Computer Integrated Manufacturing
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Lecture 15
Computer Numerical Control (part 4 of 4)

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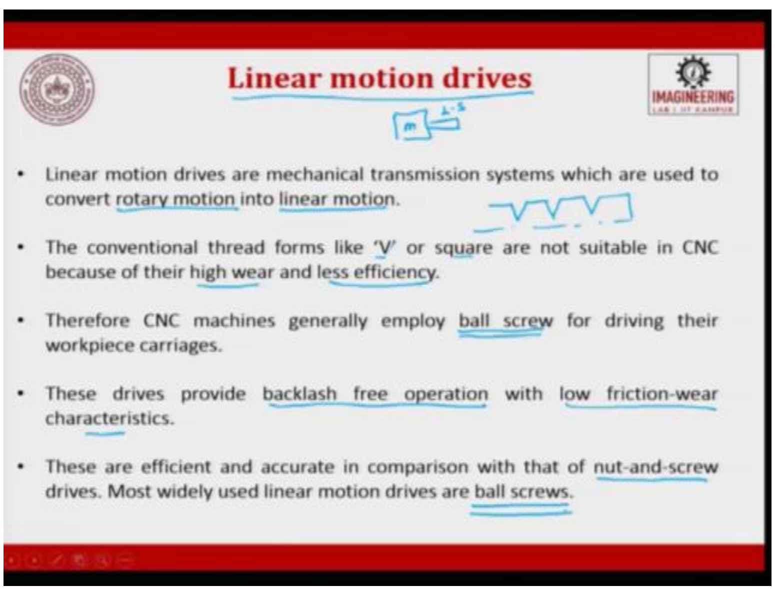

So, welcome to the next lecture on Computer Numerical Control. So, let us move ahead further discussion in the drives, today we talk about linear motion drives, the linear motion drives are mechanical transmission systems which are used to convert rotary motion into a linear motion, as I told you a motor is converting, moving in a with a lead screw so are used to convert rotary motion into a linear motion.

The conventional thread form like V, or square which we are talking about when we try to see the side view of it. This is what we see in the threads, at least we represented like this, right. So, we see a V or a square are not suitable in CNC machines, because they have a high wear and less efficiency.

So, we are talking about V form of threads or square form of threads, square form of threads are used for very heavy loads, V are the normal threads which are generated on a nut or a bolt or on a screw. Therefore, in CNC machines to have lesser wear and higher efficiency, we have to convert this thread into ball screw, these drives provide backlash free operation with low friction wear and characteristics this is because of the ball screw.

These are efficient and accurate in comparison with that of the nut and screw drives which are commonly used. Most widely used linear motion drives are ball screw mechanism in a CNC machine.

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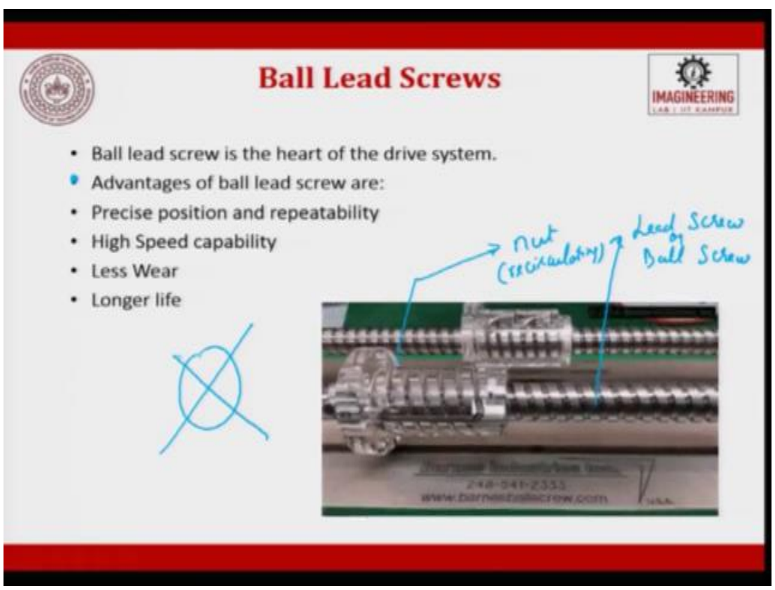

So, this is how a ball screw mechanism looks like, so you will, this is which is nut and this is the lead screw or which is other, or ball screw, the nut is otherwise called as recirculating nut. So, basically here what will happen is between the nut and the lead screw you will try to have a ball, this ball will try to convert a line contact to you a point contact, the profile of the nut will be gothic.

So, that you will try to have along the line so you can see here recirculating, because of the recirculation the friction is less and it is almost like point loading. So, that also reduces the friction and it has a very high efficiency. So, this is a static one, this is the moving one, so where in which the table is attached to the nut, the lead ball, lead screw is the heart of the drive system.

If the friction is very high and there is lot amount of losses you will not get the resolution what you want, however, good stepper motor you attached. The advantage of the balls screw are precise positioning and repeated loading, a high speed capability, less wear and longer life. Since it this is a recirculating nut so the balls get circulated, the balls are preloaded and it is covered. So, there is no possibility of a dust particle to come in between.

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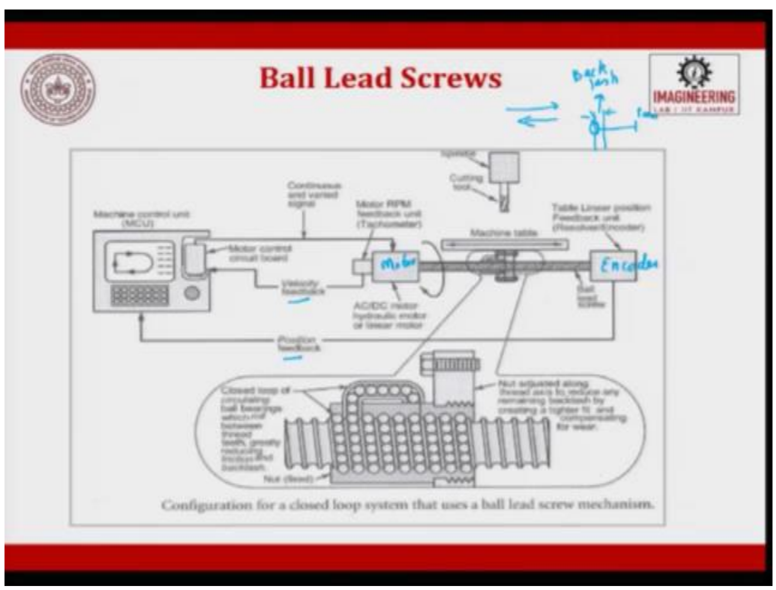

If you look into the schematic diagram, this is how it is. So, you will have a motor which is attached to a ball screw, which we saw recirculating balls screw mechanisms, today it is available in a very-very economical price up to 30 centimeter 1 foot. It is very economical available, the resolutions are very high today.

So, that is attached to a machine table and then the end of the lead screw is attached to a, to encoder so you have encoder is nothing but a tachometer which tries to generate the rotations whatever is given here. It tries to check here and here you try to take the output in terms of velocity and then you try to take in terms of position.

So, this is in turn fed to an MCU which we already saw in detail and then you try to get the feedback. So, the position feedback is given from here, and the velocity feedback is given here. So, velocity is given from the encoder, and the position is given from here. So, what you have told the encoder to move so this encoder will try to give the position and this is the motor attached.

So, the motor will try to give the velocity, so velocity and position are taken, so this is the motor and this is the encoder, I am sorry, I would have, I thought in the beginning I told this is a motor sorry, this is the motor and this is the encoder, the lead screw is attached here, table moves here.

So, in the recirculating ball screw mechanism as I told you closed loop of the circulating balls screw which rolls between the threaded tooth greatly reducing the friction and backlash. What is backlash? When you move in the front, forward direction and when you move in the reverse direction, you start from 0 and go to 1 and then come back from 1 to 0 it has to go to the same position.

If there is an error in returning back that is called as backlash, which is a very common thing in all mechanical system. In order to avoid this backlash we try to go for this recirculating balls screw. The nut adjusted along thread access to reduce any remaining backlash by creating a tighter fit and compensating for wear is given. So, this is an adjustment which you can do to compensate the wear, so this is a schematic diagram of a CNC machine, which is attached with the ball screw.

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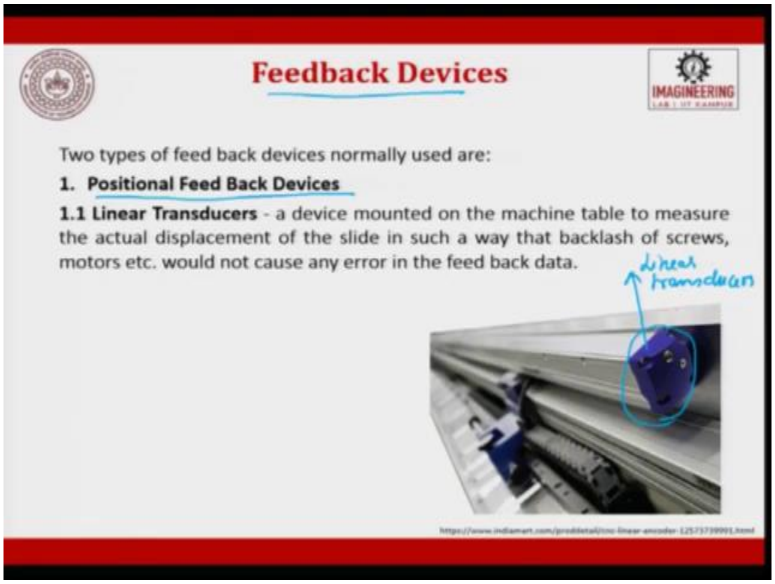

Feedback devices, so when we started CNC we saw there are 5 sections, so in that we saw motors, we saw drives and then now we have come to the last which is nothing but the feedback device. There are two types of feedback devices, one is called as the positional feedback device, the other one is called as a velocity feedback device.

So, in position feedback device you have linear transducers used, a linear transducer is nothing but a device mounted on the machine table to measure the actual displacement of the slide in such a way that backlash of the screws and motors would not cause any error in the feedback data.

So, you can see here, this is the linear transducer which is attached so which tries to check what the program has intended to move and whether this fellow has moved. So, if there is an error it checks the error and tells it, so this is the linear transducer and this is falling under positional feedback drives.

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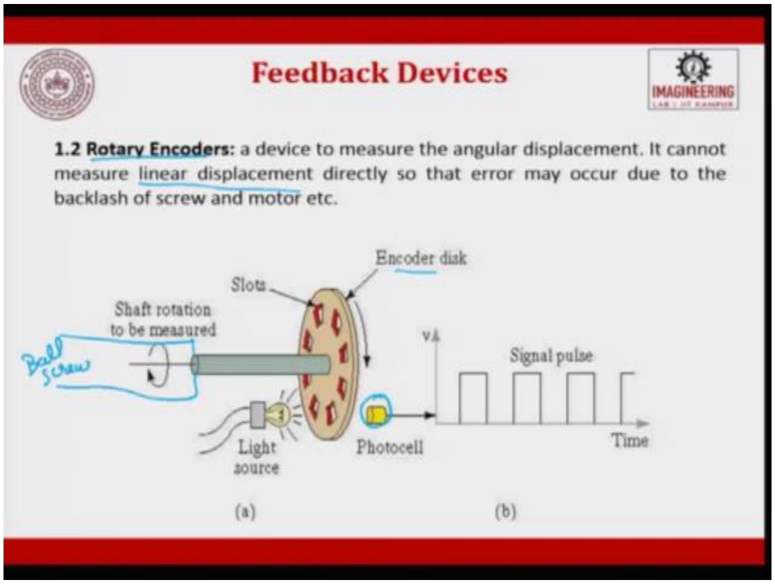

You also have rotary encoders, linear encoders will always occupy lot of space and rotary encoders are compact. Rotary encoders are devices to measure the angular displacement, it cannot measure the linear displacement directly. So, that the error may occur due to the backlash of the screw or the motor, it does not measure linearly but it converts the rotary and into linear and then you can try to measure the linear. It cannot measure linear displacement directly. It rotates, finds out and then it gets converted.

So, the error may occur due to backlash of screw and motor, so this is compact type and these encoders are used, in the encoder you will have an encoder disc which has opaque and transparent slots. So, these slots through these transparent slots the light is passed through, the light whatever gets passed through is collected by a photo detector, the photo director gives pulses.

Now, I count the pulses and then find out what is the resolution, or what is the movement it has happened. So, this is attached to the ball screw, so if you see that this is the balls screw attached. Okay so, now using this light I am using the disc and then trying to find out the position of the shaft moment.

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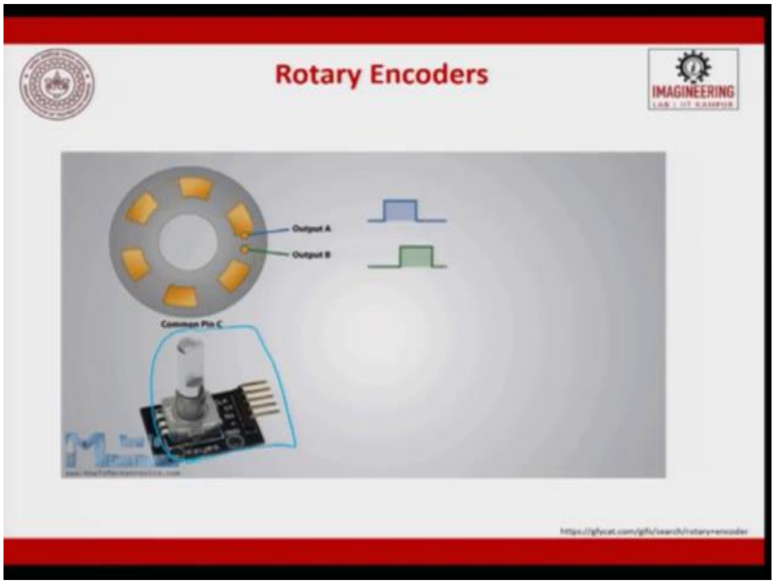

So, in animation, you can see here there are two outputs when the, when the light falls you can see A getting activated, then output B is getting activated entry and then accept. So, you can see at both the things very clearly, so it enters so this is an output which is taken and it is fed to a system where in which it is processed. So, in reality it looks like, in reality it looks like this.

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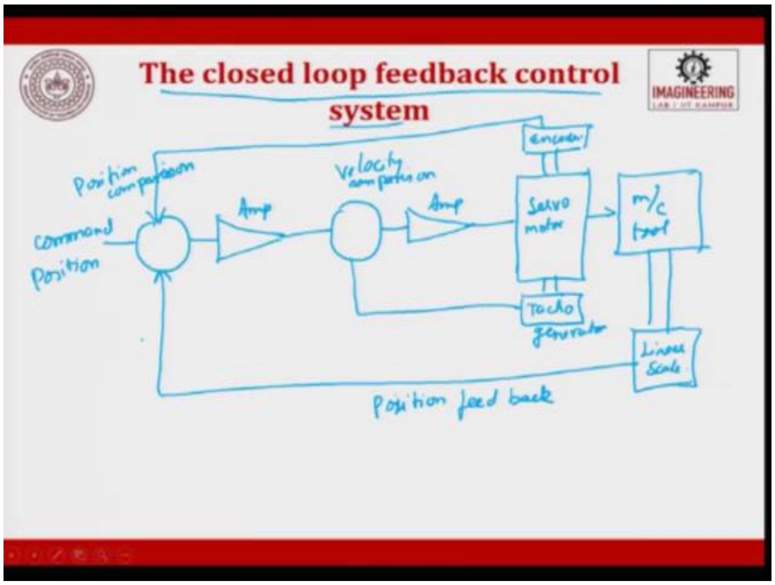

The closed loop feedback system, so the closed loop feedback control system, which we can draw a schematic diagram and see, you will have a command for position, command for position, this in turn is attached to an amplifier, this in turn is attached to a velocity comparator, comparison and this is again amplified and you attach this to a servo motor, and this in turn is attached to a machine tool, this is in turn attached to a linear scale and you will have position feedback and then the servo motor will have an encoder and this in turn will be attached to this.

Okay so here we do a position comparison, so this is for position feedback and we have, to this we also have a tacho generator, tacho generator is nothing but measuring the RPM, tacho generator this tacho generator intern is attached to the velocity amplifier, we try to get the signal. So, you see servo encoder is attached, tachometer is attached, velocity, position, the servo motor is attached to a machine tool and you have a linear scale which intern gives the data.

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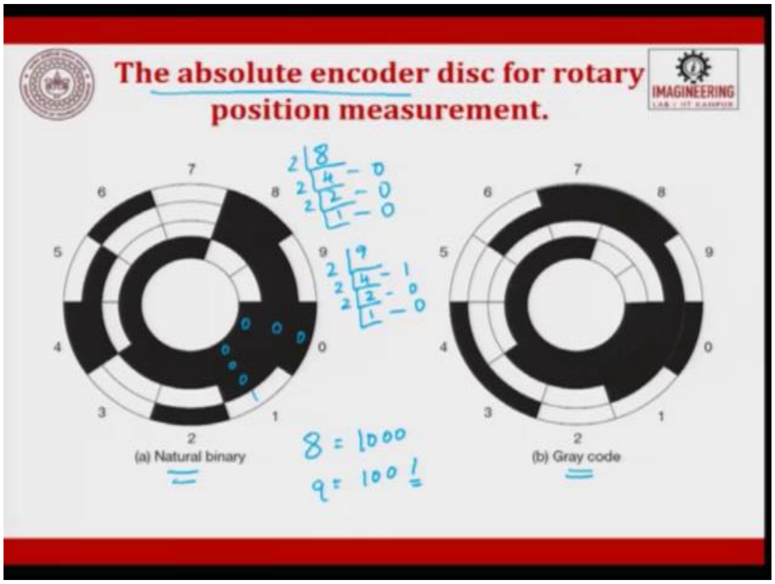

So, the absolute encoder discs for rotary position devices, this is natural binary and this is gray. So, when you have a number and then you want to convert it into binary so what we do is we divide it by 2 we say 4, 0, 2, 2, 0 and 1, 0. So, if you have a digit 8 so it is nothing but 1 0 0 0 so if you want to go to 9, this 4, 2 then you have 1 here, then you have 2, so if you have 9, it is 1 0 0 1 okay.

So, here, if you see from number to number when it changes you will have only one bit changing okay. Here it is so happens that the changes only one bit. So, it can check when it goes to the next number from the previous it will check only one bit change, but whereas when you change a certain numbers you will have two digits changing, for example you can have 17 and 19. So, you will have two digit number changing.

So, when you do, when you want to convert a number into binary, you do like this and here 1s and 0s are nothing but the 0s are the dark region, 1 are the transparent region, when the light is passed through according to this you will have 8 tracks or 4 tracks, these tracks are further sub segment tracks are divided you will have opaque and transparent discs, which are there light passes through and then you count.

So, for example this is 0, the next track is 0, the next track is 0 maybe it is 0, so it is 0 0 0 it can come, or here you can see 0 it can be a 0 0 1, so it will be 1 0 0 0 something like that. So, this is how we read the current position, the difference between binary and gray-scale is, in gray-scale it always has only one bit change as compared to that of your previous digit whatever you show.

So, that is the advantage of grey code compared to binary code, so in CNC machine and in absolute encoders we always prefer to have grey code as compared to that of a binary, in the examination I might ask you to solve some problems giving a digit and then converting into binary, or giving a digit asking you to convert into grey code and try to find out what is the signal which is required for a absolute encoder.

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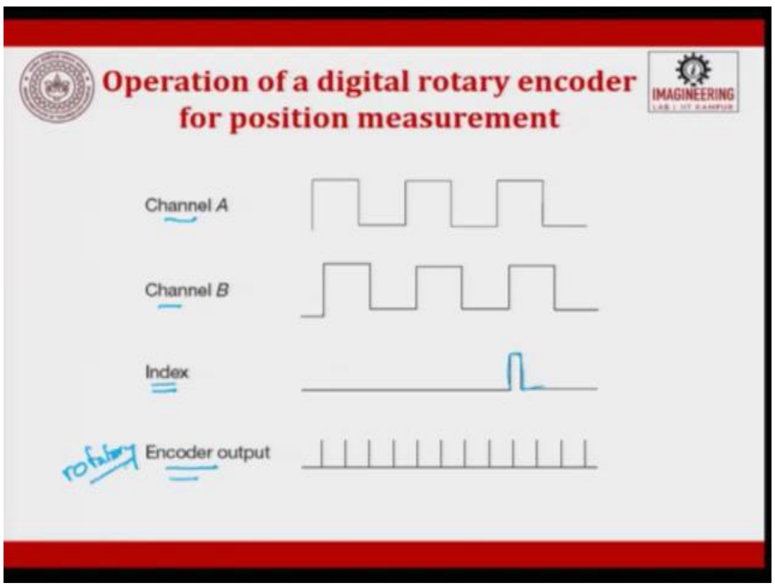

When you look at the positions of the digital rotary encoder, channel A, channel B and it tries to say an index where there is a difference and that is index is given as a pulse here. So, these are the encoder output, these are the index, index are nothing but a shift between the two comparison whatever it is and then it tries to say where there is a shift, it tries to say that is index.

And channel A output, we have seen channel B output, we have seen an encoder output will be wherever there is a conversion from 0 to 1, you will have or 1 to 0, you will try to have a pulse. So, this is the encoder output this encoder is a rotary encoder from here we try to convert into linear scale and try to get the output whatever we want.

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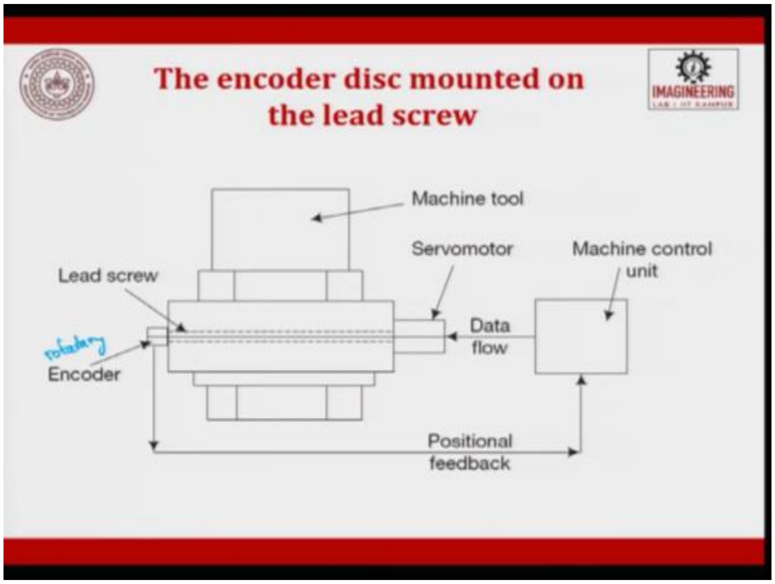

The encoders disc mounted in a lead screw, this is encoder this is a rotary encoder, and this is a machine tool we have seen enough of servo, data feed, machine tool, position feedback is given from the encoder, the velocity is given by the tacho generator.

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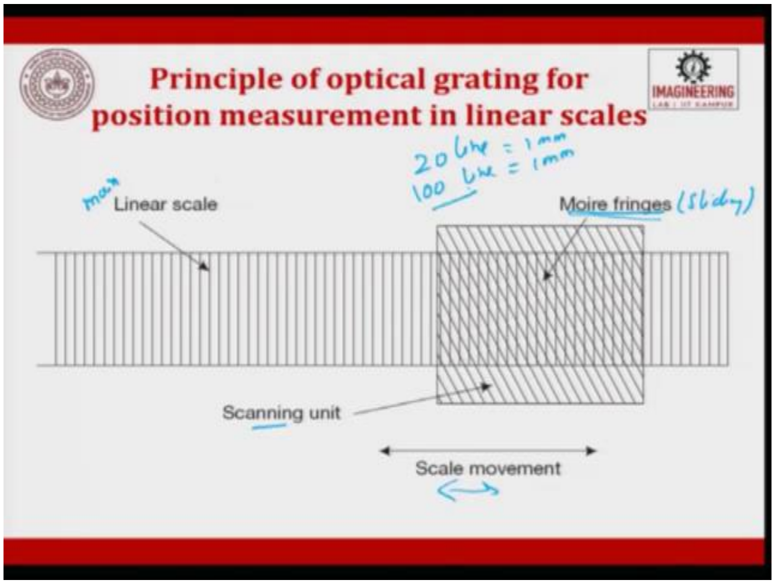

When we talk about a linear screw the principle of a linear screw works on this moire fringe pattern. Moire fringe pattern you have a linear scale and then you have a nut. So, the nut whatever it is or a sliding scale, this is a main scale and this is a sliding scale.

So, the sliding scale is present at an angle so slightly a small angle when the sliding scale is an, at an angle it tries to create pattern, fringe patterns, these fringes patterns are counted and it is converted into the position and this position will try to tell you what is the displacement it has done, again here we can use light or we can use electromagnetic field measurement to find out what is the displacement.

So, you have a scanning unit, this is a sliding scale, this is a scale moment, this is the main scale and these the sliding scale is at angle to create your moire fringe patterns, the patterns will be like 200 lines in 1 millimeter. So, the patterns whatever you generate will be of very small resolutions. So, here the angle with which the gratings are done will be very high, it can be 20 lines per millimeter, or it can be 100 lines per millimeter. So, you get a very high resolution to measure the linear scale.

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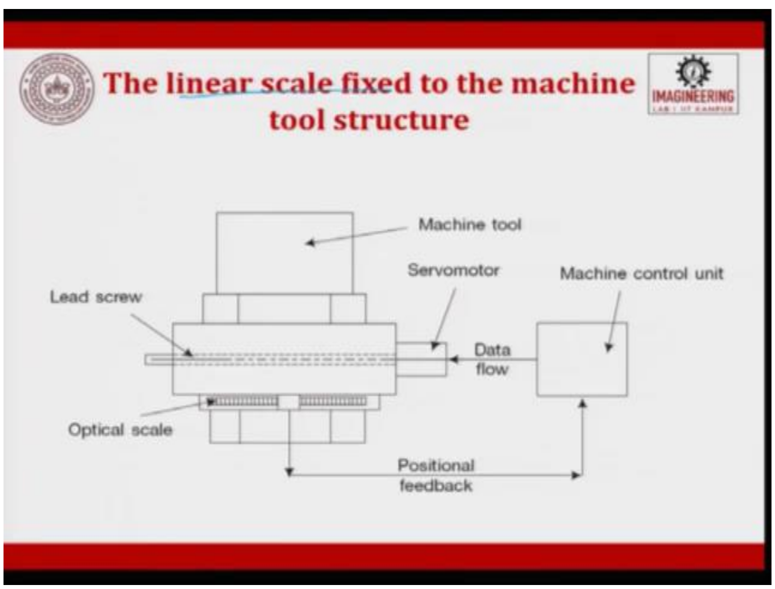

And the linear scale when it is fixed to a machine, it is fixed along here and here is a sliding scale, the position is taken and it is given to the machine tool, this is how a linear scale is attached to a machine tool to get the output.

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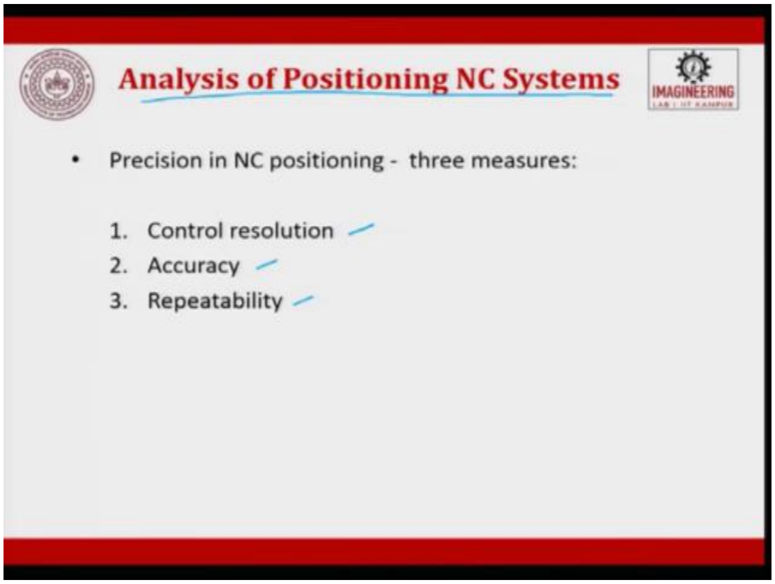

The last part of the discussion is going to be on the analysis of positioning of NC machine so the precision in the NC machine positioning there are three measures you can have control resolution, you have accuracy, and you will have repeatability. So, three things are very important when we have to measure about the position in a CNC machine or in a NC machine.

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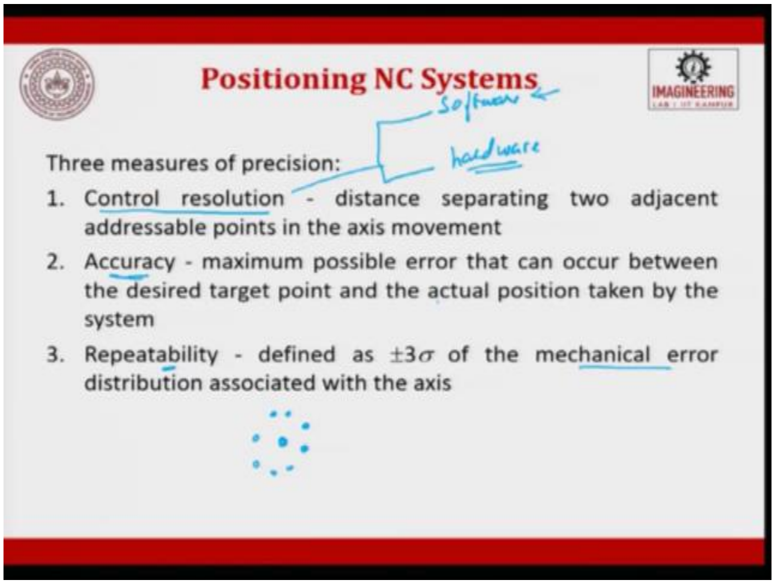

What is control resolution? The control resolution is nothing but distance separating two adjacent addressable points in the axis movement is controlled resolution, it is otherwise called as just resolution. Again I told you in CNC machines you will have software resolution and hardware resolution, the digit what gets displayed here on the screen is a software resolution. It need not replicate or it did not tell what is happening in the hardware there.

So, be very careful of hardware resolution and software resolution, generally the limiting resolution will be hardware resolution, then the other two points are accuracy and repeatability. Accuracy is the maximum possible error that can occur between the desired target point and the actual position taken by the system.

So, if it has to intend to move to one point and you try to do that how close it goes to that point is called as accuracy, maximum possible error that can occur between the desired target point, which you want to go and the actual position taken by the system is the accuracy. So, I am supposed to go here, I only went here so my accuracy is not so good. So, that is accuracy resolution is the minimum distance, for example, in a screen the resolution is pixel, a monitor okay, accuracy is maximum possible error.

The repeatability is defined as plus or minus 3 sigma of a mechanical error distribution associated with the access that is repeatable, when I repeat to do the same operation, am I able to go towards the target is called as repeatability. It is defined as plus or minus 3 sigma of the mechanical error distribution associated with the access, that is repeatable. So, three important things which we have to see as far as positioning of CNC, or NC system, is control resolution, accuracy and repeatability.

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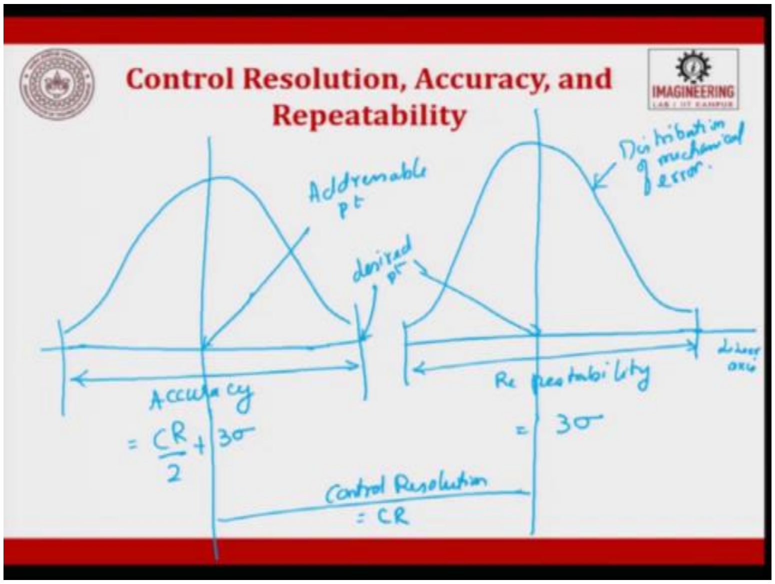

If we wanted to represent it in a figure form let me do it, these two are called as addressable points this is called as the accuracy, which is nothing but CR by 2 plus 3 sigma. So, this is the repeatability, which is equal to another 3 sigma, this we are moving it in a linear access you can also have on a rotating access so here is the desired point.

So, this is called as the control resolution, the definitions are clear, the figure is also clear please understand and then do it. What is this bell curve? The bell curve is the distribution of mechanical error, this is the representation of the control solution, accuracy, and repeatability, the definitions which we saw here.

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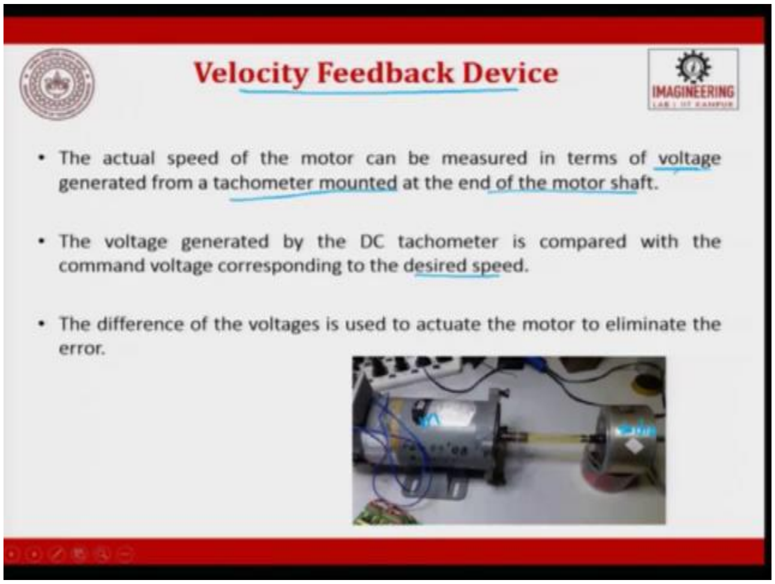

The last one is the velocity feedback drive. The actual speed of a motor can be measured in terms of voltage generation from a tachometer. So, this is a motor, this is a tachometer it tries to generate a voltage signal and that from the tachometer is taken as output and again attached.

The voltage generated by a DC tachometer is compared with the command voltage corresponding to the desired speed, the difference is measured and then we try to find out the error and we try to eliminate the error, the difference of voltage is used to actuate the motor to eliminate the error, this is the motor, this is the tachometer. The voltage signal is taken from here and it is used, this is for positional feedback.

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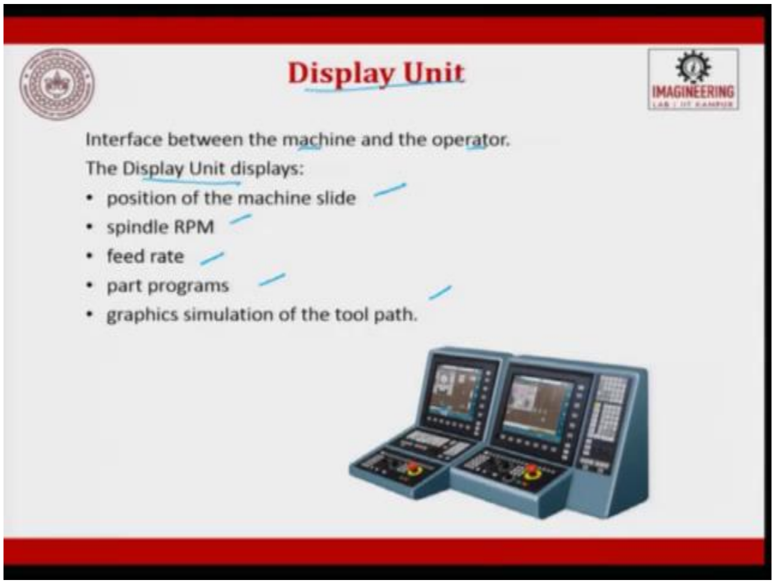

The display units are going to be it will try to display position, spindle speed, feed rates, part program, and graphical simulation. So, all these things will be done in the interface between the man and the machine. So, you can see the position of the machine tool, you can see the speed with which it is operating, feed rate moving, part program run based on the part program simulation.

So, all these things are seen in the display unit it is a interface between the machine and the operator is nothing but the display unit.

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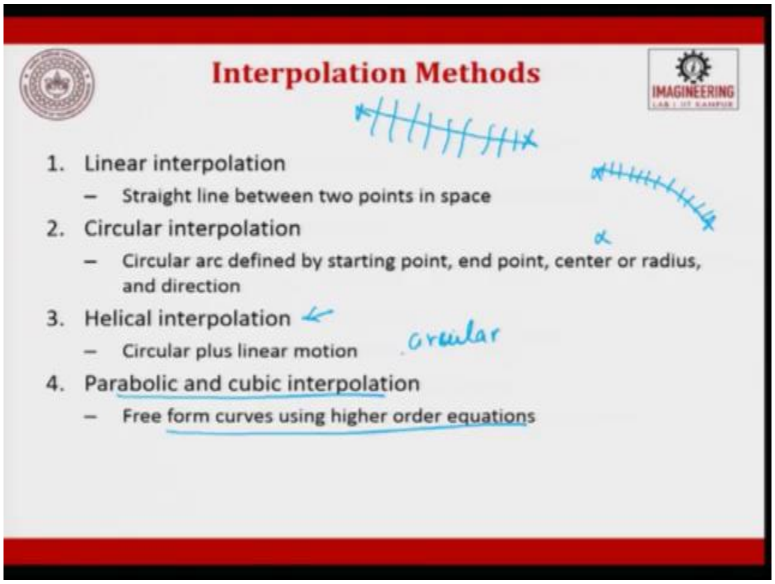

We will see about the interpolation methods, so when we talk about interpellation I told you linear interpolation, we will have circular interpolation, we have helical interpolation for complex jobs we have parabolic and cubic interpolation. Linear interpolation is start point, endpoint, between these two points discretizing several points is linear interpolation. Straight line between two points and space linear interpolation, shortest distance between two points.

Circular interpolation, circular arc defined by straight points, start point, so I told you already start point, endpoint, the radius you give and then you also try to center. So, you try to find out so many points in between which is called as circular interpolation.

A combination of these two is circular plus linear, circular plus linear is the helical interpolation the higher order interpolation techniques are parabolic and cubic, which is used for free form surface, where in which we try to mimic the nature. So, generally we exhaustively used helical, circular and linear, these are the three things which we exhaustively used

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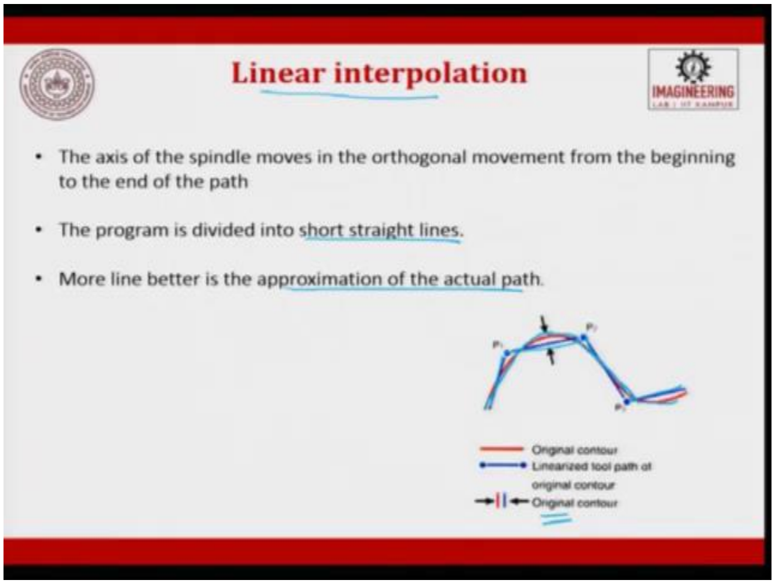

What happens in linear? The axis of a spindle moves in the orthogonal movement from the beginning to the end of the path, it moves only orthogonal. So, if you want a point like this you will try to move, if you want a curve like this you will try to move in points like this. The original contour what you wanted and the linearized machine moment, why?

Because the machine can move in steps and it can move in X and Y, it can move together, it generates a diagonal if it moves one or the other it goes in a straight line. So, this is how the linearized tool path so when you do the linearized tool path you have to discretize. So, that is what is done in the linear interpolation, there is an error always which happens that is the difference between the orange line and the blue line.

The program is divided into short straight lines and many lines better the approximation of the actual path, but many lines if you do it takes more time to execute and you will have lesser error. So, there has to be a tradeoff between these two.

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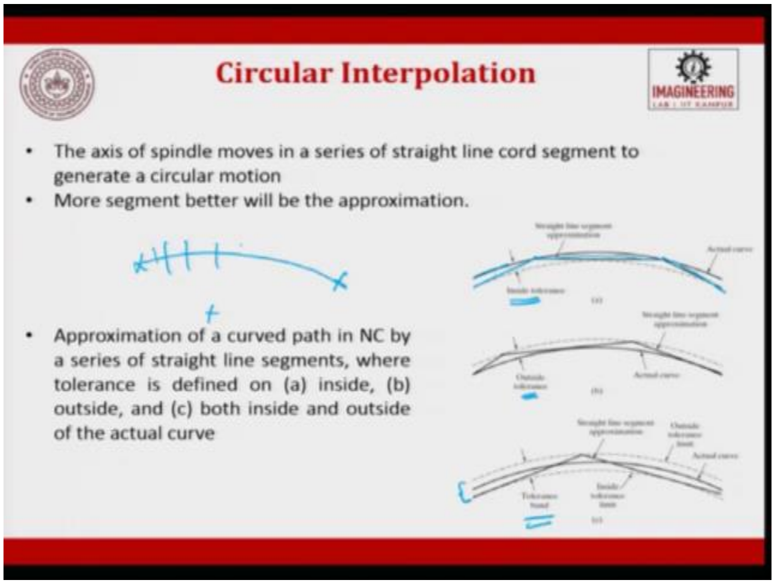

Next when we look at circular interpolation, it is almost the same, the axis of spindle movement in a series of straight line cords segments to generate a circular path. So, this is the original you want, the arc which you want and this is how the linearized motion happens, the distance between these two is called as the tolerance, inside tolerance.

So, the straight line these are points which are discretized along the arc, you can have inside tolerance, you can have X, outside tolerance, this is the actual curve, this is the linearized curve you get. So, you have a tolerance band, so this is the tolerance band which is inside tolerance plus outside tolerance put together is tolerance band. So, more segments better the approximation in circular we have a start point, endpoint, center and a radius. So, you are able to discretize into several points.

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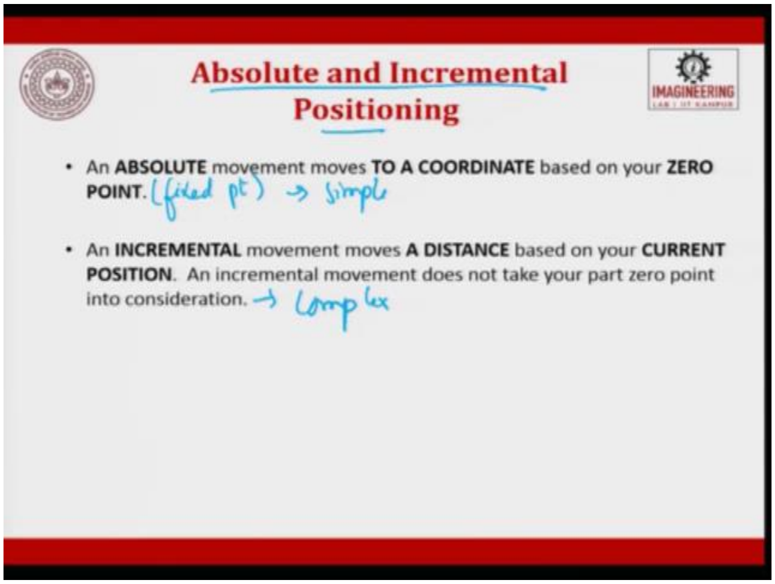

The last part is about absolute and incremental part, absolute and incremental position. An absolute movement moves to a coordinate based on your zero point, for a fixed point, for a zero point is called as absolute. An incremental motion moves a distance based on your current position, an incremental movement does not take your part zero point into consideration.

For your complex job we always go for incremental movement and for a simple geometry we always go for absolute. In a program you can have a combination of both you can start with absolute, end with increment or start with increment, end with absolute, or start with absolute, work in increment and go back to absolute to finish the program to make a part.

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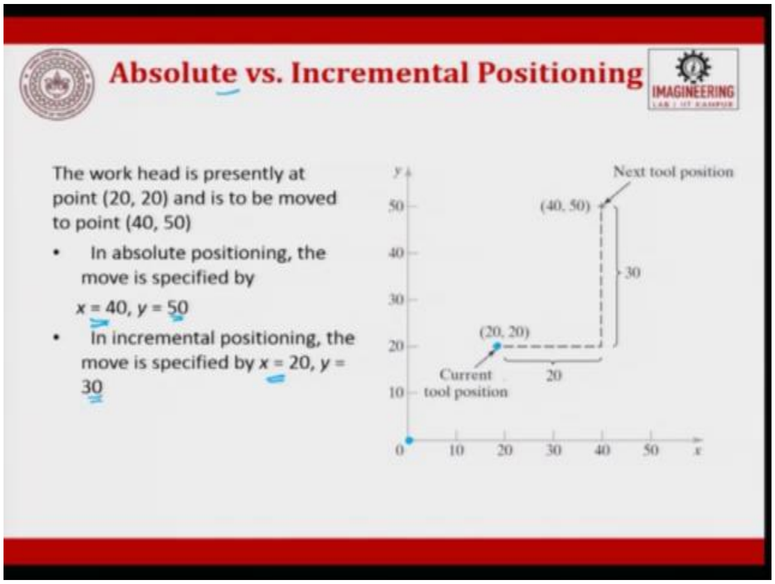

So, these are the examples for absolute and incremental, so absolute is you are trying the work head is present at point 20 comma 20 is moved to the point 40 comma 50, in absolute case you will write it as X 40 and Y 50 in absolute scale because it all happens with respect to the 0. In incremental form what you will do is, you will represent X equal to 20 and Y equal to 30, because it takes with respect to the previous point.

This is the difference between absolute and incremental, this we will see more in detail in the practical class of CNC programming.

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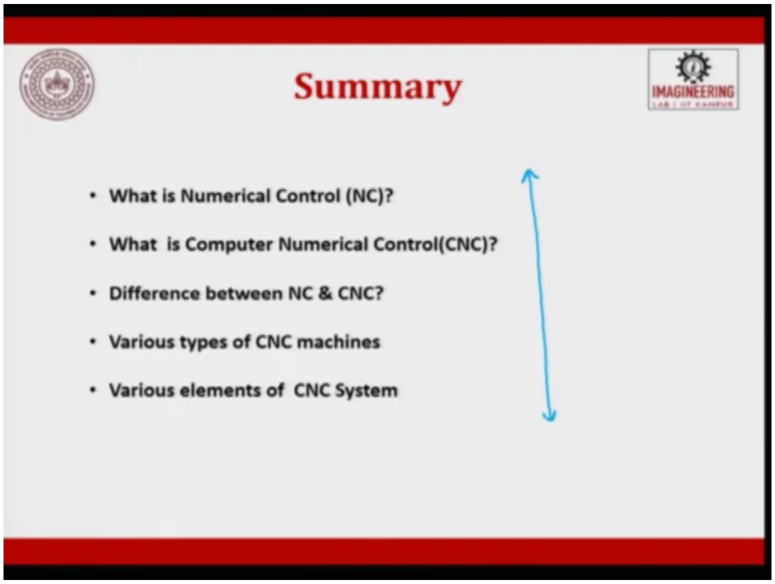

So, to summarize what all we have covered in this lecture, we have seen what is a numerical control NC, what is the computer numerical control, the difference between NC and CNC, various types of CNC machines, various elements of NC and CNC machines.

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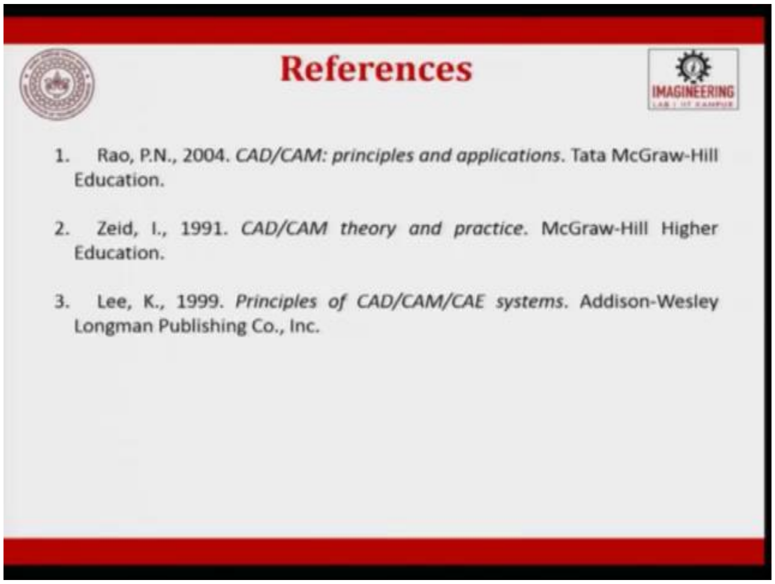

These are the references which we have used and thank you very much.