Metal Cutting and Machine Tools
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Lecture-16
Milling Machines

Welcome viewers to the 16th lecture of the open online course metal cutting and machine tools. So, in this lecture we will be learning about milling machines, their kinetic structure and what kind of specialized operations that can be done on the milling machine? So, let us start right away with the first slide. Metal cutting and machine tools; milling machines.

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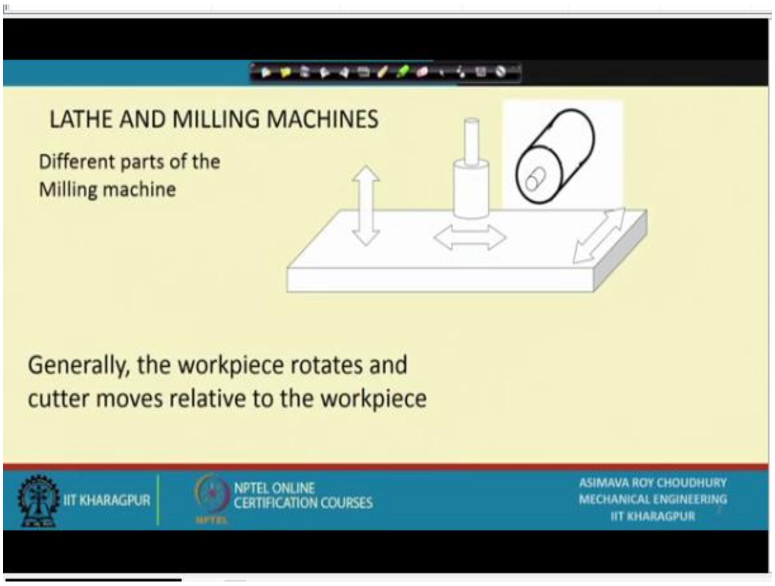

So, the different parts of the milling machine; the first thing that we get conversion with the milling machine is the table. This is the place where the operator directly interacts with the machine, the table can move vertically up and down and assuming the table to be horizontal; it can move sideways, this is the longitudinal motion and it can also move transverse, cross towards the operator or away from the operator.

This is the typical configuration of a tool whose axis of rotation is vertical and in that case the machine gets the name vertical milling machine. In this case I mean axis of this tool is horizontal and if this sort of a tool is used the machine gets the name horizontal milling machine. And what is the basic structure of the machine and of course, generally the generally the work piece.

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So, let us move on to let us try to visualize them what is the milling machine all about. So, the milling machine first of all has a table; this is the table and the machine looks just like someone who is resting the table on his leg and leaning on the machine and doing some very important work; this is the milling machine. So, from that this structure on the machine will be called knee.

And this columnar structure that his torso is creating; this is the column and we get the name column and knee type milling machine. What is this head? This part is generally concerned with the cutter; cutter rotation, cutter inclination etcetera, etcetera. And this is the table which can be put as we discussed up or down, it can be moved longitudinally, it can also move cross. So, let us now look at vertical milling machine; we have already understood that the cutter is vertical.

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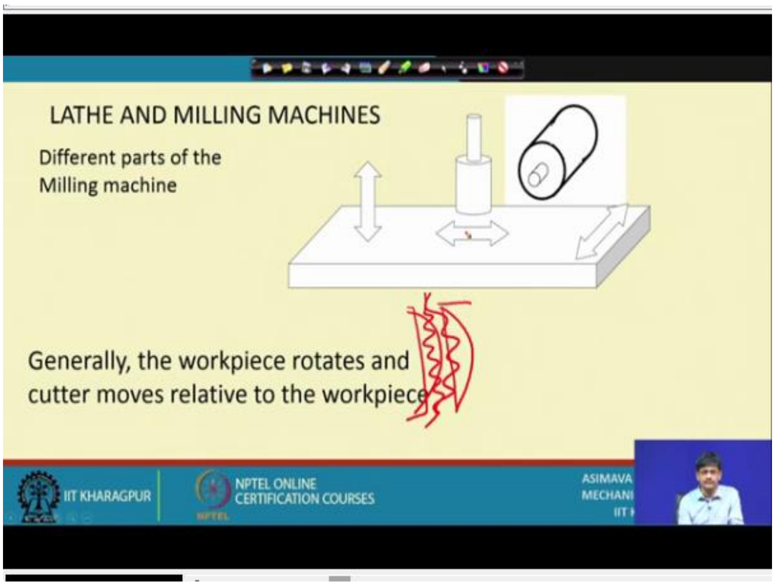

The horizontal milling machine also we understood axis of rotation of the cutter is vertical; I mean horizontal. So, apart from that the column and the knee; the column gives the structural support to all the cutters and its required rotational motion etcetera; all those things the column is at the back giving support to the main machine. And all the kinematic connections are through the column and the knee supports the table. Knee is basically if we draw it here itself knee is comprising of a vertical screw.

This vertical screw when it is rotated the table as nut moves up or down. So, this forms the basic support. If this be so, under the huge load of the whole machine table; together with the workpiece weight which can be to the order that say 200 kgs, 250 kgs like that. So, the knee might buckle; so, why go for such a structure? In fact, for production type machines generally they go for a fixed bed type machine where the table does not have such a structure and the table does not go up or down.

The cutter assembly moves down or moves up so that this question of buckling does not take place; this forms a weak point of the machine. So, this is generally restricted to those particular machines which are of low duty, medium duty and which are operator controlled. If it is column and knee type structure, the front structure is front part is open for the operator to interact. It is easier for the operator to place something on the table to unclamp, clamp something on the table etcetera.

So, for that kind of machines column and knee type structure is good, but for production machines where heavy cuts have to be taken; in that generally fixed bed type machines are preferred where there is no provision of the table to move up and down, it is supported on a very robust structure which is not columnar. So, it does not have any chance of buckling. So, with this let us move on to the next one.

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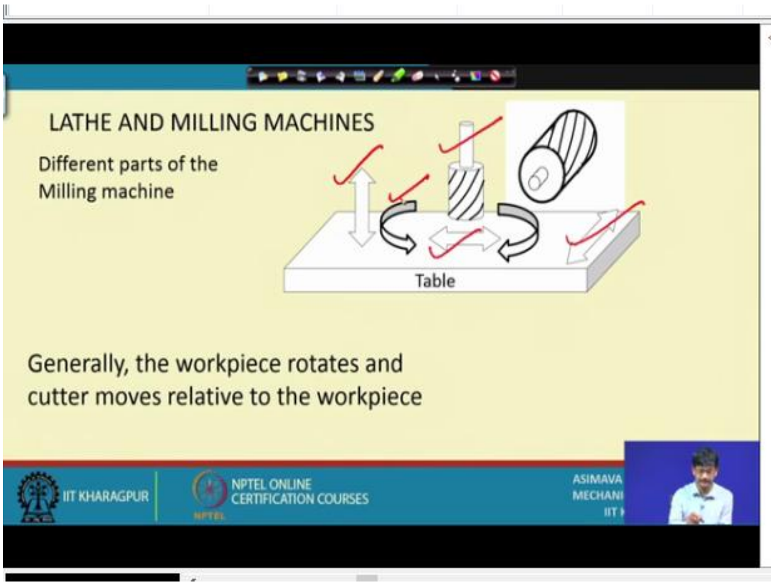

So, these are the teeth of the cutter, these are helical slab milling cutters shown. The table; apart from these 3 motions may also rotate about a vertical axis. Rotate means for setting up operations, so if it is capable of rotation about a vertical axis in that case it is called a universal milling machine. So, we might say a vertical column and knee type universal milling machine. So, what does it mean?

It means vertical column and knee type gives the structure of the basic machine and universal milling machine. These things are already there because we have named a column and knee type milling machine, where these motions will be given to the table. So, vertical column and knee type, universal milling machine; so, this way we can easily specify milling machines.

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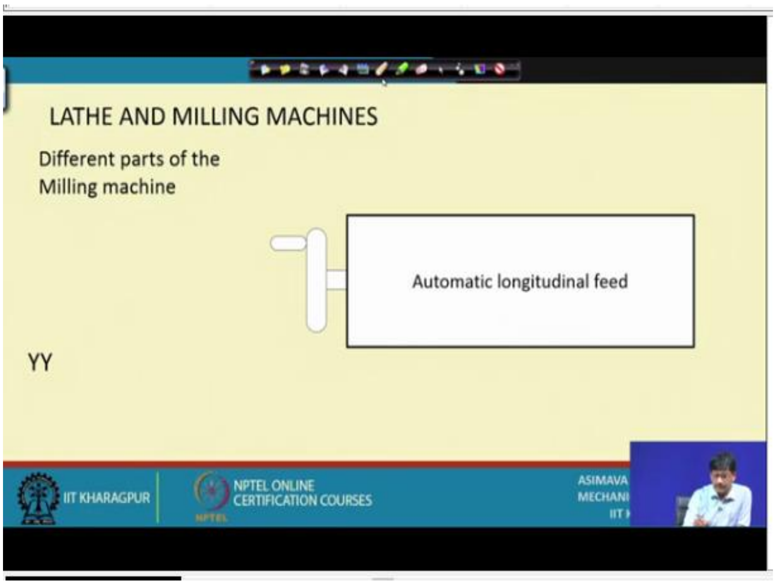

So, let us see how automatic longitudinal feed is obtained on the table; what does the table do? The table rotates this way; see the handle is also rotating automatically. So, by this very thing we understand that if the table is moved automatically, the handle also rotates. How is this made possible? Let us have a quick look.

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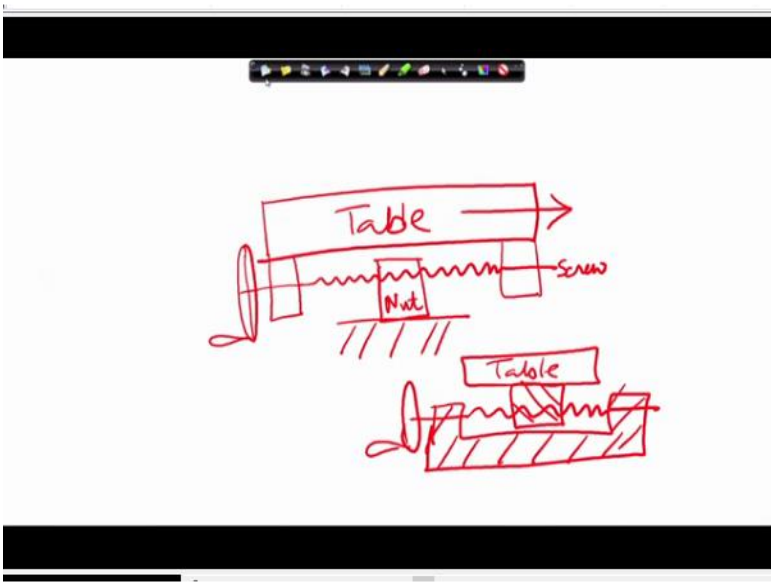

It can be made possible if this is the table, something is sticking out here and this is our handle and this is a nut; nut is fixed see that is it. The advantage of this is that mind you here is clearance; these are almost touching they should not. So, nut is fixed, screw rotates; so, the whole thing together with the handle, with the table etcetera; they start moving from one position to another due to the by virtue of this rotation; table moves these support, bearings move, this screw moves together, nut remains stationary.

Otherwise in other configurations, they would have been a distance created between the handle and the table. That is if we fix it this way say. This is the screw and this is the table with a nut, then you would have had problems, you will find that this table is moving and the distance getting created between the handle and the table; that is not so, at least in the machines that we come across; this is the thing. So, once we understand how the table is configured.

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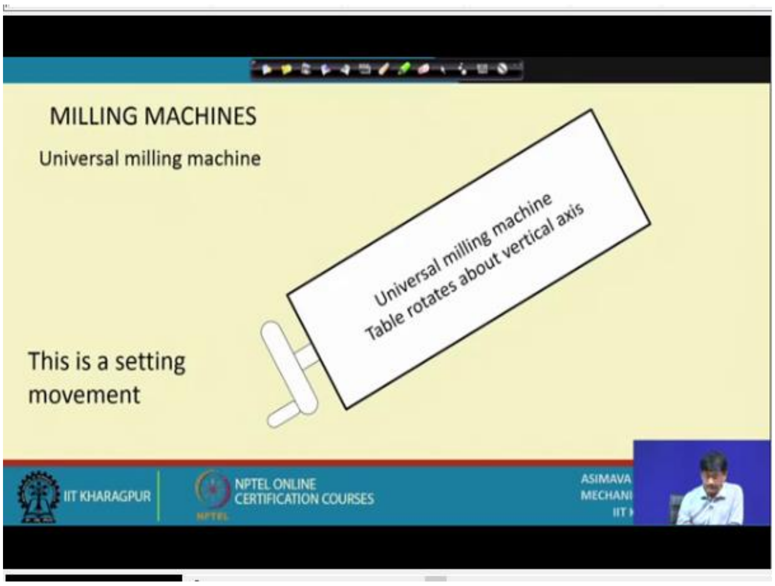

Let us see how the universal milling machine is working; how it operates? And mind you this is a setting movement. During machining generally, the universal milling machine table does not rotate about the vertical axis. So, this is the rotation that we are talking about; looking from the top you can set it to any angle that you want.

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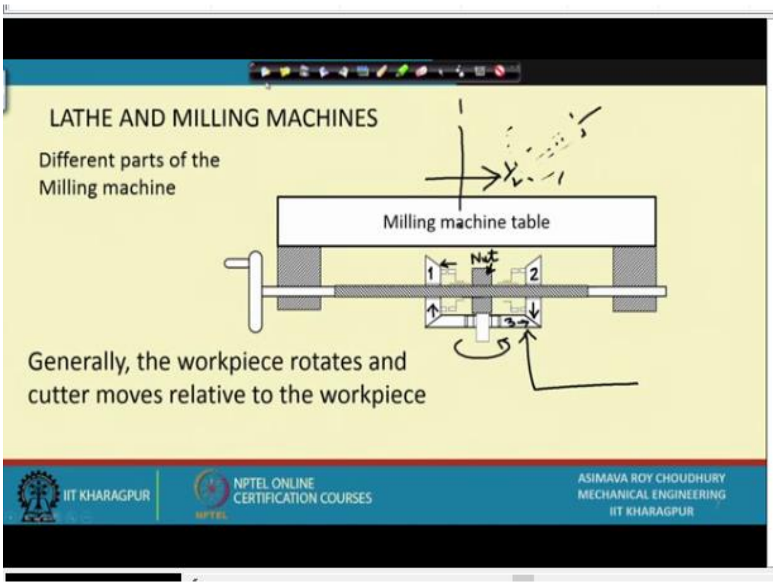

This is a possible configuration of what is going on inside; first of all, let us locate that nut that we were talking about; this is the nut and what is the nut doing? The screw is passing through it and therefore, the nut being held steady somewhere; it is making the table move. So, the table will be suffering motion like this; what are these things on the sides? These are bevel gears.

So, there is a basic a cradle bevel gear or a crown bevel gear here. And connected to that there are 2 bevel gears which if they rotate, they are going to move all around. They are going to move on these circular rails it is just like merry go around; they will go around in a sort of merry go around motion. So, if I rotate this handle; this screw moves through and the table moves.

Then what are these 2 things doing? These are called clutches, what they do is; if they move this way they connect up with this particular bevel gear 1; let us name it 1 and let us name it 2 and this one 3. So, if 3 is rotating this way; that means, it is moving this way; so, this bevel gear moves this way and that bevel gear moves that way. So, you can clearly see directions of rotation of 1 and 2; they are opposite.

So, if this clutches on to 1, it transfers motion from one to the lead screw and the lead screw rotates. So, basically I am bringing in power from the motor, I am making 3 rotate somehow and once 3 is rotating 1 and 2 rotate, but they are not intimately connected with the lead screw. Lead screw gets its connection by either by pushing this clutch this way so, that power flows from 1 to the lead screw.

Or if it is shifted this way power flows from 2 to the lead screw; that way you can derive power automatically and make the screw rotate. In addition to that you have the ability to choose the direction of rotation. So, with the help of this one this is called the clutch; so bidirectional clutch. So, I am able to choose the direction of rotation; I am able to derive a power from whatever prime mover I have that is a motor.

So, I am deriving power from the motor right up to this lead screw, I am making it rotate, I am rotating it in the direction that I want. And that way the screw is rotating, if the screw rotates the nut makes the screw the table move this way. But if I already rotate the milling machine table about a vertical axis will not the screw run out of contact with these, no. As we noticed before these will simply shift position out of the plane of the paper.

But they will still remain in contact with the prime moving bevel gear 3 because they are going round, they are not coming out laterally outside the plane of the paper; they are going round on this particular bevel gear. So, always they remain in contact simply as we saw before; the table from looking from the top is going to just shift this way. The screw is going to be this way; these are going to be the bevel gears. And they are going to go round it is something like this.

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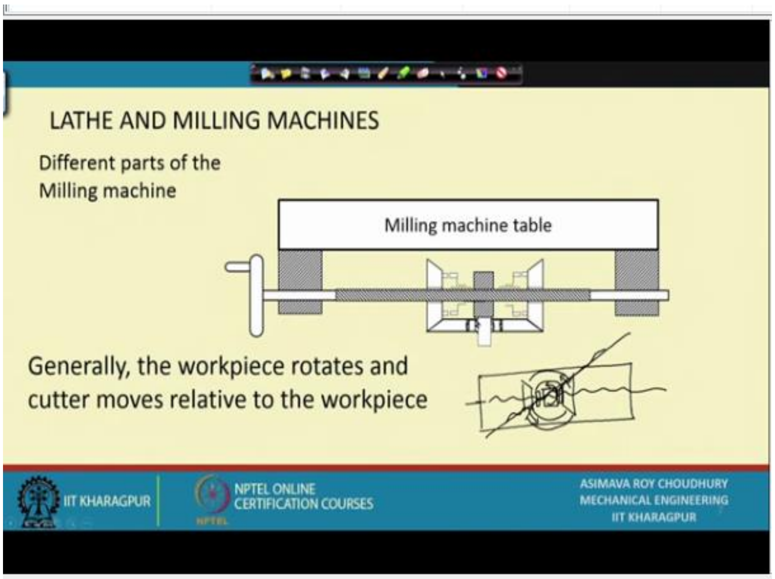

Looking from the top we have this to be the table; this to be the screw, these to be the bevel gears and they are rotating on top of another bevel gear and inside there is the nut and on this side there is the clutch. So, even if this thing changes; this moves this way, this moves that way, the screw comes here; everything still remains in contact, so this way we are taking care of it.

But what happens to the nut? The nut we said is stationary. So, the nut rotates about its axis and it is connected to this bevel gear by means of this ball bearing. So, with the screw the nut has to rotate from its initial angular position; this nut rotates. So, this way the whole thing can be taken care of. I am having rotation of table, I am having automatic motion coming to the screw, I am having direction also selected.

However, this sort of complex mechanism is not always implemented in one step itself, this clutch is taken out and it is it is made use of in a different shaft. Because this sort of y directional clutch; here it has to be in 2 parts, generally it is in a single part let us quickly have a look at it.

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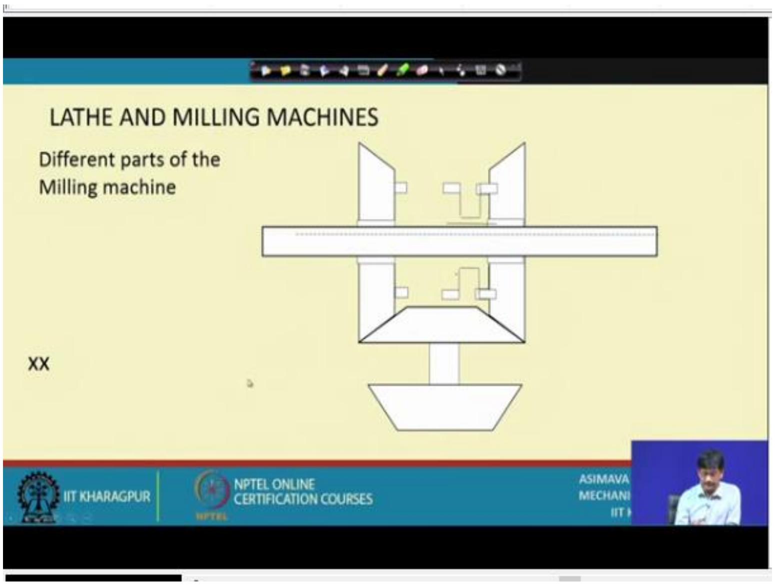

By the way this is the operation of the clutch. On one side it can clutch on to this one and it can transfer power to the shaft; how do you may understand that is transferring power to the shaft? It is keyed on to the shaft by a sliding device. So, it can either come this way or that way.

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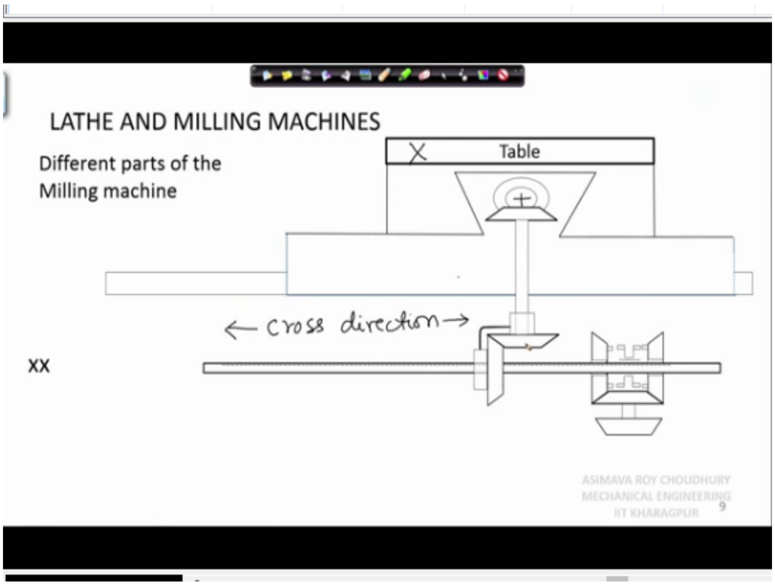

So, this is the table. This is the motion out of the plane is the one that we have discussed up till now, but the table also has motion in this direction. So, one motion we have discussed is out of the plane of the paper longitudinal motion, but it also has motion in this direction. Due to that the power going to the longitudinal slide has to always be in contact. Because if you are moving this way; will not the power connection to the longitudinal slide come out of contact?

So, for that we take a precaution; this is it; that means, this shaft is having a sliding key so that these 2 bevel gears are always carried along with the motion which takes place for this slide this way; this is the cross direction let me just write down. Let me just go ahead and write here cross; what is that or transverse direction or cross direction. This is longitudinal direction which we cannot see now; we are looking along the longitudinal direction.

So, this must be the screw of the longitudinal direction and that is what we have tried to show here, this bevel gear brings in the power for that. Now let us have a quick look how cross direction works; the cross direction has to maintain contact between the longitudinal screw and the prime mover. So, if we have a screw here; this one will be always maintaining contact by making this assembly move; that it derives the power from this screw.

So, let this derivation of power not be disturbed, this point and this screw should always be in contact. So, that is done this way. This power contact, this connection is always traveling so, that this screw gets power and the one choice of the direction of motion that is brought out here in order to make things simple.

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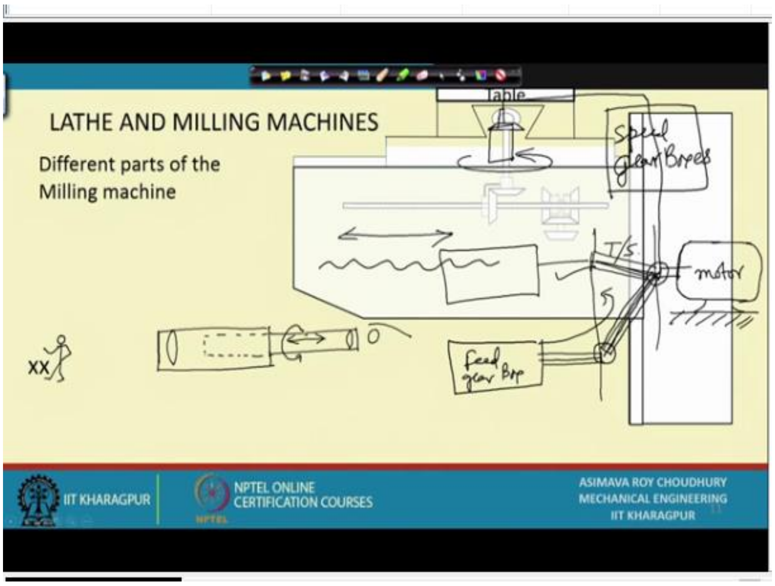

Now we are miniaturizing that part now, we have already discussed the longitudinal direction; we have already discussed the cross direction movement. Now comes the up and down movement; up till now we have understood okay the power is flowing this way how does the longitudinal motion take place here? This is the movement that we have already seen; now it is miniaturized.

How is the up and down movement taking place? This whole thing moves up and down; let us see how it is done, that is it; this whole thing is moving up and down and therein we have a problem. What is this problem? Say let us take a hypothetical case that say in this place; we are having a motor and from this motor there is a shaft and from this shaft we are having say connection to another shaft here.

And basically what is the concept? We have to bring power to this member because we have seen that it moves up and down; how does it move up and down? It derives power from a motor; where is that motor? It is here; you will say why do not we carry the motor on this one? Generally, you will find that there are many milling machines there are different types of milling machines, there are many milling machines; in which all the power for speed and feed, they are derived from a single motor.

If that be so that motor should preferably be in a stationary place and from there cutting speed, the cutter is here. Cutter is here and the cutter must be deriving the power from this motor only what is there in between? Gear boxes, so that we can change the speed of the cutter. So, let me write here speed gearbox, already gearbox we have had quite a look at gearboxes. So, I will not repeat everything we will just learn the principles.

Then you might say okay it must be having a feed gear box. Yes, a feed gear box is here; a feed gearbox will be here and from there ultimately you will be deriving power this way; so, that completes the circle. After this we know all the things that are supposed to exist; all that direction change, direction change, all that rotation of the table about a vertical axis; all those things we have discussed, then movement of this one this way, that way etcetera we have seen that.

So, now you might say where is the screw nut arrangement which is making this movement possible? Is it this screw? No it is not this one; there will be a separate screw and that will be given power; this way there will be a separate screw. So, now we are concerned about something else now; I want to get your attention to some other aspect what is that? That aspect is this motor is stationary.

So, let us make it stationary; this shaft is stationary and maybe here you have used some sort of universal joints; some universal joints are used at this place and this place so that you are still able to though it is and not having the same axis, you are still able to transmit power this way. Problem occurs when this has moved up; when it moves up so let us quickly have that. When it moves up, the problem is the connection is now different; the connection is now this way.

So; obviously, if you take directly lines this distance is less than this one, now how can rigid shafts change their size? So, for that something called a telescopic shaft is used here; telescopic shaft means if you remember the operation of the telescope, the telescope looks like this old telescopes. Nowadays, maybe we do not deal with these telescopes now; this is your eye and maybe there is one lens here and lots of lenses might be there, but say there is another lens here.

Now in order to focus upon a distant object, we can adjust the distance between these 2 lenses so, that this is movable; how is it movable? Maybe it is provided with a jacket, this is a sleeve and this is movable inside this sleeve. The same thing has to be done here and that is why it derives its name telescopic shaft. But if you give a rotation to this; if there is nothing to stop the rotation, this will rotate; this side will rotate let me rub it out and actually draw a telescopic sort of link.

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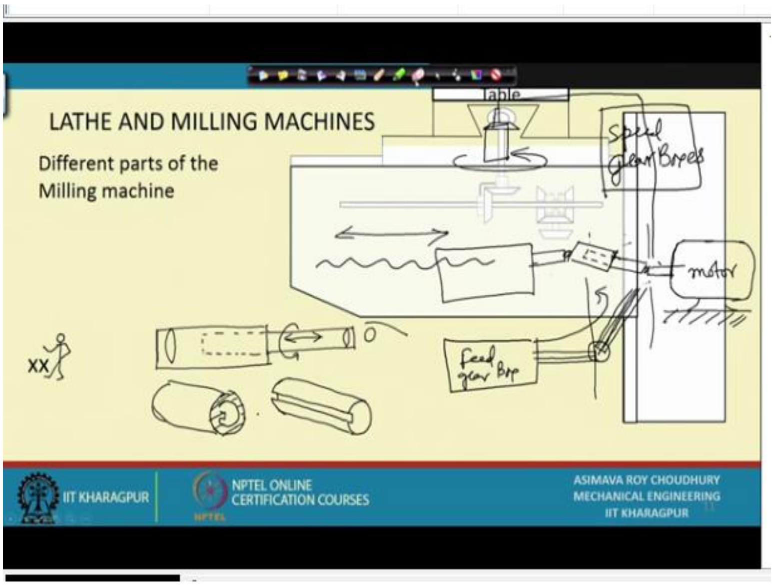

If we have such a member here that is; this is one part of the shaft and it is fitting on to another shaft. And then it is linked here by universal joints, please look up universal joints; they are very simple to understand, they allow rotation between shafts which are not aligned along the same line. So, if it is rotating this still another problem; that is this might rotate, but still this is not rotating because this is circular, that is circular there is no nothing to make this rotate.

This is going inside, this one no problem and that way length is getting adjusted. So, what we have to do is; we have to at least provide 1 or 2 key ways on this or tooth spaces on this and fitting teeth on this one; so, that they will look like this. This one looks this way; it has a depression and there is a fitting tooth on this one. So, this problem of power transmission is solved by universal joints and telescopic shafts; if you have a single motor supplying every one.

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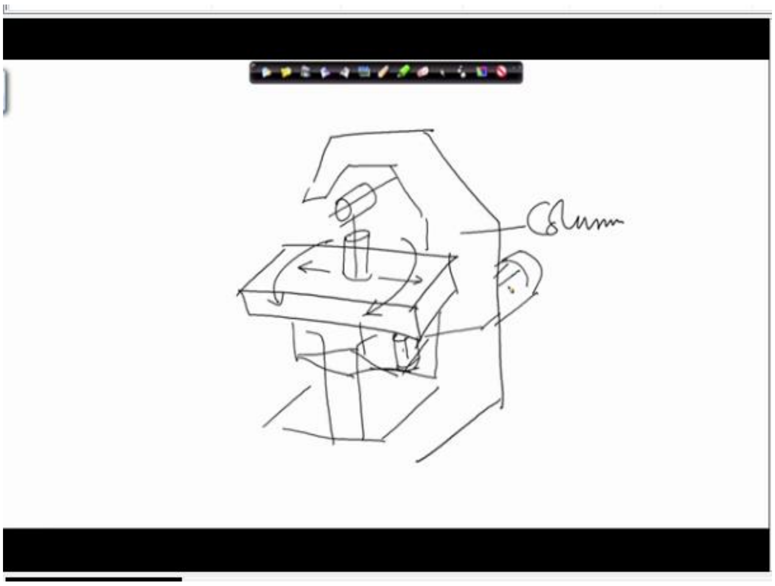

So, to sum up let us have a quick look what we have learnt today. Today we have learnt about the milling machine which basically has a shape of this type; table, column, knee. Knee is basically housing that vertical screw which will provide us with up down motion. And this one may be having vertical motion because of which it will be called universal, if it has motion about a horizontal axis; it will be called omniversal that is a little rare; if that if the cutter axis is horizontal it is called a horizontal milling machine.

If the cutter axis is vertical; it is called a vertical milling machine, if it is to have this rotational motion of the table; it has to have bevel gear connections which will allow it to rotate in order to choose between directions sense of motion for longitudinal or vertical or cross; we need a clutch. And in order to derive power from the main motor here, we need a telescopic shaft; a telescopic shaft is required.

So, this one is like this and somewhere here there will be that telescopic shaft by the side of the machine; universal joints with telescopic shafts. And last of all which I have not covered today; there might yet be**;** another motor called rapid traverse motor, which can override; that means, it will be deciding what the motion of the table will be override the feed motions set and provide a faster motion to the table slides by a device called an over-running clutch.

Why this required? If you want to rapidly position the job at some location, you cannot depend upon the slow machining feed rates which are available from the machine. There you put this motor on and apply the automatic motions that you require and the overrunning clutch will make it sure that the motion derived from this motor will prevail over the motions obtained from this one. So, with that we come to the end of the 16th lecture on milling machines. Thank you very much.