UNIT 2 CLASSIFICATION OF NC SYSTEMS

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2.1 INTRODUCTION

Classification based on feedback controlling and Classification based on control system features are described in this Unit.

Objectives

After studying this unit, you should be able to understand

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- ,
- , and
- .

2.2 CLASSIFICATION OF NC MACHINES

In present era, variety, complexity of geometry, tolerances, skill of personnel and availability of funds by considering all factors, the NC machines are designed according to meet different requirements within the cost constraints. These machines are broadly classified as the following :

(a) Based on feedback control, and

(b) Based on control system features.

2.3 BASED ON FEEDBACK CONTROL

In the NC machines, to control the position of a machine slide, a group of electro-mechanical, pneumatic or hydraulic components are used which are collectively known as Servo Mechanism. The output from the data handling equipment is passed through separate channels to servo system, which in turn drives the machine slides. This servo system, based on feedback control, can be approached in three ways :

Open Loop System

In an open loop system the machine slides are displaced according to the information loaded from the part program into the control system. Hence there is no measurement of slide position and no feedback signals for comparison with the input signal. The correct movement of slide entirely depends upon the ability of the drive systems to move the slide through the required exact distance. The most common method of driving the lead screw is by a stepper motor. The stepper motors are the simplest way for converting detail electrical signals into proportional movement. As there is no check on the slide position, the system accuracy depends upon the motors ability to step through the exact number of steps provided at the input as shown in fig.

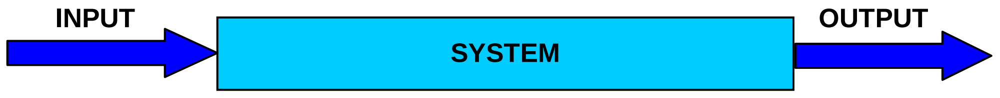

Figure 2.1 : Block Diagram of an Open Loop System

Closed Loop System

A closed loop system is sends back a signal to the control unit from a measuring device called as transducer. The transducer is attached to the slide ways. The signal indicates the actual movement and position of the slides. The control unit continues to adjust the position of the slide until it arrives it's destination, this system has feedback. Although more costly and complex than open loop system, these system gives more accurate positioning. For this type of system, servomotors are used.

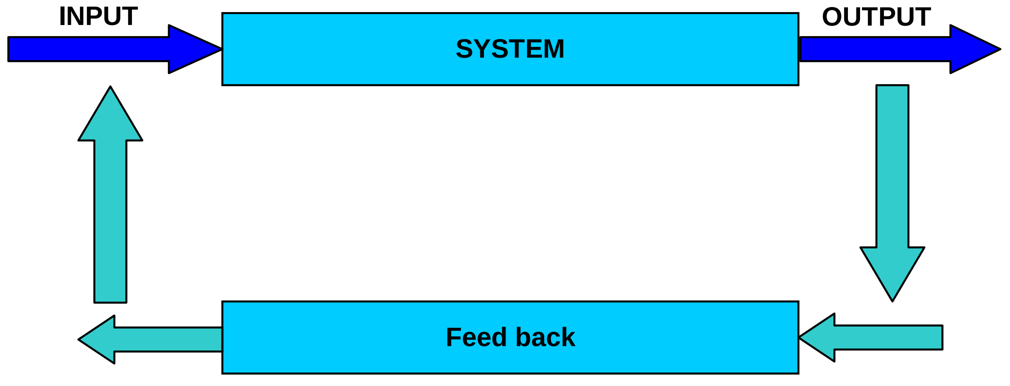

Figure 2.2 : Block Diagram of a Closed Loop System

2.4 DRIVING SYSTEM

The driving system is an important component of a NC machine as the accuracy and repeatability depend very much on the characteristics and performance of the driving system. The requirement is that the driving system has to response accurately according to the programmed instructions. This system usually uses electric motors although hydraulic motors are sometimes used for large machine tools. The motor is coupled either directly or through a gear box to the machine leadscrew to moves the machine slide or the spindle. Three types of electrical motors are commonly used.

DC Servo Motor

The force that rotates the motor armature is the result of the interaction between two magnetic fields (the stator field and the armature field). To produce a constant torque from the motor, these two fields must remain constant in magnitude and in relative orientation. This is achieved by constructing the armature as a series of small sections connected in sequence to the segments of a commutator. Electrical connection is made to the commutator by means of two brushes. As successive commutator segments pass the brushes, the current in the coils connected to those segments changes direction. This commutation or switching effect results in a current flow in the armature that occupies a fixed position in space, independent of the armature rotation, and allows the armature to be regarded as a wound core with an axis of magnetization fixed in space. This gives rise to the production of a constant torque output from the motor shaft. The axis of magnetization is determined by the position of the brushes. If the motor is to have similar characteristics in both directions of rotation, the brush axis must be positioned to produce an axis of magnetization that is at 90° to the stator field. DC servomotors are high performance motors and are useful as prime movers in numerically controlled machine tools where starts and stops must be made quickly and accurately. The lightweight and low inertia armatures of DC servomotors respond quickly to the excitation voltage changes. Also low armature inductance in these motors results in a low electrical time constant (typically 0.05 to 1.5 ms) that further sharpens motor response to command signals.

Brush Less DC Servomotors

In the brush less motor, the construction of the iron-cored motor is turned inside out, so that the rotor becomes a permanent magnet and the stator becomes a wound iron core. The permanent magnet, located on the rotor, requires that the flux created by the current carrying conductors in the stator rotate around the inside of the stator in order to achieve motor action. The stator windings are interconnected so that introducing a three-phase excitation voltage to the three-stator windings produces a rotating magnetic field. This construction speeds heat dissipation and reduces rotor inertia. The permanent magnet poles on the rotor are attracted to the rotating poles of the opposite magnetic polarity in the stator creating torque. The magnetic field in the stator rotates at a speed proportional to the frequency of the applied voltage and the number of poles. In the brush less motor, the flux of the current carrying winding rotates with respect to the stator; but, like the dc motor, the current carrying flux stays in position with respect to the field flux that rotates with the rotor. The major difference is that the brush less motor maintains position by electrical commutation, rather than mechanical commutation.

Figure 2.3 : Brush Less DC Servomotor

AC Servo Motors

These are basically the AC synchronous motors with built-in brush less tacho and position encoders. The main advantage of this machine is the low rotor inertia and high power and low weight. This makes them very attractive since they are small in size compared to the equivalent DC servo motor.

In an AC servomotor, the rotor is a permanent magnet while the stator is equipped with 3-phase windings. The speed of the rotor is equal to the rotational frequency of the magnetic field of the stator, which is regulated by the frequency converter.

Stepper Motors

A stepper motor is a device that converts the electrical pulses into discrete mechanical rotational motions of the motor shaft. A stepper motor rotates (steps) in fixed angular increments. Step size, or step angle, is determined by the construction of the motor and the type of drive scheme used to control it. Typical step resolution is 1.8 degrees. However, micro-step motors are capable of 0.0144 degree steps. Micro-step motors are hybrid 200 steps per revolution motors that are electrically controlled to produce 25000 steps per revolution.

Stepper motors are usually used in open loop control systems, though an encoder may be used to confirm positional accuracy. There are many types of step-motor construction. However, permanent magnet (PM) and variable reluctance (VR) are the most common types.

Figure 2.4 : Stepper Motor

PM Step Motors

The permanent magnet step motor moves in steps when its windings are sequentially energized. A permanent magnet rotor surrounded by a two-phase stator. Two rotor sections (N and S) are offset by one half-tooth pitch to each other. As energy is switched from Phase 2 to Phase 1, a set of rotor magnets will align with phase 1, and the rotor will turn one step. If both phases are energized simultaneously, the rotor will establish its equilibrium midway between steps. Thus, the motor is said to be half-stepping. Stepper motors have a number of benefits, Low cost, Ruggedness, Simplicity in construction, high reliability, No maintenance.

There is virtually no conceivable failure within the stepper drive module that could cause the motor to run away. Stepper motors are simple to drive and control in an open-loop configuration. They only require four leads. They provide excellent torque at low speeds, up to 5 times the continuous torque of a brush motor of the same frame size or double the torque of the equivalent brush less motor. This often eliminates the need for a gearbox. A stepper-driven system is inherently stiff, with known limits to the dynamic position error.

In the machine tool, the rotary motion from the drive motor needs to be converted to the linear motion. For this purpose a lead screw and nut arrangement is normally used. The Acme thread used in conventional machine tools has more friction and consequently the maximum feed rates are limited. In order to increase the feed rates to higher values, it is necessary to reduce the friction between the nut and the lead screw. Another problem with the Acme thread is the clearance between the nut and the screw, which causes a considerable backlash. The backlash will reduce the accuracy of the dimensions produced. Hence most of the NC machine tools use a lead screw with a recalculating ball nut.

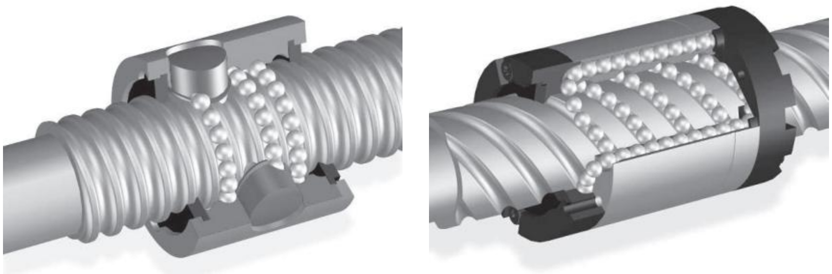

Figure 2.5 : Ball Screws

To reduce the backlash, the ball screws can be preloaded to eliminate the axial displacement. One of the methods followed for pre-loading is keeping a spacer between the two parts of the nuts such that they press against the opposite flanks of the thread. This increases the axial rigidity of the nut while decreasing the axial displacement. The recalculating ball screws have a number of advantages compared to the conventional type of screws. The accuracy of the screw can be maintained over a much longer period since the wear of the screw is relatively small. Since the friction is small, it is possible to carry heavier loads at faster speeds. Also, the power required for driving is small due to negligible friction between the nut and the screw.

2.5 FEEDBACK DEVICES

The NC machine tools generally are run with a closed loop control system. For this purpose it is necessary to provide appropriate feedback in order to achieve accurate control of the movement of the axes. The feedbacks that are normally used are the displacement and velocities of the individual axes in the machine tool. The typical positional sensors used in the NC machine tools are :

(a) Encoders, and

(b) Linear scales.

The encoder is a transducer that is connected directly to the rotor or the lead screw and hence is the simplest arrangement requiring no additional gearing. An optical rotary encoder converts the rotary motion of the motor into a sequence of digital pulses. The pulses counted to convert to the position measurement. The optical encoder consists of a disc with a number of accurately etched equidistant lines or slots along the periphery. The encoder disc is attached to the shaft of the machine whose rotary position needs to be measured. The disc is placed between a light source and a light-measuring device. When the disc rotates the lines are interrupted and the light-measuring device counts the number of times the light is interrupted. By a careful counting and appropriate calculations it is possible to know the position traversed by the shaft.

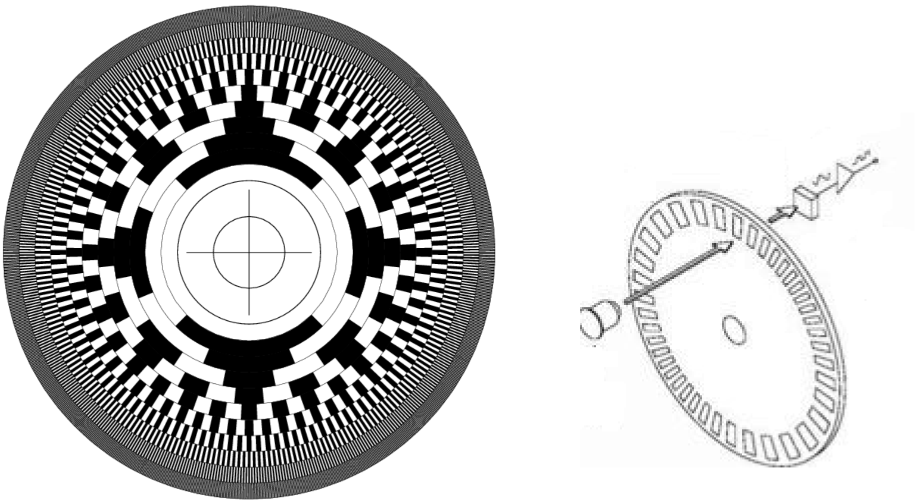

Figure 2.6 : Rotary Encoder for Angle-measuring Devices Marked in 3-bit Binary

The rotary encoder is normally mounted on the servo motor shaft or at the end of the lead screw as shown. This allows the control to calculate the actual distance moved from the rotary motion by using the lead of the lead screw. If the lead screw has any backlash then that will be reflected in the position indicated by the encoder. It therefore becomes mandatory to eliminate the backlash in the lead screw to accurately get the position of the axis. Also this requires that the pitch of the lead screw be more accurate over its entire length for accurate sensing of the position.

To obviate such a predicament, it will be better if the exact position reached by the slide can be measured by means of a transducer rather than the indirect way with the encoder. This can be done with the help of a linear scale attached directly to the slide. In this case the positional measurement will be direct and hence any of the inaccuracies present will not be affecting the measurement. The linear scale consists of a finely graduated grating made of either glass or stainless steel, which is the measuring surface attached to one part of the slide. A scanning unit is fixed to the other part. The scanning unit consists of a light source, a glass grid with graduated windows and some photo diodes as receptors.

The basic principle employed in such measurements is that when two gratings overlap each other, a fringe pattern is formed corresponding to the displacement. The actual distance moved can be calculated by measuring the shift in the fringe pattern.

2.6 CLASSIFICATION BASED ON CONTROL SYSTEM

Some machine tools require that the cutting tool and work piece shall be placed at certain positions and also be moved relative to each other. Based on the relative motion, the NC machines can be classified as :

Point to Point Motion Control System

Some machine tools for example drilling, boring and tapping machines etc, require the cutter and the work piece to be placed at a certain fixed relative positions at which they must remain while the cutter does its work. These machines are known as point-to-point machines. The control equipment for use with them is known as point-to-point control equipment. Feed rates need not to be programmed. In theses machine tools, each axis is driven separately. In a point-to-point control system, the dimensional information that must be given to the machine tool will be a series of required position of the two slides. Servo systems can be used to move the slides and no attempt is made to move the slide until the cutter has been retracted back.

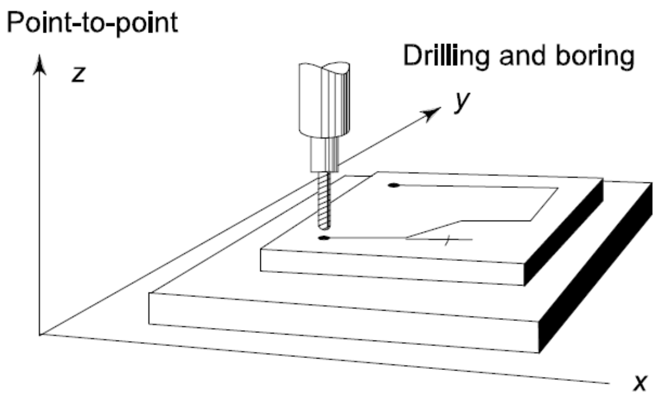

Figure 2.7 : Point-to-Point motion Control System

Straight Line Motion Control System

The NC systems, in which the tool works along a straight line in the direction of a major coordinate axis, such as along the direction of feed during turning, boring or milling operation at a controlled rate, are known as Straight line control system.

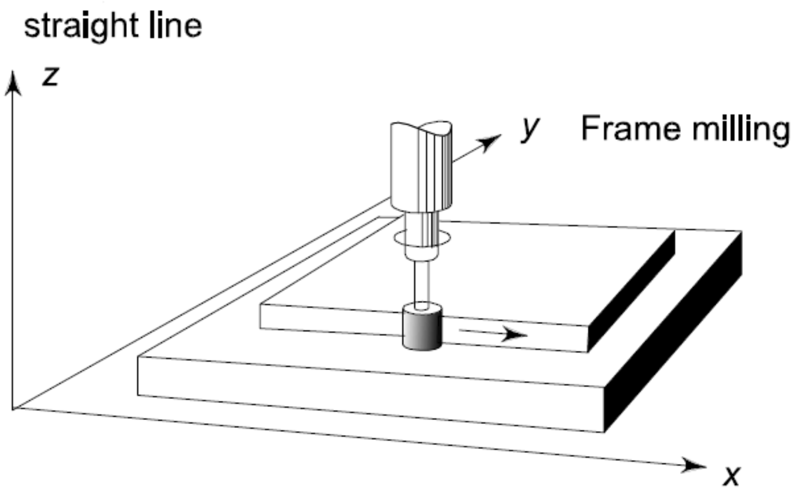

Figure 2.8 : Straight-line Control System

Contouring or Continuous Path Motion Control System

Other type of machine tools involves motion of work piece with respect to the cutter while cutting operation is taking place. These machine tools include milling, routing machines etc. and are known as contouring machines and the controls required for their control are known as contouring control. Contouring machines can also be used as point-to-point machines, but it will be uneconomical to use them unless the work piece also requires having a contouring operation to be performed on it. These machines require simultaneous control of axes. In contouring machines, relative positions of the work piece and the tool should be continuously controlled. The control system must be able to accept information regarding velocities and positions of the machines slides. Feed rates should be programmed.

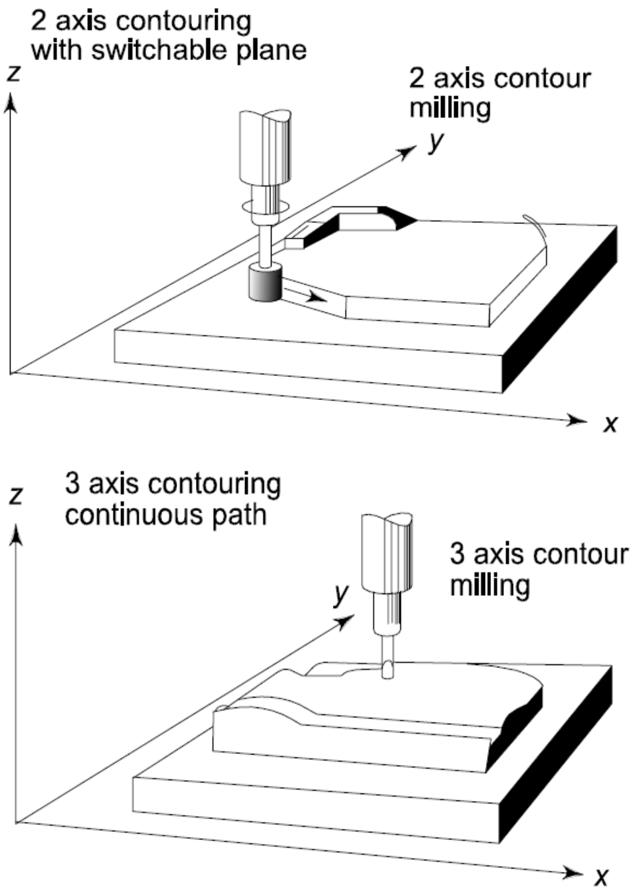

Figure 2.9 : Contouring or Continuous Path Motion Control System

Combined Motion Control System

The above all the control systems are combined as groups. Most of the Jig boring, horizontal boring and drilling machines employ this type of control system. This motions controls systems are having 3 or 4 linear axes to be controlled continuously and 2 or 3 rotary movements controlled along with the positioning facility. This combination is used for complex contouring operations, to be carried out on machining centers.

2.7 NC COORDINATE SYSTEMS

The distances or angles which specify the position of a point, line, circle or any other geometrical figure with reference to a series of intersecting planes or planes and cylinders define coordinate systems.

There are two methods of listing the coordinates of points in NC systems, which can be used independently or in combination.

Absolute Coordinate System

In an absolute system all references are made to the origin of the coordinate system. All commands of motion are defined by the absolute coordinate referred to the origin.

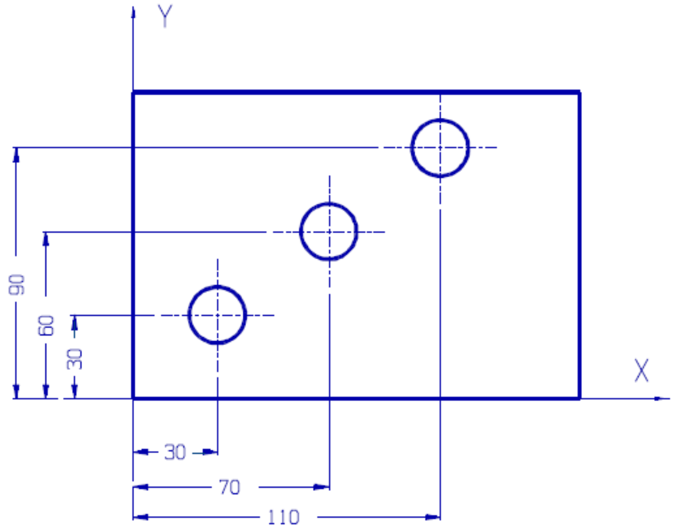

Figure 2.10 : Absolute Coordinate System

Incremental Coordinate System

This type of control always uses as a reference to the preceding point in a sequence of points. The disadvantage of this system is that if an error occurs, it will be accumulated.

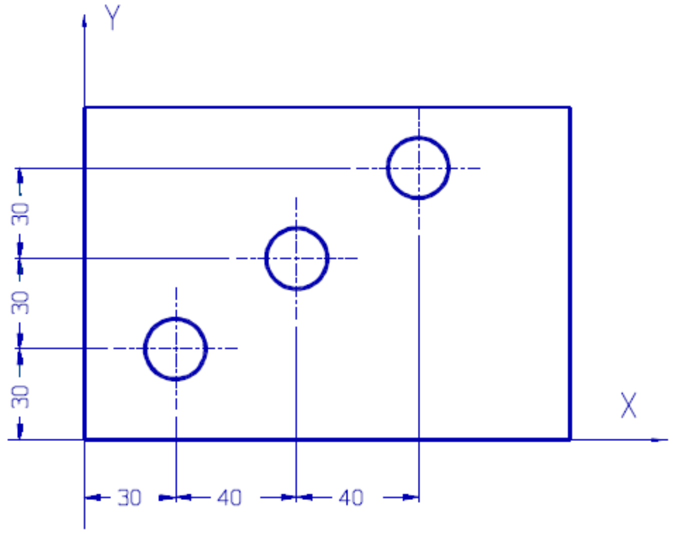

Figure 2.11 : Incremental Coordinate System

2.8 AXIS IDENTIFICATION

Generally,

***X*-Axis**

(a) It should be horizontal.

(b) It is generally the longest axis of movement of work piece or tool.

(c) It should be perpendicular to *Z*-axis.

(d) It is always parallel to surface of the holding device.

***Y*-Axis**

It should be perpendicular to *X* and *Z*-axes.

***Z*-Axis**

(a) It is always parallel to the spindle.

(b) It should be perpendicular to the *X* and *Z*-axis.

The lathe, one of the most productive machine tools, has always been an efficient means of producing round parts. Most lathes are programmed on two axes. The *X*-axis controls the cross motion of the cutting tool. Negative *X* (*X*-) moves the tool towards the spindle centerline; positive *X* moves the tool away from the spindle centerline. The *Z*-axis controls the carriage travel toward or away from the headstock.

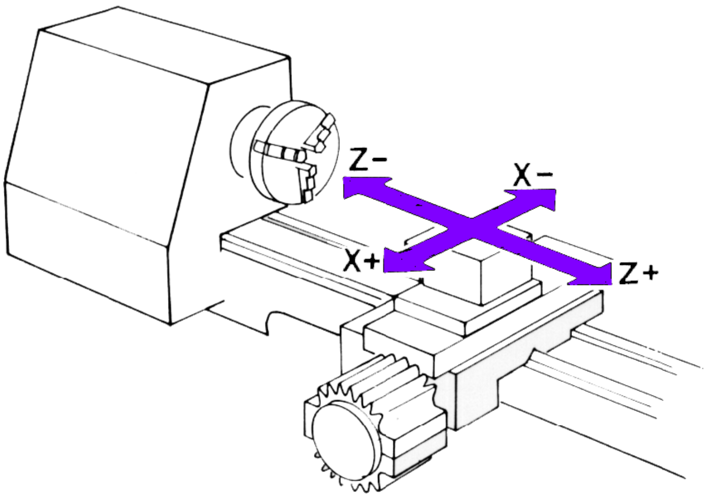

Figure 2.12 : Main Axes of a Lathe or Turning Center

The milling machine has always been one of the most versatile machine tools used in industry. Operations such as milling, contouring, gear cutting, drilling, boring, and reaming are only a few of the many operations which can be performed on a milling machine. The milling machine can be programmed on three axes. The *X*-axis controls the table movement left or right. The *Y*-axis controls the table movement toward or away from the column. The *Z*-axis controls the vertical (up or down) movement of the knee or spindle.

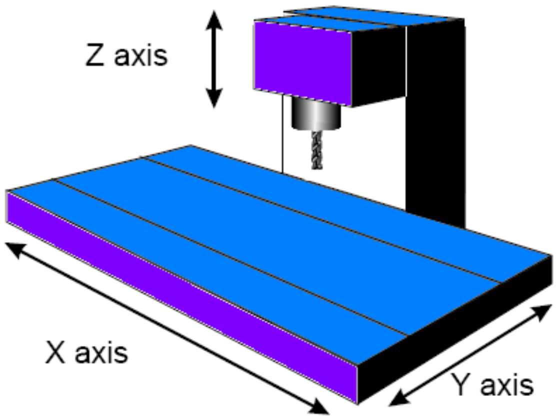

Figure 2.13 : Main Axes of a Vertical Machining Center

2.9 SUMMARY

2.10 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.