Computer Integrated Manufacturing
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Lecture 16
CNC Machining Centre (Part 1 of 2)

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Okay, the next interesting topic in CNC is going to on CNC Machines. So we saw what is CNC Computer Numerical Control and what are the different types of machine, how does a machine look like, and how, what are all the other parameters which are involved in machines. So we will see that in more details.

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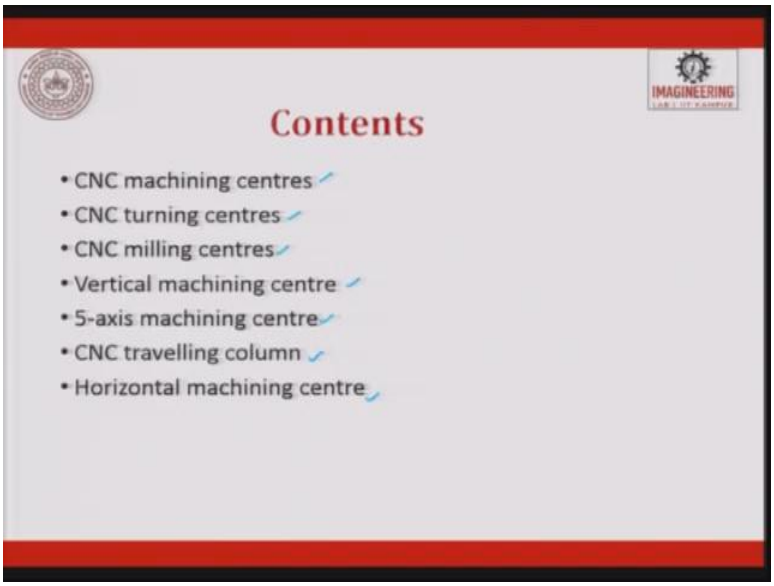

So in this topic, we will try to see machining centre, then we will try to see turning centre, then we will try to see a milling centre, then vertical machining centre, 5-axis machining centre, this is used for almost all complex jobs, then CNC traveling column, then horizontal machining centre. So these are all the different machines, CNC machines, which we will see in this topic.

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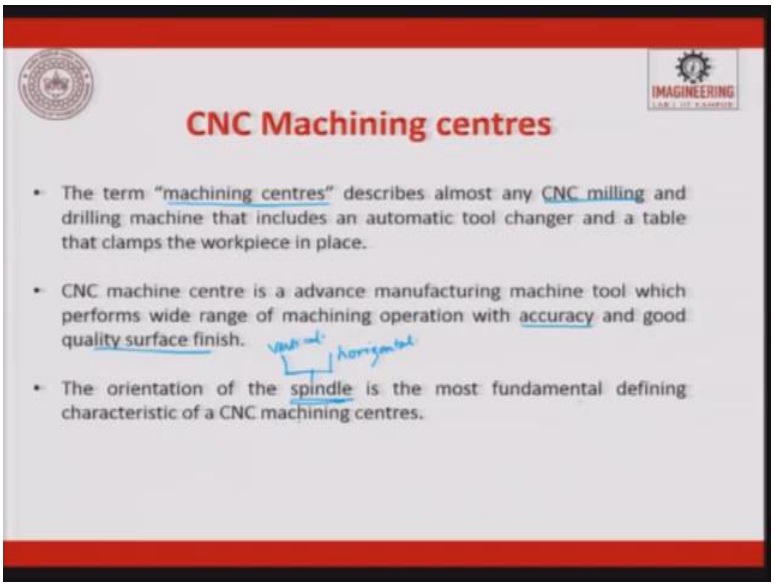

Talking about CNC machining centre, the term machining centre describes almost any CNC milling machine and a drilling machine that includes an automatic tool changer and a table that clamps the work-piece in place. So that is what is the definition for machining centre. So in a crude sense, machining centre means where the tool rotates and the work-piece is held in a very-very crude sense.

CNC machining centre is an advanced manufacturing machine tool which performs wide range of machining operations with accuracy and good quality surface finish. We have seen accuracy, repeatability, reliability and here we talk about good surface finish. The orientation of the spindle, so it has two, one is horizontal, the other one is vertical. The orientation of the spindle is the most fundamental defining characteristics of a CNC machining centre.

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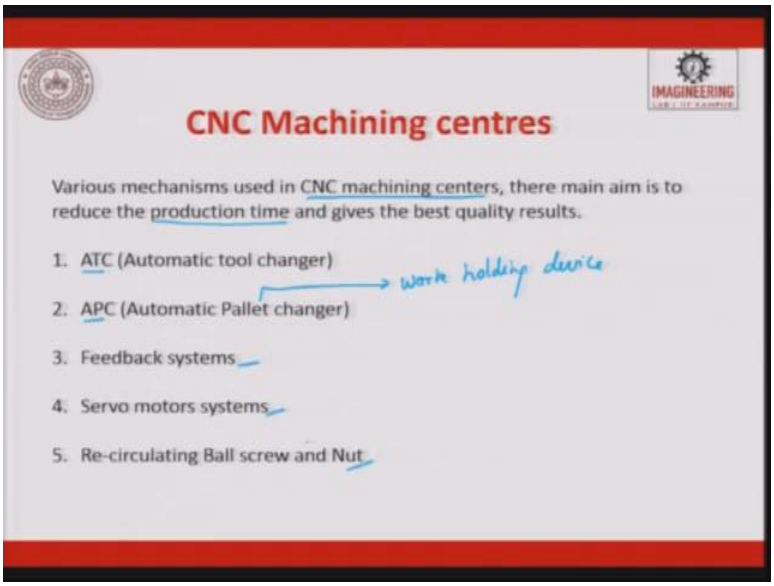

Various mechanisms, which are used in a CNC machining centre are ATC, automatic tool changer, APT, automatic pallet changer. What is a pallet? A work-holding device is called as a pallet, work-holding device. It can be just angle plate, face plate, or it can just a table where there are holes okay.

So automatic pallet changer, then you will have feedback systems which we have already seen, servomotors, re-circulating ball screw and nut. So these are all the five important things, mechanisms, which are there in a CNC machine.

The primary aim of this, all these mechanisms to be implemented is to reduce the production time. We have seen feedback systems, servo-systems and re-circulating ball screw in our previous lecture in a detail fashion.

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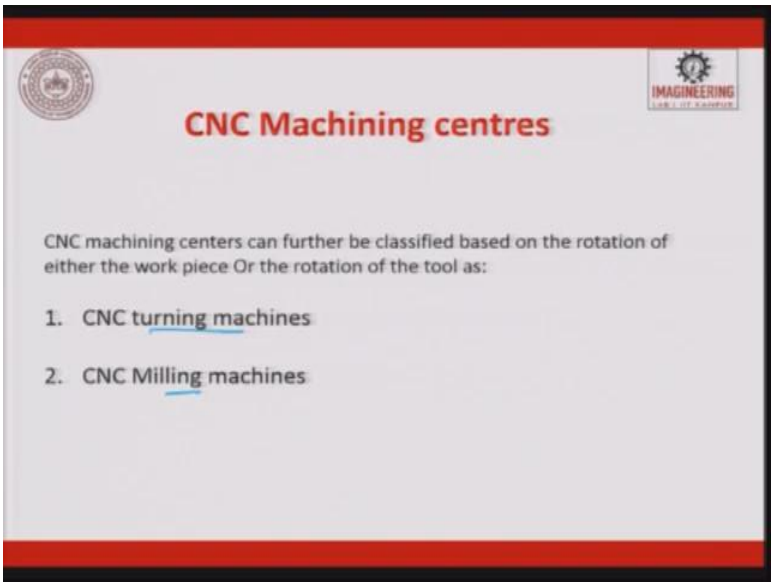

So there are two types of machining centres, one is called as a turning centre, the other one is called as a milling centre.

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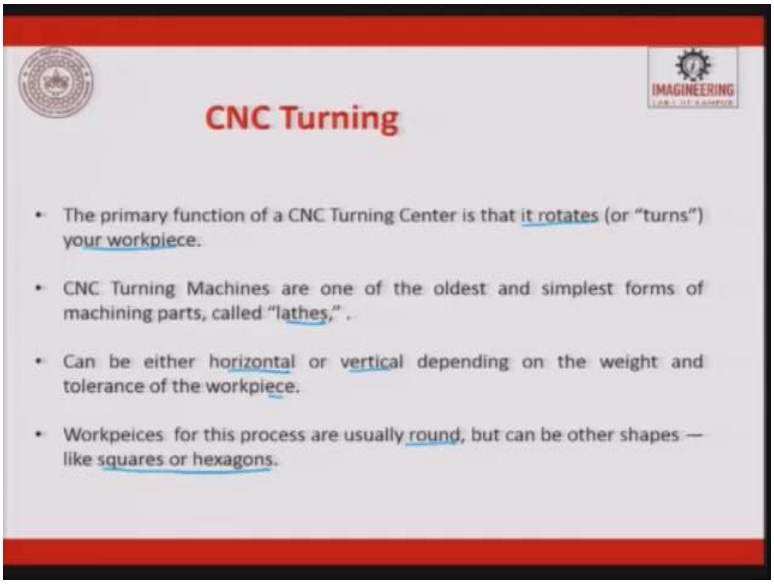

When we talk about a turning centre, the primary function of a CNC turning centre is that it rotates or turns the work-piece. CNC turning machines are one of the oldest and the simplest form of the machining part called lathes. It can exist either in horizontal type or in vertical type.

We have all seen horizontal axis lathe machines. There are also vertical axis lathe machines, wherein which the diameter is very large and the tool is held in the vertical fashion. Okay so you can have vertical, depending on the weight and the tolerance of the work-piece.

The work-piece for this process are usually round but can be other shapes also like squares or hexagons. So if you have a square or a hexagon, then we go for a four-jaw chuck and we try to put at angle plate and then we put a base plate, try to hold it in proper and then start doing machining.

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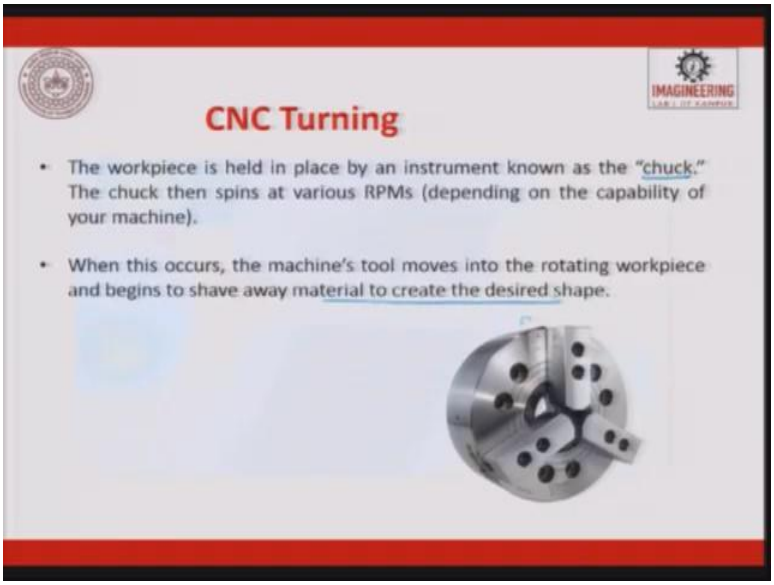

The work-piece is held in place by an instrument called as the chuck. So when we try to do a manual lathe machine, we will have a chuck wherein which there will be a nut here, you put a counter of the nut here, a tool, and then we try to move. So when we try to move one nut, there will be internally threads which are helical at a plate. So now every job will be moving uniformly.

So this is primarily used for holding the work-piece. The work-piece is held in place by an instrument known as the chuck. The chuck then spins at various RPM. Today these manual chucks are replaced by hydraulic chucks and pneumatic chucks, so that it can be controlled

with the use of a computer. When this occurs, the machine tool moves into the rotating work-piece and begins to shave away the material to create the desired shape.

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So this is how it is. So here is the chuck and here are the jaws. Jaws are moving very fast so you are not able to do. This is the rotating, this is rotating work-piece and this is the tool wherein which the movement of the tool is programmed in a CNC machine. So the work-piece rotates, chuck rotates. These are the jaws.

So here we, in a CNC machine, we will always go for a pneumatic or a hydraulic jaw depending upon the depth of cut and the machine capability.

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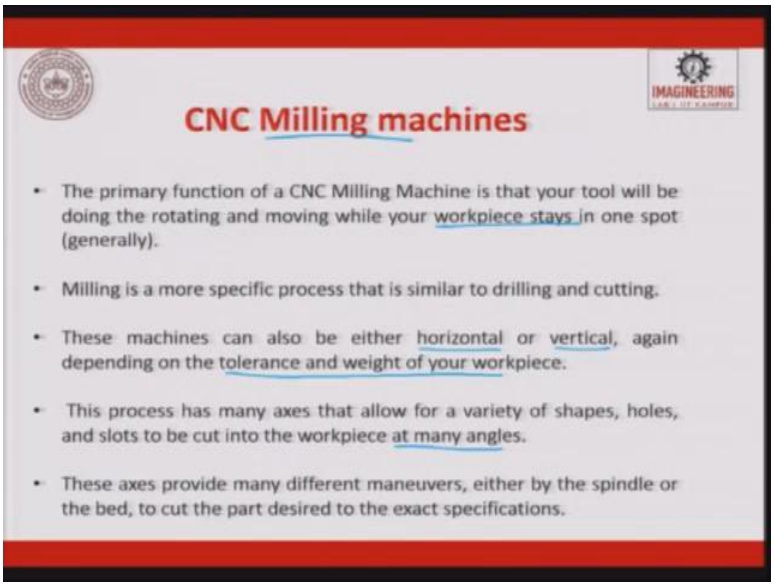

The primary function of a CNC milling machine is that tool will be rotating and moving while your work-piece stays in one spot. That is what I said, machining centre, work-piece stay. Milling is a more specific process that is similar to drilling and cutting. These machines can also be either horizontal or vertical again depending on the tolerance and weight you decide to go for a horizontal machine or for a vertical machine.

So you can have a vertical turning centre, you can have a horizontal milling centre. These two will be new to you, so you can have this, how you are defining the axis or deciding to go for those axes depending upon the tolerance and the weight of the work-piece. The process has many axes that allow for a variety of shapes, holes, slots, to be cut into the work-piece at any angle, or at many angles.

These axes provide many different maneuvers, either by the spindle or the bed to cut the part desired to the exact specification.

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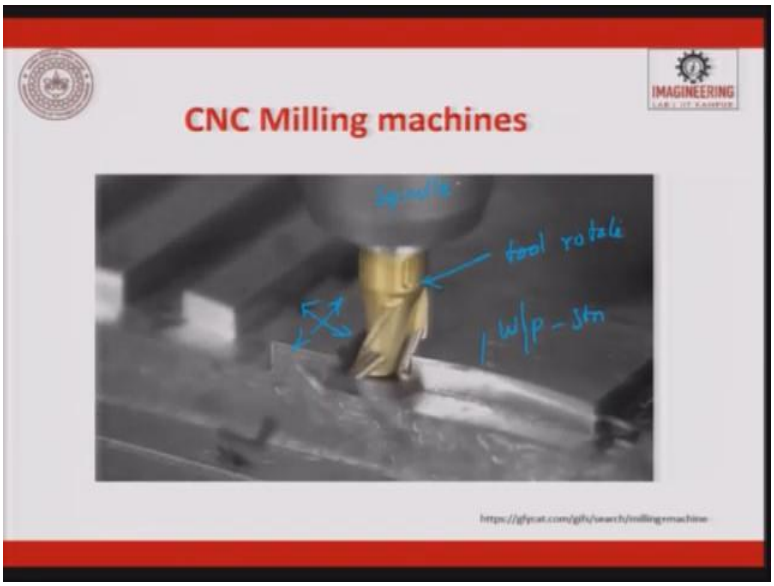

So this is how is milling. So you see here work-piece is stationary, tool rotates, tool can be given the feed rate so it can move both in this action and this action. Again, here the spindle, which is here, which is used to hold the tool can be operated either hydraulically or pneumatically.

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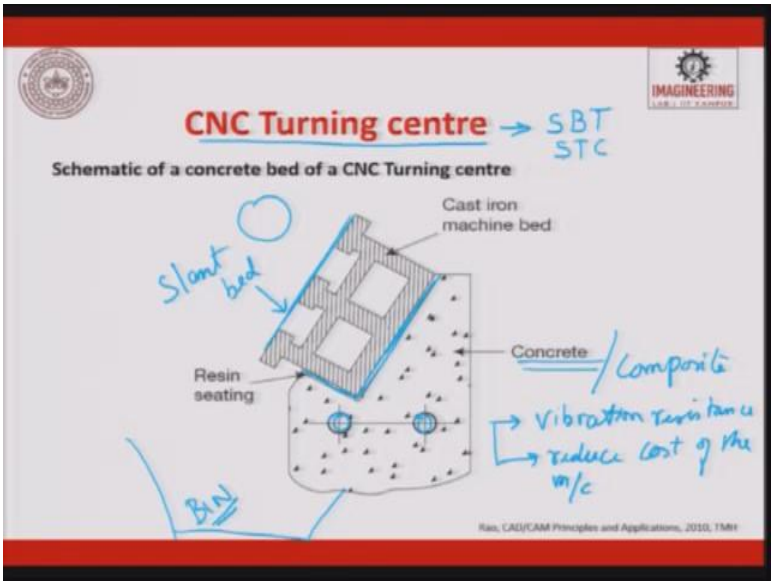

So when we talk about the CNC turning centre, we can see the latest development in turning centres in order to remove the vibration which is getting induced in the lathe bed, so they

have made the bed as concrete and this, they can be using tie rods, they can be connected with several blocks and there is a small machine bed, which is made out of casting is resting on top of the concrete bed.

So, in between the cast iron machine bed and the concrete, you will have a seal which tries to take the load from the machine bed and transfers to the concrete. And this also acts like a very soft damper which can absorb shocks. So this is the latest development which is made out of concrete, it is also made out of today, composites. So why are they done?

In order to improve their vibration resistance and they also say, in order to reduce the costs of the machine and weight of the machine. So this is there and if you look at all the turning centres, they will always have a slant bed. Why is that slant bed? This is a slant bed. S L A N T, B E D, slant bed.

The slant bed is, as and when the machining happens, the chip will fall down into a bin rather than getting accumulated on top of the table. In order to avoid that, the spindle will be here. All the chips will hit and then will slide here or it will exactly drop into the bin which is given at the bottom. That is why we go for a CNC turning.

So many of the CNC turning machines you will see, they would have been written as slant bed type, or it will be called as STC, slant bed turning centre.

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So this is what it looks like. The concrete bed dams vibration 6 times faster than any other conventional metallic structure. In order to increase the damping resistance, we always go for concrete, this is concrete and this is the bed in order to reduce the vibration. Vibration in turn will be transferred to the work-piece. They will give you chatter marks or the tool life will be reduced. This has to be done. So for this they do it.

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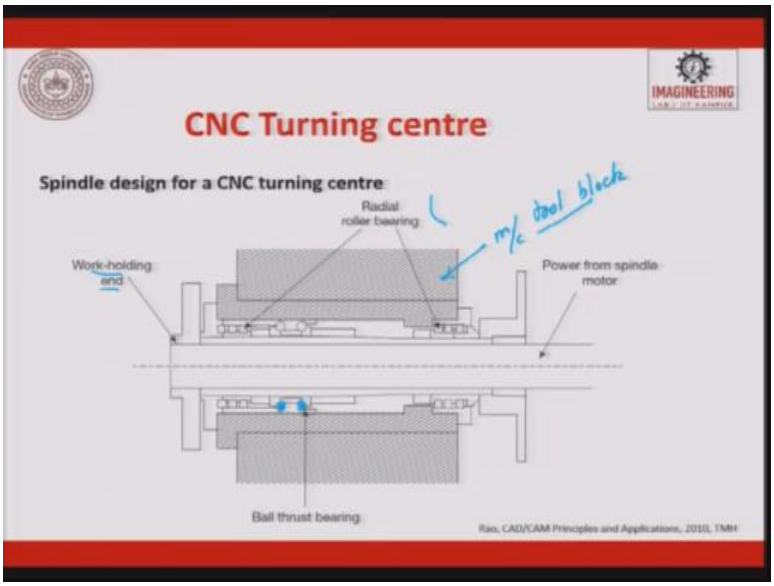

When we talk about the spindle design for a CNC turning centre, so the spindles nowadays are expected to rotate at 100000 RPM. So you see that this is the work-holding end and this is the power from the motor is given here. This is the work-holding end, this is the power getting transferred. Since it is rotating at 100000 RPM, you need lubrication on top of these bearings.

So initially when you want the run at 20000 RPM, 30000 RPM, we go at radial roller bearings okay and we also have ball thrust bearings. These are roller bearings which has a line contact, ball bearings which has a point contact. So the line takes heavier load than point. So we will have these roller bearings to take the vibration or take the loads which are getting transferred from the work-piece to the spindle. And this is the machine tool block, or the machine tool.

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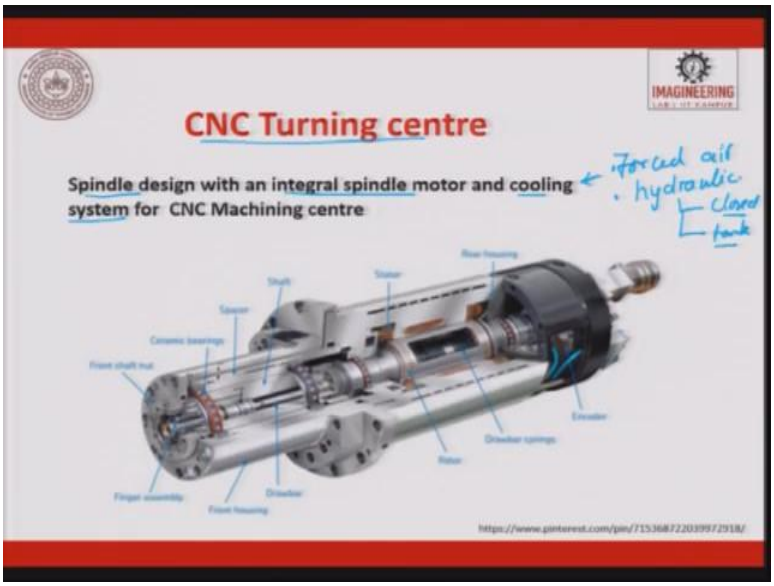

Okay and you see here, this is the latest CNC turning centre spindle. So the spindle design is an integral part of spindle motor and cooling system. When we start rotating at 100000 RPM, you should see that there will be a huge heat which is generated between the stationary part and the moving part. So you need to have a cooling system. It can be forced air or it can be hydraulics.

So that is getting circulated and then hydraulics also, it can be closed loop, or it can be attached to a tank. Closed loop means you just pour it inside and then it has a small casing, so the oil gets circulated among that itself and then you start lubricating the entire spindle. So this is an integral spindle motor wherein which the, and it is been attached with the cooling system also to make sure that the spindle does not vibrate or does not expand because of the heat.

Thermal expansion does not happen, it is intact. So these are the latest developments of the CNC turning centres. In our late machine, normal late machine what we use in our academics, will be around about, we rotate at 2500 RPM. So there, there is only bearings, roller bearings and ball bearings. These are the two bearings used.

But when you talk about 5000, 10000, 50000, 100000 we go for such type of integral spindle motors and cooling systems.

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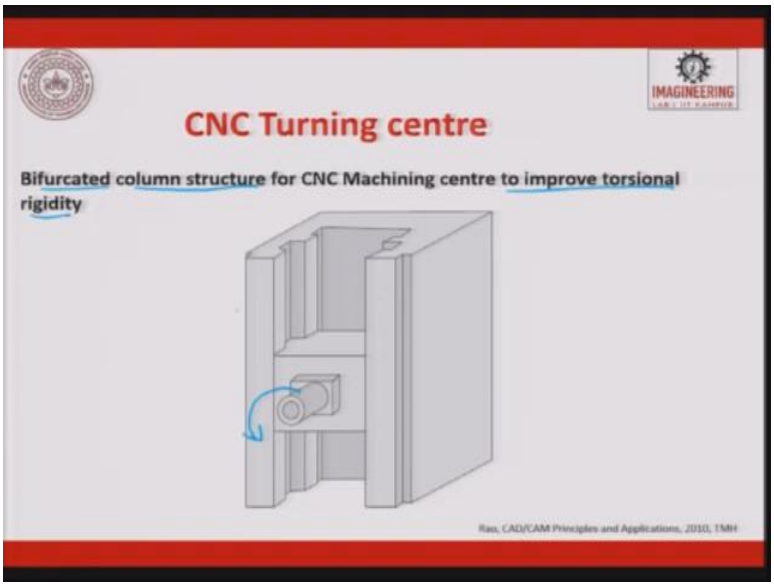

So this spindle is attached to a column okay. So now there are several modifications which are happening in the column in order to maintain a high damping coefficient and reducing the vibration transfer. So you can see here bifurcated column structure for CNC machine centres are used in order to improve their torsional rigidity, because this fellow when it rotates, there is a torsional load which is coming up when it starts milling.

So this will try to give you a torsional load in order to improve the torsional rigidity, we try to load the spindle in a bifurcated column structure. These are bifurcated column structures.

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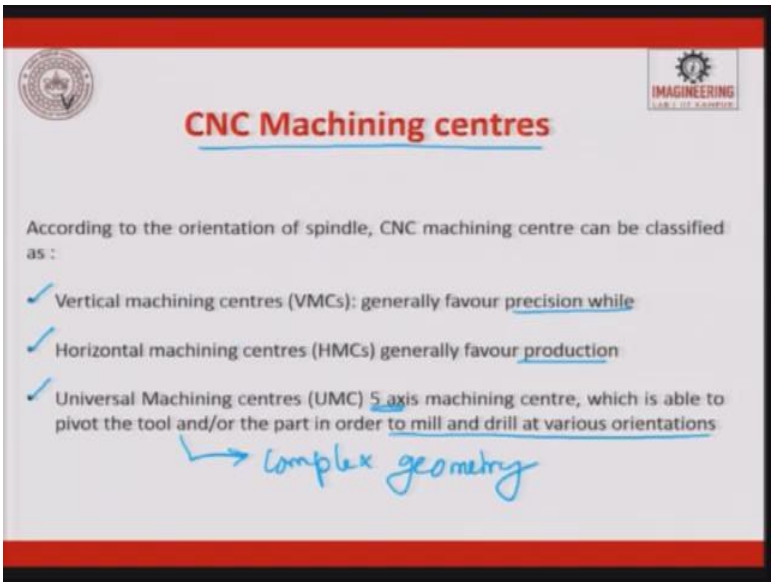

When we talk about the machining centre, according to the orientation of the spindle, CNC machining centre can be classified as vertical machining centre, horizontal machining centre and we also talk about universal machining centre. Vertical machining centres they generally favor precision, while horizontal machining centre generally favors production.

Horizontal for production, vertical for precision, universal axis where it is 5-axis machining centre which is able to pivot the tool and the other part in order to mill and drill at various orientation, we go for universal machining centre. So there are three classifications vertical, horizontal and universal, universal for complex geometry, and vertical for precision, horizontal for production.

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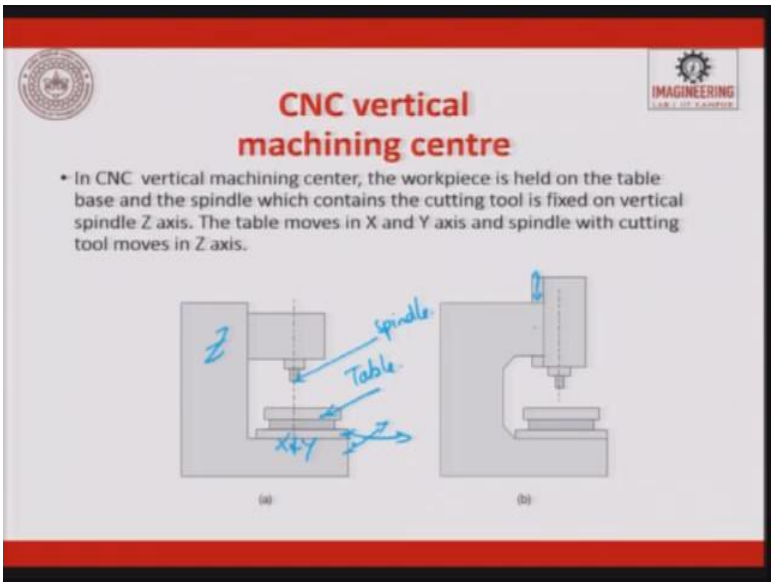

So these are typical vertical machining centres. We are just showing how are these spindles getting supported to the base machine. In CNC vertical machining centre, the work-piece is held on a table. This is a table okay and the spindle which contains the cutting tool, this is the spindle, which contains the cutting tool is fixed on the vertical spindle axis, Z.

This is the Z axis. The table moves in X and Y direction, this is two directions and the spindle with cutting tool moves only in the Z direction. So you can have directly mounted here or this column can be mounted and there can be, Z can be sliding on this column.

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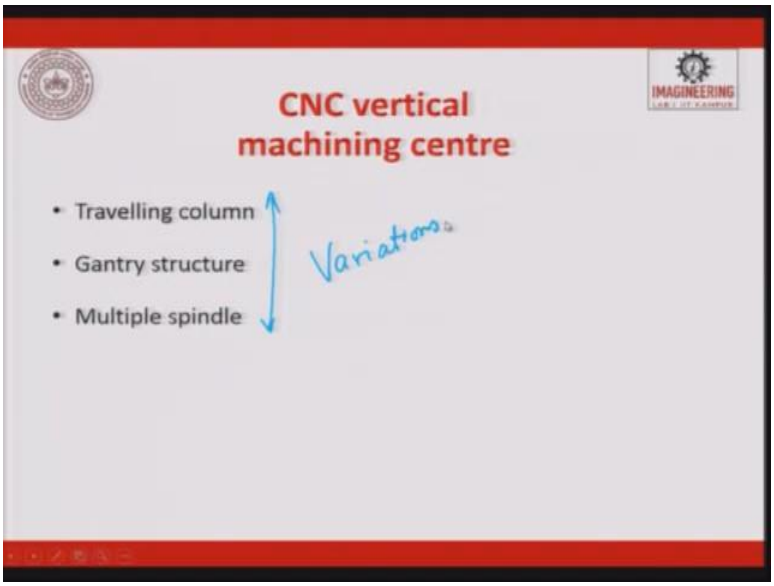

So in the CNC machining centre, you can have travelling column, gantry structure and multiple spindles. These are the variations you can think about, variations.

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So, CNC vertical machining centre, this is the vertical machining centre. Present days production vertical axis CNC machining centres use Bridgeport VMC 500. This is the machine, the Bridgeport is a machine name, VMC, vertical machining centre 500, 500 can be the capacity or the volume of the work-piece which you can mount.

So this is just for your understanding, how do they say? I said STC. So same way we have used VMC, vertical machining centre.

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So this is a 5-axis machine, so 5-axis machine will have X, Y, Z in any two axes we can have r and theta or it can be theta and gamma, can have. So this is what it is. So you can see it can move in X, Y, and then Z. This is the Z axis and then here what happens, it can rotate about this and it can rotate about this axis. So that is how you can be able to machine this.

This is a 5-axis, 5-axis machines are predominantly used for turbine blade machining or if you want to typically do your face, your face if you want to machine, so then you use a 5-axis machining centre to do it. 5-axis machining centre by the way, the X, Y, Z can be manually programmed but moment there is a theta and a gamma component coming into existence, you will have to use a support of a CAM software.

You cannot write manually, varying thetas along the X, Y, Z direction or gamma along the X, Y, Z directions. So this is 5-axis machining centre for a 5-axis machining centre programming, we have to use a CAM software, any software according to your choice.

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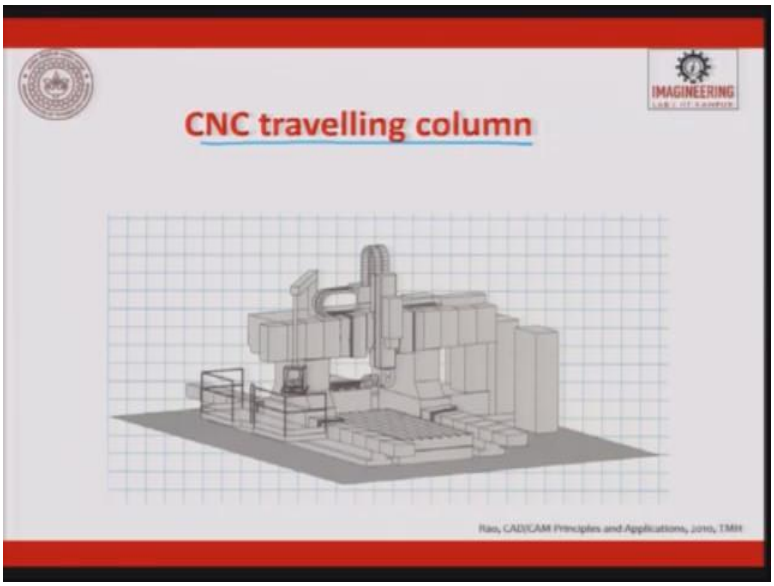

So this is a CNC travelling column. When we have a large work-piece, we used to have, we used to use a travelling column. For example, when we are trying to machine a wing of a plane, when we are trying to do a large aerospace component, if you are trying to machine a wind blade, blade of a wind turbine, windmill, so then we use this CNC travelling. Big turbine blades which are for used by the marines, or by ships, are machined by CNC travelling column.

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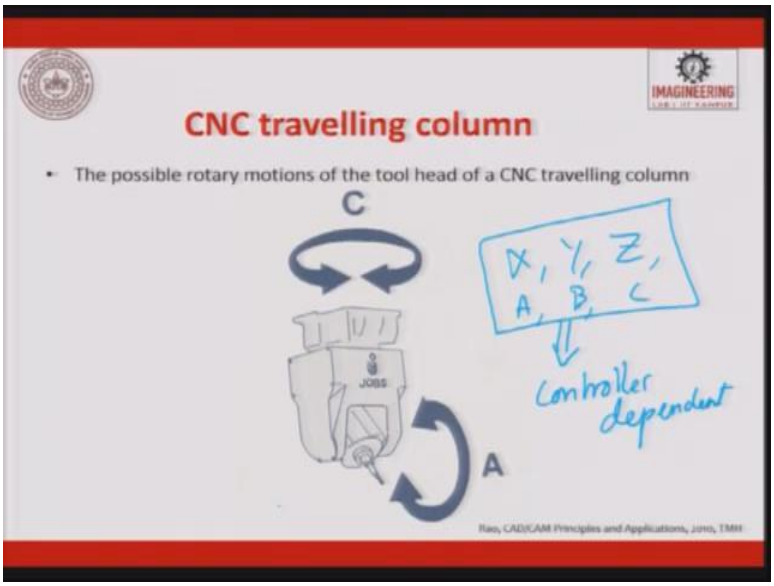

So the travelling column, the possible rotary motions of a tool head of a CNC travelling machines are, this is C and this is A axis. So this is C axis, this is A axis, so X, Y, Z you can also have A, B and C. So I said gamma and theta that depends on the controller. So please check these characters are controller dependent.

There are certain machines to the best of my knowledge where they do not use X, Y, Z they use A, B, C and the axes, A, B, C, linear scale. So depending upon the controller, you can choose whatever you want. So here you see that it can rotate about the axis and it can swivel about, the tool can swivel about this axis.

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So here also you can make 5-axis, it is almost equal to 5-axis machine. This is how a typical 5-axis CNC travelling column, CNC machine looks like, machining centre looks like. You can see that complete component, a large heavy component can be there and it is directly mounted on the floor. So you do not have to worry the weight resting on the table. The table is also on the floor.

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So the other one is gantry type CNC machine. So here I have just shown you a DMC 65V. So DMC 65V is a machine, so which is used for a very high speed machining centre. Here the speeds what we talk about is 100000, okay.

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These are 4-axis CNC machining centre 4CUT for high speed machining. So here we have 4 axes only. I am just showing all these machines because you should have a feel how big it looks like and what are all the components you can speculate and see this can be

machined in the centre. These numbers, 25L or whatever it is, this signifies either the volume or the model name.

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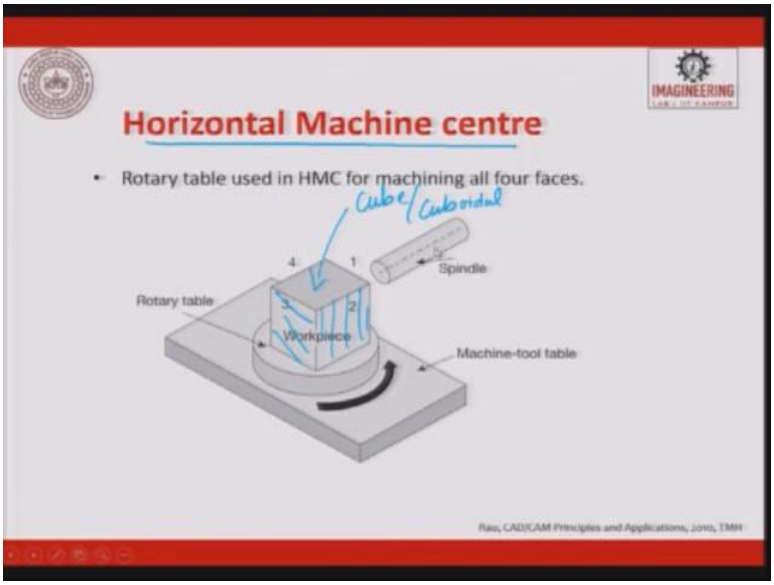

So when we talk about horizontal machining centre, till now what we were seeing is vertical machining centres. When we start looking at a horizontal machining centre, you will see there, there is a table and in that table you will see that the work-piece, the work-piece is placed on top of a rotary table and here you have a spindle which is coming.

So if you want to cut a cube or a cuboid, or you want to make straight edges right, so then we will try to use these machines, horizontal machining centre. Spindles, which will machine and try to generate 4 sides and these sides can be parallel to each other.

So this will be resting on a rotary, until and unless you have this setup, you cannot make a cube or a cuboidal shape, cuboidal. So you cannot make either cube or a cuboidal shape. So here we use a vertical machining centre.

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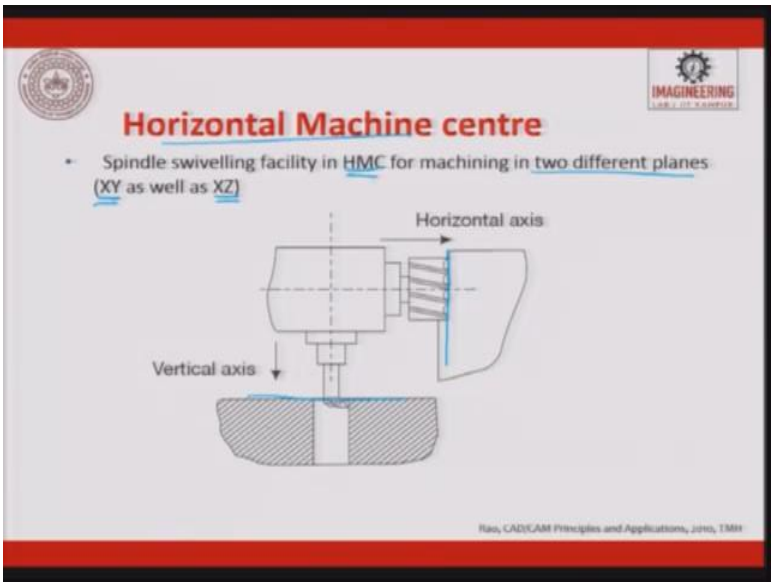

So horizontal machining centre and vertical machining which we can have a combination. So here you can see here a spindle swiveling facility in HMC, horizontal machining centre, for machining in 2 different planes it does on a horizontal plane, it does on a vertical plane. So it does on XY and XZ. Now you should understand, when we try to write programs for CNC in a machining centre, there is something called as plane definition very important.

We will see this in detail when we see the part programming, but all you have to, something has to flash you is so I see I am trying to machine on a XY plane, I am trying to machine on a XZ plane. Now we should have a provision of activating these two, part programming has it. We will see that, there are codes, we will see that okay.

So here in the horizontal machining centre, it can be used for machining two different planes, horizontal and vertical, to get the required output.

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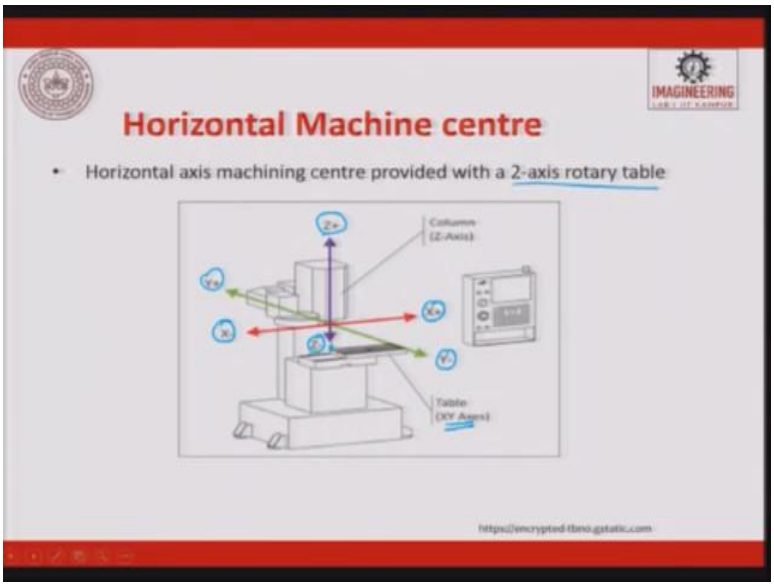

So horizontal machining centre provided with 2-axis rotating table. So this 2-axis rotating table you can have. So here what we have defined is, we have defined the axes, so it will have Z, which is tool when it moves away from the work-piece it is positive, towards the work-piece it is negative and depending upon this as zero, you will have a negative X and a positive X, positive Y and a negative Y.

So this is a table which is used for X and Y axis, so this moves X and Y and then you will have a column which is used for rotation. So here is a column rotation which is there.

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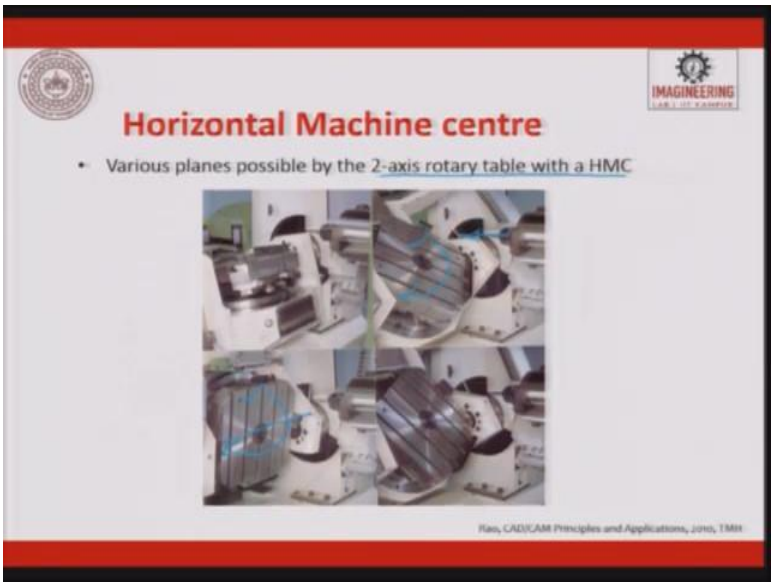

So these are the various planes by the 2-axis rotating table in a HMC. You can see here this is a table, HMC is horizontal machining centre. You can see the table can be swiveled and you can bring it like this, you can take it to an angle, you can bring like this. Here is a tool, but now you buy just controlling that table movement, you can try to have a complex component machine.

So this is a 2-axis rotatory table. So the table can rotate about this axis and in this axis, two axes, so that you try to get all the machining done. Thank you.