Computer Integrated Manufacturing
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Lecture 13
Computer Numerical Control (part 2 of 4)

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So, welcome to the next lecture on Computer Numerical Control.

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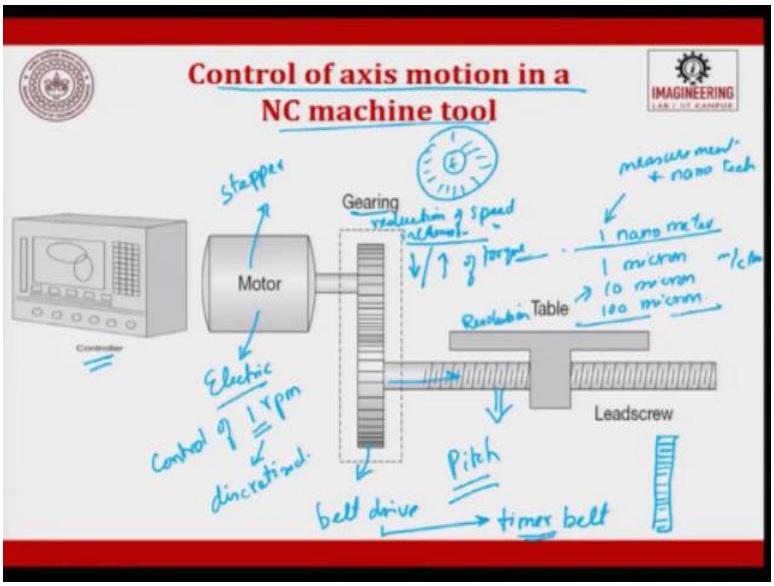

So, now let us see control of axis motion in a machine tool. So, controller we know, we know a motor, so this is ordinary electric motor, electric motor what happens you can control maximum of 1 rpm but really in a machine tool we are looking for accuracies. So, what are the accuracies of the table? We are looking at 1 micron accuracy, 10 micron accuracy okay, or 100 micron accuracy, today we are also started looking at 1 nano meter, nano meter accuracy.

So, this is a different ball game, so this is all in nano scale and this is what is currently which is used in machine tool, this is used in measurements and nano technology. So 1 nano metre is a resolution. So, it is very clear if I have a control of 1 rpm how can I get 1 micron? So, now it gives you a lead saying that even this 1 rpm has to be discretized okay. So, this motor will now discretize 1 rpm into several steps.

So, this motor when I use it in CNC, I call it as stepper motor. So, the 1 rpm is divided into several steps and we control this rpm by giving stepwise function and that is given as an input. So, after this, this is given to a gear so there is, here you can do reduction of speed, increase of speed, reduction, or increase of torque. So, that is done in the gearbox, so that is called as a gearing here depending upon the shape, number of teeth you can decide the reduction or increase.

So, then this in turn is attached to a lead screw, again in the lead screw you have a terminology called pitch. So, depending upon the pitch the rotation you can try to control the resolution, you

can try to control the resolution and get whatever it is. If the distance between the motor gear and the table gear is slightly far off then we always go for a belt drive, in many of the CNC in order to have reduced friction and a positive drive we always use something called as a timer belt.

So, the timer belt are belts like this when you see the cross section or when you see the internal of this belt you will have striations like this and here the gears or the pully will have striations matching striations, we always attached it to the distances are far off to your belt drive attached it with timer belt.

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So, this when you look at the elements of a CNC machine this is what turning so this is nothing but a Turning machine there is a big difference between a turning machine, and a milling machine, turning machines are otherwise called as turn centres. So, in turn centres the work piece will rotate the tool will be approximately stationary, okay.

And here you will produce axis symmetry parts circular, then terminologies what is given here overlaps with that of your conventional machine, you will have your headstock, you will have your bed. This bed whatever it is should be frictionless. So, you cannot use the same bed what is used in the conventional machine.

So, we will always try to improvise the bed in terms of friction, we will try to reduce the friction, then we will have a foot controller paddle to switch on and switch off the paddle. So, we have foot

controllers and then we this is the console which I was talking to you which is computer control panel. If you want to do it manually it is called as manual data input we can give and this is a computer what I was talking to you about simulations can be executed, you can type it and see the program, or you can type it and see the simulation.

Simulation is nothing but basically a drawing which is executed on the screen to show that the program what you have written is correct or not, then you will have tail-stock, then you will have a turret, turret means a tool turret where in which it is the tools more number of number of tools are held here. So, that is why it is called as a turret, it can be 8, it can be 16, it can be 6.

So, if there are 6 tools to be held it is called as a tool turret and here in which will have a chuck, these chucks will be pneumatically or hydraulically operated, pneumatic, or hydraulic operation. Because you have to quickly open and close with the pedal. So, we will have it as pneumatic and hydraulic. So, this is the elements of a CNC machine, a turning machine. So, it is otherwise called as turn centres.

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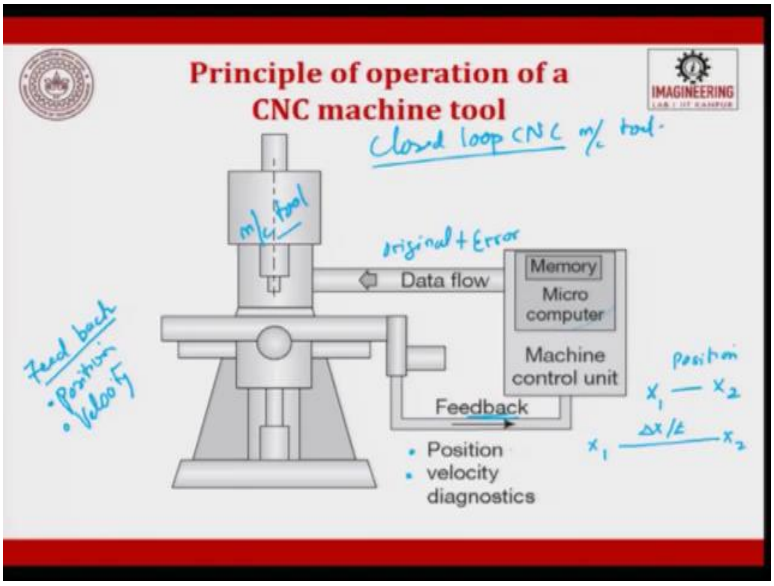

So, this is what I said last time, so it is a closed loop NC or a CNC machine tool, so you had a computer, you had a memory so the data was pulled out from the memory the program was executed, the data was given to the machine tool. The machine tool did execute whatever it was

supposed to execute, after it has executed then what you will try to see is you will try to see what I gave, what you are executed is the same.

So, that has to be evaluated by feedback. So, what are the feedback signal? Generally happens in a CNC machine it will be position, it will be velocity, it will be two things only, say, for example, X from here X1 to X2. So, you talk in terms of position and now you have to move from X1 to X2 with respect to.

So, delta X with respect to time so velocity. So, these two things are used as feedback diagnostic information which is fed back into the machine control unit, then it is subtracted from the signal whatever was given. So, it is original signal and if there is a error, then error signal is added and given to the machine tool such that we try to produce the part to the exact requirement.

So, the feedback information, feedback information are going to be position and velocity, because velocity talks in terms of relative. So, position and velocity are the two feedbacks which are taken from the machine and given to the controller.

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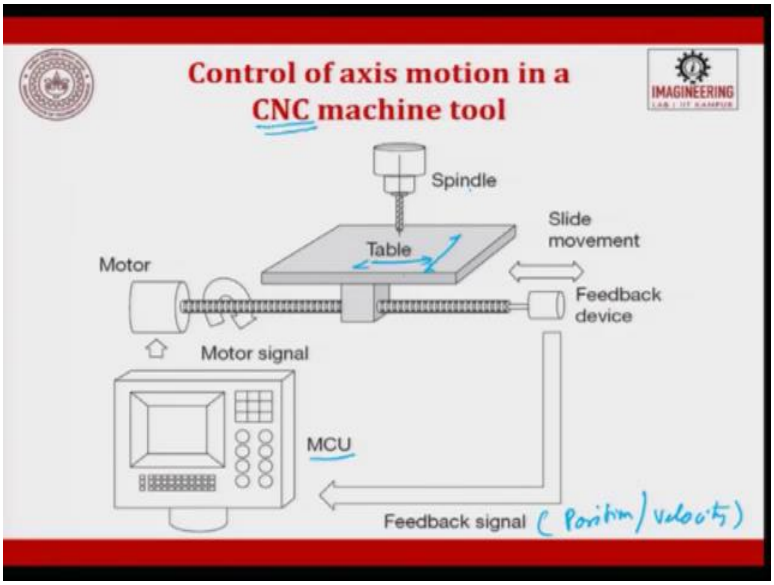

So, if you put that schematic diagram and if you fix it into a machine so you can see that table spindle and then you have a motor which is attached to a lead screw, lead screw in turn is attached to an encoder, which is a feedback device, okay this slide which is the spindle, table the slide movement is table movement, okay.

So, this is what and then you get a feedback signal, position, velocity you can get both or you can get one whatever it is and attached to MCU and then the signal is given back. So, what schematic diagram we saw, we are now super-impose a schematic diagram into a schematic diagram of the machine tool and we have displayed. So, this is the control of axis in a CNC machine.

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So, this is a NC machine, this is a CNC machine, computer is attached here, okay this is a NC machine.

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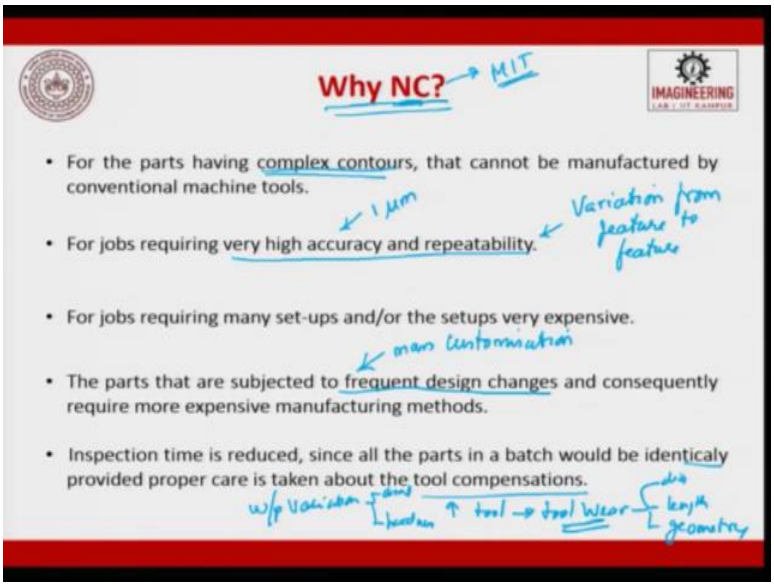

So why NC? For the part having complex contour that cannot be manufactured by conventional machine tool we always go for NC that is what I was trying to tell you after the World War, MIT was asked to make because the part complexity has increased. So, multiple parts have been integrated into single part so the geometry of the part of a single has become more complex.

Next, for jobs which needs very high accuracy and repeatability, where here accuracy we are talking about in terms of 1 micron the solutions right, accuracy very high accuracy we are talking about wherever we need a very high accuracy and the repeatability, variation from part to part variation from feature to feature, has to be very less.

So, that means to say the repeatability has to be as high as possible, for jobs requiring many setups or and or the setups very expensive. So, if there are multiple setups what we do is we will have multiple tools, for example, turning, drilling, boring, and then threading, all these things can be done integrated putting several tools around a turret and have the work piece in a spindle and start doing the consecutive operations, one after the each other in a single setting. This leads to very high accuracy in terms of referencing.

The part that are subjected to frequent design changes and consequently require more expensive manufacturing methods we always go for NC, this is very-very important, why? Because today

people look at mass customization. So, then there is a frequent design change in the part to meet to the customer requirement.

So, frequent design change and consequently more expensive manufacturing methods are used so where we always go for NC. Inspection time is reduced since all the parts in the batch would be identically provided, proper care is taken about the tool compensation okay. So, here what I am trying to say is moment there is a tool getting into action there is a tool wear, the wear can be in terms of diameter, it can be in terms of length, it can be in terms of geometry.

So, how are we going to compensate this and then try to execute the same part with the best accuracy to get the output? So, there we also use the NC machine, whenever there is a tool variation, or a work piece variation. For example, work piece variation in terms of dimensions, in terms of hardness, we increase or decrease the speed such that we get the output. So, everywhere we use a NC machine.

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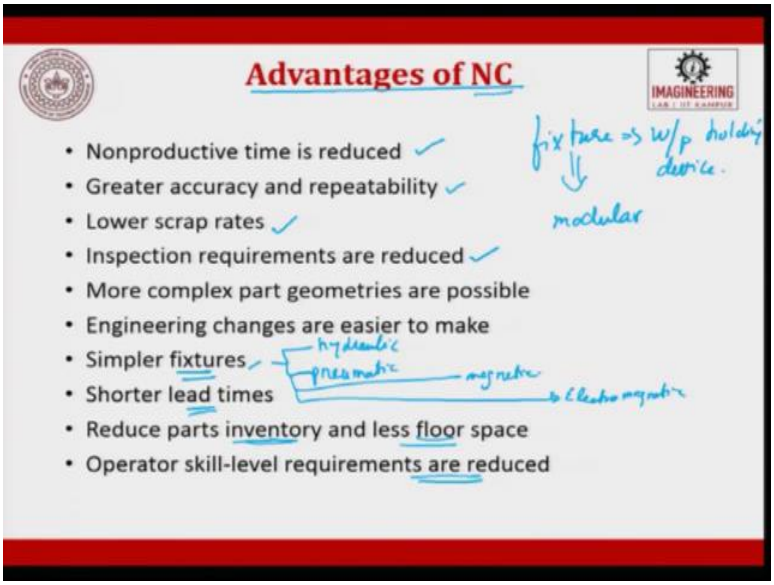

What are the advantages of an NC machine? The nonproductive time is reduced so that means to say, the loading, unloading time is reduced to a large extent, greater accuracy and repeatability can be achieved, lower scrap rates are generated, inspection required are since we have online monitoring itself say for example, we have a feedback device. So, which gives back to the MCU some instructions, this MCU start working and you get the required output.

So, inspection required are reduced after the part is made the inspection is reduced. So, online inspection goes on so you produce quality output more complex part geometries are possible. Engineering changes are easily accommodated that is a biggest advantage of NC machine. Simpler fixtures hydraulic and pneumatics are used. Hydraulics, pneumatics, we can also have magnetic, we can also have electromagnetic, basically fixture, fixture is nothing but a work piece holding device, okay.

So, simpler fixtures so in order to easily accommodate more number of engineering changes we will try to develop fixtures and these fixtures can be modular fixtures. So, it gives you a freedom of adding and deleting fixture elements such that you can design it to your requirements that is possible biggest advantage of NC.

Shortening the lead time, moment the CAD is ready the program get ready, program is ready the part gets executed. Earlier, the process planer sits and understands the drawing then he tries to write a program or then he tries to arrange for all the fixtures everything then get them. So, that lead time is reduced.

Inventory, reduced part inventory and lesser floor space, so what was done in 6, 7 machines could not be done in 1 machine and since 6, 7 machines are there lined up, between each machine you will have an inventory. Now, all these things happen in one machine. So, the inventory is also reduced, the floor space is also reduced.

Operator skill level requirements are reduced. Initially we used to think of operator who has a very high skill in setting it, aligning it to 1 micron accuracy, today it is not so since all other things are inbuilt and it is pneumatically and hydraulically controlled. So, the skill level of the operators has also gone down for making complex parts, these are some of the major advantages of NC machines.

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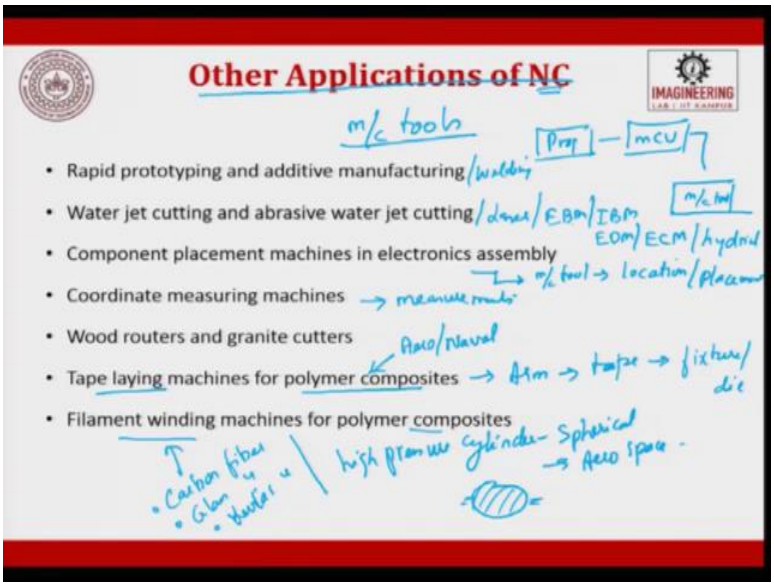

What are the other applications of NC machines? One is we were rapid prototyping and additive manufacturing. Again the machine tool is using the NC machines. Water jet cutting machine and abrasive water jet cutting machine uses NC. So, we are these are nothing but the machine tools, that is all. I have the program, I have a MCU, I have a machine tool.

So, these are the different machine tools which are used for rapid prototyping, additive manufacturing, water jet cutting, abrasive jet cutting, you can also have laser, you can have EBM, you can have IBM, electron beam, ion beam, you can have EDM, you can have ECM. So, many things you can have many of the hybrid machines, you can have welding, so additive manufacturing welding.

Okay then component placement machine in electronics assembly. So, here what we are talking about is here it is not a machining so here you will have a machine tool where in which it is used only for location and placement of the parts at the required spot. So, in for example IC chip in a PCB. So, these are the component placing machine.

Then coordinate measuring machines these are used for measurements and these are wood routers, and granite cutters then you have tape layering machines for polymer composites. Today what is happening is in additive manufacturing almost the same analogy you will have an arm, then you

will have a tape, these tape are laid, these tapes are laid on a fixture or on a die, and then this die is further processed, so you get the output.

So this is exhaustibly used for aerospace industry and naval industry, they are using this tape layered processes. And finally, filament winding machines for polymer machines, here the filament is nothing but a carbon fiber wire, carbon fiber, or it can be a glass fiber, or it can be a kevlar fiber, it is like a fiber which is bound around a mandrill and then you put epoxy there, remove the mandrill out you get.

For example all the high pressure, high pressure cylinders which are spherical used again in aerospace industry are made out of filament winding process. It is like a shell, something like this. So, you will have a fabric which goes everywhere and you can also use this filament winding machines to wind the pipe where in which you need to have very high compressive, very high hoop strength.

So, you can do it with a filament winding machines. So, these are the other applications of NC machines and these are the other machine tools which are attached.

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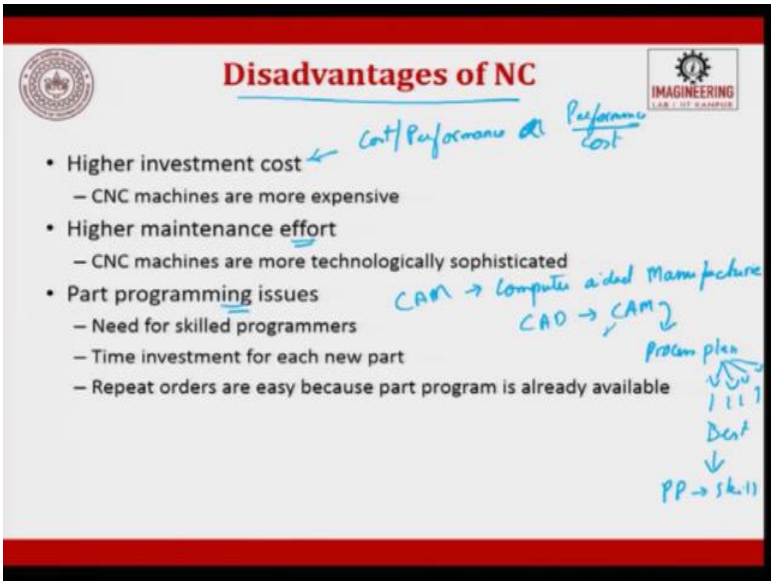

So, what are the disadvantages? So, it is not only advantages, you have also few disadvantages. So, few disadvantages are yes, the investment cost is high, CNC machines are more expensive but

the cost is high. So, you should make a tradeoff with cost to performance we have to see, or we can put it the vice versa, or we can try to put as performance to cost, you can also have this.

So, ratio has to be taken and you should really work out if there are small parts to be made and if the costing is extremely low for example less than 1 rupee or less than 1 dollar. So, then it is better to avoid NC machines because you will never be able to come to the breakeven. So, that is what it is expensive.

Maintenance, it needs lot of maintenance of course because hydraulic, pneumatic, computer is there, drives go bad, does not go bad so fast but there are drives which go bad. So, once it goes bad been really need to have a high maintenance and sometimes there are issues on part programming.

However, today you have CAM softwares, where in which CAM softwares are computer aided manufacturing softwares are there. So, these softwares what they do they try to manufacturing software. So, this try to acquire data from CAD and then they go to CAM and what they generate is a process plan.

So, these are automatically done but whatever gets generated it gives you multiple options we have to tweak the options and try to get the best out of it, then find the best process plan. So, here you need to have a skilled person. So, that is what we said, need a skilled programmer if it is a complex part and if there are multiple options given for editing and then time investment for each per new part is slightly high and then repeated orders are easy because part programming is already available.

If it is mass customization in every part is a program of its own, then it is going to take a lot of time. So, these are the three disadvantages. However, these three disadvantages are very small, minuscule. So, you can always use the NC machines for your advantage.

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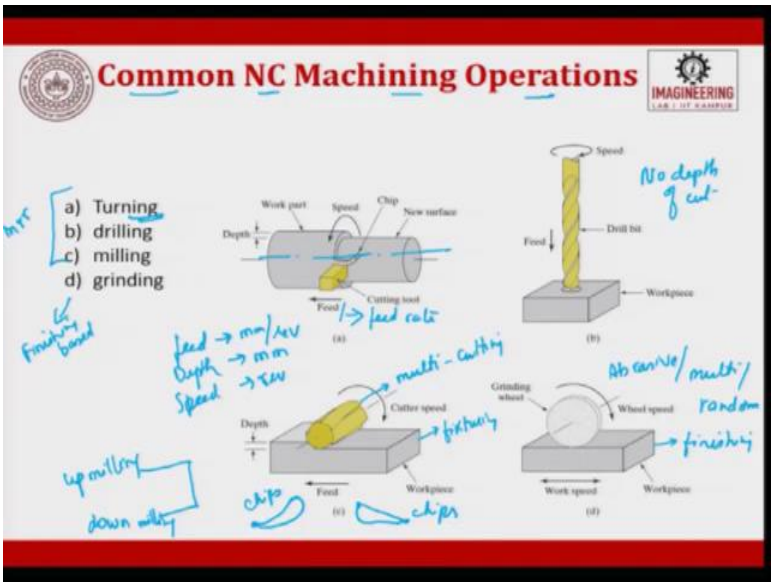

Some of the common NC machining operations are turning. So, with this is work piece, cylindrical work piece which is loaded onto a spindle. The spindle will be hydraulic and pneumatically done, and just like your conventional machine, you will have a feed which is given. So, feed leading to feed rates okay, with respect to time, then you will be given a depth of cut, all the other things are just like your normal machine, the terminologies are almost the same.

So, you will give a feed rate, you will give a depth of cut, and then you will also give the RPM, otherwise you give feed, you tell it at as mm per revolution and then you give depth of cut in mm, and then you give speed in terms of revolutions. So, then you can try to convert feed, feed rate and then try to get it. Basically, machining means it is a relative motion between a tool and a work piece or a harder surface and a softer surface.

So, this is a single point cutting and if you have two point cutting it goes to drilling, in drilling here we will know depth of cut is there, no depth of cut rest all is just like your CNC, your like turning, you will have the same thing here, when we talk about milling. So, you will have a milling there are two interesting things.

So, here it is a cuter which rotates, so there are two things which is very important, up milling, and down milling, up milling and down milling. Why is this very important? Because in milling you will have multiple cutters, so it is multi-cutting. So, in multi-cutting you will try to have so many

teeths, when the teeth rotate, when the cutter rotates against the work piece, or along the work piece right, movement along or against will try to decide whether it is up milling or down milling.

So, what is the big deal there up milling, or down milling? The difference is you will try to get a chip which starts from 0 and goes to maximum and in the other milling, down milling you will start with maximum and go with a minimum. So, why is this very important? These are chips. Why is this important? It is important because this will try to dictate the forces. So, why are the forces very important? Forces will lead to vibration and it leads to proper fixturing.

So, that is why this is very important, when we go to grinding, so grinding is abrasive, abrasive is used as a cutting tool here and there are multiple abrasives and they are random in nature, in milling the geometry is fixed, in grinding the geometry is random. So, with this random geometry we will try to use for machining here we talk more in terms of finishing and we do not talk in terms of material removal rate.

So, these three processes are MMR based, material removal based this is more of finishing based, so that is very clear that we remove a very small quantity of material and here the depth of cut is very high. So, we remove large amount of material. So, this is all the other common NC machining operations, which are used where CNC is attached or NC is attached.

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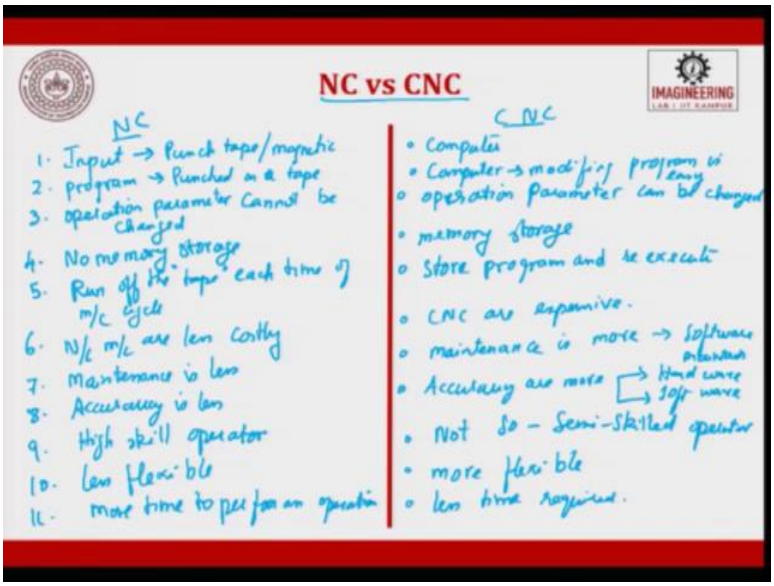

Now, let us see the difference between NC and CNC. So, this is numerical and this side we will write it as CNC. So, let us write down the difference 10 points, 1st point is input here is punched tape slash magnetic whatever it is. So, here it is computer, only computer. Next is, the program will always be punched on a tape. So, here it is used in a computer, so modification of program, modifying program is very easy, modifying is easy.

3rd point, operation parameters cannot be changed, operation parameters cannot be changed. For example, if you say that run it at 500 RPM it will run here. So, here what you can do is you can operation parameters can be changed, there is only a program so it can be changed. 4th point. So no memory storage is there. So, here there is memory storage.

5th point, so here there is something called as a run off the tape each time of machining cycle, of machining cycle you have to do. So, here store the program and re-execute, store program and re-execute. 6th point, NC machines are less costly. CNC are expensive, compared to these two. 7th point, maintenance is less, is more because you have a computer attached and other things, here majority of the time this software gets updated, or corrupted, software is updated or corrupted, software maintenance is expensive.

8th point, accuracy is less. So, here accuracies are more, so here you have two types of accuracies, one is hardware, the other one is software, so you have two things, so you can try to have little more better accuracies as compared to that of NC machines.

Then it needs high skill operators, here not so or I will say semi-skilled is more good enough. 10th it is less flexible. Here it is more flexible. And the last point, 11th point more time to perform an operation. Here it is less time required, okay. So these are the comparison between NC and CNC machines.

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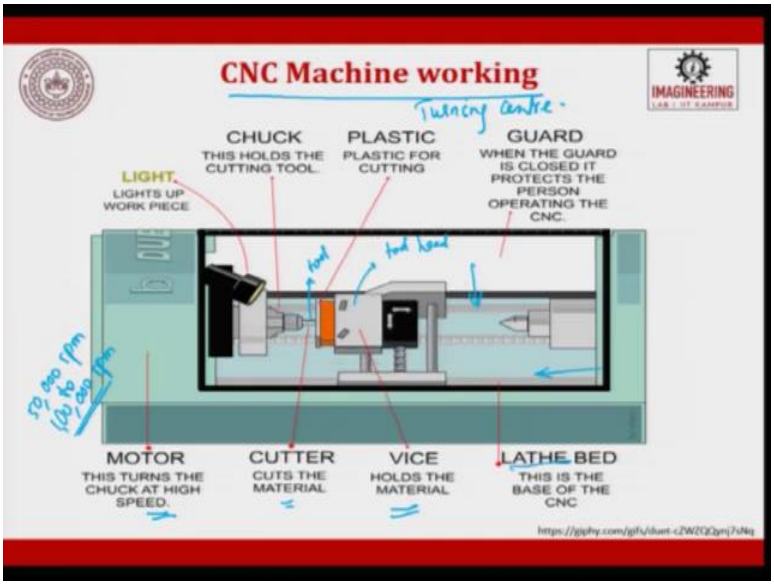

When you look at a CNC machine working, it will, you can see that there is a spindle, you will always have a light to aid you in the measurements or in see the execution, so there will be a light. So, there is a chuck, which holds the machine tool, so here it is pretty interesting you have fixed the tool here, the tool here and the work piece is attached to the tailstock, or I can put it, it is attached to the tool head in a normal machine. I am just trying to put another machine.

So, that you will understand all the time that work piece need not be held only at the spindle, you can hold it on the other end so this is moving in XY direction. So, you can see a lead screw given here and this does machining, slightly difficult to understand work piece was here earlier. Now, we are put a tool, in the tool holder what was there where we put a tool I have put the work piece.

So, you can see that the tool holder will move in XY direction to get the required output. So, plastic is the material which is used for cutting, the tool is given here. So, the tool is given rotation and that is used to cut material, you will have a motor and stepper motor which can run at very high speeds, today we are even talking about 50000 RPM to 100000 RPM. So, it need not be controlled by ball bearing and roller bearing, because that used to put a lot of restriction in the friction when you go higher speeds.

Now, it is all hydraulic you have aerostatic bearing, hydrostatic bearing so all these things have changed. So, motors can go at very high speeds, this is what I was talking to you about the tool holding and these are the guards, when the guard is closed it protects the person. So, there is a sensor, when the guard is closed, it can come from here to here, or it can go from here to here, depending upon your design.

So, you close it then only the machine starts, otherwise the machine does not start. The lathe bed where in which it is used to host the tool movement which is attached, this is the base of the CNC machine is a lathe bed. So, this is an interesting part, I have just shown unconventional, CNC machine where in turning machine. So, turning centre right, so I have just shown you so that for your understanding.

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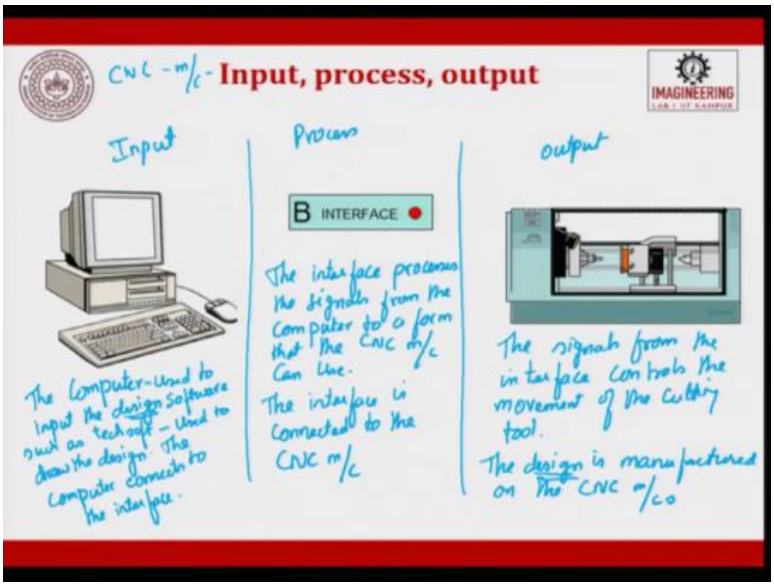

So, when we talk about CNC machines, CNC machines will have 3 inputs okay, 3 phases. So, one is input, you will have interface, you will have output. So, let us write down what is the function of this. The computer used to input the design software such as take whatever take I am just giving it as a tech soft, which is used to draw the design, the computer connects to the interface.

Next, the interface plays a very important role. The interface processes the signals from the computer to a form that the CNC machine can use. So, what design is giving information that fellow has to be converted in such a form, such that the machine tool can understand. The interface is connected to the CNC machines.

Last, the signals from so this is input, this is process, and this is output, the signals from the interface controls the movement of the cutting tool. Next point, the design is manufactured on the CNC machines. So, what design we are talking about here is manufactured in a CNC machines. This is all about CNC machines, input process and output.

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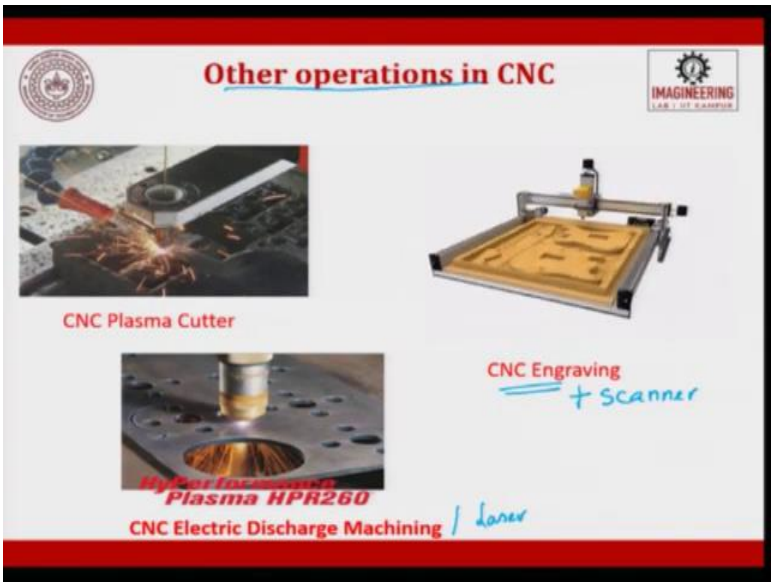

The, as I told you the other operations in CNC machines, today which is getting attached are two plasma cutter, if you look at this is also getting attached to a engraver, today they have started integrating processes. A machine today has engraver plus scanner. So, it scans the data from an object converts the data into XY signals that converted XY data is engraved on your board and you try to get the object.

So, the other operations of CNC are plasma, engraving and it is also used for electric discharge machining and laser assisted machining. So, these are the other processes, where CNC is exhaustively used today.

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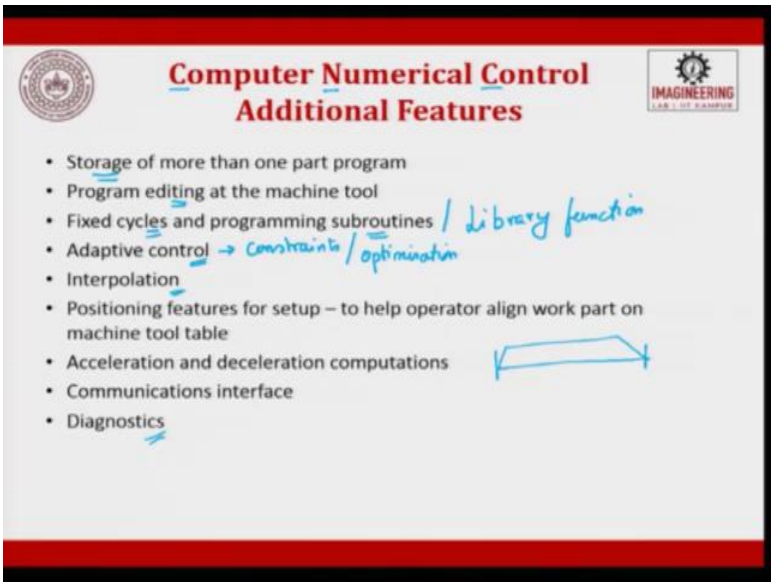

What are the additional features CNC machine has? It has a storage feature, it can allow you to edit feature, it has a fixed cycle and programming subroutines, fixed cycle programming subroutines if you are not able to visualize, you can think as a library function. So, library functions does a set of operations, where in which you give one or two parameters and get the entire operation done.

So, for example, if you take your power point, which is offered by Microsoft, you will see there are library functions of a sphere, or a cube, or a cuboid. So, what you do is pull up that function, place it in your screen and then you give only one data, drag it and give the data. So, the entire cuboid or the sphere, whatever it is gets generated. So, here there is a library function, for that library function there is a set function.

So, that is what is told about in fixed cycles and programming subroutines, we will see what are fixed cycles when we do the programming part. Then they can be adaptively controlled see the adaptive control can be with terms of constraints, or it can be terms of optimization. So, constrains are if the torque crosses a certain limit, stop the machine, if the thrust crosses a certain limit stop the machine, these are constraint based.

Optimization based it tries to take the tool wear, it tries to take the thrust, it tries to take a torque and then it evaluates and then it tries to adaptively control reduce the speed, or increase the speed,

for their requirement. So, then the CNC machines can do interpolation, which we saw circular interpolation, linear interpolation and helical interpolation. The positioning features of setup to help the operators align work parts on the machine tool table. So, this is an additional feature they have.

Acceleration and deceleration on computations can be done, so that means to say start from here, go up to here, stop here. So, when you do that it has to accelerate, then maintain at a certain thing, then you will have to decelerate. So, acceleration, deceleration, computations can be done. Then communication with other interfaces can happen, it also can help us in diagnosing. So, these are the additional features which is offered by CNC machine as compared to that of your NC machine. Thank you very much.