Computer Integrated Manufacturing

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Lecture-19

CNC Part Programming- Part 1 of 4

The next important topic in CNC is going to be Part Programming. So, in this we will see how to write a program in such a way such that we can produce a component. If you look at the name itself, it clearly says Part Programming. So, in CNC we call the programming as Part Programming, because the output what it is going to be generated is going to be a part.

So, till now we saw what is CNC? What are the components of a CNC? What are the 2 types of CNC? That means to say, machining center, turning center, what are their variations and we saw about the cutting tools also. In this we will be more focused towards part programming.

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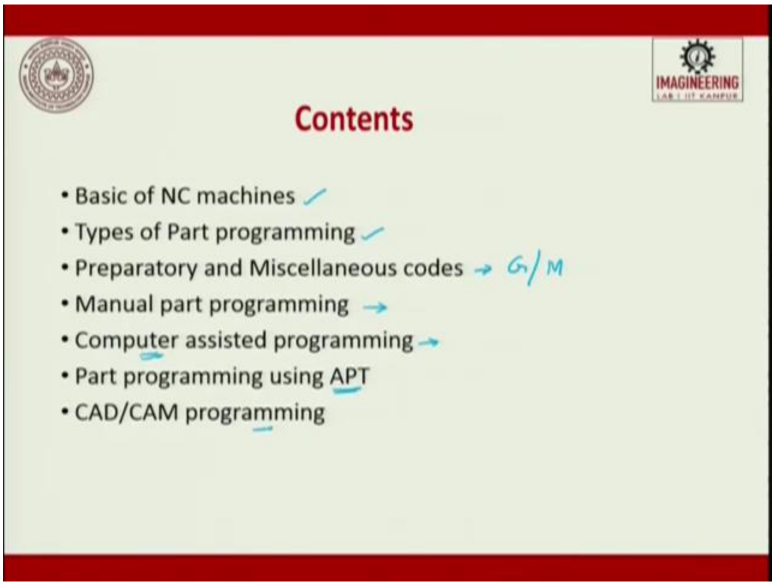

So here, we will see a basics of NC machines, then type of part programming, this is only a recap, so type of part programming. Then we will see what are preparatory codes and miscellaneous codes, these codes are going to be part of programming. Then we will see manual part programming, then we will see computer assisted part programming, part programming using ATP and finally, we will see CAD/CAM programming.

Manual programming is for simple components, wherein which beginner or a slightly a semiskilled the person can look at the component, look into the features, look into the dimensions and he can make a part program. But in reality, today it has become, the part features are going to be more and more complex. So, we are going to use computer for assisting in making the programming, where apart from part programming, they are other ways of writing programs.

So, this is G codes and M codes. So, there is other way to write, that is what is, that we will see as APT's. And finally, we will see CAD/CAM programming which is part of the Sims environment.

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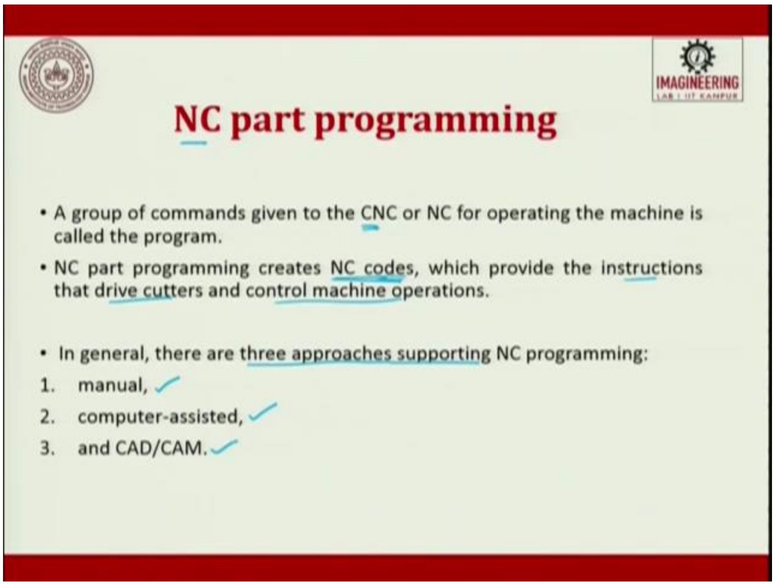

When we talk about NC part programming, a group of commands given to a CNC or a NC for operating the machine is called a program. So, here you write program using alphabets, numerical, that is alphanumerical and you try to control the complete machine. The logic what is used here, the hardware what is used here in a CNC machine, is the same which we will use it for rapid prototyping also.

So, if you understand CNC, almost all automations you can understand very clearly. So, CNC is common for many things. So, it can be used for inspection, it can be used for rapid prototyping, it can be used for machining, it can also be used for assembly by the way. So, a group of commands given to the CNC or NC for operating the machine is called as program. NC part program creates NC codes, numerical control creates a numerical control codes, which provides the instructions.

So, why are we talking about codes? So, we know these are the features to be executed on a part. So, now each feature, if you can write a library function and use that library function for executing the program, so, then it finally generates a part. So, here that library function are nothing but the codes. NC part programming creates NC codes, these codes are library functions which does a specific task.

Which provides the instruction that drive cutters and controls machine operations, movement of the cutter and the machine execution. See one way is on a system, on a computer you can allow a simulation to happen, that simulation is allowing the cutter to move on top of a part where there is no machining. But finally, what we want is it has to be machined a part so we have to also control the machines. So, both things are controlled by NC codes.

In general, there are 3 approaches supporting NC program, one is manual which we will see exhaustive index. Next is computer assisted, where Dr. Amandeep Singh will do a demonstration for you. And finally, CAD/CAM environment. So, 3 approaches are there.

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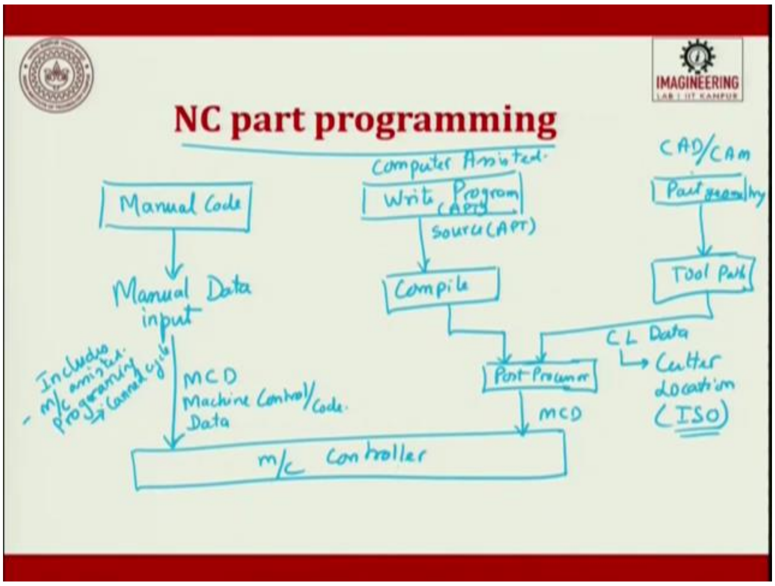

When we see this part programming, if I want to put in a block diagram, this is going to be manual code. So, you see from a library function and then you manually input, manual data input and then you try to get the machine control, this is the machine controller. So here, it will be, it includes, machine assisted programming. So, we will see that currently just register the name CAN cycle, we will see what is CAN cycle little later. And then we will also have MCD, which is nothing but Machine Control Data, people otherwise call it as code date also.

This is manual, then we will see what APT. So, this is APT, so this is computer assisted, here we are manually writing, but here we are using computers to assist us, computer assisted. This goes to a compiler and then it goes to a post processor, goes to a post processor and then it goes to a MCD. So here, there is a source. So. you will have a source code, source for APT, compile.

So, the next one is going to be CAD/CAM environment. So, here we will look at the part geometry and then this will try to generate a tool path, from a tool path we tried to go to this post processor. Here what we do is, we try to do CL data which is nothing but Cutter Location data, which is in ISO format. Because from controller to controller you keep changing and so, you have to have a standardized one. So, we always use the international standards.

So, cutter location data is given and that comes to the post processor and finally, it goes to the MCD. So, if you look at it, 3 verticals, so one vertical is manual, which you look into the component, you write the program, it is given to a controller and machine controller happens or we can put it as machine. So, the other way around is looking into the part the computer itself generates a program, that is write program, then it gets compiled, then it is then sent to a post processor, it is sent to the machine controller.

CAD/CAM is you draw the CAD, from the CAD the tool path is generated and from the tool path generation you see the cutter location, because here the cutter moves relative to the workpiece. So, you see the cutter location data, it is postprocessor and then it comes into a controller.

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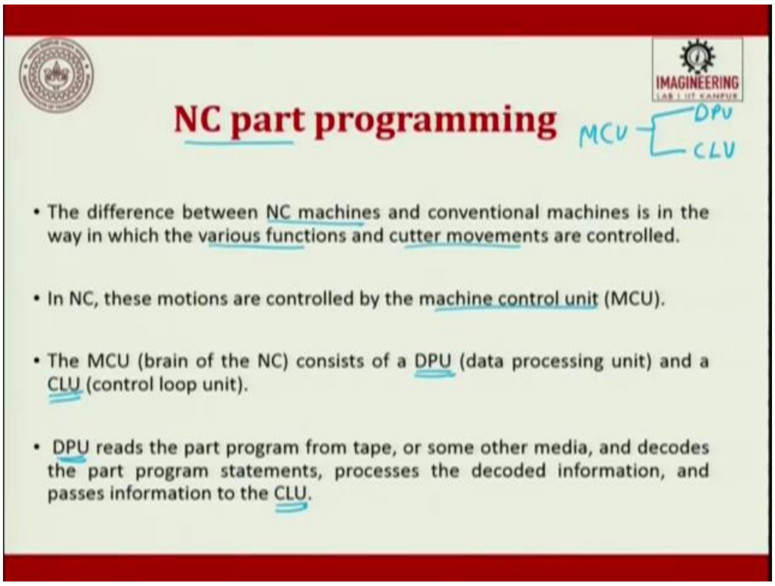

So, when we look at the NC part programming, the difference between NC machine and the conventional machine is the way in which the various functions and the cutter movements are controlled, this is the only difference. In NC machines these motions are controlled by MCU. MCU is nothing but the brain of a NC machine which consists of 2 things, one is called as data processing unit, the other one is control loop unit.

2 things are there, MCU has to process the data and also control loop, it has to have. So, MCU is split into 2, DPU and CLU, Cutter Loop Unit. The DPU reads the part program from the tape. Today tape is not there, earlier it was punch card, then it went to tape, then it went to cassette. Now it is all stored in computer itself, server itself. So, DPU reads the part program from the server or some other media and decodes the part program statements, processes the decoded information and passes information to a control loop unit. So, DPU, Data Processing Unit pushes it to a control loop unit.

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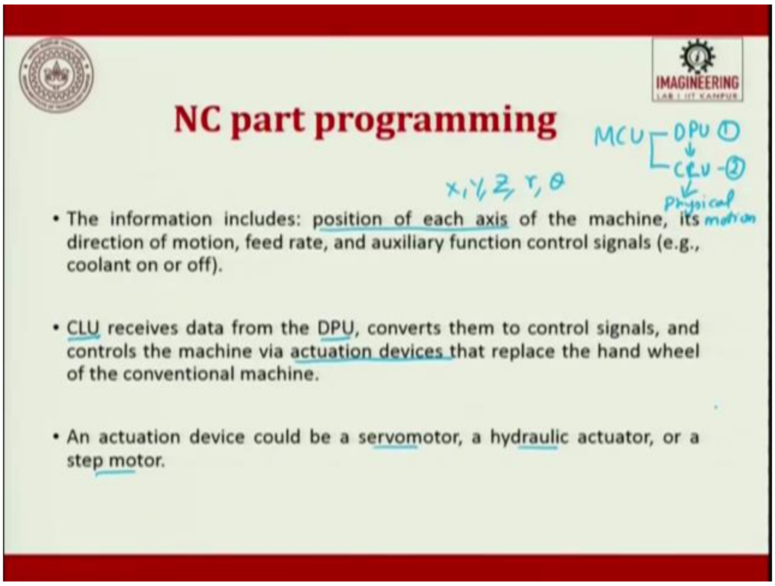

The information which is included are, position of each axes, we have seen x axis, y axis, z axis, r, theta all these things. So, these are all the position of each axis on the machine. Its direction of motion, feed rate and auxiliary functions, function controls signals example coolant on, coolant off. These are the information which are included in the part program. CLU receives the data from DPU, converts the controls, converts them into control signals, and controls the machine via actuation device that replaces the hand wheel of the conventional machine.

So, it is very clear, MCU first has 2 parts, DPU does its first operation and then it gives to CLU, this will be the second. This is going to convert a physical motion of spindle on, spindle off, coolant on, all these things are going to be controlled by CLU. CLU actuates devices, very important note it down. CLU actuates devices, DPU position etc. An actuation device includes servomotor, hydraulic actuator, or a stepper motor or a step motor.

So, we have seen all these things in detail, servomotor, stepper motor, hydraulic drives, pneumatic drives, all these things are actuations which are controlled by CLU. So, the MCU does the most important part, that is why it is called as the brain of a computer.

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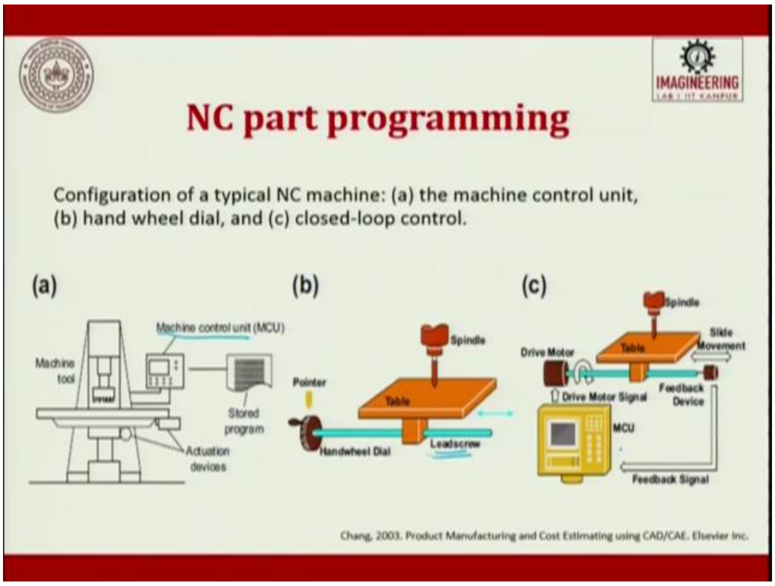

So, you can see schematic diagrams. So, here you can see a configuration of NC machine. So, you see an MCU, this is an MCU, though it looks like a monitor, behind that it has so many processing units. So, that does the MCU job and this is the typical machine. So, these are the actuation drives, and here is a storage device, it can be a pen drive or a USB or it can be a floppy disk, it can be a hard disk. So, so many things can be a storage program device.

So, if you look at it, a hand wheel type, a conventional type, you have a pointer you look at the reference of a pointer keep rotating the wheel. So, much of advancements happens in the lead screw and the table moves up and down. So, you will have a spindle where to activate it so that you can drill a hole or not. So, this hand wheel dial is replaced in a CNC like this. So, you will have a drive motor, this drive motor is attached to a lead screw, the lead screw in turn is attached to a feedback device, that feedback device gets the signal and give it to MCU.

So, MCU decides whether to give error function compensation or not. So, this is the closed loop system and this is the open loop system conventional type. So, these 3 figures clearly tells you what is an MCU, where is an MCU and then how is it in a hand wheel type conventional machine and in a closed loop controller.

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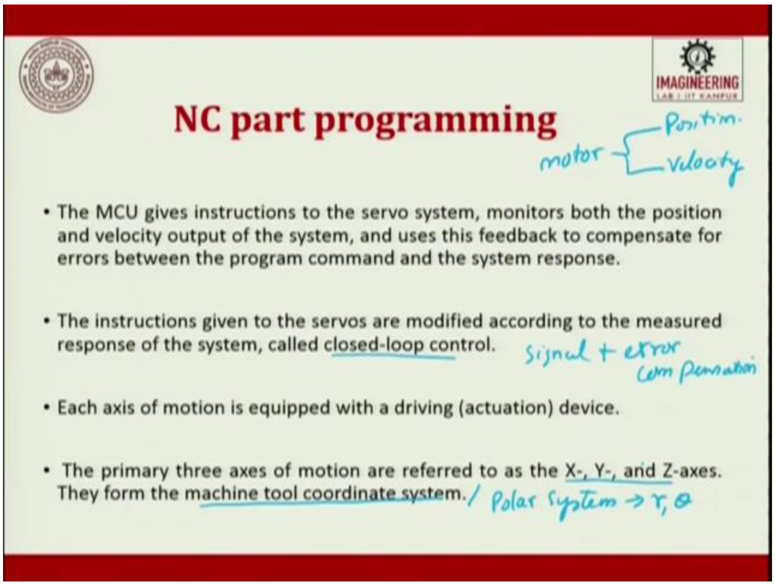

The MCU gives the instruction to the server system, monitors both the position and the velocity of a system. I told you as far as motor is concerned, you have only 2 things to monitor, one is the position, the other one is the velocity, with which you can try to control the movement of the tool or the work piece. So, monitor both the position and the velocity output of the system and uses its feedback to compensate for error between the program command and the system response.

The instruction given to the servo are modified according to the measured response of the system called as closed loop. If there is no feedback, it is an open loop system. The figure what we showed for a conventional type, it is an open loop system. If you want to have a closed loop, so then you get the error signal from the lead screw and give it to the MCU. MCU compares it and then it gives signal plus error compensation, so that you try to reach the required output.

Each axis of motion is equipped with a driving device. The primary 3 axes are given as X, Y, Z and then it forms the machine tool coordinate system. You can also have polar coordinate system, which talks about r and theta. Polar coordinate system is also possible in a CNC machine. But by and large all the CNC machine uses only Cartesian coordinate system, wherein which we have X, Y, Z as a primary axis.

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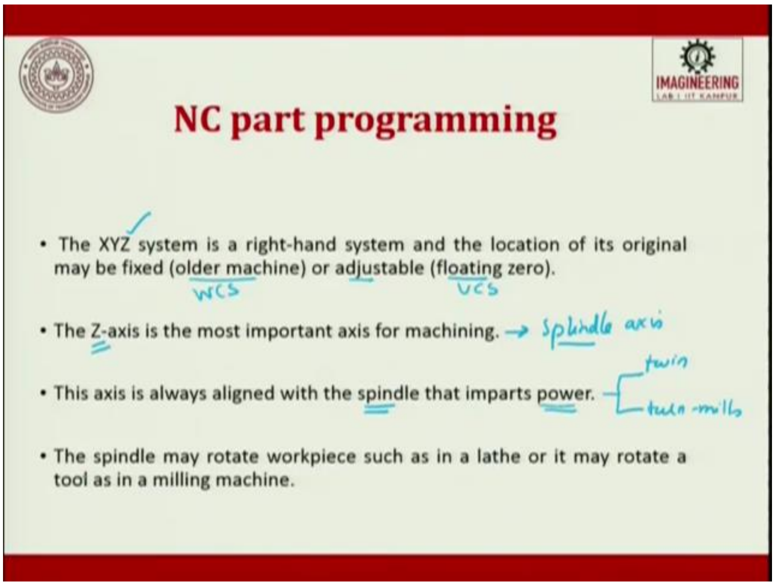

The XYZ system is a right hand system, and the location of its origin may be fixed or adjustable. So, this is what I said world coordinate system or user coordinate system. So, we call here in CNC as old machines, that is a fixed one or we call it as adjustable which is floating 0. The Z axis is the most important axis of the machine, where it becomes the spindle axis.

So, when we use the right hand system, we first to fix the Z axis, then these 2 are orthogonal to it. So, you can quickly find out what are the X and Y axis, the axis is always aligned with a spindle that imparts power. So now the question comes, we saw twin spindle and we saw turno mills. So here also, these are the variations we saw in the turning machines and in the milling machines, CNC.

So here also, we will always see a spindle where power is imparted will be the Z axis. The spindle may rotate the workpiece such as in the lathe machine or it may rotate a tool in a milling machine, immaterial of it, the spindle which is powered becomes the Z axis.

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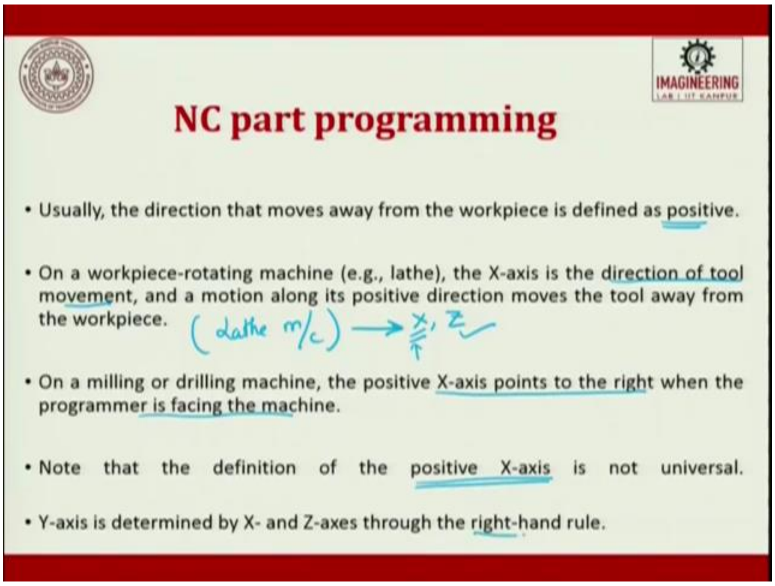

This is the convention followed, however there are machines where today they have 2 spindles where both the spindles are powered.

So, at that point of time I would request the students to go look at the manual which is attached to the machine and understand and then start programming. Today so many advancements are happening. So, in this, so you are supposed these are the logics if you understand it is excellent. And then, please look at your manual before writing a program for a particular CNC machine.

Usually, the direction that moves away from the workpiece is defined as positive. On a workpiece rotating machine, example lathe machine, the X axis is the direction of the tool movement and a motion along its positive direction boost the tool away from the workpiece. So, in a lathe machine it has only 2 axes because this we know it has a spindle axis. So, then you will have X and Y. So, here you have only X and the X is the direction of tool motion.

So, on a milling machine or a drilling machine, the positive X axis points to the right, when the programmer is facing the machine, X axis points to the right when the programmer is facing the machine. Note, that the definition of the positive X is not universal. Repeatedly I am saying, these are the conventions. Before writing a program for a CNC machine, please go through their manuals and see what are the coordinates they are using. Y axis is determined by X and Z, Z is fixed, X is fixed, now what is left is Y, X and Y are orthogonal, so you can easily find out your Y axis by using right hand rule system.

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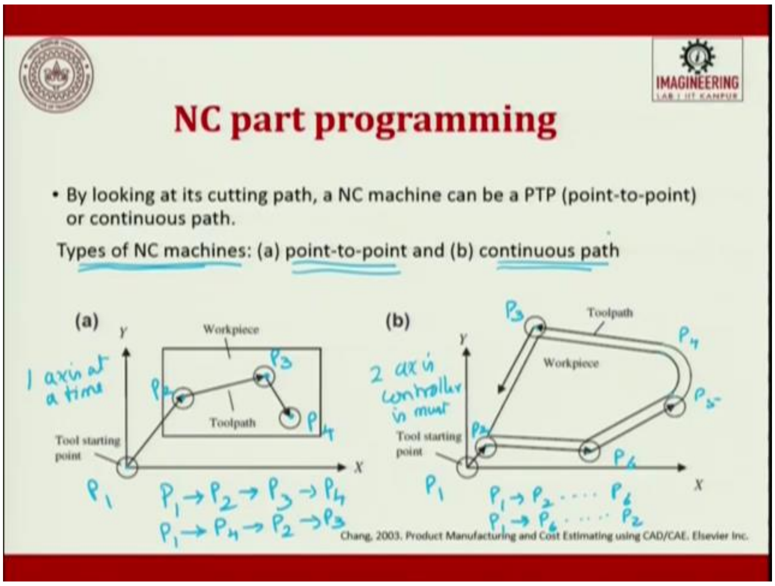

There are 2 types of NC machine programming, one is called as point-to-point, the other one is called us continuous. In point-to-point programming, we are only worried about the starting point and the ending point, we are least bothered the path it which it traces towards the output. For example, let us take this as P1, P2, P3, P4. So here it is said as, P1 go to P2, then go to P3, then go to P4.

You might ask a question, since these points are only important, why should I go from P1 to P2, you are left free, for example, you can start on P1, go to P4, do P2 and then come to P3. We are only worried about the points and we are not bothered about the path in which it traces. So, what is the big deal here, the big deal is you can move only 1 axis at a time, you can move in X first, and then move in Y, move in Y first and then move in X.

So, these machines are the first primitive machines, which came in CNC. So, the point-to-point machine was the first primitive machines, where they automated and then they started drilling. So, for drilling operations, it was playing a very, very important role. And why did they come, because you do not have to relocate the component to do multiple things. So, that was a big advantage.

From here they moved to continuous path, in continuous path, it is not the points, it is also the path which it has to generate is very important. Again P1, P2, P3. Let us take it somewhere here, we will have one more point P4, then we should have one more point P5, then we will have P6, and then P2. So, here what happens, you can start from P1 to P2 go up to P6, or you have another logic which can start from P1 to P6 go up to P2 and finish.

In between points you can not change the sequence. So, here apart from the end points, the path in which it is tracing is also important. So here, I need to have 2 axes control simultaneously, control, controller is must. So, this is the difference. So, from drilling, as and when we started understanding more and more and more, we started controlling 2 axes, of course, today you can control 5 axes simultaneously, this was in the primitive stage.

So that is why we say, there are 2 types of NC programming, which is point-to-point and continuous. When we are trying to drill it is point-to-point, when we are trying to punch it is point-to-point, when we are trying to paint it is continuous, when we are trying to machine, milling, continuous, when we try to do lathe, turning, continuous. So, there are 2 such, even today point-to-point is used. Point-to-point machines are less expensive machines as compared to that of continuous.

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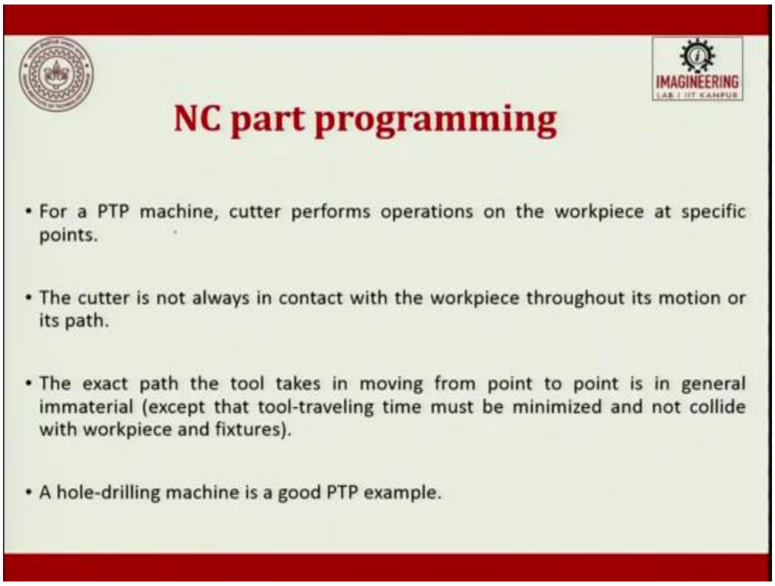

For a point-to-point machine, the cutter performs operations on the workpiece at a specific point. The cutter is not always in contact with the workpiece throughout its motion or its path. The exact path the tool takes in moving from point-to-point is in general immaterial. This is what we explained and I have also told you, what is the hardware involved behind. Hold drilling operation machine, is a good example for point-to-point.

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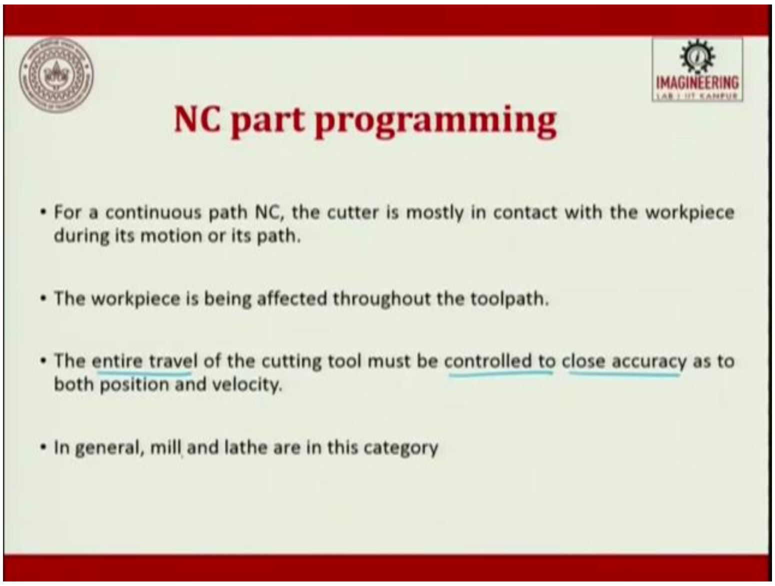

For a continuous NC machine, the cutter is mostly in contact with the workpiece during the motion. The workpiece is being affected throughout the toolpath, the entire travel of the cutting tool must be controlled to close accuracy as to both position and velocity. And in general, milling and lathe machines falls in this category.

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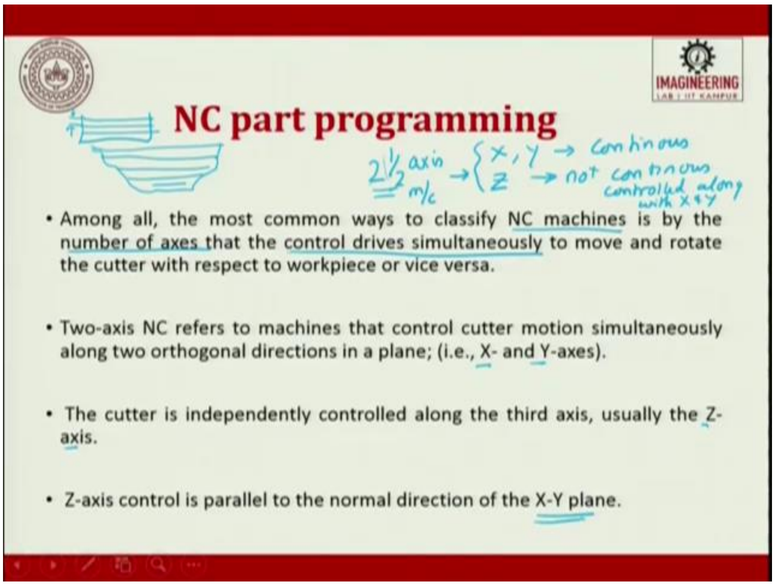

Among all, the most common way of classifying NC machine, is by the number of axes that the control drives simultaneously to move and rotate the cutter with respect to work piece or vice versa. So here, we are now defining the NC machine, number of axes simultaneous control. Now, we are going into continuous simultaneous control. So, there are possibilities where X and Y is continuous and Z axis is not continuously controlled, controlled along with X and Y axis. So, these machines are called as 2 and a half axis machines.

I will repeat, among all, the most common way of classifying NC machine is by the number of axes that the control drives simultaneously. So here, the 2 axes are simultaneously controlled, after going to a particular spot then you try to move the Z axis or you set the Z axis to certain depth, and then move X and Y. So, these machines are called as 2 and a half axes, you have 1 and a half axes, 2 and a half axes, 3 and a half axes, 4 and a half axes machines. One and a half axes machines, is nothing but point-to-point. So, we leave that.

So, we start with 2 and a half, 3 and a half and, 4 and a half axes machines. Moment I say half axis, then this half axis is not simultaneously control. I will fix a Z depth, and move X and Y. If I want to make a standard pocket, I do layer by layer machining. So here, I give the Z depth and control X and Y. But if I have a contour to be made, while machining without undergoing layer by layer, it is not possible with 2 and a half axis machines. Again, here also you will do layer by layer. So, this is what it is.

The 2 axis NC, refers to the machine that controls cutter motion simultaneously along 2 orthogonal directions X and Y. The cutter is independently controlled along the third axis which is Z. So, Z axis control is parallel to the normal direction of X, Y plane. So, this is a 2 and a half axis machines.

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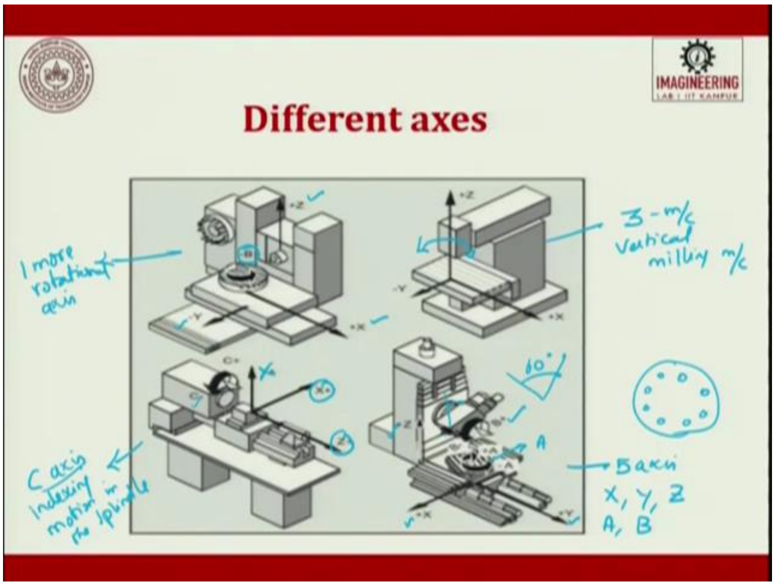

So you can see, different axes I have put. So, this is a 3 axes machine which is vertical milling machine. So here, it is the same vertical milling machine, but I have an axis more one is, I have one more rotational axis. You have Z, X, Y and you also have B. So, now let us try to go for these milling machines. Let us try to go for a turning machine. In turning machine, I have X axis, Z axis, I will not use Y axis, I also have here one more axis which is C axis.

The C axis is going to give me an indexing motion in the spindle. So, generally spindle rotates, you cannot control 1 RPM. So here when you have a C axis control, even that 1 RPM we can able to discretize and control very precisely. So, C axis indexing motion in the spindle, so you will try to control it even the 1 RPM. So, here it is, rotation is RPM, controlling 1 RPM. So, that is C axis.

Please understand, if you have a disk and you have to drill holes, now what you do is in a flange we try to turn the flange, and the remove the flange out, and then go to a drilling machine and start doing it. Now, here what happens I am giving you a freedom, you index and start drilling. So, C axis control. So, it has 1 more rotational control is given. When we come to here, it is a 5 axis machine.

So, you can see X, Y and Z and then you are having 2 more rotations, one is this spindle varies there on the cutter, is able to swing that is B and what we give here B, we are able to have a control over the pilot rotation which is A. So, here you will have X, Y, Z, A and B. This is a 5 axis machine, and here the B axis will not be 360 degrees, B axis will be like, maybe 60 degrees. So, this can swing this is a 0, 30, 30. Here it will go 360, A axis.

So, these are the different axes. So, you should understand, first how to fix the axes using the right hand rule. It is very clearly said the spindle access, powered spindle axes will be Z, then right hand rule you will have X and Y. So, now, rotation about X, rotation about X becomes A, rotation of a Y becomes B, and rotation about Z become C. So, rotation about Z becomes C, rotation about Y becomes B. So, here it is A and B there, but this is a convention, please look into the controller manual before writing a program.

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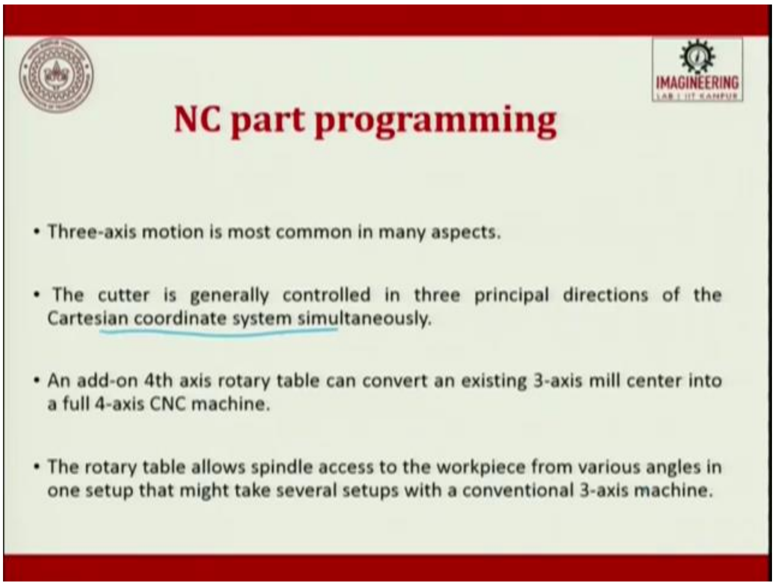

The 3-axis motion is the most common in many aspects. The cutter is generally controlled in 3 principal axes of Cartesian coordinate system, so it is mutually perpendicular. And, addition of 4th axis rotary table can convert and exist in 3-axis machine into a four-axis machine. So, today if you want to machine a complex job, you need a five-axis machine. A rotary table allows spindle access to the workpiece from various angles in 1 setup that might take several setups with a conventional 3-axis machines. For example, last lecture we saw on a cylindrical shaft you had a square which is made and holes made.

So, all these things if it has to be done in one go, in one sitting, then we go for higher and higher axes.

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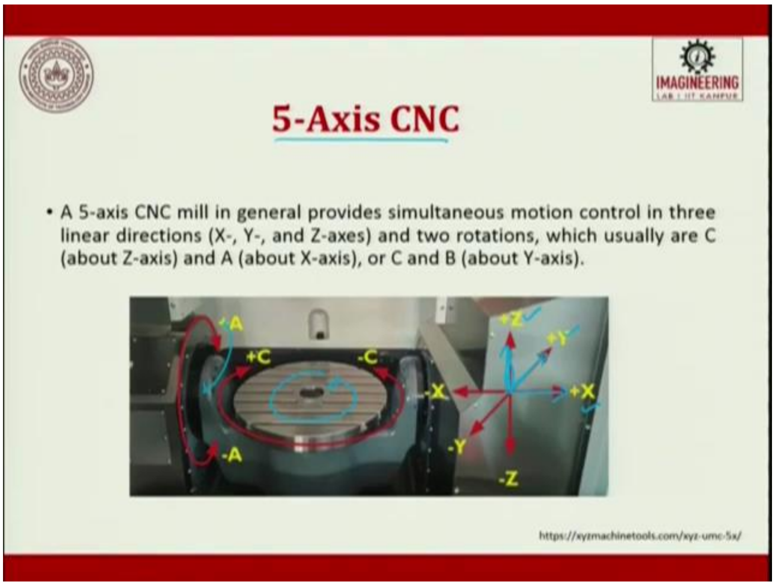

We have seen in depth, so one more example, so that you clearly understand. X, Y and Z which are mutually perpendicular, so this is your X, this is your Y, and this is your Z. So, the same thing, negative. Now, let us go here about X rotation, it is A axis, so it will move like this. So, it can swing like this, it can swing. And then, about Z you have C axis which can rotate like this. So, this is a 5-axis machine.

So, for 5-axis machine, manually writing program is next to impossible because as an when X, Y, Z keeps moving, you also will have 2 terminologies called as r and theta. So, either you develop an equation, define the equation, ask the program to go along with the equation, so you interpolate the points or you use CAM software. So today, it is advised to use CAM software for writing programs for 5-axis machines. Thank you.