Computer Integrated Manufacturing
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Lecture 12
Computer Numerical Control (Part 1of 4)

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So, welcome to the next lecture on Computer Numerical Control, till now in our course we were seeing the importance of computer, the digitization how it revolutionized manufacturing, then we went into CAD, we saw fundamentals of CAD and we also saw a little bit of mathematics involved in terms of transformation and free form curves. Now, from there let us move to the next part of the course on Computer Numerical Controls how is computer used to control manufacturing using the numerical data. So, this is otherwise called as CNC.

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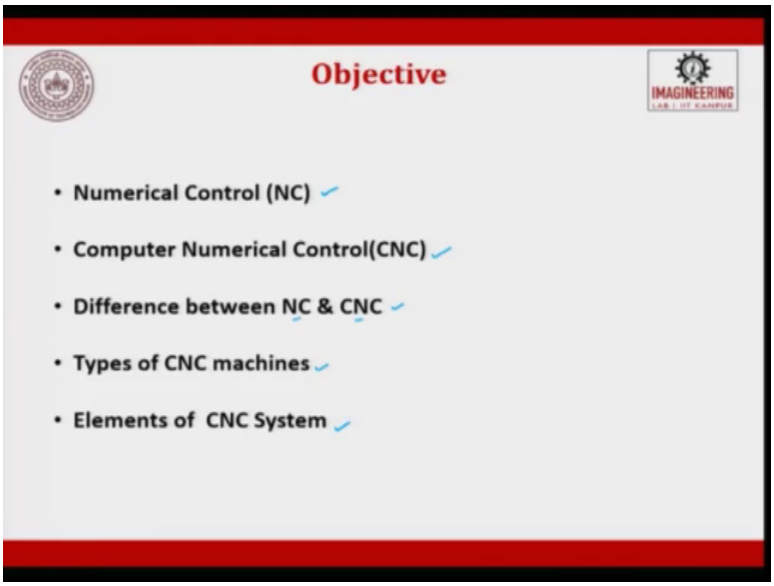

So, in this lecture we will see what is NC, Numerical Control, how did it give a lead to CNC? Then what is the difference between NC and CNC, the different types of CNC machines and at last we will see what are the elements of CNC system.

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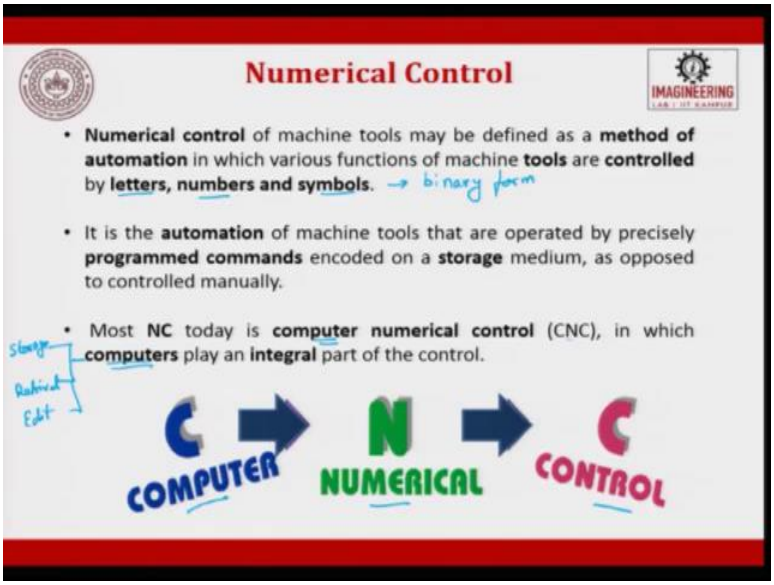

What is numerical control? Numerical control of a machine tool may be defined as a method of automation in which various functions of machine tool are controlled by letters, numbers and symbol. So, if you see letter, number, symbol, all these things can be converted into binary form,

and when you are working on a binary form you can try to see how a binary is used to control the machine tool. It is the automation of machine tool that are operated by precisely programmed commands encoded on a storage media as opposed to controlled manually.

So, what I am trying to say if you are trying to repeat a part so many times so then what you do is a program is written and it is stored, this program will have letters, numbers, and symbol which can be retrieved whenever you want to re-run the same program to produce the same part. It is the automation of machine tool that are operated by precisely programmed commands encoded on your storage media as opposed to control manually.

Most NC today is Computer Numerical Control, initially it was numerical control where in which they used to have cards, printed cards, these cards will be read and then it will try to execute as in when computer evolved and the programming skills also evolve.

So, today we have directly integrated computer to numerically control the machine, most NC today is CNC. So, today we do not call the terminology NC, we call it as CNC in which computer plays and integral part of control. Moment I say computer it has storage, it had retrieval and it also gives me a freedom of edit. So, with this three I am able to change the program, customize the program towards the output part required.

So, this made computer and integral part of numerical control, computer evolution in terms of memory, in terms of retrieval, editing gave a big breakthrough in numerical control. So, computer, numerical, control are the three key words which are used to control in making a part.

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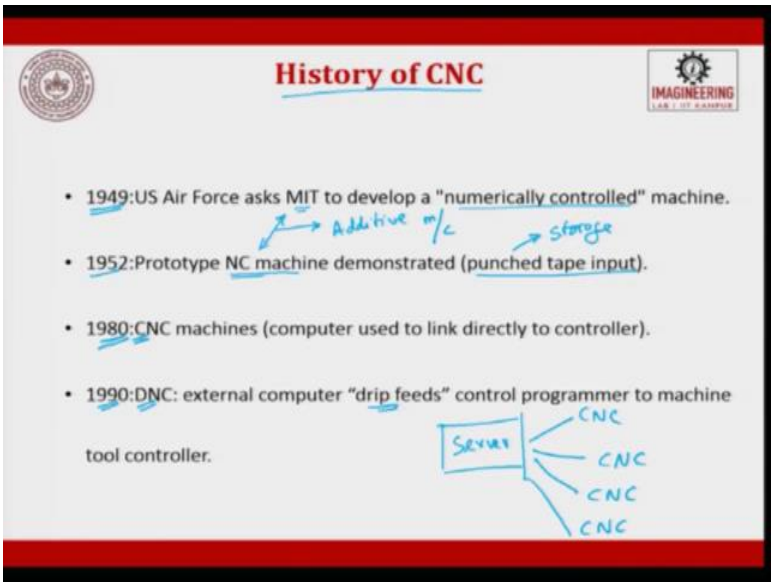

Then we talk about the history of CNC machine. In 1949, US Air Force asked MIT to, MIT is Massachusetts Institute of Technology, which is in USA to develop a numerically controlled machine, because they were trying to get ready for war and there were a lot of complex parts to be made, because in aerospace industry as well as in defense they needed complex geometry parts to do a multi-functional requirements.

So, there they gave a project to MIT to ask them to develop numerically controlled machine such that their batch sizes are less and they can be used to produce complex parts. So, they gave this project in 1952, the first prototype NC machine was demonstrated using punched tape input. This punched tape is an older version of storage, they demonstrated in 1952, whatever was common developed in this period is now extrapolated or to various other machines.

The knowledge whatever is brought in here in NC getting integrated with C is now used even in additive manufacturing. In additive manufacturing when you talk about additive manufacturing machines, these machine today works on CNC codes only. In 1980, the NC became CNC computer used to link directly to controller was developed and demonstrated in 1980.

In 1990, there came on new terminology called as DNC which is nothing but drip feed control programmer to machine tool controller. So, here what happens, more and more complexity of the parts have started gaining and in that time we needed to have very long lengthy programs. So,

computer server had a restriction in memory, so the program was completely stored in a main server and as and when it is required when the program gets executed may be 50 lines, 100 lines, will be called from a server that will be brought to the CNC machine and then used. These 50 lines today it has gone to the level of even 500 lines.

So, basically here you will have a main server so the CNC machines are attached to the main server so they pull the program from the server and start using it to meet out the requirements. So, that is called as DNC, today we also have wireless communication between server and CNC machines coming into existence.

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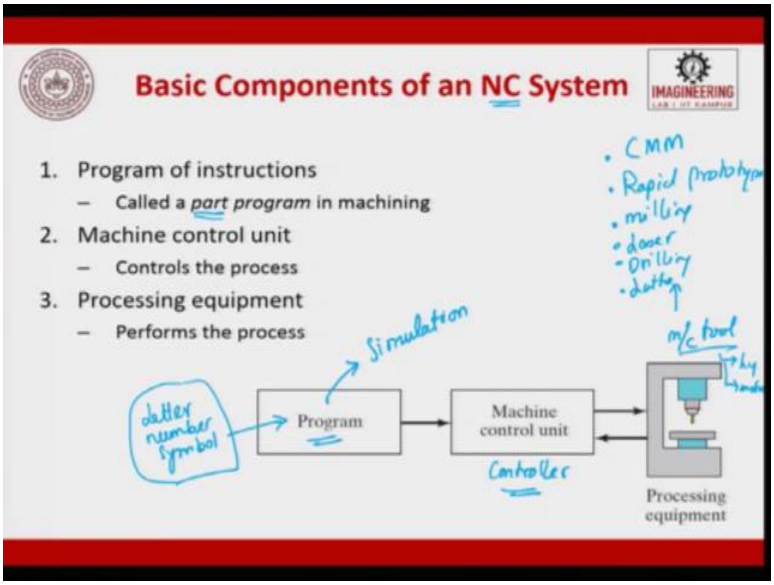

What are the basic components of a NC system? There are three basic components, one is program of instructions, so basically called a program, a part program in machining. So, this is the first basic component, a program for instructions. So, here is a program, so in programs you will always have letter, number and symbol, and this is used to controller which is used in machine control unit, okay.

So, this is program and program you can take a simulation and run and see whether the part what you are intend to make is the program correctly executing it. We have not touched the option of talking to the machine tool controller, so its only simulation, okay. So, here we are now talking about NC, so C is not there so stimulation is not there as of now but I am just saying a program is

done and then you can do a simulation and see okay, a program of instruction called a part program is used in CNC or NC we always call it as a part program not a program, because the output of the program leads to make a part.

So, in order to maintain the identity that it is a CNC program, not a C, C plus-plus program we call this as part programming. So, called a part program in machining. Machine control unit, this machine control unit based upon the symbols and number whatever you use we have a controller here, which accepts the data values from the program and tries to execute it or convert the software instruction into a hardware instruction and then communicates to the machine and the third entity is going to be processing equipment performance of process.

So, this is nothing but the machine tool okay, this is the controller is used and here is a program, so you need a program, you need a controller and you need a machine tool to do. Today you can replace this machine tool with anything, laser, you can use it with the drilling machine, you can use it with milling machine, you can use an additive rapid prototyping machine, you can attach it with the coordinate measuring machine for measurements.

So, this machine tool is you can have anything of this option, you can have a lathe machine right, so all these things are machine, so this is a machine tool. So, here in this machine tool is attached to a controller, the controller will understand program whatever is there and then this machine tool will convert it into such an information such that you can execute the movement which is happening here, inside the machine tool we will have hydraulic drives, we will have motors, all these things are part of the machine tool, okay.

Three basic components, programming is 1, machine tool control is 2, and processing of equipment is 3. So, what is the function of a program of instruction is called a part program, then machine tool controls the process, processing unit performs the process.

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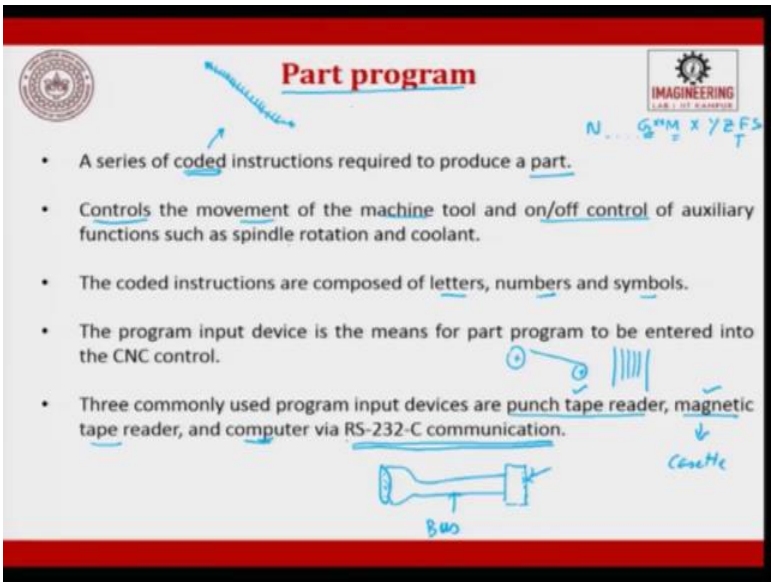

So, let us understand, what is part program? A series of coded instructions required to produce a part is called as part program. So, what are they? For example, coded informations can be the start of a line, it can try to have some codes, G codes, M codes, some X, Y, Z, F, S.

So, these are all X, Y, Z coordinates and then you will have a feed, speed and then you will have tool, tool number or tool whatever it is, G codes will see in detail G codes, M codes, these are all letters, each letter has its own specific function, then it will be followed by a number and then you will have symbols, a series of coded instructions, coded instruction.

So, what, for example, if you wanted to move from one point to the other, so you will draw a line and the intermediate points are called as interpolation is done. So, this is nothing but a coded information so that is what we said, a series of coded instructions required to produce a part is part of, part programming, controls the movement of your machine tool and on-off control of auxiliary function, such as spindle rotation, coolant, etc-etc, okay.

So, this code is for movement of tools, it is also used to control the movement of machine tool and on-off control. The coded instruction are composed of letter, number and symbol, as I told earlier, the program input device is the means for part programming to be entered into the CNC controller. Part program has to be entered, three commonly used to program input devices are punched tape reader, magnetic tape reader, computer.

So, these two are getting outdated, so this was a big tape was used and it used to roll from one end to the other end, when you look at a tape you will have several tracks. So, each track had a function, when you got a magnetic it was almost like a cassette, like a cassette playing, audio songs cassette playing, video song cassette playing. So, it was a magnetic tape reader was there.

Then all these things got out dated, today it is all with respect to a computer and in a computer we used to attach a computer and a CNC machine connect them with the RS-232-C communication. This is very-very important, RS-232-C is nothing but a cable where in which you will have several of these pins and then you will have a wire and then you will have one more connected here.

So, this is called as bus, a set of wires which is used for communication and then you will have pins here. So, these pins are also of certain standard to RS-232-C is a standard which is used to connect a CNC to a computer. So, using this we connect a computer to the machine and then get start executing the program. So, part program is used to produce a part, so there are letters, numbers, and symbols as part of the program and the input program devices are punch tape reader, magnetic tape reader, and computers.

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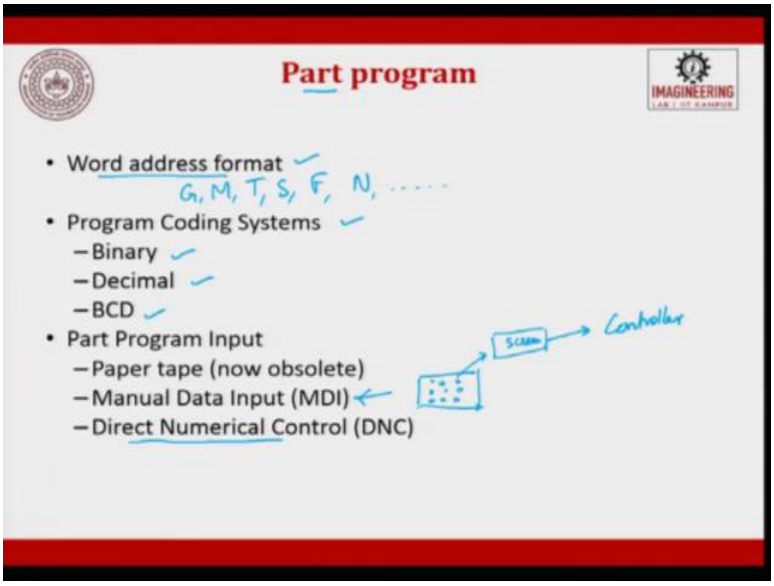

So, in a part program we will have word address format, we will have program coding system, it can be binary, it can be decimal, it can be binary converted to decimal, it can have part program inputs which is paper tape, MDI. MDI is you will have a console and in that console like a

calculator you will have all these symbols and other things and then this will be used to be attached to a screen and then this will be attached to a controller.

So, here this is called as Manual Data Input, so here in which the operator tries to punch the information whatever he wants and then that can be seen in a screen and then that will be converted to this thing and then we say about direct numerical control. So, these are the part program input today, the word address formats are we will have G, M, T, S, F, N. So, all these things are word address formats which are used in part programming.

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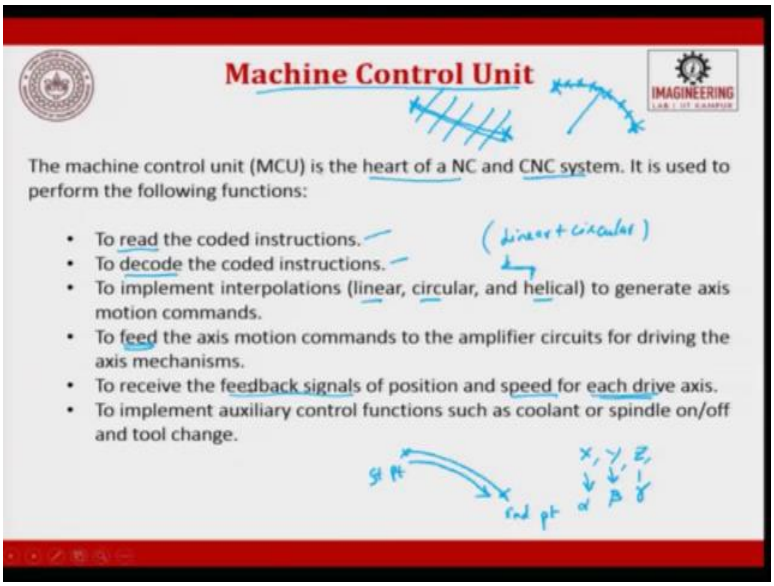

Next, we will see about machine control unit which was the second block in the sequence, in the schematic diagram of a CNC machine, which is machine control unit. Machine control unit is the heart of NC and a CNC system, machine control unit because the C whatever you had you are only punched words, letters, and symbols, but these words, letters, and symbols should be communicated to the machine tool, this happens by this machine control unit.

So, the machine control unit is a heart of a NC and a CNC system, it is used to program the following functions. First to read the coded instruction, next to decode the coded instruction, first it will read, then it will be decode. So, please understand read, then decode to implement the interpolation such as linear, circular and helical. So, what is linear? Start point, end point, straight line, linear interpolation. What is interpolation? I have given the end points and I have given the equation of this line.

So, now I wanted to find out the discrete points in between is called as interpolation. So, linear is this, circular is this, so I have given you the start point, I have given you the end point, I have given you the radius. So, now I will try to tell you if I have to find out what are all the intermediate points then I can try to do interpolation which is circular interpolation which is done, and the third one is helical interpolation which is nothing but linear plus circular which leads to a helical.

So, this is helical interpolation, to implement interpolation linear, circular, helical, to generate axis motion commands is the other function which is done by MCU, then to feed the axis, first to tell the tool from here to here how it is to move, then you have told the starting point, ending point.

Now, the next step at what speed it has to move? So, that comes the feed, the feed of the axis motion command to the amplifier circuit for driving the axis mechanism is also a function of MCU. Next, to receive the feedback so you have asked me to go to this location start point, and then you have asked me to go towards the end point, and have I gone there? How do you know that? So, if I have to know that then I should have a feedback device.

So, that is what is receive the feedback signal of position and speed for each drive and please note down each drive. So, this clearly says for X you will have one drive, Y you will have one, Z you will have one, and if at all there is a rotation about this you will have one more drive so that you try to control every drive okay.

So, to implement auxiliary functions such as coolant on, and spindle on-off and tool change, all these things are instructions which are performed or these are the functions which are performed by MCU, the most interesting thing read, then decode, read, understand then after you understand you try to figure out whether it is linear, circular, helical, then you try to look at the feed rates, then you try to look at the feedback signals, and at the last you will try to look at other miscellaneous functions. So, these are the functions of a machine control unit.

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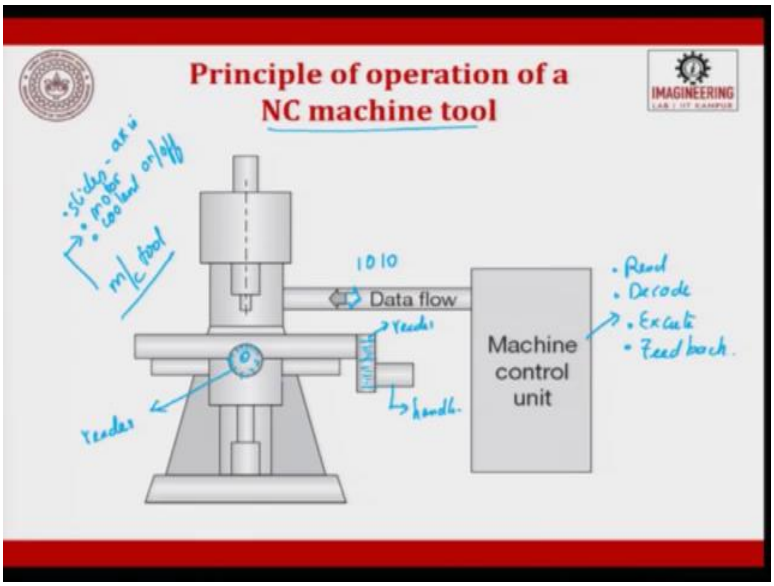

So, principles of operation of a NC machine tool, this is a machine tool, this is nothing but a machine we call it as a machine tool. So, you have MCU so this is where we saw read the code instruction and execute and analyze the feedback, all is done in this right, and then what you do is, what you give to the machine is nothing but the data, what is data? Data is nothing but 1 0-1 0 that's all, binary data you give it to the machine and then the machine moves accordingly.

So, what is there in a machine tool you will have slides, that means to say axis motion, then you will have motors, then you will have coolant on-off okay all these things are there inside a machine tool. So, that data is given, so if it has a feedback then you will have one more arrow, if it does not have it will have only one arrow. So, this is one way, so it is only giving the instruction and if the data if I put it in the other side it is giving in, and giving out so state assistant.

So, it can be open loop system or it can be a closed loop system. So, these are if you take a conventional these are nothing but the handle and these are the readers, okay you will also have reader here, so what we do if we have graduations and we look at these graduations and then we try to rotate the handle. So, here also it will be the same you will have graduations. So, you will have graduations and you look at the graduations and rotate the handle to get the output.

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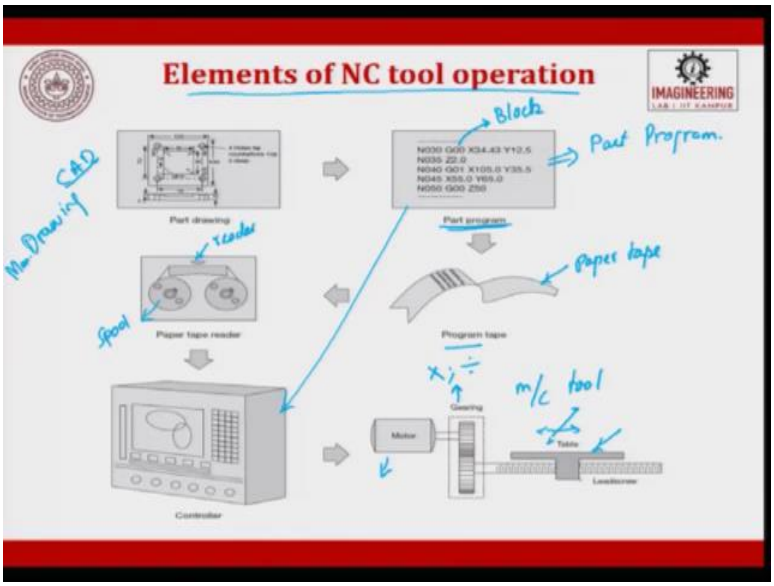

So, these are the elements of NC tool operation. Suppose, let us assume you have created this part drawing using CAD. So, this is, what in CAD? This is a drawing and this drawing is nothing but a manufacturing drawing, the difference between drawing and manufacturing drawing is drawing will have dimensions, manufacturing will have dimensions and tolerance, okay and it also will have references.

So, you have created this using CAD, now what you do is this if it has to be converted into a product this will be written in form of a program. So, this is nothing but a part program which I have given it here, so part program. So, each line is called as a block, so there will be several of these blocks, so each block is a set of instructions given and depending upon the instruction the controller listens to it and then start executing to it.

So, today it will be from here to here, here to here, otherwise the program will be returned and then it will be punched on to get a tape, this is a paper tape, and this paper tape will be used several times for running the same component to produce in a batch. So a program tape is done and this program tape is put in a tape reader.

So, this if it is a long lengthy tape so then it is put in a spool, there is a in-spool, out-spool so the program runs through it. So, here is a reader this can be a pneumatic reader, optical reader,

whatever it can be a mechanical reader, so we can use this reader and then we understand the program.

This program is communicated to the controller and this controller pushes it to the machine. If you say this is nothing but the machine tool and here you see a motor, this motor is attached to a gear, so gear is basically a mechanical device of multiplying or dividing whatever is the number you give here. So, if you want to multiply a torque accordingly you changed it, or if you want to reduce, you try to do division.

So, you see what is to be done and this in turn is attached to a lead screw, this lead screw has a table, wherein which the table you keep the work piece or the tool is moved left and right. So that you try to get the part what you have drawn here to get it executed here, these are the elements of a NC machine tool which is used for making a part.

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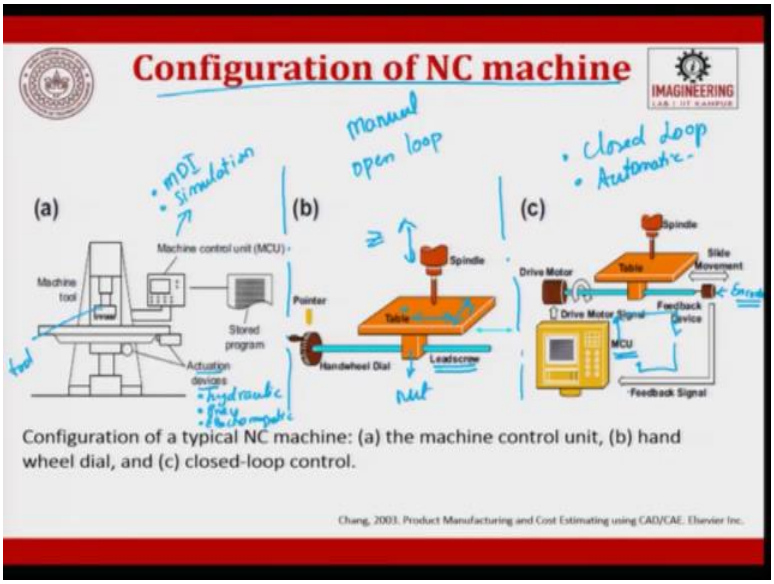

So, when we talk about the configuration of a NC machine tool. So, this is nothing but a manually operated machine tool. So, this first thing is to understand, how does a machine tool look like? So, this is the machine, this is a vertical milling machine, machine tool, these are the machining tools, this is a machine control unit where in which you can do manually data input and you can also see if there is a computer attach a simulation to see how does a program runs and then for this you will have.

So, the control unit will be attached to a actuation device this can be hydraulic driven, this can be pneumatic or it can be electromagnetic. So, these values will be given to these drives and accordingly the machine tool will move, if you are going to do it manually what we do is we have a handle, this is attached to a pointer, where in which there is a reader, there is a dial wheel.

So, an operator looks at the dial wheel, sets the reading and rotates it left and right to make sure the table moves in X direction or in Y direction and the spindle also can be moved in Z direction, it can be X, it can be Y, it can be Z. So, by setting this thing manually he can start doing it. So, here we always have a lead screw, because lead screw gives you a lead in terms of moment so it is just like a screw and a nut.

So, assume that this is a nut and this is a screw, so when you try to rotate the screw, you can see that nut getting advanced or come back. So, this is done manually. If you wanted to convert this manual into a computer attached and then form it as a closed loop where in which the feedbacks can be got this setup looks like this, the configuration looks like this, this is open loop and this is manual, this is closed loop and let us do it as automatic CNC control.

So, here CNC gives a drive motor signal, the drive motor rotates the lead screw, the lead screw rotates the table at the end of the lead screw you have an encoder, encoder tries to read whatever you have said here is the same thing coming here. Here you try to rotate it, here you again count the rotation and based upon the encoder reading, I try to get the feedback and give it back to the machine control unit, then this machine control unit tries to give error signal plus the original signal accordingly the table will be moved to get the required output.

So, the (a) is nothing but a machine control unit, (b) is hand operated open loop machine tool, third one (c) is nothing but your closed loop, you can see here is a loop which is closed, this is a closed loop. Thank you very much.