Laser Based Manufacturing
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Module - 7
Lecture - 23
CNC for Laser Based Manufacturing

Hello everyone, I welcome you all to the second lecture of week 7 of NPTEL MOOC course on Laser Based Manufacturing. In this week, we have started discussing about application of lasers in automation, in particularly the manufacturing automation. In our previous lecture, we have seen in a comprehensive way where and how the lasers can be useful in an automation.

We have seen how the distances can be measured by using lasers and how the lasers are useful for navigation of automated guided vehicles. overall, the lasers are very much useful to obtain the desired objectives as far as the manufacturing automation is concerned. Now, there is an integral part or element of this manufacturing automation and that is the CNC control.

The CNC is nothing but the Computer Numerical Control. And almost all the machine tools which are used in the industry in the tool rooms nowadays are CNC numerical control. it is very much essential for a laser engineer or a Laser based manufacturing engineer to have some knowledge about the CNC, CNC controls and how the CNC machines are getting operated.
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With this objective, let us study in today's class, the CNC for Laser Based Manufacturing. CNC is almost being applied to all sort of manufacturing processes. The mechanical transformation processes such as material removal or forming or rolling or the welding operations, that is the joining processes and for the laser based as well, now we are using CNC based controllers. let us see what is the meaning of this CNC and what are the various aspects of CNC for Laser Based Manufacturing.

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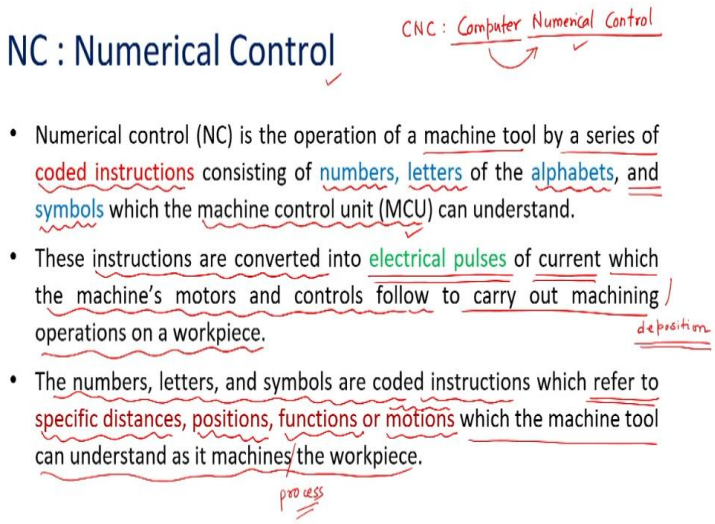

CNC in a broad way has 2 terms. here I will write CNC and it is Computer Numerical Control and it has 2 terms or 2 parts; numerical control and computer. let us see one by one, what is the meaning of numerical control? And how computers are helping for better numerical control? let us see the meaning of numerical control first. Numerical control is the operation of a machine tool by a series of coded instructions.

Numerical control is a control operation of a machine or a set of mechanisms and this communication or this control is being carried out by executing coded instructions by following the instructions which are in certain codes. what these coded instructions have? These have numbers, letters, alphabets. These coded instructions are given in the form of numbers, letters and alphabets.

It also has certain characters or symbols; special characters or symbols are also part of the coded instruction. this coded instruction is given to the Machine Control Unit that we call the MCU; it is an acronym of Machine Control Unit as far as the CNC control is concerned. This Machine Control Unit is understanding decoding the instructions given by the user or the

programmer. And based upon that instructions, the machine tool operations would be carried out.

Now let us see what these instructions are. these instructions are converted into electrical pulses of current. if we just look at all the CNC machine tools, they are equipped with DC motors or AC motors. to operate the motors, electric motors, we need generate electrical pulses. And these electrical pulses are based upon the coded instructions given by the controller.

The electrical pulses of current which the machine's motors, controls follow to carry out machining operations on the workpiece. In additive manufacturing processes, it may be the deposition operation. In welding processes as well, it is a welding operation. whatever the intended operation would be carried out by having the control over the actuators, the prime movers or actuators and these are the electrical motors which are there in the CNC machines.

Now, what these numbers, letters and symbols, they designate? the numbers, letters, symbols are coded instructions and they are referring to specific distances, positions, various functions to be carried out or motions to be generated, which the machine tool can understand as it machines the workpiece or as it processes the workpiece. here, what these coded instructions will have?

We have to communicate about the distances. We have to communicate about laser that to follow a certain distance from one location to the other location. We have to designate the work part inside laser machine volume, and that positions of the work part fixtures to be communicated to the machine tool. positions, specific distances, third is functions. various functions need to be carried out. These are the auxiliary functions.

For example, door close, door open, movement of the laser or the movement of the table to its home position, and many other auxiliary operations such as inert gas on, inert gas off. all these operations are to be communicated to the Machine Control Unit. Accordingly, the Machine Control Unit will act upon. Then, motions; various motions to be carried out, whether it is in a rapid mode or it is in a given speed, that to be communicated to the machine tool.

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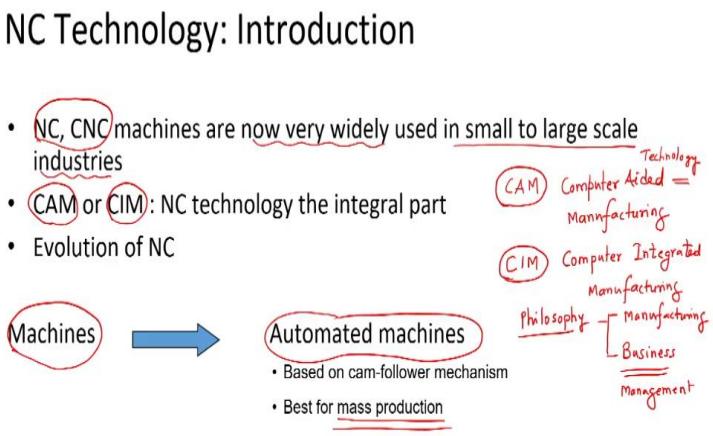

Nowadays, as I mentioned, the NC or the Computer Numerical Control machines are very widely used in small to large scale industries. These are now the integral part. everywhere you will find the NC machine tools or CNC based machine tools are readily available. These are the integral part of CIM and CAM. CAM is the acronym for Computer Aided Manufacturing, CAM that we call quite often, Computer Aided Manufacturing.

And CIM is the acronym of Computer Integrated Manufacturing. CIM is a philosophy and it is a broader term. It involves the manufacturing operations as well as the business operations or we will consider the management related operations. However, CAM is more focused on the technology, like conversion of the CAD drawings into CNC part program, control of the CNC machine tools, on and forth.

CAM is more on the technology and CIM is a philosophy which covers up the manufacturing aspects as well and business-related aspects. While the CNC machine tools are the integral part of both the things; of course, CIM is the superset which has the CAM and the CAM has the CNC machine tools. the ordinary machine tools or very basic or conventional machine tools or machines were transformed to the automated machines sometimes in mid-nineteenth century and they started using the CAM follower mechanism, and the objective was for the mass production.

Typical machine or manually operated machine was not able to come up with the faster production for multiple number of atoms. by having the CAM follower mechanism, the engineers started developing the products at a mass scale; but that was also not sufficient, the

accuracy or the product quality was not that good. with the advent of electronics, we started using numerical control to control the operations of the machine tool and that was a revolution.

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Now, let us see the term computer and how the computer is helping to enhance the numerical control. here we will be studying the word C and it represents Computer; Computer Numerical Control. earlier when the numerical control was started being used, the engineers, they were feeding the instructions in the form of magnetic tapes or they started using it by using punch tapes.

But the problem with punch tape cards is that editing. If we want to change the program, if you want to change the instructions, then we have to discard the entire punch card which used to be in mechanical form. The punch card used to be in mechanical form, and if you want to change any instruction on the punch card, you have to discard the entire punch card, you have to redesign or redevelop the punch card.

That used to take lot of time, that used to be the bottleneck in using the NC machine tools. with the computer, now we can edit the program very easily, we can have the graphical simulation of the program on our screen. After verifying the program, then we are giving the program to the CNC machine tool. Graphical User Interface is the biggest advantage of going for computer based numerical control.

Here, it is very easy to go for on-machine or online programming; otherwise, we have to carry out the offline programming. Offline programming means we have to write the program and

convert that into the punch card. here, the online means on the machine tool or the graphic user interface itself we can write the program, we can generate the program and then give it to the MCU.

Moreover, the CNC machine tool is also helping us to provide various auxiliary functions such as automatic tool changing. automatic tool changing is possible nowadays. Then, the palette changing: pallets are nothing but the platform over which the work parts are arranged in arrays. And these pallets are fed to the machine tool. The tools are coming, the lasers are coming and they are processing the work parts in one go.

By the time we carry out the machining operation or deposition operation using lasers on one set of parts which are mounted on the pallet, the other pallet we can make ready for the next set of operations. the automatic palette changing is also a prominent advantage of going for the computer based numerical control. With computers, now we can easily have the network communications.

As we know that our all computers may have the local area network that is a LAN or we can use the Wi-Fi that is a Wireless Fidelity networks. In a similar way, the CNC based controllers can be connected in LAN or we can connect them by using the Wi Fi. by using these network communications, a central computer can control various CNC based machine tools which are there on the shop floor.

Network communications boosted the capability of the CNC based machine tool on the shop floor. The CNC based machine tools added one important feature that the machine tools now can run unattended. there is no need to monitor continuously by a human being the machine tool or the machining operations. you program the intended operation and then the programmer or the operator can do other work; the machine can be run unattended.

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One such CNC based machine is there in front of you. this machine is having its bed. this is the bed of the machine. This is the processing head. this is the GUI, the interface of the machine with the user, and it is the keypad through which the user is controlling or operating the machine tool. Well, we will be studying some of these elements in our next few slides.

A modern CNC milling machine nowadays are getting intelligence. we are calling these machine tools as intelligent machine tools. in what sense these machine tools are intelligent? these machine tools are equipped with the sensors and these sensors are continuously monitoring the performance of the machine tool itself; for example, the temperature sensors.

During the laser cutting operation, if something goes wrong; consider there is a huge heat is getting generated due to application of large laser power, then there are chances of having sparks or arcs and there may be some sort of hazards to the machine tool and the user as well. in this case, the machine tools are equipped with the safety sensors, process monitoring sensors such as temperature sensors, force sensors, limit switches.

It is very important nowadays to have the limit switches for the safety doors. when such operations are being carried out at a high energy input and if something is not proper with the machine tool, the sensors are giving input to the controller and controller is taking action according to that, or it is giving alarm to the user. in that sense, all the machine tools are nowadays intelligent machine tools.

Moreover, by using these sensors input, the machine tools are having the adaptive control. They are changing the process parameters. It is not only the off or on of the actuators, it is with respect to change in the process parameters as well. based upon the data, based upon the data collected from the sensors, the microprocessors of the CNC based machine tools, they are taking, they are correcting the process parameters and that is called as the adaptive control.

The process parameters fed by the users are altered or changed or fine-tuned based upon the experience gaining or based upon the condition getting generated during the operation intelligently.

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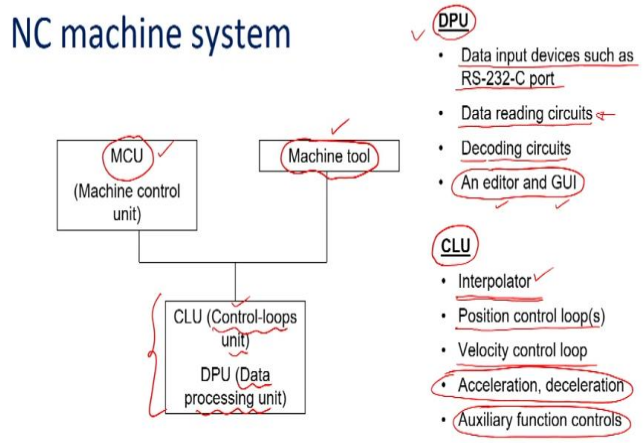

A typical machine tool has basically 2 parts. The first is the control unit that is the Machine Control Unit and the next group of units is Control Loops Unit and Data Processing Unit. to run a CNC machine tool, there is need to have a Machine Control Unit and that Machine Control Unit is processing the data given by the user and it is generating the control loops; it is generating the movement of the work parts; it is controlling the movements of the tool in relation to the work parts.

And these are to be meticulously executed as per the instructions given by the user. data has to be read; the data has to be decoded; and then, the control loop has to be executed in a proper way to control the machine tool. the DPU that is a Data Processing Unit, it is connected to the external environment with certain hardware. the earlier the hardware was RS-232-C port, but nowadays we can use the flash drives to communicate or to feed the data to the CNC machine tool.

The DPU also has data reading circuits. The data will be read by these data reading circuits. That data will be decoded by the DPU and then it is given to the control unit. this Data Processing Unit is also working along with the editor and the Graphical User Interface. The next is the Control Loop Unit. And the Control Loop Unit is having the circuitry or the logic related to the interpolation.

It is having an interpolator. We will see what is the meaning of interpolator in our coming slides. The CLU is generating position control loops, velocity control loops and it is also controlling the acceleration or deceleration of the various physical elements of the CNC part. we have to control the position of the work part inside the machine volume. Not only the position, we have to control the velocity by which the parts are moving in relation with each other.

Moreover, the Control Loop Unit is also controlling the operations related to the auxiliary functions such as the inert-gas-on, inert-gas-off or removal of the work part or the making the home position or getting the part to the home position.

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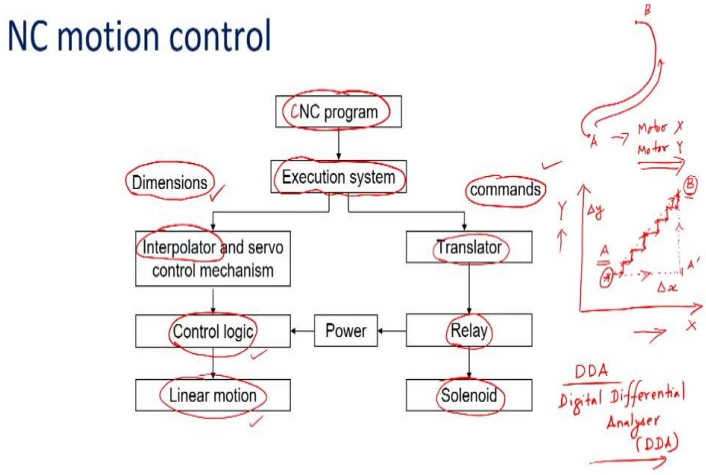

A typical CNC program or we can call a typical NC program as well, it has an execution system. And what this execution system does, it first understands or decodes the dimensions. it first tries to find out the dimensions. certainly any CNC operation you will see or any CNC program you will see, we are providing the information about the locations and the positions.

The movement of the work part, movement of the tool with respect to the work part, this is the first basic thing the machine tools are carrying out. And the second one is, it is executing certain commands. It is controlling or it is carrying out certain operations according to commands. These commands are like open, close, start, stop. all these are related to certain operations like shutter-open, shutter-close or application of laser beam or starting the inert gas or making it off the inert gas.

All these are the operations; these are communicated in terms of the commands; dimensions and commands. the dimensions are fed to the interpolator. The interpolator is nothing but a system where the distances, or based upon the positions given by the user, the controller is generating the pulses. now, let us consider that in a plane XY, we are having a point A and there is another point B.

Now, we have to give the command or we have to operate the machine and we are asking the machine to move from point A to point B. we will be giving the information to the machine tool about the initial position that is A and the final position B. Now, the CNC machine tools, they do have 2 motors. The first motor is controlling the movement of the table in X direction.

The second motor is controlling the movement of the table in Y direction. If we independently operate the motor X, then there would be movement of the table along X direction only. If we operate the Y motor, then there would be movement along the Y direction. But if we move both the motors simultaneously, then the table will follow the diagonal movement in the XY plane.

If the Delta x and Delta y are same, and the velocity of X motor and Y motor is same, then there would be a trajectory from point A to point B. Otherwise, if we do not follow this, the interpolator or the machine tool will take the movement from point A along X direction up to this point that is A dash, and the motor B will be taking the point A dash to the destination. when we are moving from A to A dash, the motor Y is not working, only motor X is working.

When we are moving from A dash to B dash, motor X is not working, motor Y is working. But if we allow motor X and motor Y to be run with the same feed, then we may reach from point A to point B. there has to be certain algorithm; there has to be certain program which is

computing these steps Delta x and Delta y and this is called as the interpolator. we have to have some circuitry some program which is taking care of this.

There are lot of algorithms being used. The very basic algorithm is DDA algorithm. This is Digital Differential Analyser algorithm. Well, the details of DDA is out of scope of this lecture, but you try to understand the working of the interpolation. to get the efficient movement of the table from one location to the other location, we have to incorporate the interpolator.

Now, in this case, it was very simple or very easy to have movement from A to B, but consider there is a complex curve along which you have to find out the movement. let us see. This is the contour from A to B that you have to interpolate. in this case, we have to go for some advanced algorithms as well. then, the pulses that to be given to the motor X and motor Y would be different.

That data has to be generated and it has to be executed by the control unit. the control logic is to be developed. And accordingly, we have to carry out the linear motions. if you consider the movement of point A to point B along the diagonal direction, it is nothing but in the steps only; Delta x, Delta y. these are the stepwise movement along this. these pulses are nothing but the discrete small amount of linear motion along X and along Y.

Further, as far as the commands are concerned, these commands are to be translated and these are to be given to the relays, and relays are operating the solenoids. The solenoids are electromechanical actuation systems. We are providing the electrical signals and that electrical signals would be converted into the mechanical switching operation.

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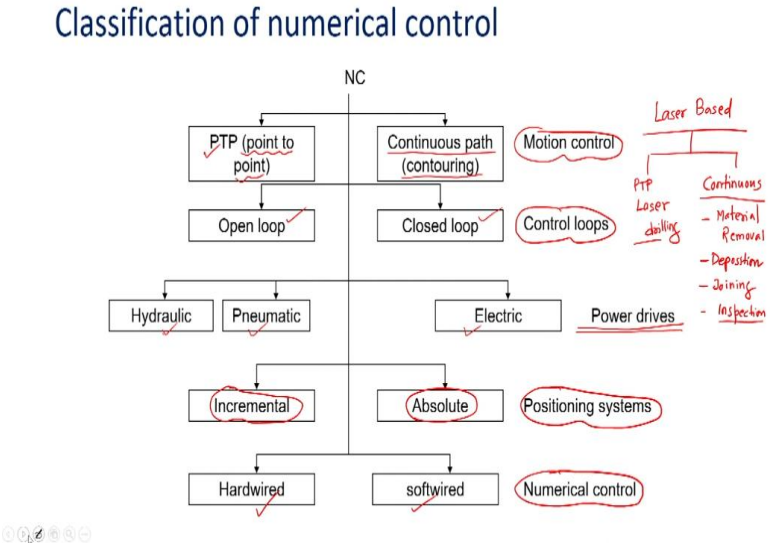

Now, let us see how to classify the numerical control. numerical control is classified based upon the motion control. here we can have PTP that is point to point or we can go for the continuous path or the contouring. In Laser based manufacturing, we required both the things. we need to go for the PTP as well and we have to go for the continuous mode as well.

The PTP is basically a laser-based drilling and the continuous mode is for the material removal, deposition, joining and the inspection as well. both the things are required as far as the laser-based things are concerned. point to point means, the controller will have the capability to move from a specified point A to specified point B. And accordingly, the controller is taking the best possible route, the optimised route.

In continuous path, the user is defining the path and the controller is following the defined path only. Then, based upon the control loops, we can classify the NC machine tools as open loop and the closed loop. we will study the meaning of open loop and closed loop in next slides. Then, power drives: the prime movers or what is the primary energy that you are using; either the CNC machine tools are electrically driven or in certain cases, the hydraulics or pneumatics are also being used to control the operations, but mostly the Laser based manufacturing CNC machine tools are electrically driven.

Then the NC machine tools can also be classified based upon the positioning system. whether the NC is following the incremental mode of the positioning or the absolute mode with respect to certain reference or the datum. And the last one is whether it is a soft wired or the hardwired. let us see one by one the meaning of this classification.

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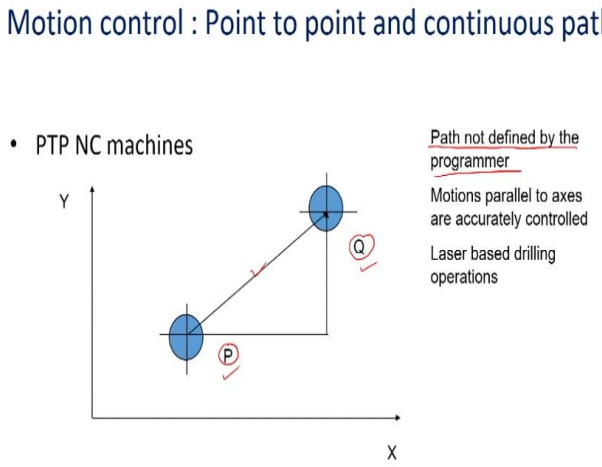

This is the PTP machine. Here the path is not defined by the programmer. There is a plane X and Y and we are having point P to Q, and the programmer is just providing the coordinates of P and Q. This path would be computed by the control unit. that we call PTP programming, point to point programming.

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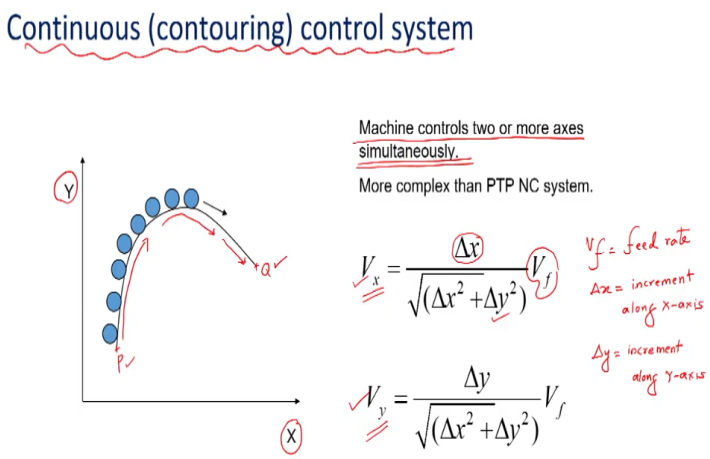

In continuous or contouring type of control systems; as I mentioned, consider we have to move from this point P to this point Q in the specified route itself. this curve has to be followed in XY plane to reach the point Q from point P. the machine controls 2 or more axes simultaneously. as I mentioned previously, we have to control the X-axis and Y-axis simultaneously with a certain velocity.

And this velocity is the function of the incremental movement along X direction, incremental movement along Y direction and the specified feed. V_f is the feed of the movement, feed rate. Delta x is increment along X-axis. Delta y is increment along Y-axis. Then we can certainly find out the velocity of the drive along X-axis and velocity of the drive along Y-axis.

Once we got the velocity along X and Y-axis, that velocity can be converted into the number of electrical pulses that we have given to the motor. It may be a stepper motor or the servo motor. And based upon the information given to the servo motor, the servo motor will act upon and it is rotating or it is carrying out the intended operation.

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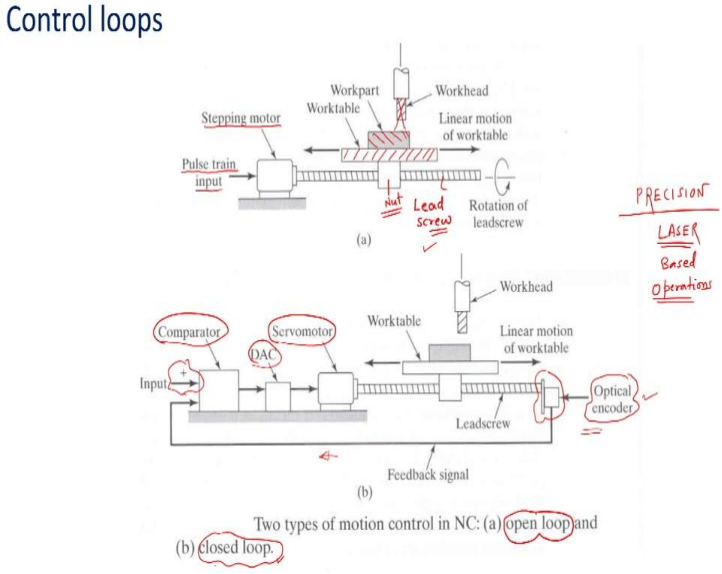

Now, let us see what is the meaning of the classification based upon the control loops. we are having the open loop and the closed loop. on your screen, you can see a typical arrangement of the movement of the table. here we are using a leadscrew; this is the leadscrew and there is a nut. This is very typical arrangement, the screw and nut. The screw is getting rotated by using a motor and that is the stepping motor or the stepper motor, and the pulse train input is given by the controller.

Now, as the leadscrew is getting rotated, there is a translation of the nut along the axial direction of the leadscrew. Now, here we are interested to have the precise moment of the table. over the nut, we have mounted the work table; over that table, the work part is mounted; and then we are processing by using our laser. Now, unless and until there is a precise movement of the work table, we cannot achieve the required product quality.

In this case, can we have certain mechanism which will give the feedback whether the table is moving in a precise way or not? that is all dependent upon the rotation of the leadscrew. The pulse train input is giving certain input; but whether that input is really getting converted into the desired rotations of the leadscrew, that has to be monitored continuously.

If there is certain error, then that error can be rectified by the controller. when we do not have such arrangement, that is called as the open loop. there is no feedback from the machine tool about its own performance. that we call the open loop, there is no feedback. Consider we are having one optical encoder which is mounted here. this is optical encoder which is mounted at the end of the leadscrew.

Here you just notice that the encoder is mounted at the end of the leadscrew. The leadscrew is rotating. As the leadscrew is rotating, the optical encoder is computing or it is recording the rotations of the leadscrew and that data is given to the comparator. comparator is an electromechanical device which is getting the input from the optical encoder and it has a standard value which is given by the microprocessor.

The comparator is comparing the standard value or the desired value or the ideal value with the feedback which is getting from the optical encoder. by comparing these two, the microprocessor is taking the action. If there is an error in a positive or a negative way, accordingly, there would be changes in the signals given to the servo motor. The motor will get the modified signal if there is an error.

And accordingly, we can adjust or we can get the efficient movement; not only efficient movements, the precise movement of the table for the given input data. that we call the closed loop control systems, which is very essential when we talk about the precision Laser based manufacturing operation. for the precision operations, we have to go for closed loop systems. Of course, when we add this instrumentation, the cost of the system would be increased.

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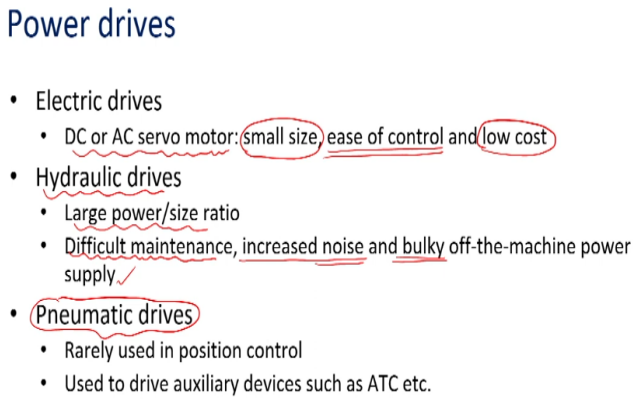

Now, based upon the electrical drives, we can classify. we can have the AC or the DC servo motors. The electrical drives are small in size and there is easiness in their control. the drives are very easy to control, very easy to handle and the cost is also low for the electrical drives. But when we consider the hydraulic drives which are having very large power to size ratio in the industry or in the shop floor, we are also using hydraulic drives which are the CNC controlled.

These hydraulic drives are providing us large power to size ratio, but they are difficult in maintenance, they do have lot of noise and the structure is quite bulky to handle. such systems are not that useful or such systems are rarely being used in the laser-based applications. Pneumatic drives are also being used, but these are for the auxiliary purpose; for example, cleaning purpose or actuations or actuation of some auxiliary operations such as closing or opening or changing of the tool in the CNC based machining operations.

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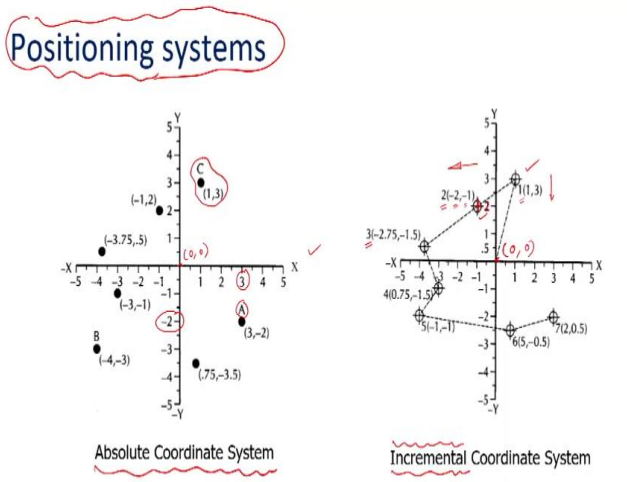

- Modern CNC controllers allow the user to choose the positioning systems

The CNC based laser machines are also classified based upon the positioning system. we are having the absolute coordinate system. here we are specifying the coordinates of the vertices or the corners or the spatial points that to be attended based upon the same reference point. here we are considering the reference point is 0, 0, that is the origin of this plane or the coordinate system.

And with respect to this 0, 0, all the coordinates are specified. here you just notice the point A, the coordinate is 3 along X-axis and -2 along the Y-axis. The C is having 1 and 3. this is 1 along X-axis and 3 along Y-axis. Well, in case of the incremental coordinate system, the coordinate of, or the specification of coordinates of a point is dependent upon its previous point or previous location.

Let us consider that the system is having origin at this location. And now we have to specify the point 1 which is having the coordinates 1, 3 with respect to the origin 0, 0. That is fine. Now, we have to define the coordinates of point 2 and it has been designated as -2, -1. -2 is along the X direction from right to left. this is along the X direction; 2 units from right to left in a negative X-axis direction.

And -1 that is a negative Y direction by 1 unit. it will go down. And we got the point number 2 over here. Then we have to specify the coordinate of point 3. That should be with respect to point 2 only. in this method, we are specifying the coordinates in an incremental fashion with respect to its previous location.

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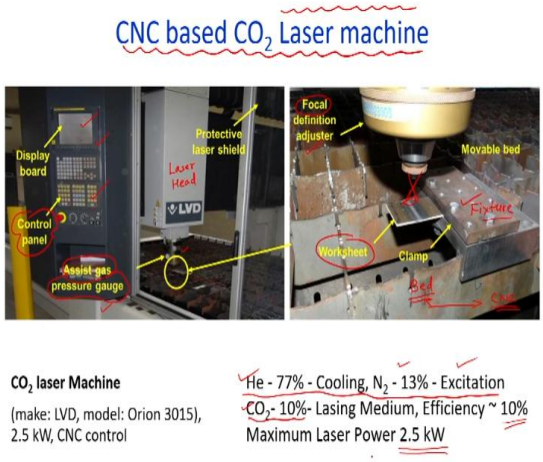

Well, now let us see a typical CNC based CO2 laser machine. till now, we have seen the classification, various elements of a CNC based machine. Now, in a laser machine, what are the various elements are there? , as I mentioned, there is a head; , this is the laser head; and the bed; , this is the bed over which we are using a clamp or a fixture. The movement of the bed along X and Y direction is CNC controlled.

On the laser head, we are having focal definition adjuster. And as we have seen that we need to have a control unit and that control unit we should operate by using certain device that is called as the control panel. To control the operations, we have to communicate with the CNC machine tool, and that would be done by using a keypad and a display device. There are many sensors or monitoring devices are also placed in a laser machine.

And as we have seen in our previous class, for CO2 based laser cutting, we need to have some assist gas. , to control the flow of assist gas, a pressure gauge is required, and that is also mounted. , this is a typical CO2 laser machine. This arrangement may be different or it may be changed in a little way for variety of other utilisations. For example, welding, the features may be different; for depositions, the head may be different; or based upon the manufacturer's idea or the manufacturer's design, there may be little changes in the arrangements of the CNC based machine tool.

Overall, the every CNC based machine tool will have a bed which is getting operated by the X and Y the electrical motors which are controlled by CNC machine tool. A laser head and we should have a GUI or the control panel through which we can communicate with the machine

tool. The controller is the integral part of the CNC based machine tool. , all these parts are common. Their arrangements may be different from the machine to machine.

Moreover, you can see a worksheet which is mounted on the fixture and the laser will come and it will process and it will carry out the intended operation here. Find the various gas combinations are there in front of you. , this is CO2 gas based laser where we are using CO2 of 10%. Helium is the assist gas that is of 77%. And the excitation gas is the nitrogen. The CO2 has efficiency about 10% and the maximum capacity of this particular machine is of 2.5 kilowatt.

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Now, as I mentioned previously, there is a palett changing operations also can be done. , consider in the CNC laser machining operation, we have to process a number of parts simultaneously. we can ready the pallet. , here one pallet is getting ready; simultaneously, the other pallet which is having a number of parts which are mounted here, they are getting processed.

Once the CNC has processed this first set of pallet, it would be removed. And then the second set would be fed to the machine tool unit. , this will save lot of our time. , these kinds of facilities nowadays are available with the CNC machine tools.

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CNC controller

- Consists of
  - Mechanism to read the information
  - Electronics hardware and software that converts the coded tape information into machine tool instructions
- Magnetic-control cabinet
  - Magnetic relay and starting switches

Operator's console

The controller of the CNC machine tools are having the mechanisms to read the information; that we have already seen. And the controller is also having electronics hardware and software which converts the coded tape or the coded instructions; and coded instructions are nothing but the program, the CNC program; into the machine tool instructions.

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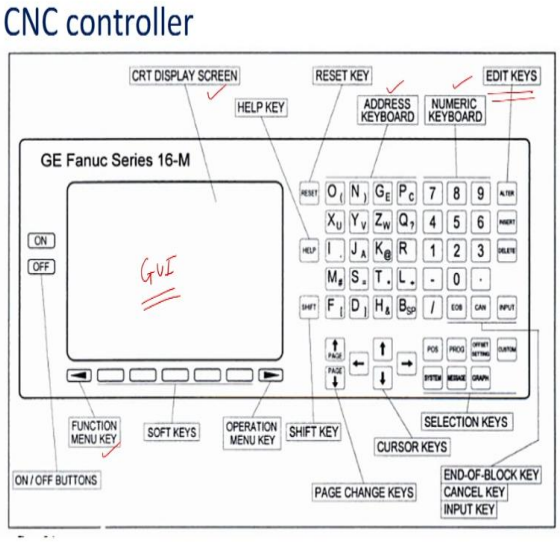

A typical display or a GUI is there in front of you. this is the graphics user interface. It has a keypad. You can see here, lot of keys are provided. This address keyboard, the numeric keyboard, then there are lot of edit keys are there. This is the CRT display screen; various function keys are there. And all these keys are to be utilised to control the operations of the machine tool.

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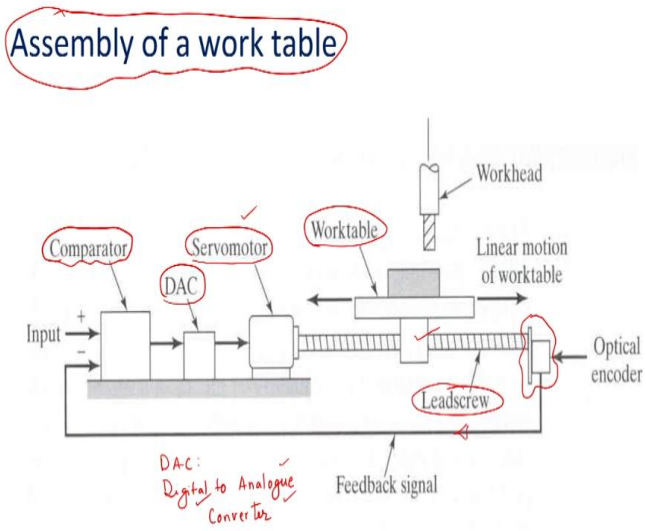

Now, the assembly of a typical work table. , as we have already seen that, we are using a leadscrew over which the nut is mounted; and over the nut, there is a work table. And the precision moment of the work table is all depends upon the accuracy of nut and leadscrew relative motion. , the leadscrews are operated by using servo motor. This is the DAC. The DAC is Digital to Analogue Converter.

We have already seen the function of comparator. Comparator is generating the digital signals and these digital signals are to be converted into analogue signals; because, as we know that electrical motors, we need to feed the analogue signals but the microprocessors are generating the instructions in terms of the digital format, binary format. Yes, there is need to have the optical encoder, the feedback system through which the process is being continuously monitored.

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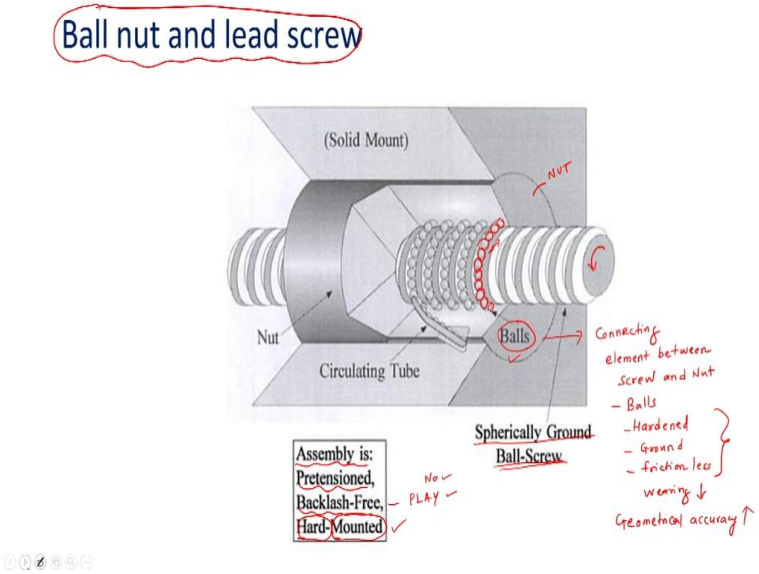

Typically, in the CNC machine tools, we are using ball nut and lead screw. It is not the acme threads or we are not using the typical screw and nut arrangement. Here special balls are being used. These are ground balls; hardened ground steel balls and the screws are having helical grooves. The cross section or the shape of the helical groove is in general is a V shaped, but in this case, we are using semi-circular shape; and through this semi-circular shape, we are using the hardened ground balls.

The benefits of these hardened ground balls is the efficiency. During continuous relative motion of the V-threads, there is a chance of having wearing and tearing. And due to wear and tear, there may be a play, there may be an offset of the information given to the leadscrew and transformation of motion from the screw to the nut. This play is affecting the geometrical accuracy of the work part.

Now, to minimise the effect of play, we have to ensure the continuous or constant contact of the screw and the nut, and that is possible by using a number of ball screws which are mounted, and these are recirculating. These screws are rotating, and during the rotation, they are transferring the motion and they are transferring the power as well. This assembly is pre-tensioned and it does not have the backlash or it does not have any play.

These screws are hard mounted; there are no play. The screws are hard mounted and the balls are also hardened and they are ground. You can see here, this is a spherically ground the ball screw. , the transfer of motion would be carried out in a way that the electrical energy will be

converted into the mechanical energy. The screw is rotating and there is a transfer of motion from the screw to the nut through the balls.

Balls are considered to be the connecting element between the screw and nut. The balls are, as I mentioned are hardened and they are ground; the friction is less. Due to that, there is wearing would be less and the geometrical accuracy would be high.

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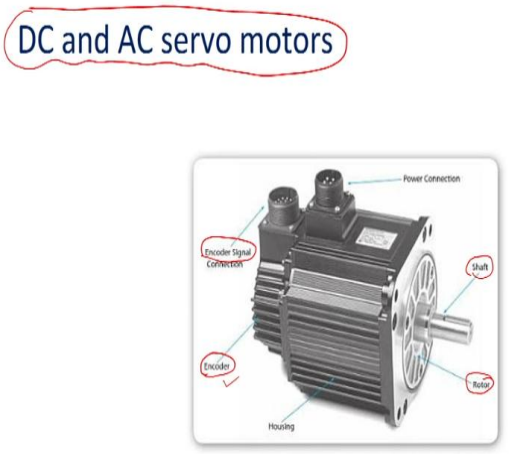

In CNC machine tools, we are using servo motors, the servo motors along with the encoders. Here the encoder has to be mounted. This is the encoder and this encoder is continuously monitoring the rotation of the shaft. This is the shaft and this is the rotor arrangement. And based upon the electrical signals given to the motor, the shaft is getting rotated. The encoders are just monitoring their performance continuously.

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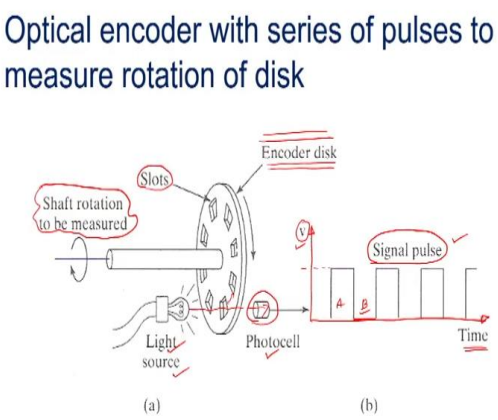

This would be done by using the optical encoder arrangement which is there on your screen. , this optical encoder is having a disk and this is called as the encoder disk. This encoder disk is having slots or there are perforations along the circumference. We are using a photocell and a light source arrangement. This light source and photocell arrangement is there on your screen.

When the encoder disc is rotating, the slots or the perforations are allowing the light to be passed through and we are getting some energy at the photocell. But when there is nothing available between 2 slots, then there is interruption or interception of the light and we do not get any energy, we do not get any voltage output. As the encoder disk is rotating continuously, we are getting the signal pulse.

The higher voltage we are getting when there is a passage of light through the slots or the perforation. And when there is no light is passed, then we are getting no energy, no voltage. By reading the number of pulses per unit time, we can easily compute the rotation speed of the disk. If we mount this encoder disk on the shaft which is getting rotated, then we can easily monitor the rotation of the shaft.

The same arrangement we are using to monitor the rotation of the shaft of this DC motor. By using this, we can easily monitor the accuracy and the precision of rotation of the shaft or the movement of the worktable.

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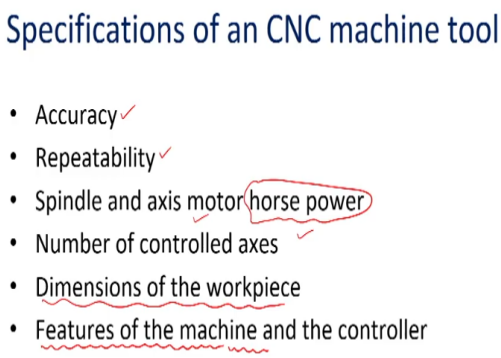

How to specify a CNC machine tool? In general, the CNC machine tools are specified based upon the accuracy of the work parts or the accuracy of the products which are getting developed. Then, repeatability: How, to what extent we can repeat this same performance of the machine or the same performance of the laser-based operation; that is the repeatability. Then, the power of the machine tool in terms of the HP, that is the horsepower of the motors which are mounted.

Number of controlled access: the machine tools may have the 2-axis control or 2.5 axis control or 3 axis control or multiple axis control is also possible. Based upon the simultaneous control of number of axes, we can specify the machine tool. Dimensions of the workpiece: There is a capability of the machine tool in terms of the dimensions of the work parts it can handle.

Moreover, the CNC machine tools are also specified based upon various features the machine has. Basic CNC machine tool may not have the sensors which are mounted for the performance monitoring, but the advanced machine tools may have the sensors which are mounted to monitor the performance of the machine tool. They may have some intelligence incorporated inside to take the corrective actions.

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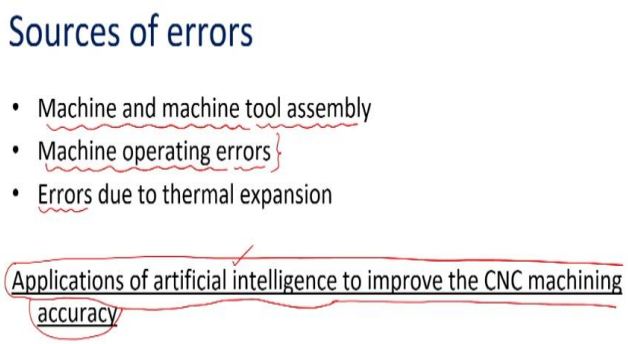

Well, my friends, when we work on the CNC based machine tools, there are lot of errors which are being created. And the sources of these errors are machine and machine tool assembly. , these errors are due to the construction of the machine tool itself. Moreover, there may be operating errors, the part setting or the fixture setting. These are the human or the operator-based errors.

Then, the thermal expansion errors: All these machine tools are having the mechanical parts which are made up of metals. When we are working in a high temperature zone, high heat zone such as in additive manufacturing, the machine tool equipment parts are also getting heated up and , there may be expansion of the machine tool parts. And due to the expansion of this machine tool parts, we may not get the required precision or the accuracy.

In such cases, we can apply the artificial intelligence to improve the CNC machining accuracy artificial intelligence is being used to rectify these errors by adjusting the process parameters. Consider there is a thermal expansion and due to the thermal expansion, we may not achieve or we may not reach to a certain point accordingly, the controller will take the action and it will give an extra input to the DC motor to reach that particular point.

That we call the AI based CNC operations. As in now, lot of concepts are coming up that AI or the machine learning approaches, nowadays, this AI is helping in building up the intelligent machine tools and lots of concepts such as machine learning or deep learning being utilised to improve the Laser based manufacturing operations as well.

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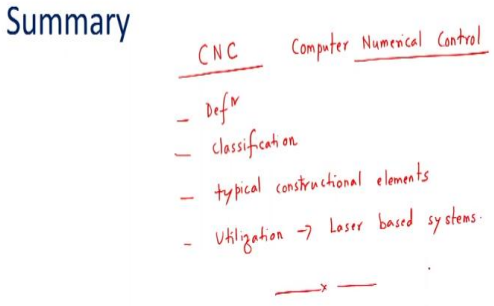

With this, let us summarise our lecture. In this lecture, we have seen the term CNC; it is a Computer Numerical Control. Computer Numerical Control, its definition, classification in detail, that we have seen. Typical constructional elements, that we have seen. And at the end, we have seen its utilisation in the perspective of laser-based systems. Fine, with this I conclude this lecture. Thank you for watching this video or lecture. Goodbye. Thank you.