Design Practice - 2
Prof. Shantanu Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology-Kanpur

Lecture - 26
Numerical Control Programming

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Hello and welcome to this design practice to module 26 this week we will be focusing mostly on the computerized machines particularly the computer numeric control machines. We will also be looking into aspects related to rapid tooling and rapid prototyping and what these are in terms of the current technology. So, the reason why we want to integrate this area to the overall area of design is that rapid prototyping happens to be a very, very amenable tool for 3d visualization particularly creative visualization in 3d space.

Anything which is you know laid out in terms of computer-aided design package can be realistically made into a certain form or shape. And it is very important for designers to realize such creative visualizations of 3D geometry for which it is important that rapid prototyping as a process is very heavily used. In fact there are relative manufacturing processes like the SLS selected laser sintering as well as FDM fusion deposition modeling which are principally in principle made with an aspect of you know designing and prototyping before development of the product in in mind.

So, therefore it is absolutely important for us to know some of the aspects as a designer of how you will integrate and try to compare to control machinery how would you use to do aspects related to rapid prototyping or rapid tooling. And you have already extensively looked into how CAD geometry is handled during the first part of the beginning of this course where we talk about various aspects like coordinate mapping.

We talked about various aspects like curve fades how to generate a surface profile in terms of a database you know of coordinates so on so forth. So, the idea is going on this once you have the CAD model ready how would you interface it or what you're going to do to be able to realize such a complex 3S object.

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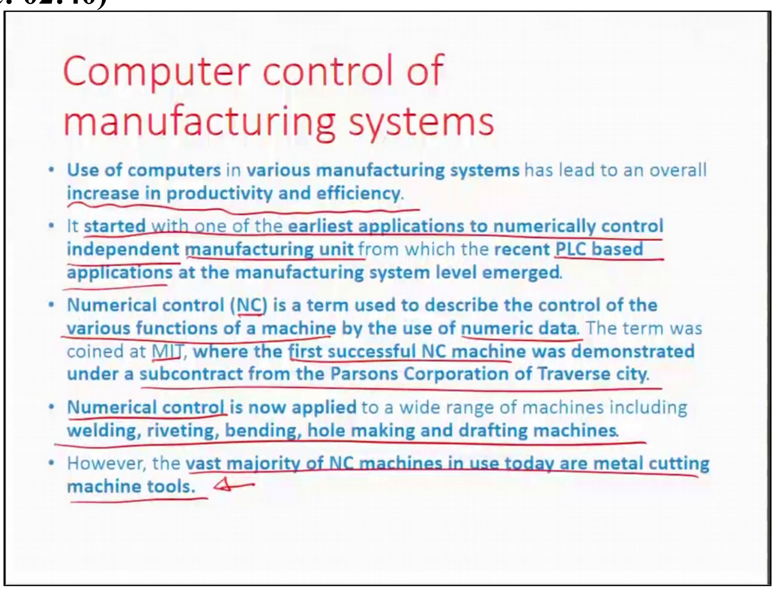

So, let us first justify why it was needed for the industry to come into control manufacturing systems and how it gives you a lot of user convenience when we talk about computerization of various manufacturing systems. So, obviously there has been a great amount of work towards how to increase the overall productivity and efficiency of any system from design to development to the whole phases of product lifecycle.

In fact in design practice one course there was a dedicated section to concurrent engineering where we talked about how to take a design forward with a bunch of different activities of an organization. So, that you can realize a full and final design in terms of you know laying out in terms of the process which is subsequently involved and also in terms of different aspects of the product lifecycle. If you move all at once with everybody all stakeholders involved. So, there it is important that if we could have this freedom and luxury of controlling the manufacturing through a CAD enablement where whatever we change on the design can be rapidly altered you know can be rapidly manufactured.

It will always be leading to a very useful ecosystem so when we talk about characterization of manufacturing systems it started with one of the earliest applications which is also otherwise known as numerical control. So, in fact the idea was to make a certain manufacturing unit independent through control using some numerix. And from this particular concept now in the recent times there has been an emergence of this programmable logic controller based applications and even factoring system level.

So, numeric control or NC as we popularly know if you look at historically it is about the utilization of various functions of a machine through a numeric data. So, how beautifully we can control the different functionalities in a machine typically we would like to see either the workpiece moving with respect to the tool or the tool moving with respect to the workpiece. So, if we could actually menu over that through in a logical manner through numeric data very rapidly.

It will automatically lead to precise manufacture of whatever be the design it will also have an aspect of manufacture the designers requirement. So, if the designer has an enablement of you know a caddy Nabal menteur whatever he is designing he would be just changing the CAD design and everything will fall in place and get manufactured accordingly. So, that is in fact the vision through which one can think of these computer controls related to manufacturing systems which is actually the sort at the end of the road for any design to go through.

So, the first successful NC machine historically were demonstrated really in MIT there was a subcontract from Parsons corporation of the Traverse City which actually resulted in retrofitting and otherwise normal machine with a variety of motors and the controller which was actually invented to begin with in the late 1940s by DC do all. But this was one of the first applications of that controller.

So, it could actually record something and playback okay and so this first initiative of retrofitting a machine knows towards recording something which was like a set of commands which it would play in of instructing variety of different motors which would enable relative positioning between the work piece and the tool to happen in a very precise manner in a repeatable manner.

So, whatever emerged from here today the very famous numerical control in fact it has left the domain of machining and emerged as a general domain where not only machining.

But a variety of other applications like welding pressing riveting bending whole making you name the application of manufacturing system they are all CNC enabled today. So, a vast majority of fencing machines in use today are metal cutting machine tools most of the machining shops find a lot of utility of this computer numeric control machines. And so what I am interested to sort of let you know is that what are the different features that these machines would have and how would you develop a common language through which you would interact with these machines. In other words I am going to teach you a little bit of CNC programming as we go along.

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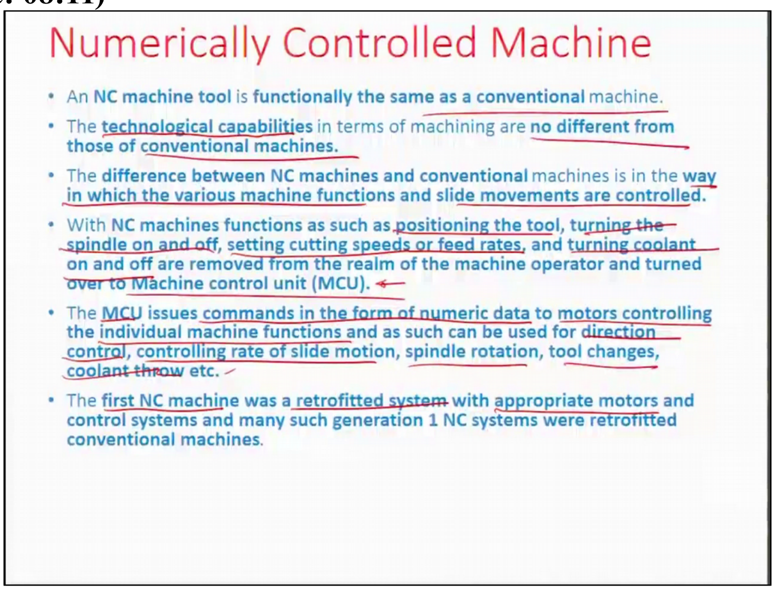

So, when we talk about NC machine tools they are functionally same as convention machines of course in terms of technological capabilities you do not really find many differences from conventional machines only difference between NC machine and convention machine is that there is a difference in way in which various machine functions and slight movements are controlled.

For example positioning of the tool turning the spindle on and off setting cutting speeds or feed rates turning cooling stream on or off etc are now controlled through something called a machine control unit. It is removed from the domain of work of the operator or the you know with manual switches etc getting eliminated. So, it is more precise and it is also to some extent completely automated.

So, in the numerical control machine the machine control unit MCU issues commands and this commands are in form of numeric data which are able to now perform a variety of tasks including individual machine functions, including motor controls. You can use commands to rapidly change directions, you can control rates of slide motion you could also control spindle rotation tool changes coolant throw so on and so forth.

The variety of these different processes can now be controlled numerically so when we look at the very first NC machine it was a retrofitted system I think I have just mentioned in the last slide about it and such system was with appropriate motors with different torque RPM's and this was the first generation and say system. All these motors were controlled through a central control and this control was otherwise known as the machine control unit.

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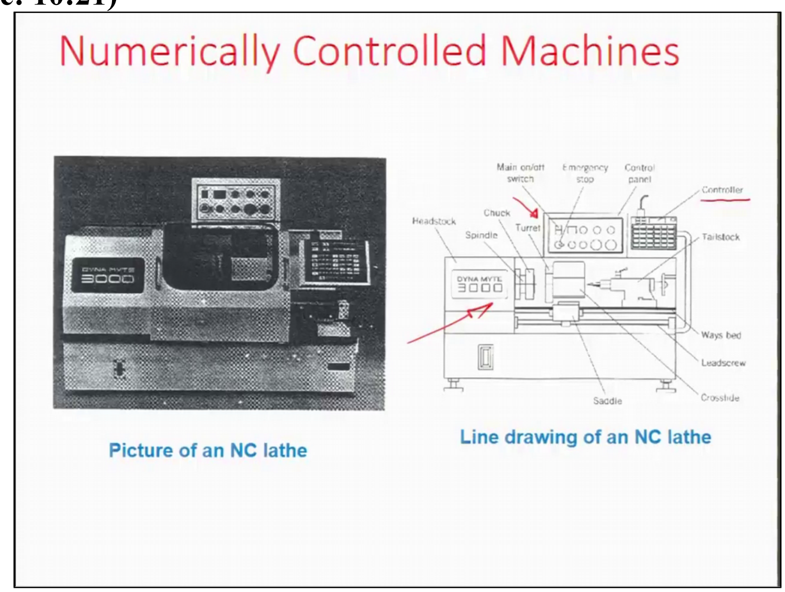

So, this is how it started off in fact there is a line diagram also and a schematic of such a machine ok you can see there is a otherwise conventional lathe here which has a headstock and tailstock, carriage, saddle, cross slides whatever normal machine normally it has but the difference that it has is that everything is controlled through this machine control unit on a controller. And there is a set of switches which are used to control through the controller the various aspects of this particular machine. This is a real picture of an NC lathe which is CSC CNC enabled.

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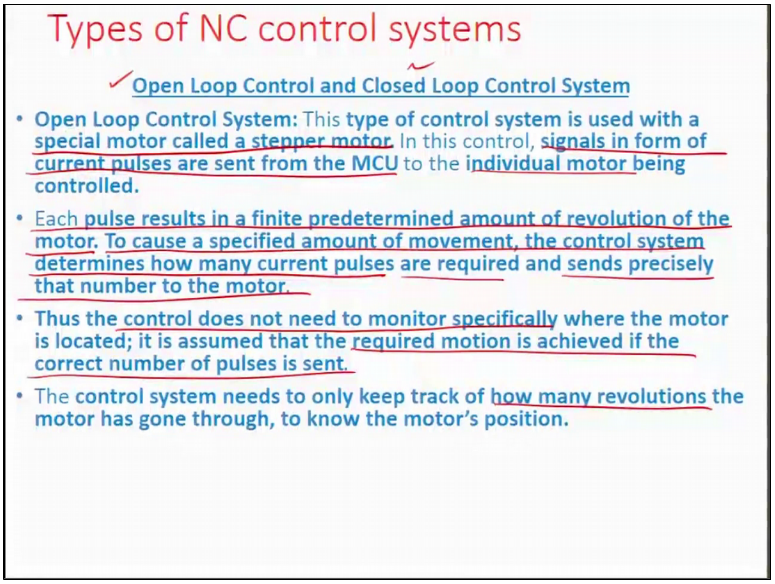

When we go into understanding the programming aspects a little bit of understanding for what all systems are available within any machines are very important. One of the very important aspects behind NC machine is the type of control that has. And we can classify such control as either open loop control or closed loop control. And as the name indicates the open loop control is really without any feedback signal.

So, the signals are so precise normally carried forward through stepper motors where you give a number of pulses and the motor operates based on these number of pulses by a certain amount. And the precision is maintained throughout as pulses are sent in. So, you really need not monitor as to was it there an overshoot or did it not reach. So, therefore in the open loop control system is used with a special motor called stepper motor.

And signals in form of current pulses are sent from the machine control unit to the individual motor and very precisely controls itself actually what happens is that each pulse results in a finite predetermined amount of revolution of the motor and to cause a specified amount of movement the control system determines how many current pulses would be needed accordingly sends precisely that number of pulses to the motor.

And therefore it is understood that the control system need not anymore monitor specifically because the motors are pretty accurate. It is assumed that the required motion would be achieved if correct number of pulses are generated and sent to the motor system. The only thing that the control system probably needs to keep track off as how many revolutions the motor has gone through and that also it is kept somewhere in the database.

So, that for future progress of how many more it would need to reach a certain destination or a target or after the operation is over reach back to the origin is determind. So, that is how you define the open-loop control system.

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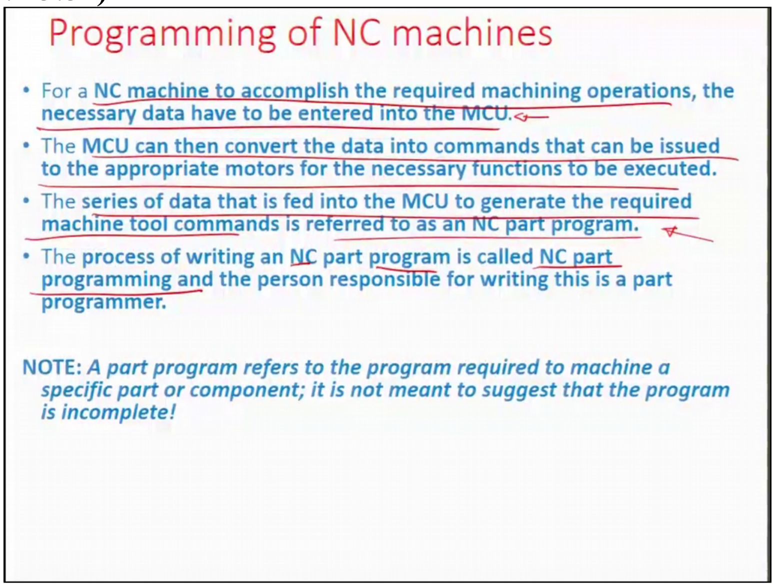

So, there is also closed loop control system in some of the particular applications and one of the reasons is that metal removal processes normally are very high torque processes and sometimes they promoters may not be sufficient and in and in such high traffic applications you would prefer to use conventional variable speed DC motors or more popularly known as servo motors. And the advantage that stepper motors have over servo is that steppers have very less self inertia aspects and they can quickly start and stop whereas salvos do not.

So, they overshoot or they sometimes you know undershoot based on what is signal that is provided to such DC motors. So, DC motors definitely have an important advantage of being able to generate very high level of torques and also the advantage that they can be reversed instantly however they cannot be cost to move in very precise amounts. And therefore this control system would be slightly different so it will need a signal as to what would be the movement executed.

And supposing that is overshoot from the target position or you know there is a gap between the current on the target position. You need to be able to know about it and so the Machine control unit has a closed loop control through something called as a solver. So, what the resolver does is to give a signal of whether the target position was achieved and what is the difference and accordingly a signal is generated again by the MCU to ensure that the target position is finally achieved.

So it is fed back as a signal to the controller from the resolver and there is all where is responsible for any of the error determinations and subsequent Corrections in terms of additional motor movement which is executed by again the central control. So, that is what closed-loop control would typically mean. So, having said that let us also talk a little bit about some other basic programming aspects of NC machines.

Because in this particular module I would like all of you to go through this topic of how you can logically make a machine control you need to understand the requirements which come from a CAD geometry aspect which you have done in details earlier. So, for our NC machine to accomplish the required machining operations the necessary data have to be entered into the machine control unit.

And MCU can then convert the data into commands that can be issued to the appropriate motors for necessary functions to be executed. And the series of data that is fed into the MCU to generate the required machine tool command is what we refer as NC part program. So, one has to very clearly understand that part program is merely ah qualitative term which means programming for a certain part or an item it does not mean that it is a partial program or something.

So, do not confuse okay a part program is not a subroutine it is actually a program written for fabricating a machine part okay or an item. So, obviously the part of writing the NC program is called part programming the person responsible for this part is the programmer.

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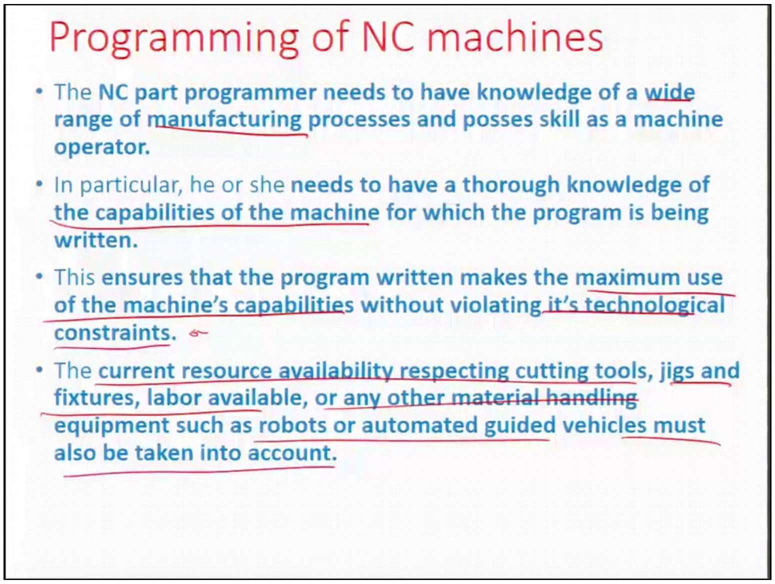

So, the first thing that a programmer needs to understand why is starting to write an algorithm for the machine to execute a certain operation is a wide amount of manufacturing knowledge okay. Because obviously how a certain CAD geometry can be executed in terms of machining decisions would be known to somebody who is trained in that art. And so therefore a part programmer necessarily should pretty possess the necessary skill as a machining operator or a operator for a certain manufacturing process for an NC part program to generate.

So, the one aspect that one needs to have in mind is thorough idea of the capabilities that the particular machine has for which a program needs to be developed. And while maximum usage of the machines capabilities are being targeted one has to be aware of its technological constraints and there should not be overshoot so that the constraints become important okay. And the current resource availability in respect of cutting tools jigs fixtures labor available any other material handling equipment so just robots or automated guided vehicles must somehow be also taken into account when we start doing NC programming see part programming.

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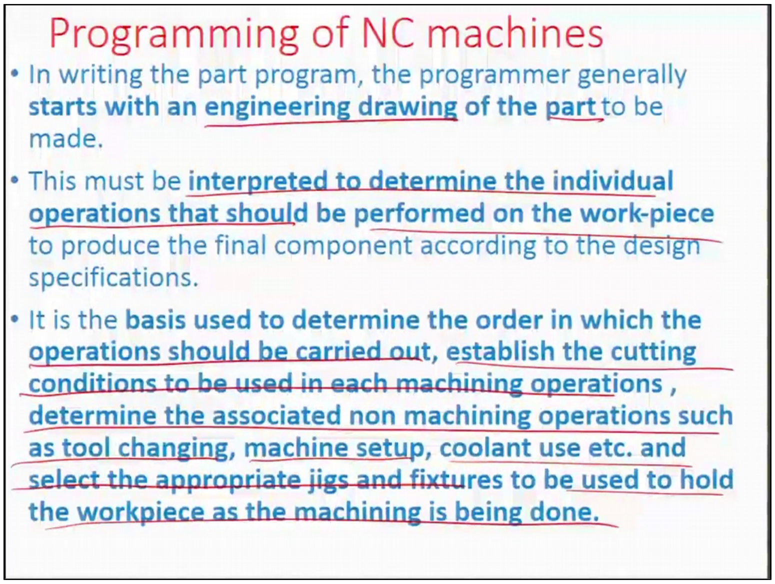

So, what a programmer needs to do is to start from a engineering drawing or a CAD drawing of the part which contains numerical data and the first thing he must look at is look at the data and interpret to determine the individual operations that should be sequentially performed. So, that a certain shape can get realized eventually an engineering part can get realized eventually. So, this is the the basis used to determine the order in which typically operations should be carried out okay establish the cutting conditions to be used in each machining operations determine the Associated non machining operations such as tool changing machine setup coolant used etc.

Select a property jigs fixtures to be used to hold the work piece of the machining is being done and somebody trained in the art can only understand these things well.

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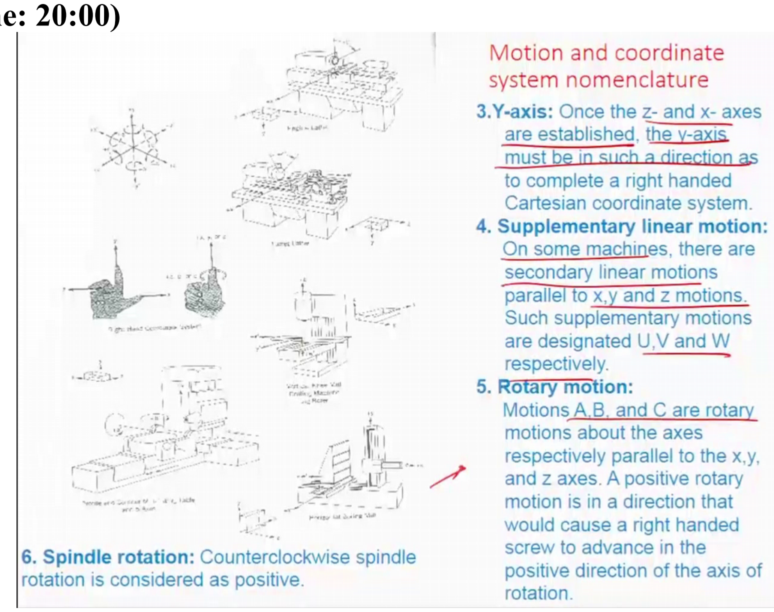

So, because NC system or NC motion involves the relative positioning between the tool and the workpiece in aspect on that machining or cutting happens one has to have some guidelines in order to know what would be conventionally used as the positive XYZ directions and similarly XYZ rotations or rotations along these directions. So, the most important axis for machining is the Z axis okay and a certain nomenclature is followed for determining the coordinate system and how you move from one coordinate to the other.

So, one has to always remember that the Z axis is always aligned with the spindle that imparts the basic cutting power to the particular machine now there can be various cases there can be a case where the spindle rotates or there can be a case where it rotates the workpiece probably a case in lathe or it might be a tool that it rotates in case of meaning for example. So, based on different machines you have spindle doing variety of different operations.

But the cutting power is done or is imparted by the spindle and their axe is always alliance with the spindle direction or the spindle axis. Supposing there exist no such spindle x-axis there are machine tools for example cleaners and shapers where there is no spindle as such which rotates you know there is probably a horizontally oscillating tool head which does scratching or scrubbing you know of the material workpiece while metal is removed okay.

So, in those cases one has to assume the Z-axis to be perpendicular to the workholding surface and having said that the positive motion in Z would tend to increase the separation between the work piece and the tool. Let us look at for example the different cases that are mentioned here this particular case shows a vertical milling machine probably a face milling system okay where there is a spindle which is in this particular direction okay.

And now the worktable which is put here so obviously the workpiece is kept on the work table and the spindle contains the the end mill which can be used for in milling operations. Now when the mill milling cutter moves towards the workpiece it always is considered as the negative Z. So, obviously Z is along the spindle and negative Z is when the tool workpiece gap decreases on the other hand positive Z is when the tool work with Chris cap increases.

So, when we are looking straight ahead let's say into the the column which is holding this particular tool we are looking from the spindle towards the column okay so that basically would mean the column going is that that negative would mean the column going down towards the workpiece and that positive would mean the column going away from the workpiece, so, having said that in this kind of a situation if you were to look at the positive X-direction.

The positive x direction would be going right words as you know you have a positive and negative Z going right words to the spindle okay would be treated as in the positive X-direction. So, there are other machines here for example in this case there is a rotating workpiece what piece of course is mounted in the spindle what happens in a normal lathe. So, the Z axis would actually align to the spindle here and it would be part of the workpiece.

And so if the tool which is somewhere here goes into the workpiece or towards the work piece so that it starts shaving off the material ok would be treated as a negative Z and if the tool moves away it is treated as a positive Z. So, these are some examples of how Z axis could be in the mind. So, once the positive negative Z is freezed the only thing you need to do is to freeze the positive X axis direction.

Because obviously the right-handed coordinate system being utilized the Y-direction would depend on the positive Z and the positive X-direction. So, the X axis again is the principal axis of motion in which moving elements is positioned it is parallel to the workholding surface and is arranged to be horizontal if possible on machines with rotating work pieces it can be radial it is radial and parallel to the cross slides on machine with rotating tool.

If the z axis is horizontal the positive X motion is to the right when looking from the spindle to the workpiece I think I had mentioned it in the a few few minutes back that when we were looking from the the spindle axis the Z axis of a vertical mill towards the column on your right is the positive X axis and so if your positive X axis is only right. But obviously the y axis would be towards the column the positive y axis would be towards the column from the particular spindle.

So that is how you determine the XY and Z axis directions and obviously if we were to use the right hand grip rule if the thumb pointed out towards the direction of the positive Z then the direction of rotation positive rotation along the Z axis would be actually how the fingers coil okay so this direction that would be looking from the top it is actually anti-clockwise okay so the fingers are coiling in this case from the top end anti clockwise direction.

So, that is positive Z rotation and similarly you have positive X rotation along the positive X direction with thumb pointing towards the positive X direction and so so on so forth in the Y direction as well. So, that is how you define how the different axes and the different angles are in all the three axis. so once the Z and X axis are established obviously the Y axis automatically completes right-handed coordinate at a scene coordinate system.

There are also certain supplementary linear motions on some machines there are secondary linear motions parallel to X, Y and Z motions and such supplementary motions are designated as U V and W and I think I have mentioned about the rotary motions ABC to be based on the positive X, Y and Z directions and the right hand grip rule being applied. So, I think I will end this particular lecture here but in the next lecture given all this basic information about computer enabled machines we would like to start doing some programming in terms of numerals and understand the language of the mythology behind such machines, thank you very much.