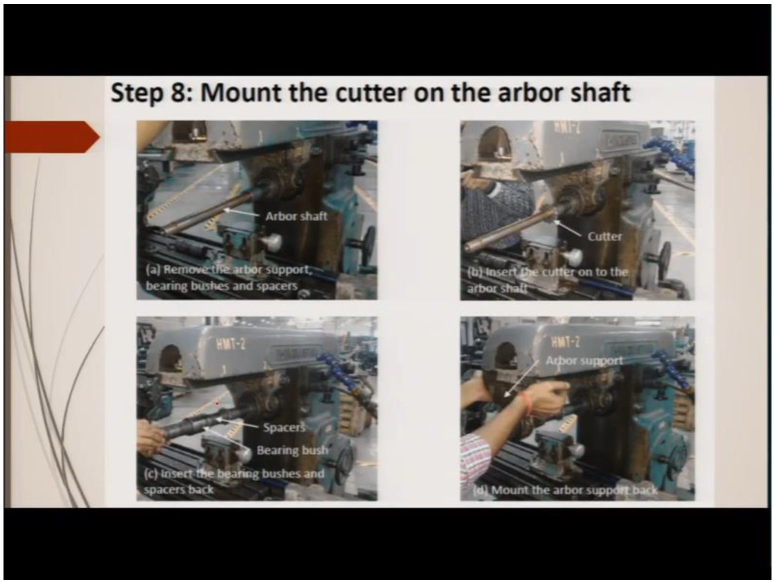

And then the next steps are: this is the arbor shaft, so from the arbor shaft you have to remove the support and you have to remove all the spacers and the cutter can be mounted. Now the cutter goes in here and the cutter as I said is mounted on the arbor with the help of the key and the keyhole so the key hole is there in the cutter and the key hole similarly there in the arbor also.

Then insert the cutter on the arbor shaft with the help of the key and the keyhole then put the spacers because the spacers are required to hold the milling cutter on the arbor properly. These are the spacers and here we have the bearing bush. Now bearing bushes and spacers have to be taken back on the arbor and then the arbor support has to be placed on this bearing bush this is mounting the arbors support back.

Therefore, now on this arbor the milling cutter is mounted because the milling cutter may have to be changed depending on the requirement of the diameter or the number of teeth in the cutter. So, we have to change the cutter frequently therefore normally after milling operation the cutter is removed.

To remove the cutter you have to remove the spacers, remove the support and then you are putting another cutter and those spacers and supports have to be mounted back.

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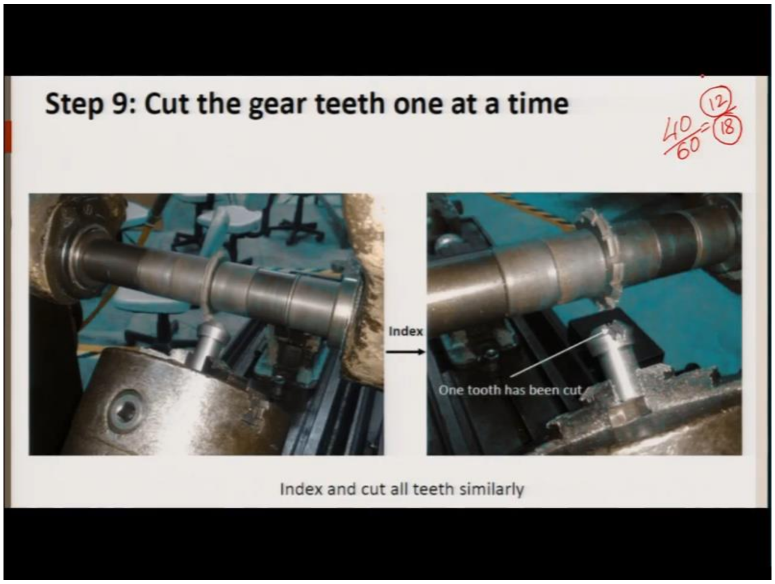

Then index and cut all teeth similarly, one tooth after another. Now you can see that one complete tooth has been cut here after that you stop that rotation, adjust the indexing head according to the angle, according to the number of movements that I have shown you a while ago and that you will completely understand when you go to the laboratory and see how it can be rotated and how much it can be rotated when we will show you there.

All the other teeth you cut similarly after indexing using the indexing head. So, once again, you have to rotate that indexing head complete circle depending on the number of teeth that you are cutting. Suppose, you are cutting more than 40 teeth. The same formula can be used; 40 by let us say 60. So that will be 4 / 6, which means 12 / 18. So that means when there are 18 holes on the periphery, out of that only 12 holes you rotate not complete rotation but up to 12 holes. So that is how you can cut any number of teeth that is required

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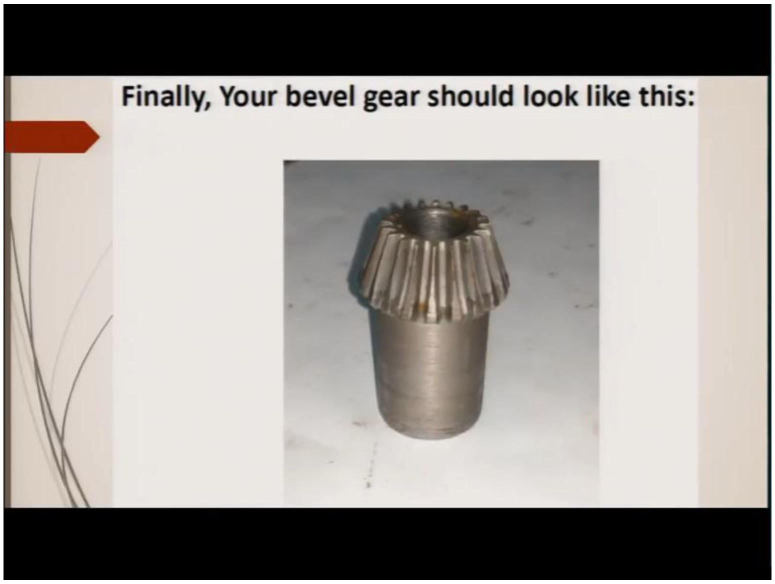

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Here you see the bevel gear that you have actually cut it. Now while doing so, you must have used these kinds of tools, that is, this the cylindrical blank, this is the drill with a 12.5 millimeter diameter, this is the drill with eight millimeter dia. If you remember that we had a pilot hole and then we have a final hole. These are the pilot drills that are used for making the final drilling, center drill for for marking and this is required for the actual drill, the pilot drill and the actual drill to make the final hole.

All the time you need a vernier scale to measure the diameter. This is the gear cutter that has been used. This is the single-point cutting tool that has been used for making the turning and the conical shape of the blank in the turning lathe. Spanners required to tighten or loosen the screw and this is the drill chuck in which these drills are mounted; you can see these drills are of lesser diameter of up to 12.5 millimeter.

These drills are supposedly not required so much of torque for drilling the hole. Therefore, the torque carrying capacity as I told you earlier of these kind of drilld with the lesser diameter is less and therefore, the shank is made as cylinder. For cylindrical shank, here is a collet type drill chuck.

I will give you an example of a collet chuck that you are familiar with. You have seen or used the mechanical pencil. It has a collet chuck; so, this is equivalent or similar to the collet chuck where you can actually mount the drill with the cylindrical shank and then the collet chuck has to have the a taper surface same as the shank, so that the taper shank can go into the drill holder or the drill chuck. These are the steps of bevel gear fabrication. In case of fabrication of spur gears, many of the steps are the same as we have discussed earlier, so those I am not going to repeat again.

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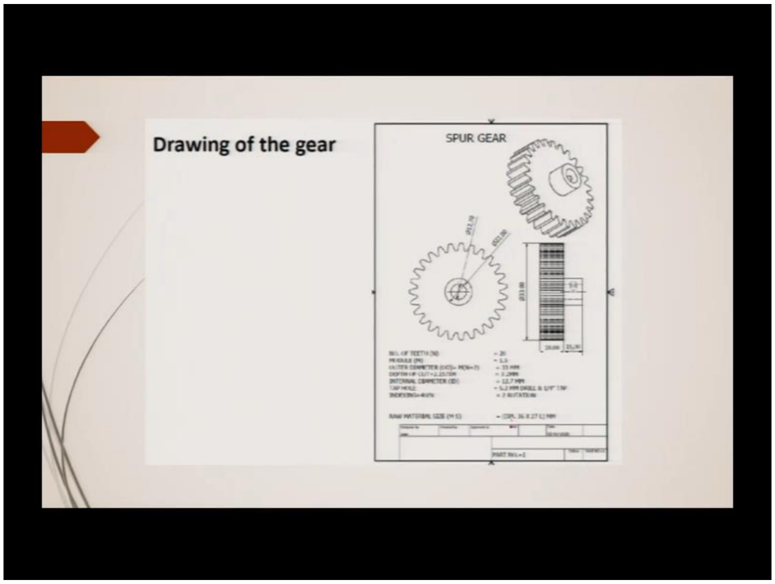

Now for the spur gear here is the picture pictorial view. This is the drawing like we have made the drawing of bevel gear. Here the complete engineering drawing of the spur gear has to be made with all the dimensions and these are the parameters, in the parameter you have to write the number of teeth in the drawing itself, this is the module that we have given, cutter diameter, depth of cut, internal diameter, tap hole and the indexing, i.e. how many rotations you have to make.

So that indexing will be made depending on the number of teeth. Here probably the 20 number of teeth has been selected. So 2 rotations are made for the indexing raw material you have to write what is the raw material here it is written mild steel, diameter of this is the blank diameter. So, before you cut this, you need to have the blank and the blank diameter is given here in the drawing.

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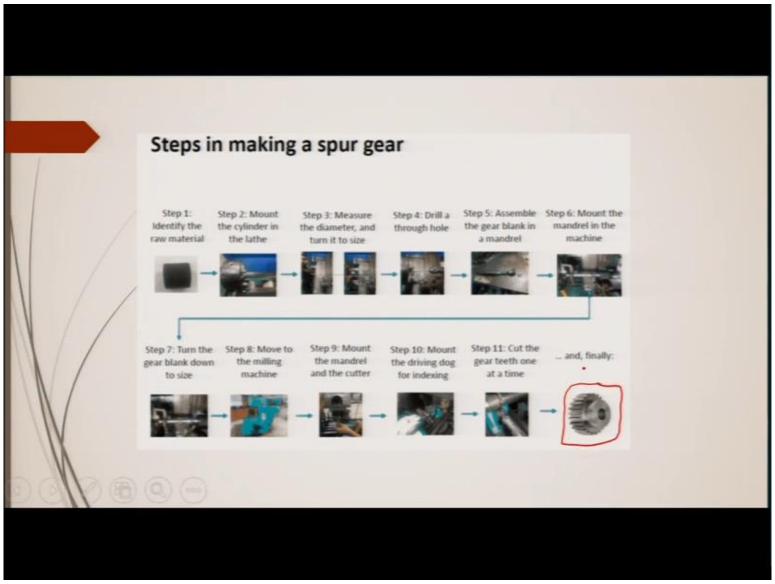

The steps are the following. Identify the raw material like we have shown the steps in the bevel gear; here mount the cylinder in the lathe, measure the diameter and turn it to size. A through hole along the centreline, like in the bevel gear, is to assemble the gear blank in a mandrel; mount the mandrel and turn the gear blank down to size; move to the milling machine mount the mandrel and the cutter. These are the same steps as in case of bevel gear fabrication.

I will show you in details one by one. Mount the workpiece for the indexing, this is something new for making the cylindrical part; cut the gear teeth one at a time, the procedure is almost the same as in case of the bevel gear except that here it is the straight teeth that we are talking about and what you get is finally the spur gear ready for the use.

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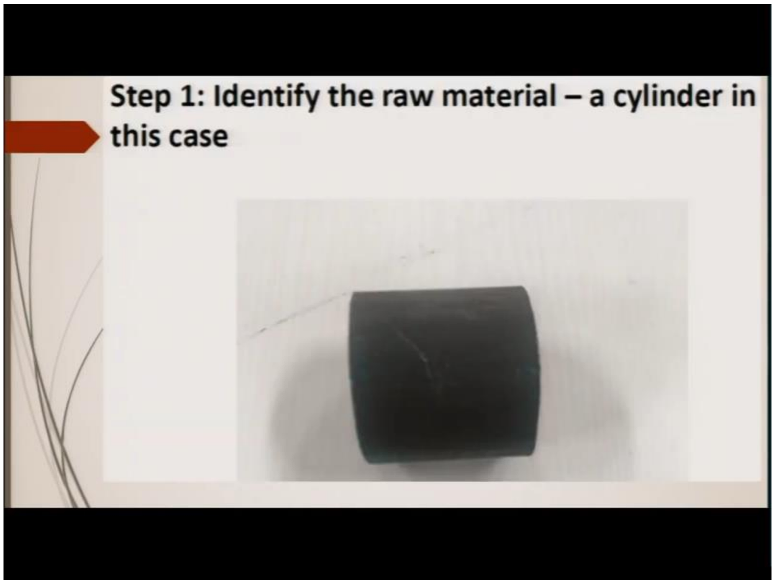

These are the steps the raw material has been identified this is a cylindrical job, in this case a cylinder.

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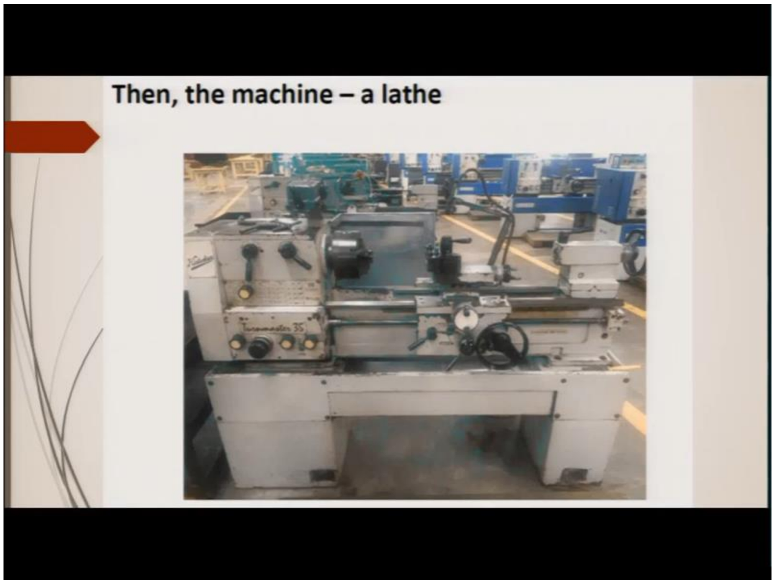

Then the machine this is the lathe machine on which the job will be mounted. I am not going into details because I have already described how this can be mounted on the lathe and what are the descriptions of the lathe, the same lathe can be used for making that because what we are doing initially is that we are turning, turning the outer surface facing so that the blank can be made for cutting the gear.

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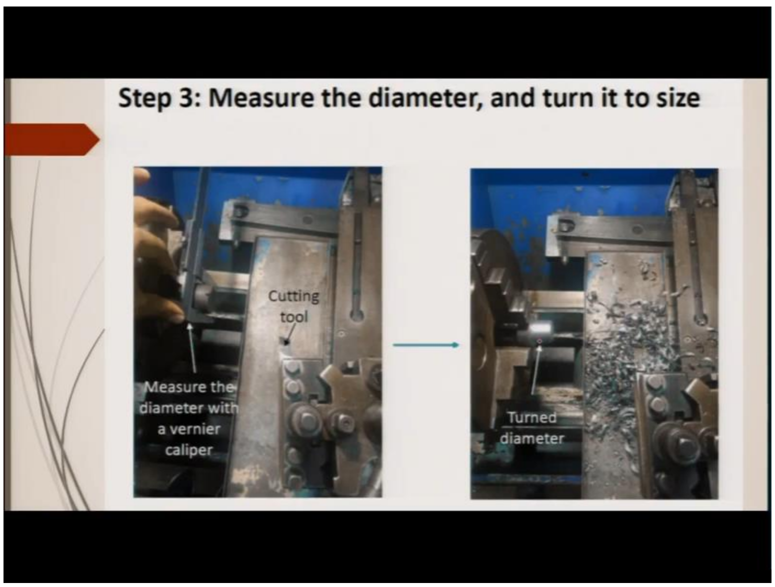

You can see here this is mounted on the 3-jaw chuck, this is the cylinder, this is blank. Here this is the cutting tool that you can see, this cutting tool is on the tool post with the tool holder, measure the diameter with the vernier caliper and then turn it according to the diameter which is required. While doing so, you have to finally measure with the help of the vernier again to check whether the proper turning has been done.

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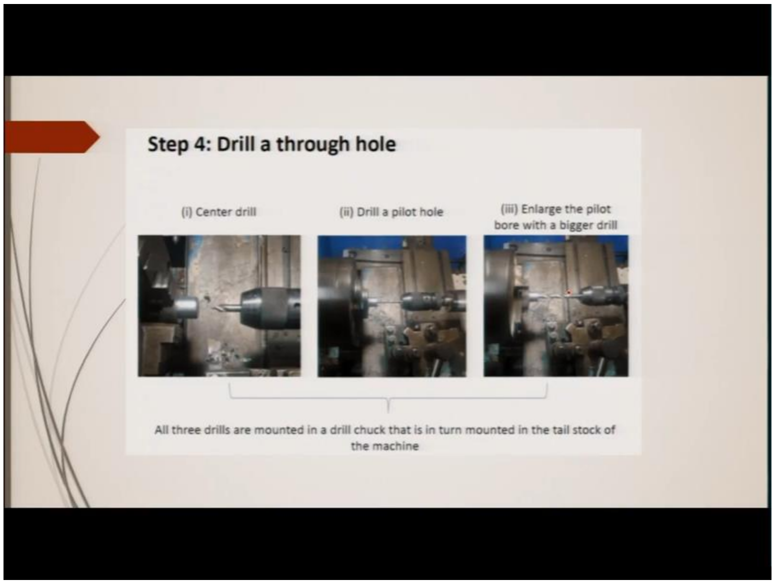

Drill a through hole; so first you have to have a center drill to mark the center then you are using the pilot hole, then you are using the bigger drill for enlarging the pilot bore. This procedure as a matter of fact, is the exactly same as the procedure I have already discussed in the case of the bevel gear cutting.

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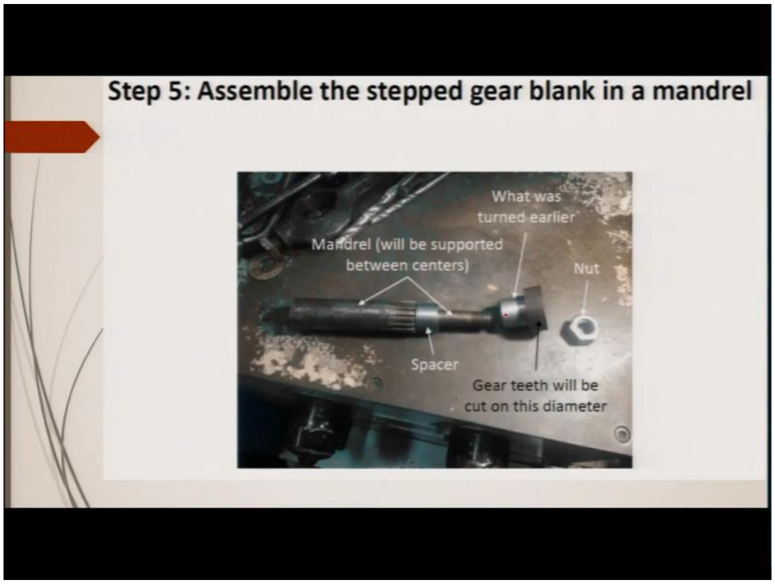

Assemble the stepped gear blank in a mandrel: this is how the gear blank can be mounted with the spacer in the mandrel that will be supported between the centers. The gear blank is very small in the length. So that length cannot be supported fully on the centers between the centers not convenient. Therefore, it is mounted on the mandrel and the entire mandrel will be then mounted on the centers between the headstock and tailstock.

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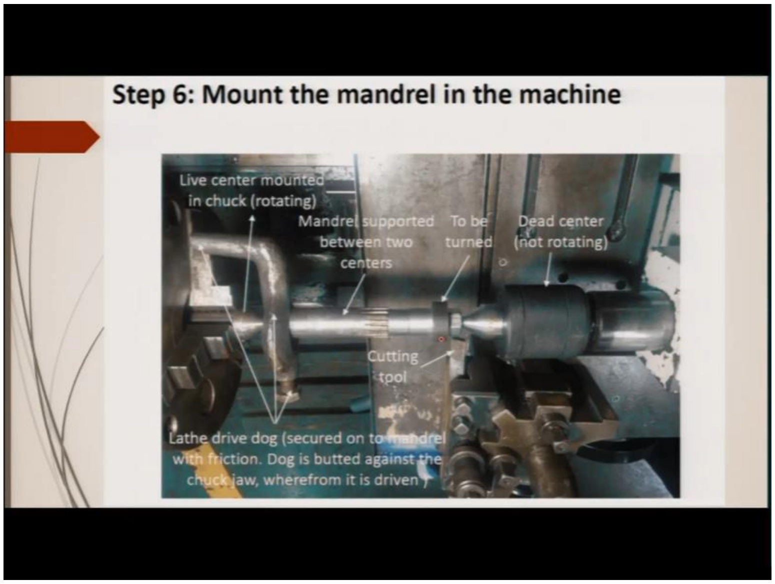

Here you can see that this is the mandrel, this is the gear blank to be turned and here is the dead center which does rotate on the tailstock and here this mandrel is held in the 3-jaw chuck. But now it can be mounted on the centers and in that case this is the lathe drive dog to transmit the rotation to the mandrel and the blank. Mandrel is mounted on the centers.

Then with the help of the lathe drive dog which is secured in one of the jaws of the 3-jaw chuck, as the spindle rotates this will transmit the rotation to the mandrel and subsequently to the workpiece which has to be turned. This is a cutting tool which will turn this job.

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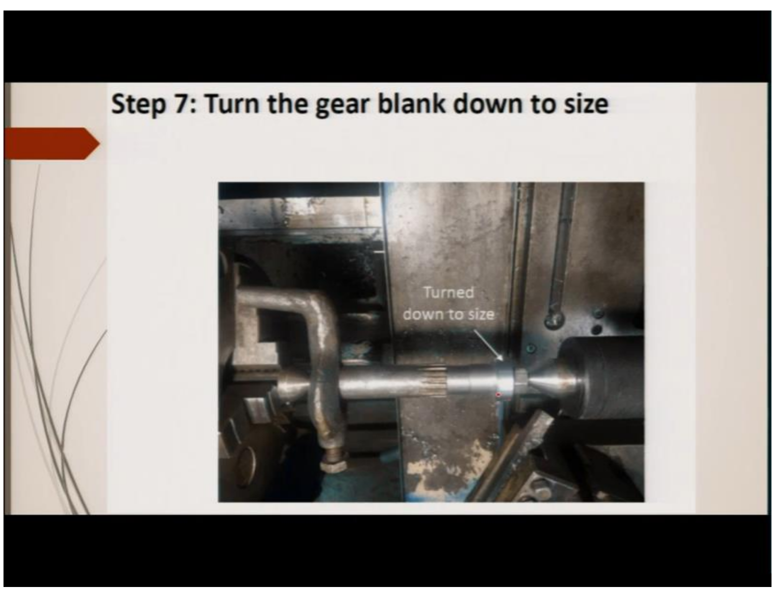

This is now turned to size that means this is according to the diameter that is given and this face is according to the length that is given in the drawing.

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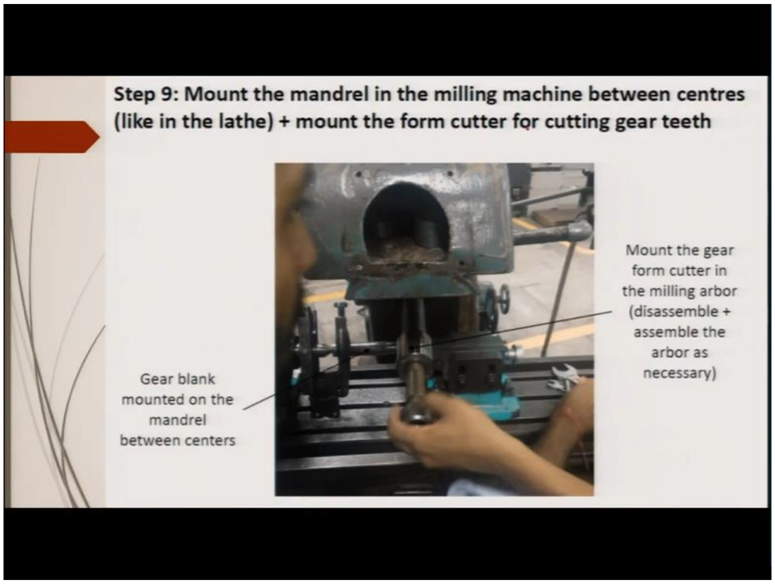

Now you move to the milling machine where the gear will be cut, teeth will be cut. You can see that the process will be more or less the same, i.e. mount the mandrel in the milling machine between centers, mount the form cutter of cutting gear teeth. Here the milling cutter that will be used is a form cutter.

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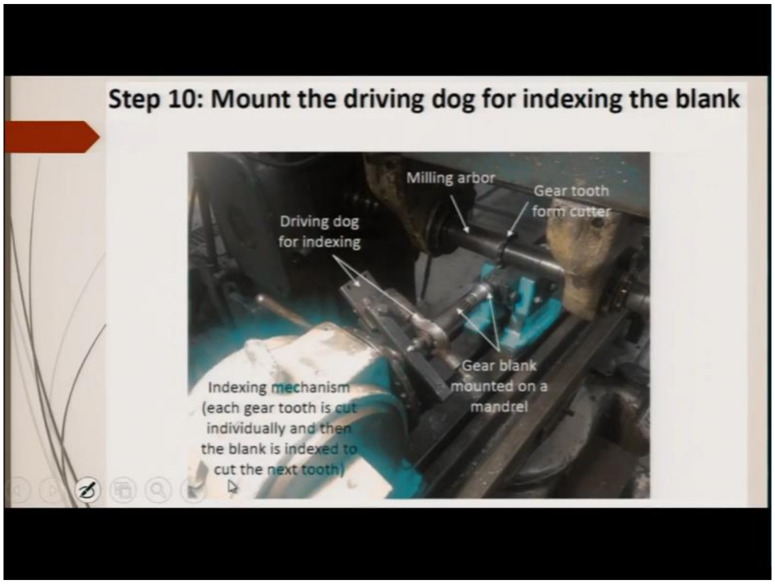

Driving dog for indexing the blank: this is the gear blank and this is the milling cutter mounted on the arbor like we have shown you in the case of the bevel gear cutting. Each gear tooth is cut individually and then the blank is indexed to cut the next tooth this I have already explained that here in the drawing it was given that there should be 2 complete rotations of the indexing head or the plate. That means we must be using 20 number of teeth; if we have to cut 20 number of teeth then 40 / 20 is 2 which is that 2 complete rotations of the indexing plate.

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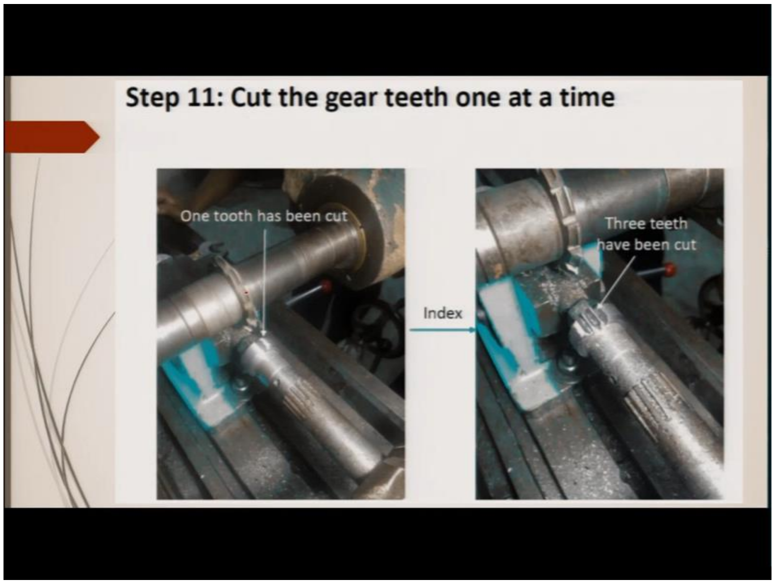

This is how one tooth has been cut, this is the milling cutter. For milling cutter as I said this is the workpiece and here you can see the tooth is cut. Similarly, the other teeth can be cut using the same for milling cutter but in this case, it has to be turned to that angle or to that many turns of the indexing plate as have been calculated.

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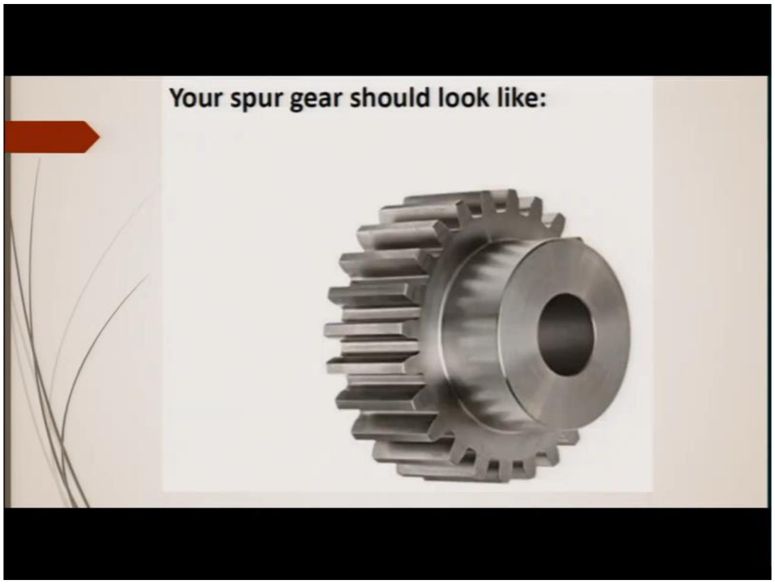

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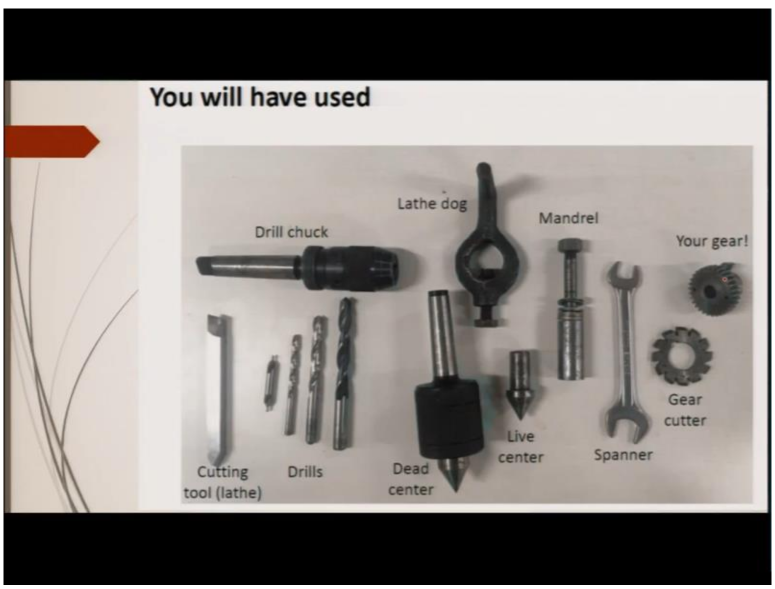

And then this spur gear is ready. These are the tools that you must have used. The drill chuck for making the center drill, the pilot hole and the subsequent enlarging of the pilot hole, cutting tool, lathe dog is something new because when the workpiece is mounted on the centers between the 2 heads, headstock and the tailstock then we have to have the this kind of mechanism which is the lathe dog to transmit the rotation from the spindle to the mandrel or to the workpiece.

This is the mandrel in this case this is the dead center which does not rotate which is mounted at the tailstock. This is the live center which is like the dead center but it is mounted normally in the headstock and this rotates, that is the difference between live center and the dead center, spanner used, gear cutter which is used for the cutting the gear and finally the gear which has been machined here.

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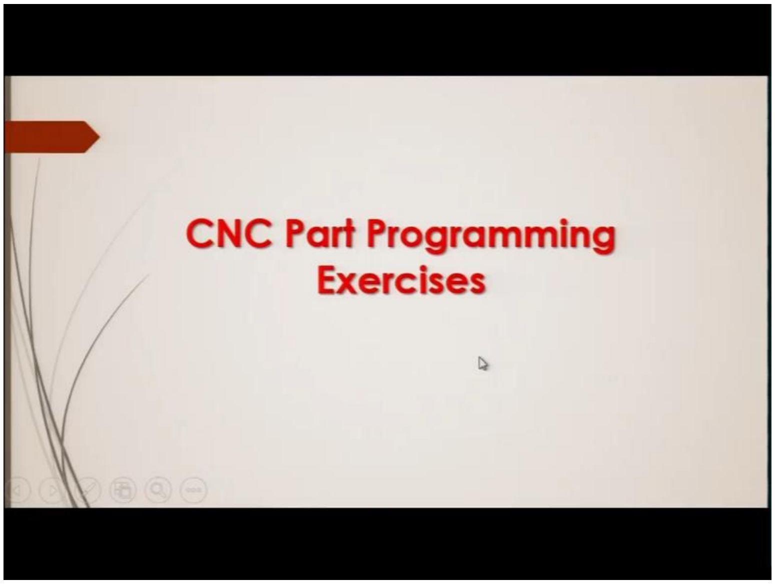

These are the steps for making the spur gear. I have shown you some slides on the tools which are used on the measuring tools that are used in the lab and as I said that you will see them. Now after that I have told you in details about the technological process of manufacturing and fabricating spur gear as well as a bevel gear. I also told you that in the lab you will see the conventional machines as well as the CNC and the NC machines.

On which we actually give the hands-on training to our undergraduate students irrespective of their disciplines. All the students go through such kind of a training and in the CNC and the NC machines we particularly tell them how to make a part program. So that they could be equipped with making a program for any kind of part that they encounter in the practice. Similarly, I also would like to expose you to all this through our discussions.

You will be exposed to the part programming in the CNC and the NC machines which you will find rather easy. Related to part programming, I will show you some steps for making a part on the CNC lathe as well as on the CNC milling machine. These things you will be shown and demonstrated in the laboratory on the machines as well. Now for making a part fabricating a part on the CNC machine first of all we have to make a program manually.

And then that program has to be tested, in the sense that there are simulators, you will be shown those simulators as well in the lab. Nevertheless, I am going to tell you to some details about those simulators and how the simulation is done. So that we could be sure that there is no fault in the program that we have written, we have made for that particular part. I will show you how those simulators work.

And then after we get confirmed that there is no error or fault in the part programming, we put that program on the machine as an input and then run the machine to fabricate the part. I will show you in 2 examples, one in the CNC lathe and another on the CNC milling machine. There is one alternative to that now and the software is used to make a part program.

There are quite a few different software which can be used to generate the NC programming automatically. Now for that purpose you have to make that software then the software itself will take care of getting the coordinates and making the 3-D picture along with the tool that we will select and then it will simulate how to make the part.

From that simulation the software then picks up the program which is to be made for fabricating that particular part on the machine. Therefore, this is an automatic generation of the part programming that I am going to demonstrate here now through a power point presentation and then we will show it to you in the laboratory. Well then if you look at the power point presentation this are the CNC part programming exercises.

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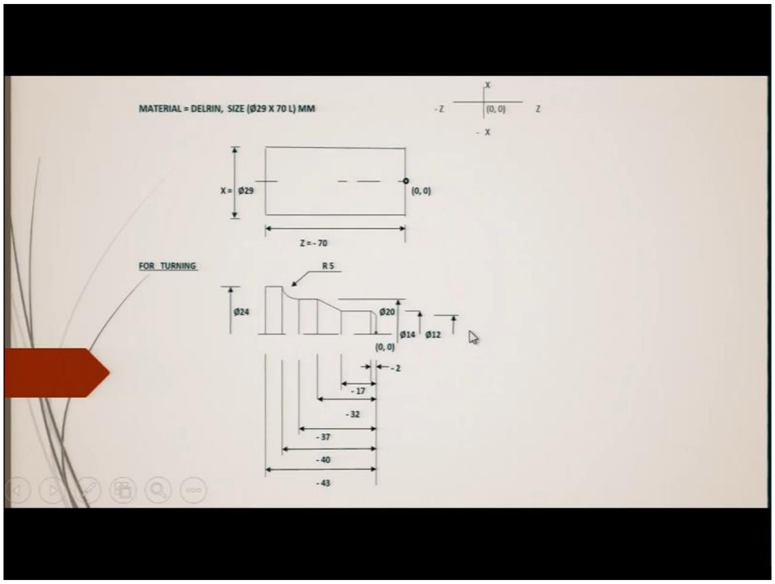

Let us take first the example of a turning. Here we have the part that we have to generate, this is the part drawing. In this part drawing you can see that this is a part which will have the flat surface, a semi circular profile, a tapered surface and here there is a chamfer.

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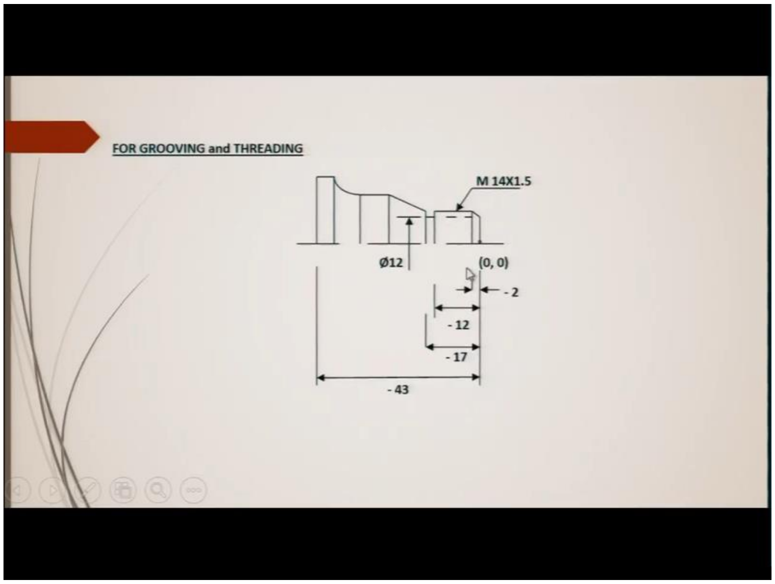

Along with that, it will also have a groove here and a thread. Now all the dimensions are given here, for example the total diameter of the part should be 24 mm. Now this radius should be 5 mm here, there is a thread which is metric thread of 14 mm and 1.5 mm is the pitch. So, this is how it is written in the drawing M 14 into 1.5 this is the chamfer where you have the 2 mm of this distance, this distance is 2 millimeter normally the chamfer angle is about 45^0.

This is to be mentioned. This diameter is 20 mm. Here only the half of the part is shown assuming that this is a symmetric part, so other half will be symmetrical to this or the mirror image of this portion. Now these are the linear dimensions which are given. The total length of the part is 43 mm from here; from here it is 37 mm.

Now you can see that in all these dimensions there is a negative sign here. Going ahead I should tell you that in case of turning CNC turning this is the system of axis x axis is here and z axis is here, out of that on the top it is the plus for the x and below the origin it is the minus this a negative and along this length that is the feed direction along this is a z axis and all the dimensions will have a negative sign if the dimensions are lying to the left of this.

And all of them will be having the plus sign when they are lying at the right side of this. Now this is the origin so now you will understand that if we say if we assume or if we make this point here, this point as the machine origin which is 0, 0 so all the dimensions which will be lying to the left side of this will have a negative sign according to this system of axes. Therefore, these are the dimensions which are made as the negative but theirabsolute value is 43 mm which is the total length, 40 millimeter from here to here.

Similarly, the diameters as you can see that on the top it is x that is a positive and below that it is negative; now for fabricating this part along with the groove and the thread, these are also part of the final product that is we have to have the final product with a groove like this of 12 mm diameter here and a metric thread head of 14 mm and the pitch of 1.5 mm, for this we select blank this blank we have taken as 70 mm by 29 mm.

Although if you see that we need only 43 mm, so the remaining we have to remove and in the diameter, we have taken the diameter of 29 and we have to get only the 24. So, this is taken because we have to have some kind of an allowance. So that the hard layers are the stock which is at the top of this blank which I have shown it to you earlier that there is a stock at the top of the blank.

And that is the oxide of the material which is very hard and the hardness of that layer is more than the hardness inside the layer. Therefore, that layer is normally removed and therefore, along the diameter and along the length some allowance is taken and for 43 mm we have taken 70 well, if you ask me why not 60, I would say you could have taken 60 as well that depends on what kind of blank quality that you are having. But it should be more than 43. That allowance that you will be having should be added to the final dimension of the readily available part, readily made part. Rest of the material I will discuss in my next session. Thank you for your attention.