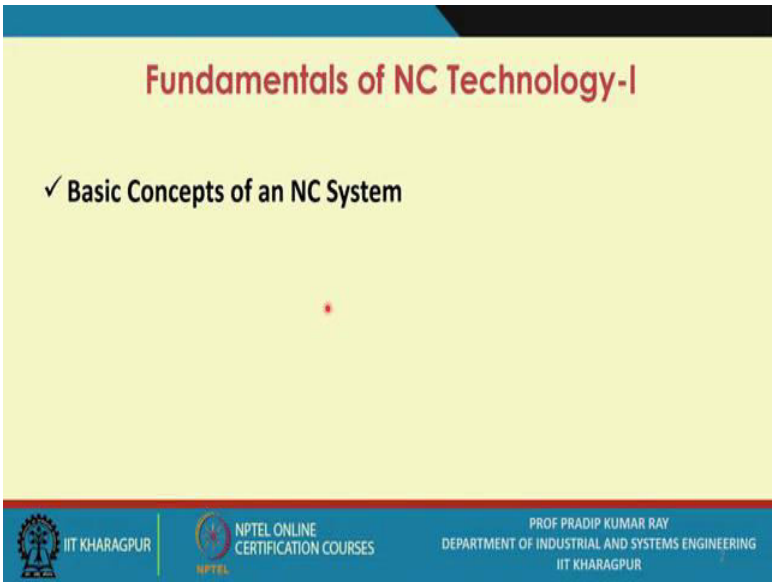
Automation in Production Systems and Management
Prof. Pradip Kumar Ray
Vinod Gupta School of Management
Indian Institute of Technology, Kharagpur

Fundamentals of NC Technology - I
Lecture - 17
Basic Concept of an NC System

During the 4th week, we have taken up one important concept to discuss that is the Fundamentals of NC Technology. in the very first lecture sessions we have mentioned why the NC technology has been adopted.

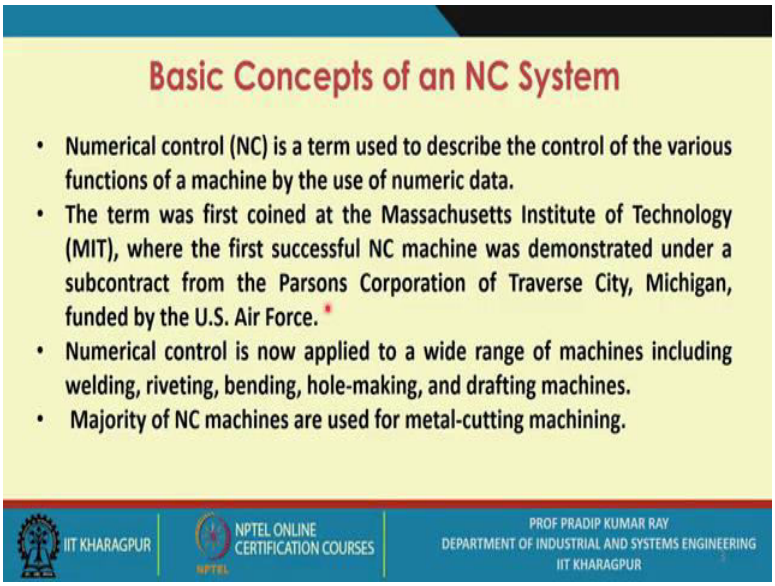
And compared to the conventional machining process, and what are the advantages, what are the disadvantages. Now, when you try to establish an NC technology-based manufacturing system we should know certain basic concepts related to NC technology. During the second lecture sessions of the week, we will be referring to the basic concepts of an NC system.

(Refer Slide Time: 01:25)



For making a system automated, you have to apply the NC technology.

(Refer Slide Time: 02:25)



Let us talk about the fundamental concepts related to NC systems or the basic concepts. Essentially it talks about developing an integrated system and once integrated system is established, you make sure that the automation related principles you have to apply, you have to verify, and then once those principles are applied, once those tools and techniques are used, then you establish or you develop an automated system for production purposes

When you refer to production processes, there are large number of manufacturing processes. Not only the manufacturing processes we also refer to various kinds of material handling system plus various kinds of material work-holding system, different types of the fixtures we have to use for loading-unloading part.

You have to look into all these activities just to check that to what extent all these activities or some of these activities are able to automate.

Initially, you will not be able to make an automated system for all the activities, for all the tasks. It is just not possible. There are certain stages of the development. The first important activities you should consider, and once you are successful in carrying out those activities automatically, and any automated system must be a cost-effective system.

Phase-wise you try to implement NC based technology and later on, you will find that for certain production systems you will be able to develop 100% automated system. The

numerical control is a term used to describe and control of the various functions of a machine by the use of numeric data.

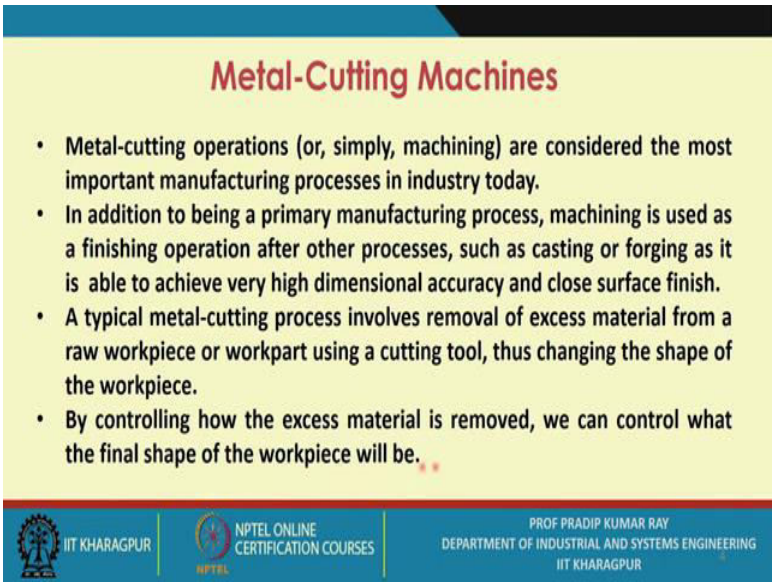
There are three kinds of the data or the coding systems. The first one is the numeric or it could be alphabetic or it could be alphanumeric. Out of these three types, you need to use the numeric data, that is why it is referred to as the NC control or Numerical Control system.

The term was first coined at the MIT, where the first successful NC machine was demonstrated under a subcontract from the Parsons Corporations of Traverse City, Michigan in US, funded by the US Air Force

Numerical control is applied to a wide range of machines not only for machining operations or typical metal removal machine tools but also you can apply NC based technology to a large type of machines as well as large types of processes.

It is applied to a wide range of machines including welding, riveting, bending, hole-making and drafting machines. The majority of the NC machines are used for the metal-cutting machining.

(Refer Slide Time: 08:03)



With respect to a particular NC machine tool not only you get one type of operations, but also multiple operations.

Metal-cutting operations for simply machining are considered the most important manufacturing processes in industry today. You have a raw material and you have to convert the raw material into the finished goods. There could be multiple operations, and normally we refer to the batch production systems.

In many products, you find that maybe few 100 parts or the components you need to use. All these components of the parts are to be manufactured and from there, work part or the raw piece or the raw material.

You try to get not only one kind of operation from one machine tool, but also the several kinds of operations, 5, 6, or even the 10 different types of operations you might get from a typical NC machine tool.

In addition, being a primary manufacturing process, metal machining, machining is used as a finishing operation after other processes.

Similarly for the forging, it is able to achieve very high dimensional accuracy. That is your objective; there will be many kinds of quality characteristics and whether you are getting all these quality characteristics as per the specified tolerances or not and the close surface finish.

The typical metal-cutting process involves removal of the excess material and this amount of excess material should be as minimum as possible and normally while you use a workpiece or work part and normally this work part or the workpiece or the basic raw material, it must be made available in standard sizes and shapes.

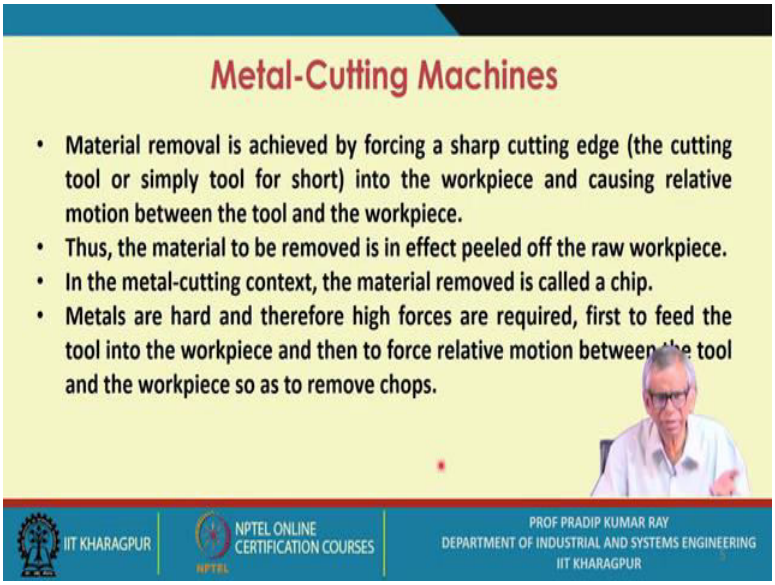
These sizes are available in specified the dimensions, whether you have these dimensions in r5 series or r10 series or r20 series, in many cases maybe r 40 series. So, make sure that you select these raw pieces in standard dimensions.

You select the size in such a way that minimum amount of material needs to remove to get the final shape and size of the component or the part. We have to remove that excess material from a raw workpiece or work part using a cutting tool.

Changing the shape of the workpiece, the engagement of a cutting tool for carrying out operations. By carrying out all these operations, you are trying to change the shape and

the size of the component or it is a basic raw piece. By controlling how the excess material is removed, we can control what the final shape of the workpiece will be.

(Refer Slide Time: 13:32)



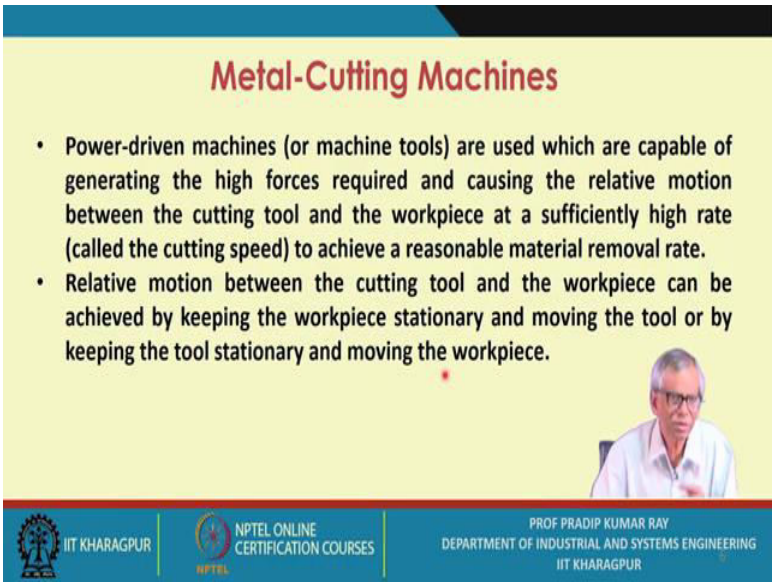
How do you get this the material removal process? You remove this excess material by forcing a sharp cutting edge. Here you have to force a sharp cutting edge that is the cutting tool or the simply tool into the workpiece

The amount of force to be exerted that you must be able to compute and as the cutting process goes it might happen that this force might be changing, there could be a variability in this cutting force causing relative motion between the tool and the workpiece. Thus, the material to be removed is in-effect peeled off the raw workpiece.

In the metal-cutting context, the material removed is called a chip. Suppose, FMS is used for metal-cutting; the chips will be generated and there should be an automated chip removal system.

The metals are hard and therefore, high forces are required. First to feed the tool into the workpiece, and then to force relative motion, between the tool and the workpiece so as to remove chips.

(Refer Slide Time: 16:05)



These machine tools are power-driven. There are many kinds of the machine tools, but those are not power-driven. Many time it could be absolutely manual-driven or may be in many cases you engage the animals but now go for the last 100 years or so, you will find that these machines are power-driven.

These are capable of generating high forces required and causing the relative motion between cutting tool and the workpiece at a sufficiently high rate called the cutting speed. This is one of the process parameters.

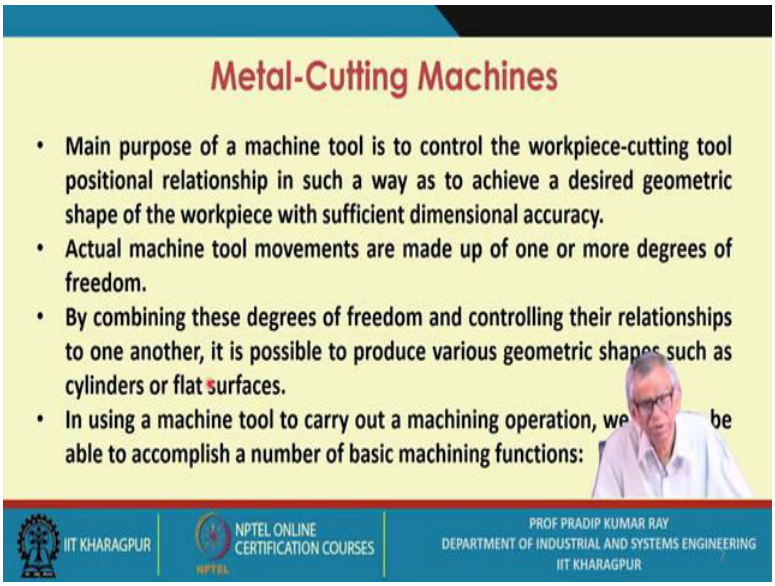
Not only you need to identify the process parameters, but you need to specify the acceptable values of these process parameters.

Many times, this whole exercise is referred to as setting process conditions optimally While you determine all these values, not only one sort of the objective you have to fulfill, usually a number of objectives, cost minimization, production rate maximization, minimization of the throughput time or it is the manufacturing lead time. So, a number of conditions you have to satisfy.

One of the process parameters is the cutting speed to achieve a reasonable material removal rate. Per unit of time how much material you are removing. Relative motion between the cutting tool and the workpiece can be achieved by keeping the workpiece stationary. Normally that is done keeping the workpiece stationary.

Moving the tool or by keeping the tool stationary and moving the workpiece, you are bothering about is the relative motion between the workpiece and the cutting tool. In certain cases workpiece remain stationary and the tool is cutting tool to move or it could be just the cutting tool remains at a fixed position whereas the workpiece is moving.

(Refer Slide Time: 19:41)



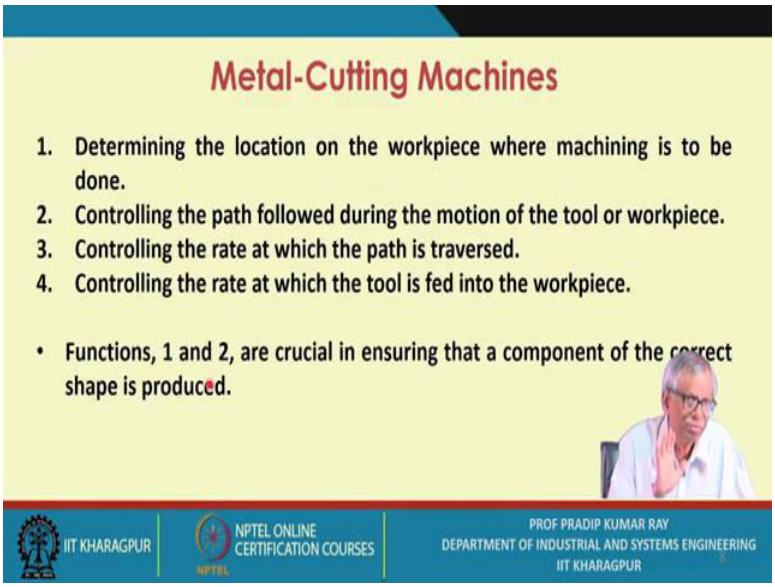
The main purpose of a machine tool is to control the workpiece cutting tool positional relationship in such a way that a desired geometric shape of the workpiece with a sufficient dimensional accuracy meeting the tolerances you must get, and this geometric shape when you look at its part drawing, you will definitely get this idea and you can define shape, whether it is a cylindrical or prismatic that will be known and by using this metal-cutting tool as well as NC machine tool, you are getting the final shape

Actual machine tool movements are made of one or more degrees of freedom. Normally 5 axis machines, 6 axis machines, sometimes only 3 axis machines. These are basically reflecting the degrees of freedom.

By combining these degrees of freedom and controlling the relationship to one another, it is possible to produce various geometric shapes. The whole process may be referred to as a contouring shape such as cylinders or the flat surfaces.

NC part programming or the coding is to be done. Through this part programming, you are getting a particular geometric shape. In using a machine tool to carry out a machining operation, we need to be able to accomplish a number of basic machining functions.

(Refer Slide Time: 22:56)



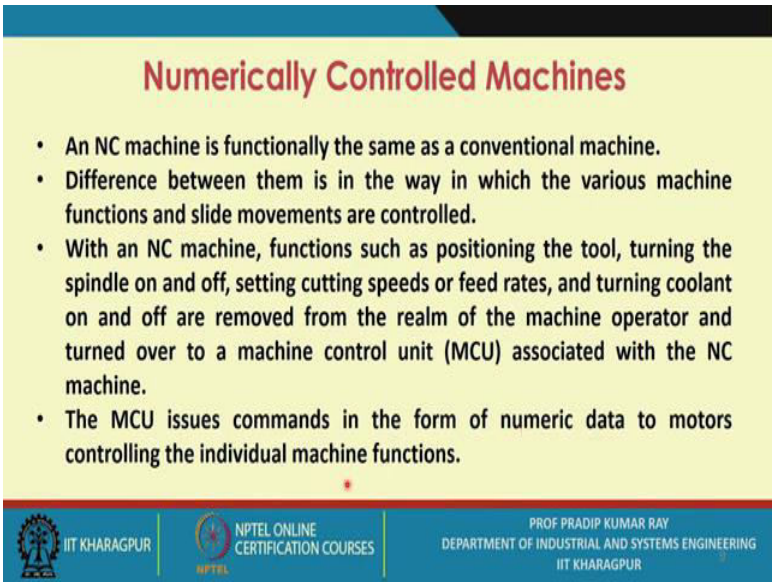
When you try to automate the system, automate the working of a machine tool, what kind of activities you are doing, what are the functions you should be aware of? First, determine the location on the workpiece where machining is to be done.

This location is to be defined with respect to a coordinate system. Controlling the path follow during the motion of the tool or the workpiece. This is basically the motion control system, motion control, NC machine motion control.

Controlling the rate at which the path is traversed. The metal-cutting rate you should know.

There is a concept called setting of the cutter that you have to specify while you write the program. Controlling the rate at which the tool is fed into the workpiece. So, there is another 4 aspects you need to consider. Functions 1 and 2 are crucial in ensuring that a component of the correct shape is produced.

(Refer Slide Time: 24:45)



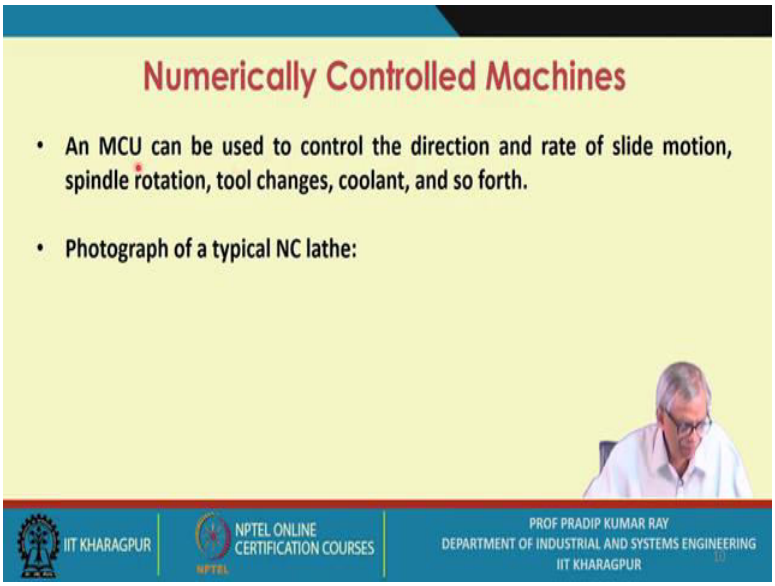
NC machine is functionally the same as a conventional machine. From the conventional machine suppose you are getting *n* number of functions or *n* number of operations, all these operations are needed or a necessity.

If you convert the conventional machine into NC based system or the NC machine tool, some set of operations you have to get from the NC machine tool. The difference between them is the various machine functions and the slide movements are controlled.

With NC machine functions such as positioning the tool, turning the spindle on and off, all these are made can be made automated. Setting cutting speeds or feed rates, and a turning coolant on and off removal from the realm of the machine operator and turn over to a machine control unit.

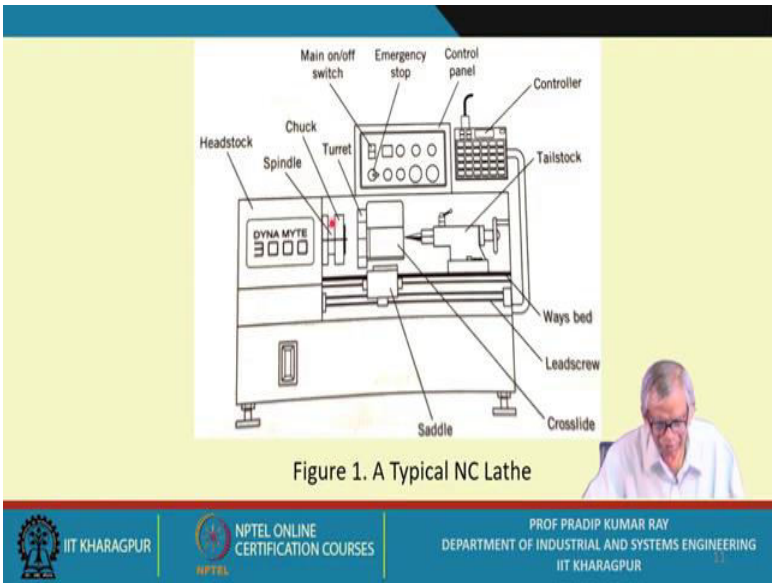
These days we will find that the machine control unit is basically nothing but computer system is a computer associated with the NC machine, the MCU issues commands in the form of numeric data to motors controlling the individual machine functions.

(Refer Slide Time: 26:21)



An MCU Machine Control Unit can be used to control the directions and the rate of slide motions, spindle rotation, tool changes, Coolant is to be used. Usually, the coolant is a source solution.

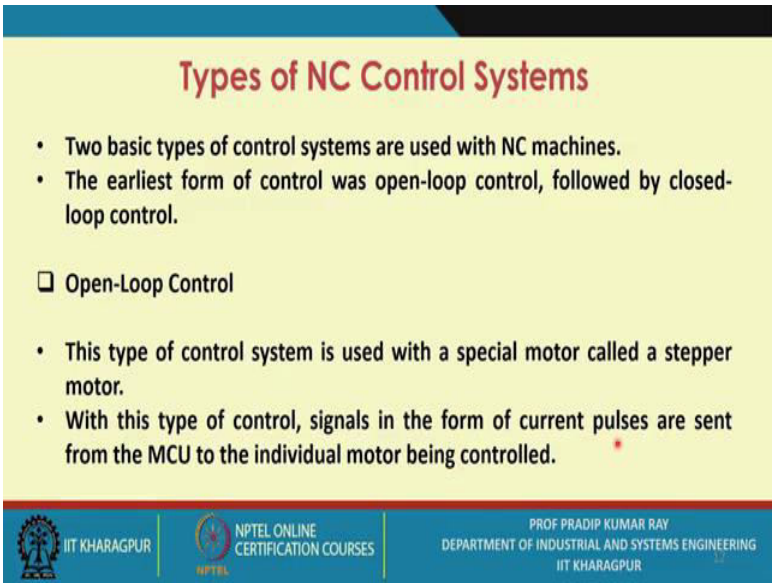
(Refer Slide Time: 26:49)



We are referring to a typical NC lathe. Head stocks, you have the spindle, the turret, the chuck and these are the switches, on and off switches, emergency stop, this is a control panel. The controller is the tailstock. You must be familiar with all these operations or a typical lathe.

It is basically sometimes referred to as a mother machine. Lathe can be of different types, engine lathe, turret lathe, capstan lathe, many other varieties are there and this is the bed and this is the lead screw, this is the cross slide, this is a saddle.

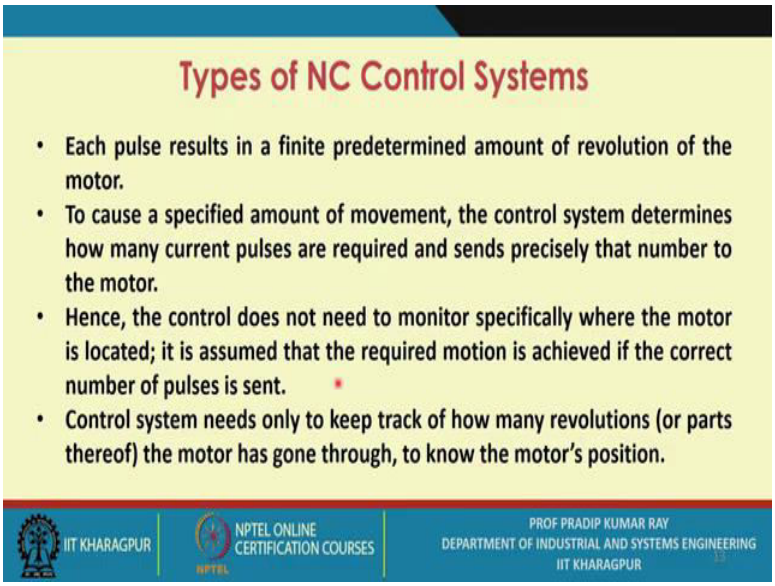
(Refer Slide Time: 28:09)



There are two types of NC control systems you come across. One is the open-loop control and the second one is the closed-loop control. Two basic types of control systems are used with NC machines The earliest form of control was open-loop control, followed by the closed-loop control.

Closed-loop means there is a feedback mechanism. This type of control system is used with a special motor called a stepper motor. With this type of control the signals in the form of current pulses, the typical signal form are sent from the MCU, Machine Control Unit to the individual motor being controlled.

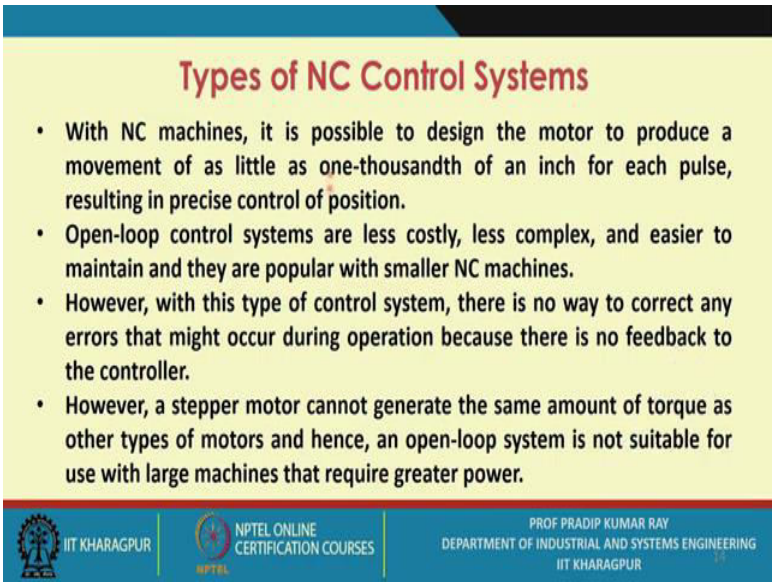
(Refer Slide Time: 29:03)



Each pulse results in a finite predetermined amount of revolution of the motor. To cause a specified amount of movement, the control system determines how many current pulses are required and sends precisely that number to the motor.

Hence, the control does not need to monitor specifically where the motor is located. It is assumed that the required motion is achieved if the correct number of pulses is sent. So, that is their control, the control system needs only to keep track of how many revolutions or parts there of the motor has gone through to know the motor's position. Indirectly you are monitoring or location or position of the part.

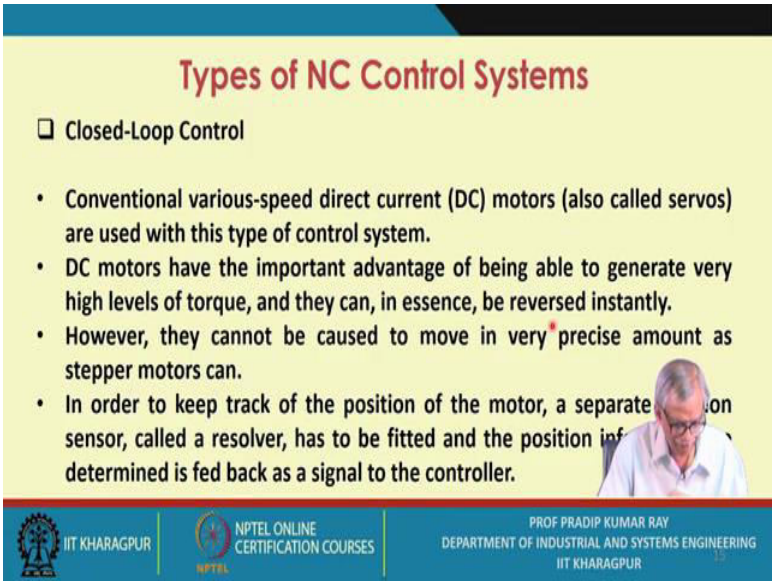
(Refer Slide Time: 29:54)



With the NC machines, it is possible to design the motor to produce a movement of as little as one-thousands of an inch. Open-loop control systems are less costly, less complex, simple and easier to maintain then they are popular with the smaller NC machines.

However, the main difficulty is with this type of control system that there is no way to correct any errors. It is one sided. That is why it is referred to as the open-loop for use with large machines that require greater power, that is the limitation.

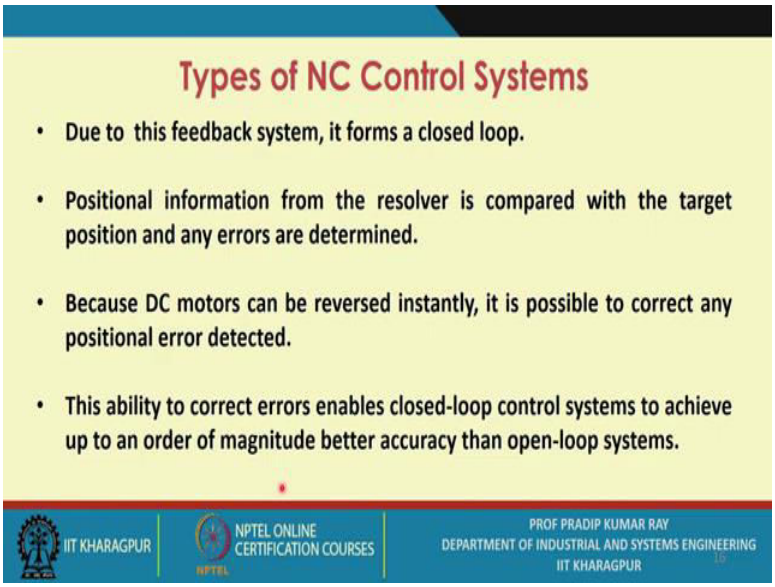
(Refer Slide Time: 31:03)



Alternatively, you can use the closed-loop control, the conventional various speed direct control, DC motors you have to use, also called the servos. These servos are used in this control system. Advantage is that a DC motor is able to generate very high levels of torque, and they can, in essence be reversed instantly.

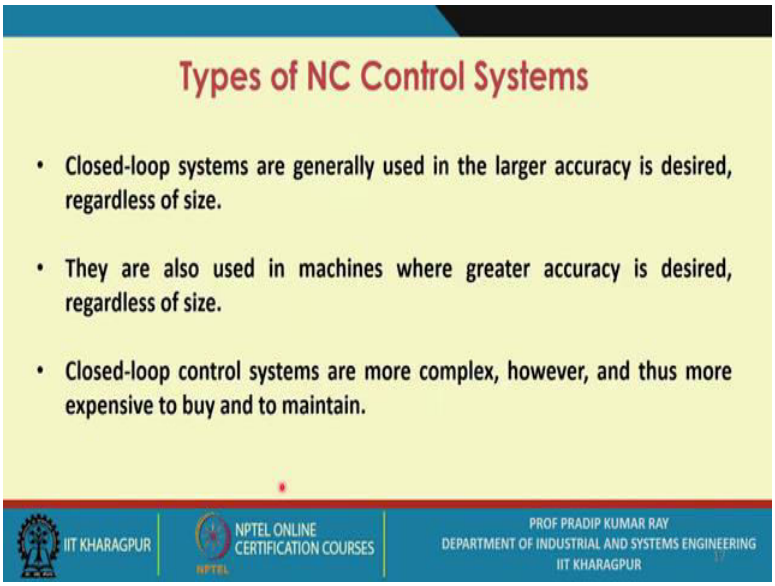
But they cannot be cost to move in very precise amount. When you require high power, this motor you have to use. In order to keep track of the position of the motor, a separate position sensor called a resolver has to be fitted and the position information is fed back as a signal to the controller. That is why it is a feedback system.

(Refer Slide Time: 32:06)



This is positional information we have to work it as the process is on, as the activities being carried out, the operations are being done. That is why the DC motors can be reversed instantly. The ability to correct errors enables closed-loop control systems to achieve up to an order of magnitude better accuracy than open-loop systems.

(Refer Slide Time: 32:49)



A closed-loop systems are generally used if the larger accuracy is desired. They are also used in machines, so greater accuracy is desired

The closed-loop control systems are more complex. However, and this is more expensive to buy and to maintain. There will be installation cost, there will be investments and all and there could be the running cost, the processing cost.

All these cost elements you must consider, and ultimately, you have to set the process parameters against the NC machine in such a way that the cost of the production cost is held to a minimum. NC technology is cost effective and that is why it is acceptable.

(Refer Slide Time: 34:10)