Automation in Manufacturing
Dr. Shrikrishna N. Joshi
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Week – 06
Mechanisms
Lecture - 19
Application of electric drives in automation

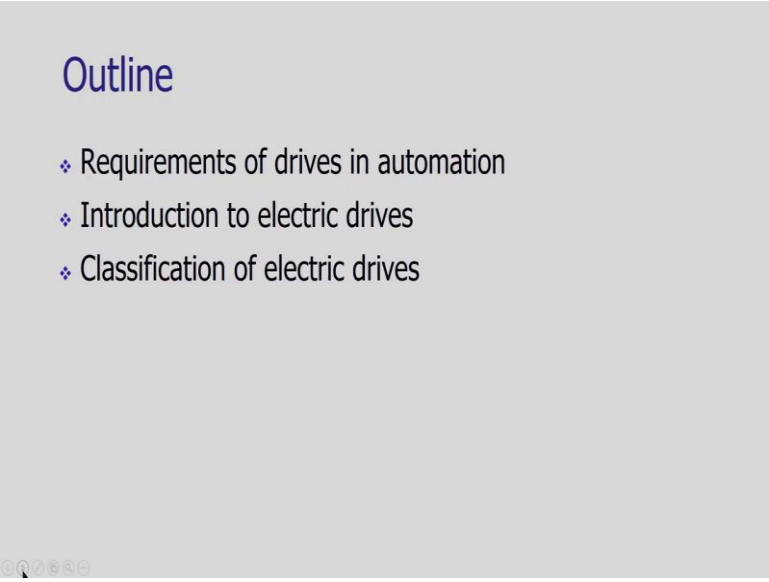
In previous week, we have seen the microprocessor technology, various components of microprocessor technology, various types of microprocessor technology such as micro computer, micro controllers and programmable logic controllers.

We have also seen how to programme a microprocessor or in addition to that, we also saw signal conditioning devices which are used in automated equipments. Let us look at the next building block of the automated system which is the drives to provide the motion to the various linkages, to provide the motion to various elements of an automated system we need energy and how to apply this energy with precision.

There are various types of drives being used in automation in industry and the most important drive is the electrical drive. To get the required work done in an automated system, electrical energy is applied. This electrical energy will be converted into the required form of energy, it may be mechanical energy, thermal energy or chemical energy. Various electrical drives are used in automation industry.

In this week, we will be seeing some of the important electrical drives which are being used.

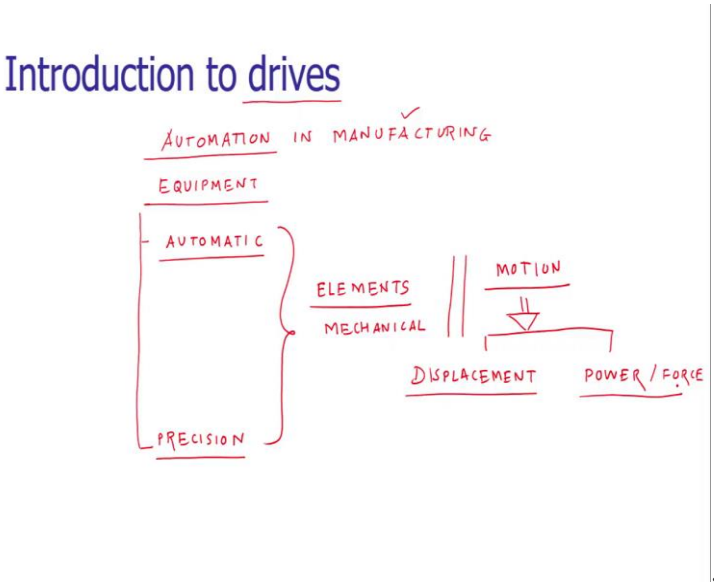
(Refer Slide Time: 02:33)



We will study the requirements of various types of drives in automation. There are basically three types of drives used in automation. These are Electric drives, Hydraulic drives and Pneumatic drives.

We will see their comparison, their applications in the automation industry after the discussion on the requirements, we will study the meaning of electric drive, its importance and then the classification of the electrical drives which are used in the automation industry.

(Refer Slide Time: 03:23)

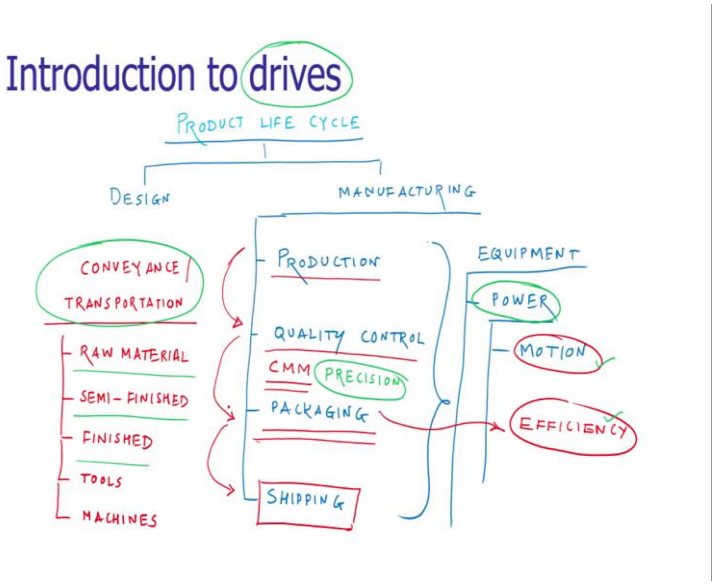


Let us study some of the fundamentals of the drives. We are studying automation in manufacturing to develop automated systems which are required for the manufacturing operations. We need the equipment. The first important requirement of this equipment should be providing the precise automatic movements.

This equipment should provide automatic and precision movements in the elements of the system and these elements are the mechanical elements. The equipment have mechanisms and these mechanisms are having the elements.

We need to have a motion of these elements and this motion is providing the displacement. The displacement may be required for the conveyance or the transportation or the relative motion is also providing power or the force. This power or force is required to transform the raw material into the semi finished or the finished product in the metal cutting operation. In the milling operation there has to be relative motion between tool and the workpiece which is providing the material removal operation.

(Refer Slide Time: 05:09)



If the product life cycle is referred, basically two different activities or operations which are design related activities and manufacturing related activities are observed. In the manufacturing, basically four operations need to be carried out. These are production, quality control, packaging and shipping operation.

For all these operations, variety of equipments are used. These equipment require power to operate and this power will be utilised to have the relative motion between the tool and the workpiece or various elements of that equipment or for the transformation which is required in the production operation like conversion of the raw material into the finished product, quality control operation, etc.

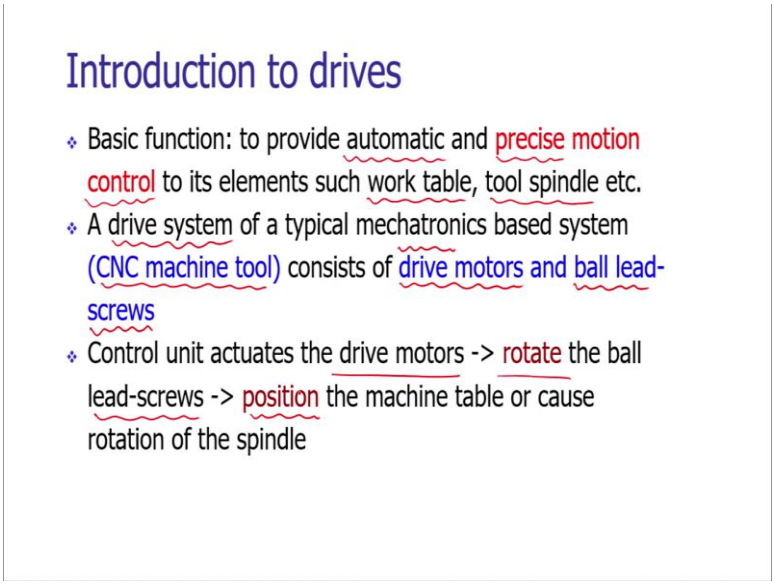
The motions are required in quality control operation. Simple example is a CMM that is Coordinate Measuring Machine. A very precise relative motion is required between the various elements of coordinate measuring machine which is giving us the measurement in microns.

After confirming the quality of the products, a packaging operation is required. In packaging, the major concern is to have an efficient operation. The packaging should be very fast or rapid and it should be economical, then the packed goods will be shipped for shipping as well. Basically the trucks or automobiles may be required inside the factory, the goods are needed to be conveyed from one department to the other department, from one shop to the other shop, from one section to the other. That means the convenience and transportation of raw material, semi-finished goods, finished work parts, tools and machines.

Certain systems are needed which are providing the power for the transformation of the raw material into semi-finished or the finished product. We need the relative motion between variety of elements and the third requirement is that the system should be precise. The power, required motion and the precision, these are three basic requirements that have to be fulfilled by a system. For this purpose, variety of drives are used to carry out these operations.

These operations are basically the production operation, quality control operation and these drives are required to carry out various activities related to the production, quality control, packaging and the transportation.

(Refer Slide Time: 09:09)

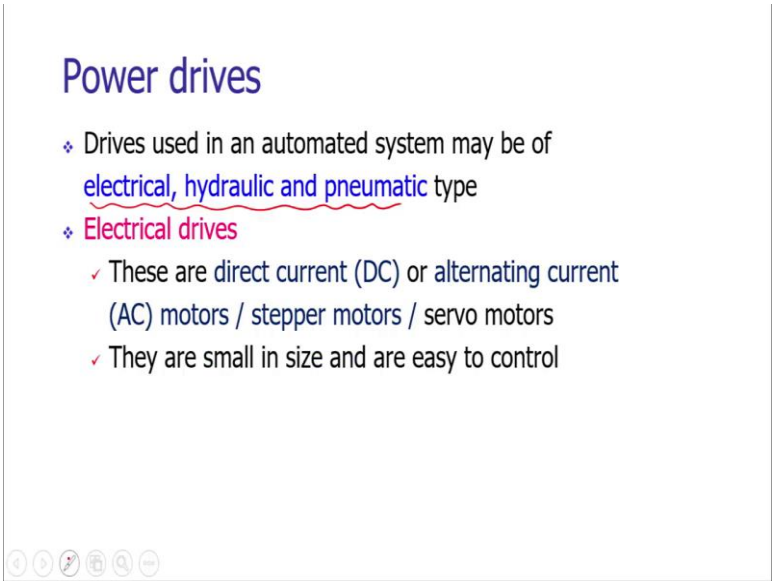


The system that provides or satisfies the three functions or requirements is called as the drive. The drive is providing us automatic and precise motion and it is controlling the operation as well of various elements like the work tables, tool spindles and many other elements

If we take an example say a CNC machine tool which is considered as the best example of mechatronics base system in the automation industry, the CNC machine tool system has various drive motors and these motors are driving the lead screws. Basically the motors are driving the system; the motors are moving the system. This is why it is called as the drive systems or the drives.

CNC machine tool here being used is a drive system which is providing driving of the ball lead screws and these ball lead screws are giving the relative motion between the tool and the workpiece. The control unit is actuating the drive motors and the drive motors are rotating the ball lead screws. The controlled rotation of the ball lead screws is enabling us to have the required position of the machine table.

(Refer Slide Time: 11:08)

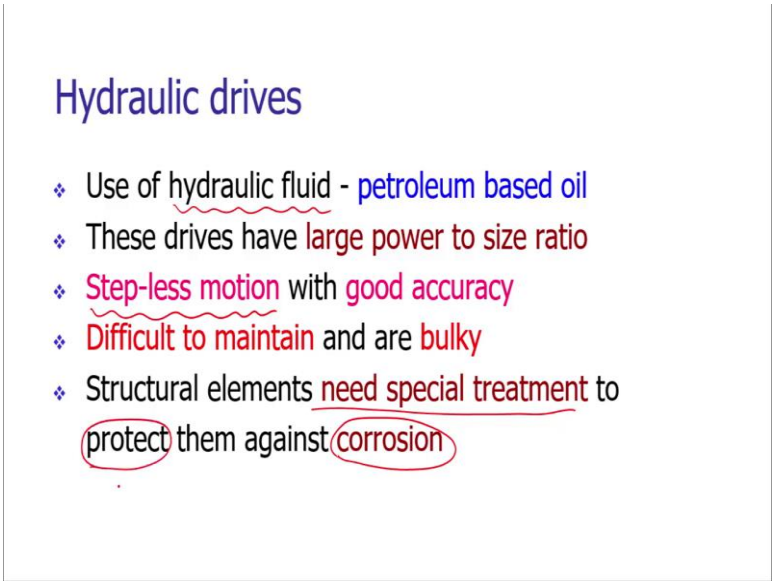


In an automated system, there are three different types of drives which are used like electrical drives, hydraulic drives and pneumatic drives.

The electric drives mainly include the DC motors that is the direct current motor and alternating current motor. The electric drives also comprise stepper motors and servo motors. We will be learning about the principle of operation constructional details and the application of the electrical drives in our next lectures.

The main advantage of electrical drive is that they are small in size and they are providing ease in controlling their operations.

(Refer Slide Time: 12:14)



The hydraulic drives are using the hydraulic fluid. In general the petroleum based oil is used at pressure more than the atmospheric pressure. This pressurised hydraulic fluid will be applied inside a cylinder which is having the piston as well.

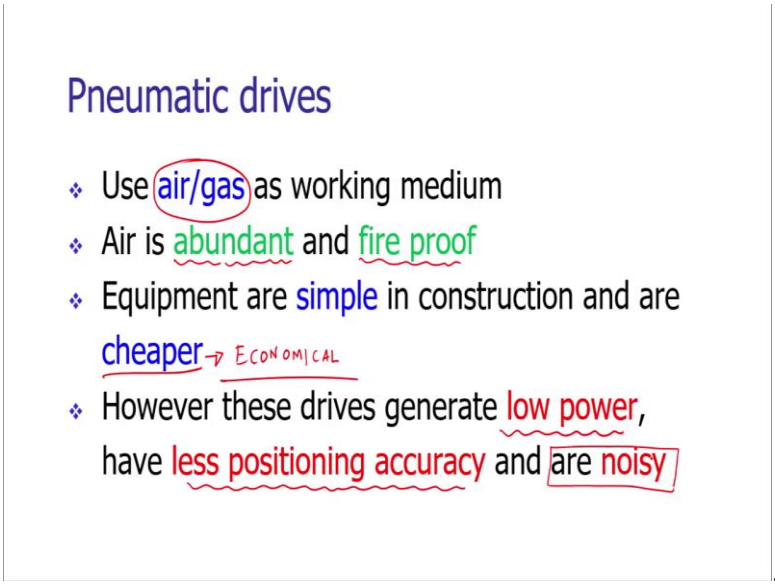
When the hydraulic fluid is applied inside this cylinder, the piston will get actuated. There is a displacement of the piston and there would be extension of the piston rod. The piston rod will come out of the system, so that linear motion of the piston rod will be utilised to carry out the intended purpose. That operation may be a relative motion or application of the force, that application may be either displacement of certain elements or application of force.

The hydraulic drives are providing very large power to size ratio. They are providing very huge power in comparison with the size of the system. Hydraulic drives provide stepless motion with good accuracy. The meaning of stepless motion is that there is a smooth transition from the low level of power to the high level of power. There are no jerks.

When the power will get transit from the low level to the high level but the limitation of hydraulic drive is that the system is bulky since it involves the fluid, there may be chances of having leakage of the fluid, or corrosion of various elements of the hydraulic drive. This is why the maintenance of the hydraulic drives is comparatively high and the size is also quite bulky as the elements are facing the problem of corrosion during the

construction of these drives. A special treatment to these elements is required to protect them from the corrosion.

(Refer Slide Time: 14:56)

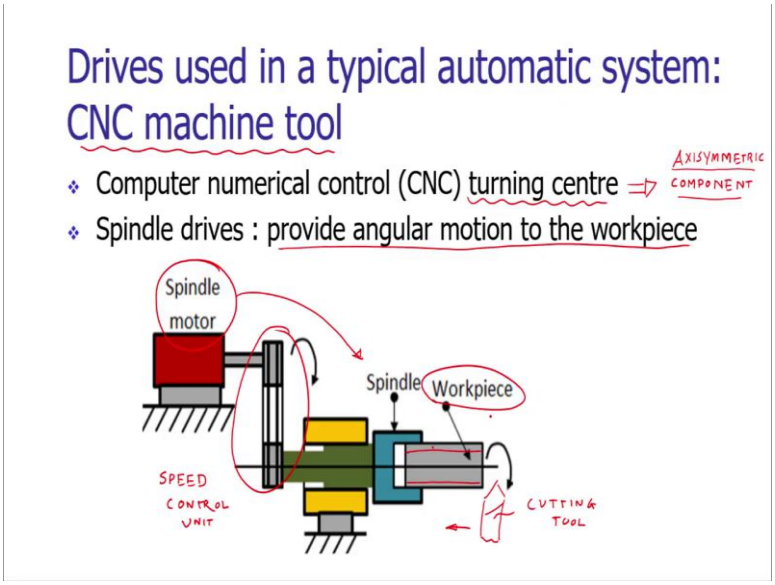


The third type of drive is pneumatic drive, pressurised air or gas is used as the working medium and by applying the pressurised air or gas, the required operation is carried out like the motion or application of certain force. The advantage of pneumatic drive is that the air is abundantly available and the air is fire proof. These are the two prominent advantages of the abundancy of the air and the safety.

The pneumatic drive equipment is simple in construction and they are economical and readily available. The compressors are readily available in the market and they are quite cheap as well but these drives do have certain limitations. These drives are generating low power. Therefore pneumatic drives cannot be used for the transformation operations. For metal cutting operation, the pneumatic drives are used for the auxiliary operations like tool changing for cleaning or the sensing operation.

The pneumatic drives are having comparatively lower positioning accuracy and they are noisy since they involve the compressor like equipment. They produce vibrations and but nowadays very good quality compressors are used which are producing less noise, but in comparison with the electric motors, the pneumatic drive creates certain noise.

(Refer Slide Time: 17:09)



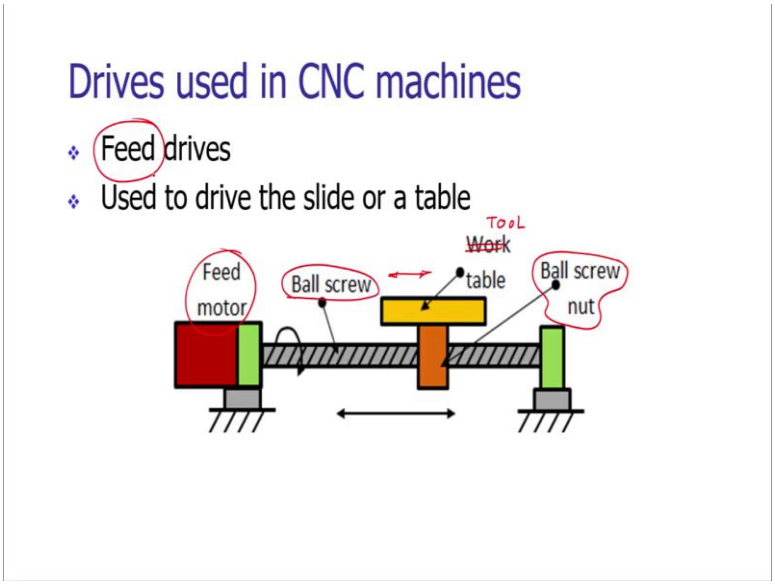
CNC machine tool is the best example to study the utilisation of drives in an automatic system to understand the utilisation of drive. Let us take CNC turning centre. The turning centre is producing axisymmetric components. To produce the axisymmetric components, we should provide the angular motion to the workpiece in relation to the tool motion.

On your screen we can see a typical arrangement that is utilised in the turning centre. Here a spindle motor is used. That spindle motor is providing power to the spindle of the machine tool. The spindle of the machine tool is holding the workpiece and the power from spindle motor to the spindle is provided through the speed control unit.

In traditional turning centres belt drives are utilised but in modern CNC machine tools, the variable speed servo motors are used. The spindle motor is providing power to the spindle and that spindle is rotating. It is providing the angular velocity to the work piece.

When the relative motion is motion is obtained of the cutting tool with respect to the workpiece, the diameter of the workpiece is reduced during this operation. To produce this angular motion of the workpiece, the power is required which is provided by the electric motor.

(Refer Slide Time: 19:43)



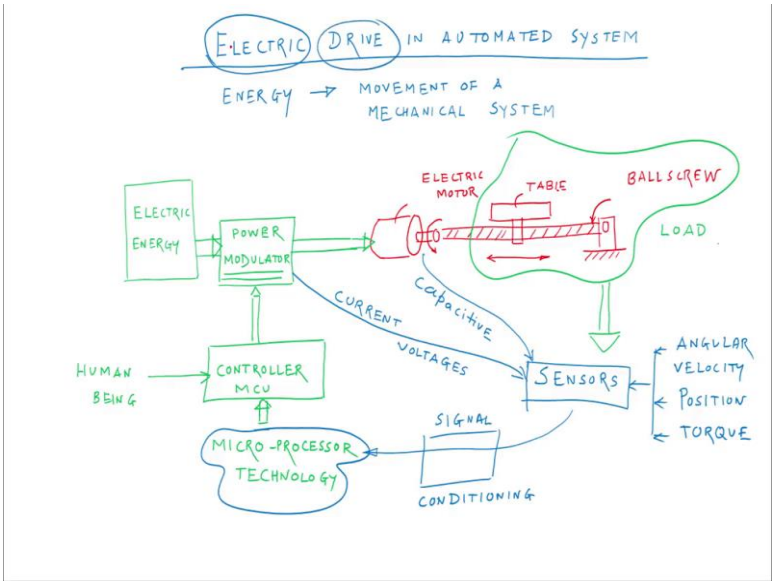
The next application of a drive is feeding the workpiece to the tool. The workpiece is rotating and it is providing the primary motion during the cutting operation, it is providing the cutting velocity, but unless and until the tool is moved with respect to the workpiece, the required size reduction in the workpiece is not obtained.

For that purpose we have to feed the workpiece to the tool. To feed the workpiece to the tool, the relative motion of the cutting tool with respect to the workpiece is required and for that purpose a table is needed. On the table, the tool is attached, the tool is mounted and this tool moment will be carried out with respect to the workpiece moment.

This linear motion is possible by utilising another motor. That motor is connected to a ball screw. Ball screw is a mechanical element, which is having ball screw nut. On this nut the table is mounted. The other end of the ball screw is supported. When the feed motor is rotating, the ball screw there is translatory motion of the ball screw nut. As the table is attached to the ball screw nut, we are getting the required linear motion.

In this way, the feeding of the workpiece to the tool is obtained and then, the required work is done.

(Refer Slide Time: 21:50)



Now, let us define the electrical drive in the context of the automated system. Electrical drive is providing the energy for the controlled moment of the mechanical system.

What are the various elements of a typical electric drive. The basic element is the electric motor. The rotary motion of the ball screw is required to get the required translatory motion of the table which is mounted on the ball screw. We will simply continue the same example. This is the ball screw on the ball screw. We are attaching the table to get the translation of the table. We should have the angular motion of the spindle which is driven by the electrical motor.

A typical electric drive system is having the electric motor. This electric motor is being loaded by a system. This entire system is called as the load which is applied on the electric motor. To operate this motor, energy is needed. This energy source is the electric energy, but directly we are not giving the electric energy to the motor. We are controlling its speed. Power modulator is required because various levels of power are needed for variety of the operations.

The same amount of power is not required for all the operation to modulate this power. A controller is required. The controller system in CNC machine tools is called as the machine control unit in manual operated systems, the human beings are controlling but the automation system microprocessor technology is controlling the power modulator.

How the microprocessor is taking the decision? The micro processors are utilising the feedback received from the system through the sensors and signal conditioning devices. We have to monitor the process by using sensors. The sensors are monitoring the angular velocity position of the table or the torque.

There are certain sensors which are also giving the input regarding the condition of the electric motor. Capacitance bases sensors are used to find out the runout or eccentricity in rotation of the spindle of the electric motor. Eccentricity in rotation will create the vibration. Either the capacity based sensors or the acoustic based sensor can be used to monitor the health of the electric mode from the power modulator. The input is obtained in terms of current and voltages which are being used.

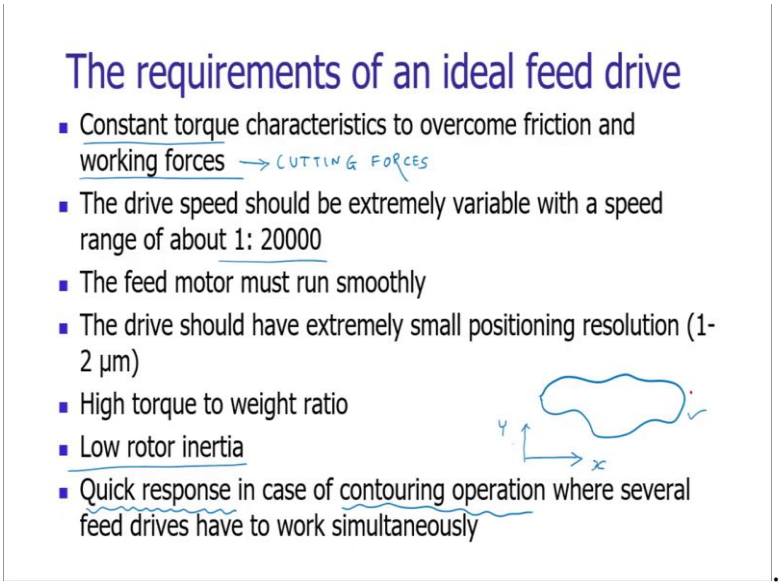
When a certain amount of current or certain amount of potential difference is applied on the electric motor, it is desired to produce the required amount of angular velocity, the required position of the table, required generation of the torque.

Therefore, the monitoring of the current and voltages for which the operations are being carried out, the positioning sensing measurement of torque and angular velocity will be utilised by the microprocessor to take the required decision to vary the application of power to the electric motor. These sensors are providing the input to the micro processors through the signal conditioning devices.

The sensors are providing the passive signals and need to be converted into the active signals which can be understood by the microprocessor technology. If we look at this diagram, electrical drives or electric drive is not only the electric motor but also, it has various other elements and these are the load or the application itself.

When sensors signal conditioning circuitry use of micro processing technology, the power modulator and the electrical energy source are combined together, the electric drive is obtained which is used in the automated system.

(Refer Slide Time: 29:09)



What are the various requirements of an ideal feed drive. The feed drive should provide constant torque to overcome the friction and the working forces. The precision machine tools or precision equipment are using ball screw based arrangement.

The feed drive should able to overcome this friction and it should provide sufficient forces to carry out the machining operation. Therefore, the feed drive should provide sufficient constant torque to overcome the friction and the required working forces in machining operation.

The second requirement of an ideal feed drive is, it should provide large variation in its speed. It is expected to have a wide range of speed variation say from 1 to 20, 000 say 0.1 rpm to 2000 rpm. The feed motor must run smoothly. There should not be any jerks. Jerks are the vibration during the operation which will definitely affect the quality of the transformation.

The drive should provide very small positioning resolution. In general, the present day drives are providing around 1 to 2 micron of the resolution. The feed drive should provide high torque in comparison to its weight, the feed drive should have low rotor inertia. In the feed drive, there are many rotating components and the inertia of the rotary component must be as less as possible, so that its efficiency would be high.

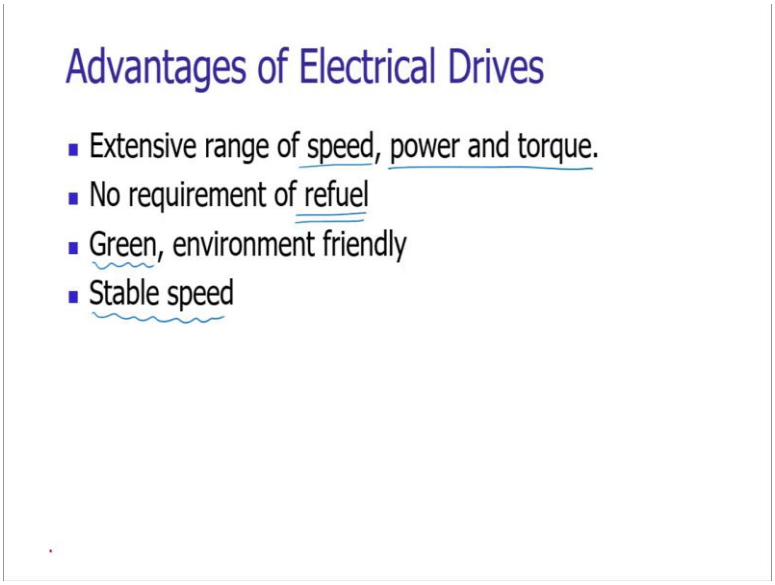
The relative motion of various elements of a equipment along the multiple axis is used. To have the simultaneous movement of the elements along multiple axis say x, y and z, multiple drives are used which are operating simultaneously.

When these drives are operating simultaneously the drives or the feed drives should provide quicker responses. If the response of the drives are not quick, response means we are applying the energy or the signals to the drive and the drive should respond to that. It should take the action as early as possible.

Let us consider example that we need to manufacture a contour. To get this contour, simultaneous motion of the tool along x and y axis is to be obtained to have the feed of the workpiece. Along x axis, one feed drive is used and to have the feed along y axis, another feed drive is used. There will be simultaneous feeding of the workpiece along x and y direction.

In this scenario, the feed drive should be quick in providing the response to the signal sent by the microprocessor to it. If the drive is sluggish and slow in responding, the required or the accurate quality is not obtained, the required contours that to be manufactured may not be obtained.

(Refer Slide Time: 33:43)

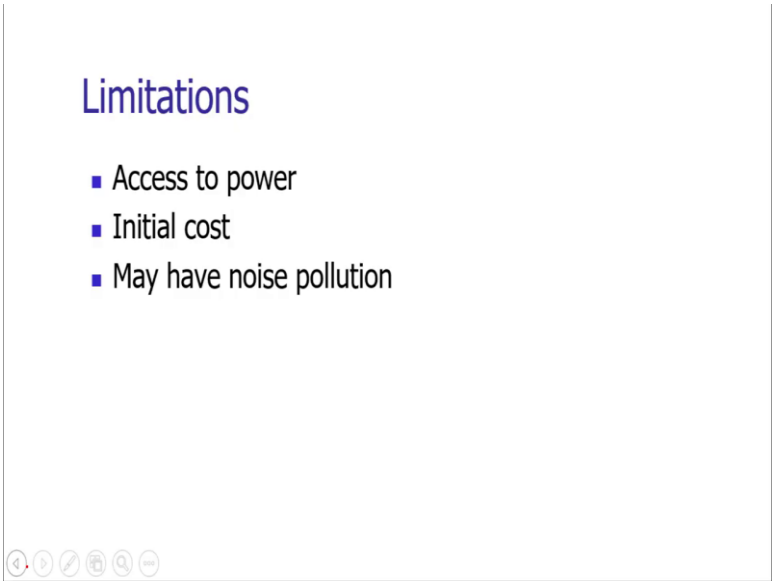


What are the various advantages of the electrical drives? The electrical drives are providing extensive range of the speed power and torque. There is no requirement of

refueling. In the petroleum based energy drives, we have to fuel the equipment, so that requirement is not there in electrical drives.

The electrical drives are green. They are environment friendly. They are not producing any toxic gases or they are not contaminating the environment. The electrical drives are providing stable speeds which is often required in many precision operations.

(Refer Slide Time: 34:58)

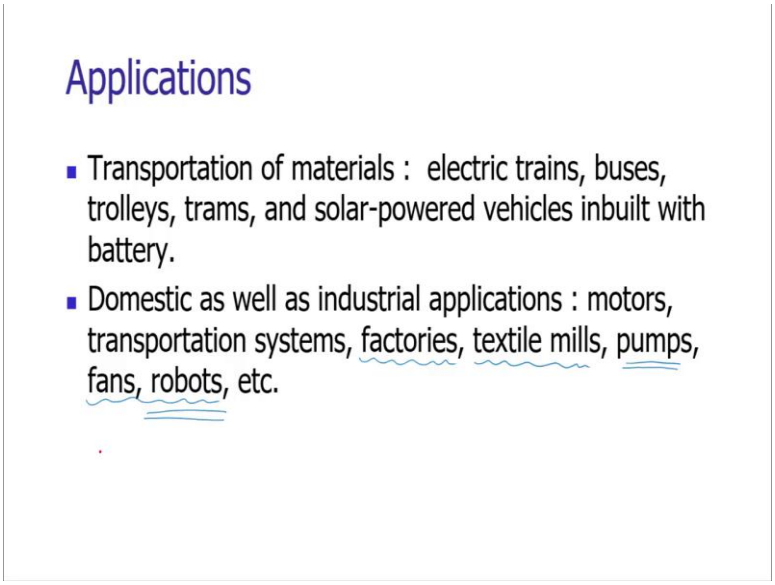


There are certain limitations to the electrical drive. The fundamental limitation is the access to power. The availability of power in remote areas where there is a scarcity of electrical energy to the electrical drive based automated system or electric drive based systems are unable to operate. This is one of the limitation to have the continuous access to the electrical energy electrical power.

The initial cost of some of the drives, some of the electrical drives is quite high. Basic electric motors are quite economical but the servo based motors or the motors which are used for the automation purpose which are having the inbuilt feedback system as well, they are quite costly.

Therefore, we need to invest little high to utilise the services of the electrical drives in the development of our automated systems. Some of the electrical drives may create the noise. When the electrical drives are not in proper condition, they are generating the pollution.

(Refer Slide Time: 36:36)

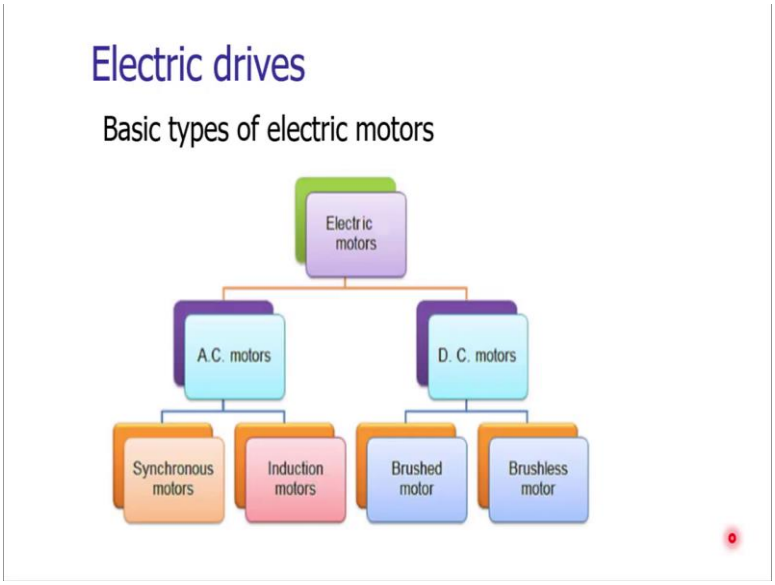


The basic applications of electrical drives have been observed in the automation, such as providing the motion and power to variety of mechanical elements and various applications required in packaging, in quality control and in the shipping as far as in general applications are concerned, the fundamental application of the electrical motors are in transportation.

We are getting the electric trains, buses, trolleys, trams and many solar powered vehicles. The solar energy will be converted into the electrical energy and that electrical energy will be utilised to get the moment of the automobile.

The electrical drives have enormous applications both at domestic as well as the industrial level. The motors are required particularly in all factories, textile mills to operate the pumps. The electric drives are required in robots which is very interesting application nowadays.

(Refer Slide Time: 38:02)



The electric motors are classified into two groups. There are DC motors and AC motor. The DC motors are direct current motors while the AC motors are alternating current motors. In addition to these DC and AC motors, there are other types such as stepper motors. When sensors are used to monitor the revolutions of the motors, these motors are called as the servo motors.

The direct current motors are further classified into two groups. These are brushed motors and brushless motors. In brushed motors, there is a commutator and brush assembly which is energising and passing the electric current in the armature.

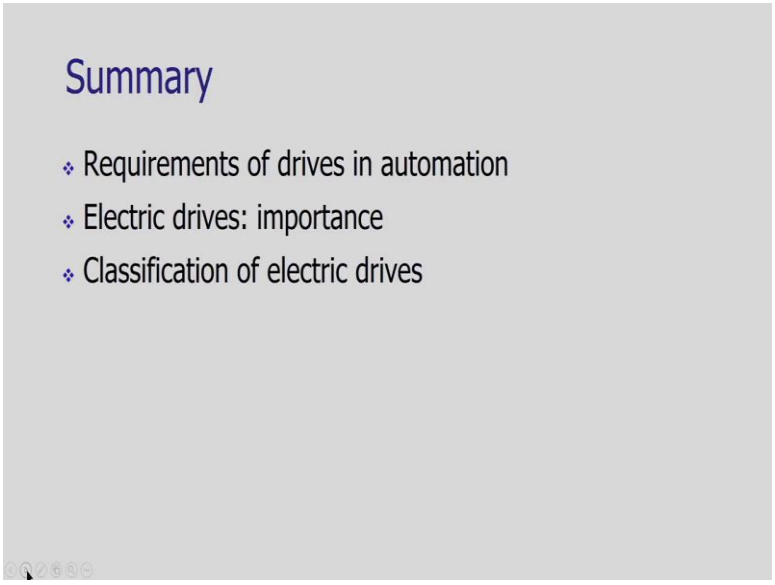
It has the arcing problem due to the friction between the brushes and the slip ring in brushless motor. This limitation has been removed. The alternating current motors are further classified into two groups viz. synchronous motor and the induction motor. In synchronous motor, three phase rotating magnetic field is used to get the required rotation of the rotor in the induction motors. The electrical property that is the inductance is used to energise the rotation of the rotor. In the next two lectures, we will be seeing preliminary level the constructional details and principle of operation of some of the important motors. These are DC motors, AC motors, stepper motors and servo motors.

In this lecture, we discussed about the requirements of motion and energy for various operations in an automated system. For that purpose we learned that we need power. That power can be obtained from electrical energy sources and that electrical energy

further may be converted into the mechanical energy, that mechanical energy will be utilised to carry out various automation operations.

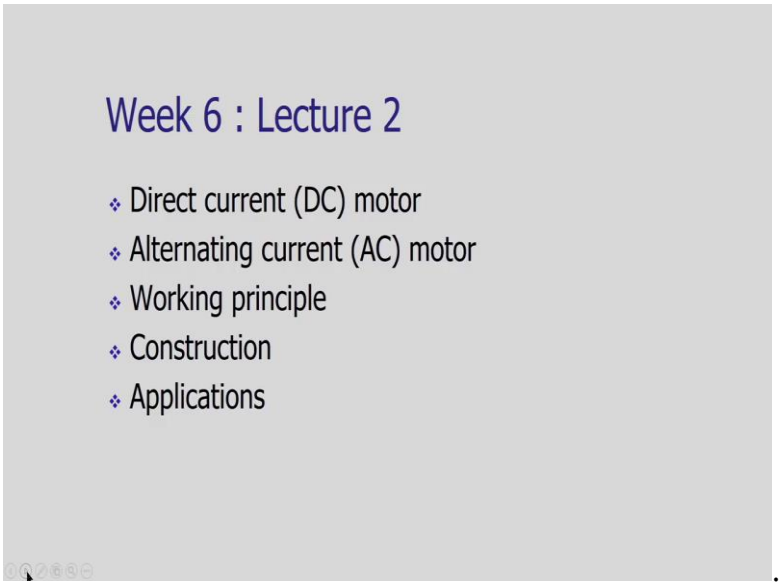
The automation operations may be required for the production that is for the fabrication or it may be required for conveying the products or packaging. There are various operations in the product life cycle. For these operations, the drives are required. To carry out variety of product lifecycle operations, there is a requirement of various drives.

(Refer Slide Time: 41:34)



The drives are electrical drives, hydraulic drives, pneumatic drives. After that we learned the importance of electric drives, its advantages its importance in the present day automated industry. At the end of the lecture, we discussed about the classification of electric drives in detail.

(Refer Slide Time: 42:02)



Now, in the next lecture that is Lecture 2 of Week 6, we will study the basic types of electric drives. The fundamental electric drive is direct current motor. AC motors are also used in the industry. We will study the working principle, construction and applications of these types of motors in detail.