Rashtreeya Sikshana Samithi Trust

RV Institute of Technology and Management®

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JP Nagar, Bengaluru - 560076

Department of Mechanical Engineering

Course Name: Elements of Mechanical Engineering

Course Code: 21ME15/25

I/II Semester

2021 Scheme

MODULE-V

Fundamentals of Machine Tools and Operations: Fundamentals of Machining and machine tools, Construction and Working Principle of Lathe, Various Lathe Operations: Turning, Facing, Taper Turning and Knurling. Construction and Working of Milling Machines and applications. Construction and working of simple Drilling Machines and applications. (Sketches of layout need not be dealt with for all machine tools)

Introduction to Modern Manufacturing Tools and Techniques: CNC: Introduction, components of CNC, advantages and applications of CNC, CNC Machining centres and Turning Centers Concepts of Smart Manufacturing and Industrial IoT. JBOS 18.10.2021 / EC 30.10.2021 Page 4 of 5

Introduction to Mechatronics: Concept of open-loop and closed-loop systems, Examples of Mechatronic systems and their working principle.

Contents

5.1 LATHE

5.1.1 INTRODUCTION: Metal cutting operations are carried out to produce a mechanical part of the required shape and size. A machine tool may be defined as a power-driven machine which accomplishes the cutting or machining operations on it. The fundamental machine tools that are used for most of the machining processes are given below.

1. Lathe Machine.
2. Drilling Machine.
3. Milling machine.
4. Grinding machine.

Lathe Machine: A lathe is a machine tool which turns cylindrical material, touches a cutting tool to it, and cuts the material. It is said to be the mother of all the machine tools.

A lathe is defined as a machine tool is primarily used to produce circular objects and is used to remove excess material by forcing a cutting tool against a rotating workpiece. Lathes are also called turning machines

Working Principle of Lathe:

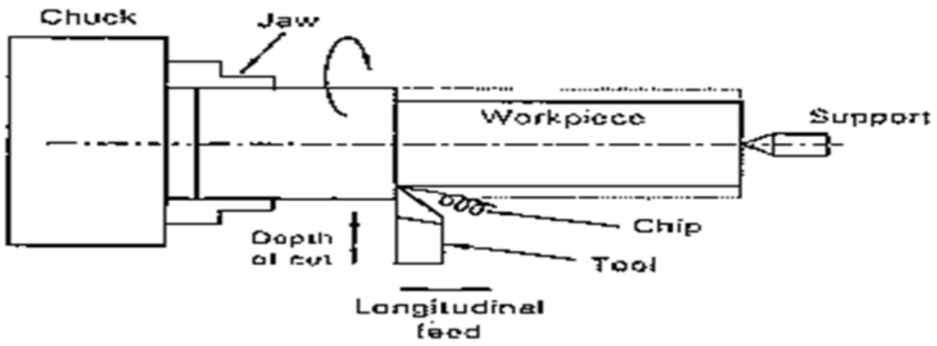


Fig. 5.1 working principle of lathe

A lathe, basically a turning machine works on the principle that a cutting tool can remove material in the form of chips from the rotating workpieces to produce circular objects. This is accomplished in a lathe which holds the workpieces rigidly and rotates them at high speeds while a cutting tool is moved against it. Fig. 5.1 shows the working principle of lathe.

Workpiece held rigidly by one of the works holding devices, known as a chuck, and is rotated at very high speeds. A cutting tool held against the workpiece opposite to its direction of rotation when moved parallel to the axis of the workpiece produces circular surfaces as shown in the figure. The material of the tool will be harder and stronger than the material of the workpiece.

Parts of Center Lathe

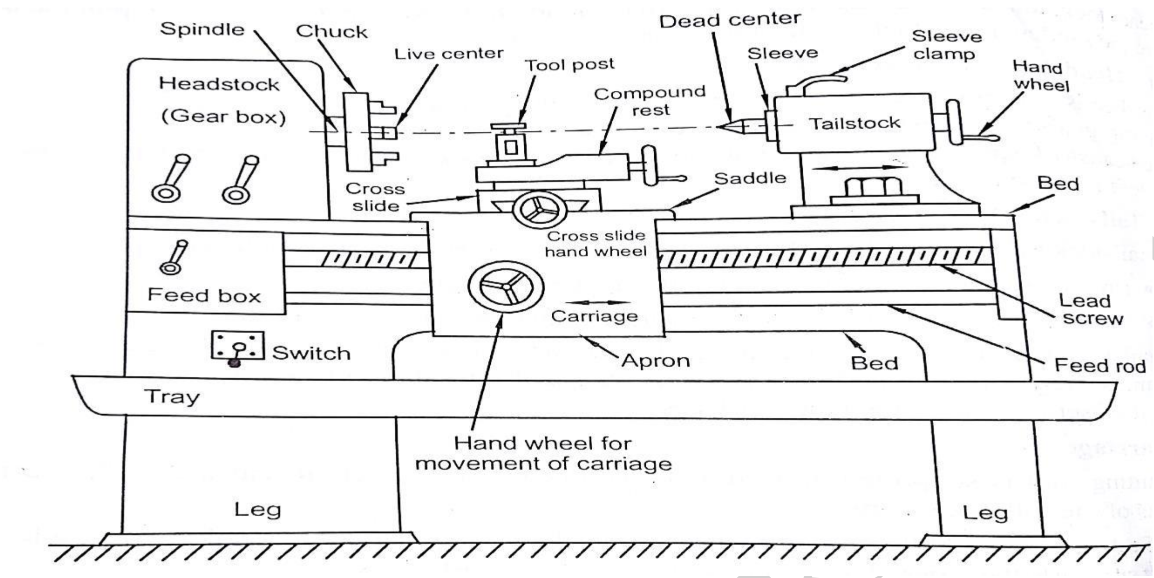


Fig. 5.2 parts of a center lathe

Following is a brief description of the same. Fig. 5.2 displays parts of a center lathe

1} **Bed**

It is a rigid structure which forms the base or foundation to support all the other parts such as headstock, tailstock, carriage, etc. It is usually made from gray cast iron. At the top of the bed are the guideways, which guides for accurate movement of carriage and tailstock.

2} Headstock {Live center}

The headstock mounted at the left end of the lathe bed serves as housing for the spindle, driving gears or pulleys by means of which the workpiece can be rotated at different speeds. The headstock spindle is provided with alive center or chuck to support one end of the workpiece while it is being rotated.

3} **Tailstock {dead center}**

The tails stock mounted at the right end of the lathe bed performs two functions:

- Provide support to other the end of the rotating workpiece

- Hold a tool for performing operations like drilling, reaming, tapping, etc.

The tailstock can be made to slide along the bed and can be clamped at any location so as to accommodate workpiece of different lengths. It can also be shifted laterally on the bed so as to make it offset for producing taper surface.

4} **Carriage**

Saddle- the saddle is a part of the carriage that can be made to slide along the bed ways. Its supports the cross slide, compound rest and tool post.

Cross slide -The cross slide is mounted on the saddle it can be made to move in a direction perpendicular to the saddle movement, or perpendicular to the lathe axis thereby providing the necessary depth of cut to the workpiece.

Compound rest- It is mounted on the cross slide and supports the tool post. The compound rest has a circular base graduated in degrees. This helps the cutting tool to be swiveled at an angle to obtain taper surfaces.

Tool post- It is mounted on the compound rest and is used to hold/support the cutting tool firmly in position during machining

Apron - It is fitted beneath the saddle facing the operator. It houses the gears, levers, hand-wheels and clutches to operates the carriage by hand or by the automatic power feed

Feed rod- The feed rod is a long shaft that gives automatic feed to the carriage for various operations namely boring, turnings, etc., except thread cutting.

Lead screw- It is a long shaft with square threads cut on it. The rotation of the lead screws facilitates the movement of the carriage during thread cutting operations

5.2 Lathe Specifications

1. Maximum diameter of the workpiece that can be revolved over the lathe bed. Fig. 5.3 demonstrates the lathe specifications.

The height of the centers above the lathe bed is also specified. One of these specifications is given by the manufacturers; however, both of them are loosely called “swing of the lathe.

2. The maximum diameter and the width of the workpiece that can swing when the lathe has a gap bed.

3. The maximum length of the workpiece that can be mounted between the centers.

4. The overall length of the bed. It is the total length of the lathe itself.

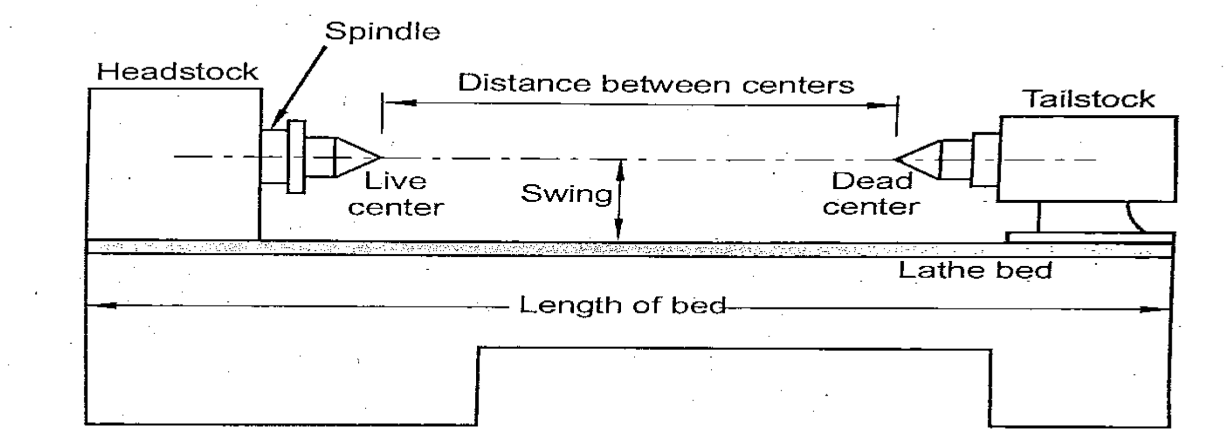


Fig. 5.3 Lathe specifications

5.3 Lathe Operations:

All most all the basic machining operations can be performed on a lathe. They are

1. Turning,
2. Taper turning,
3. Thread cutting,
4. Boring,
5. Facing,
6. Drilling,

7. Reaming

8. Knurling

9. Milling

10. Grinding

A variety of operations can be performed on a lathe. A few of them are discussed briefly below.

Turning: -

- Fig. 5.4 shows the principle of a metal cutting operation using a single-point tool on a lathe. The workpiece is supported in between the two centers which permit the rotation of the workpiece.
- A single point cutting tool is fed perpendicular to the axis of the workpiece to a known pre-determined depth of cut and is then moved parallel to the axis of the workpiece.
- This operation will cut the material which comes out as shown fig. This method of machining operation in which the workpiece is reduced to the cylindrical section of the required diameter is called 'Turning'.
- Cylindrical turnings can be done through rough turnings and finish turnings.
- In rough turnings, the excess material from the workpiece is removed rapidly by giving a deep depth of cut and a high feed rate.
- In finish turnings, the excess material is removed by giving light depth f cut and small feed

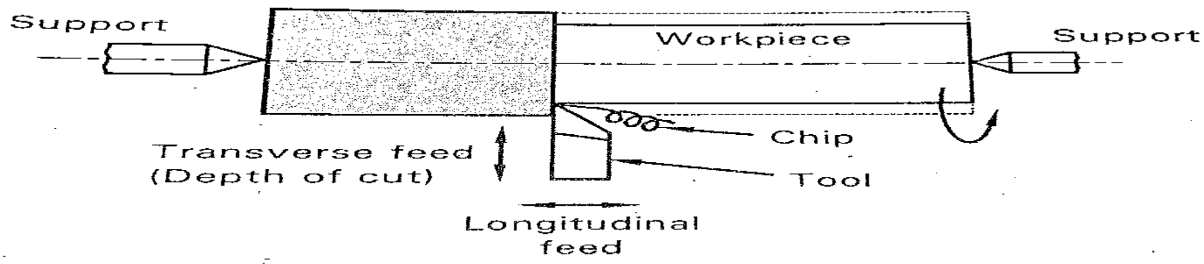


Fig. 5.4 Turning

Facing: -

- Facing is defined as an operation performed on the lathe to generate either flat-surfaced or shoulders at the end of the workpiece. Fig. 5.5 shows the facing operation.
- In facing operation, the direction of feed given is perpendicular to the axis of the lathe.
- The workpiece is held in the chuck and the facing tool is fed either from the outer edge of the workpiece progressing towards the center or vice versa. The cutting tool is held by a tool holder in a tool post.

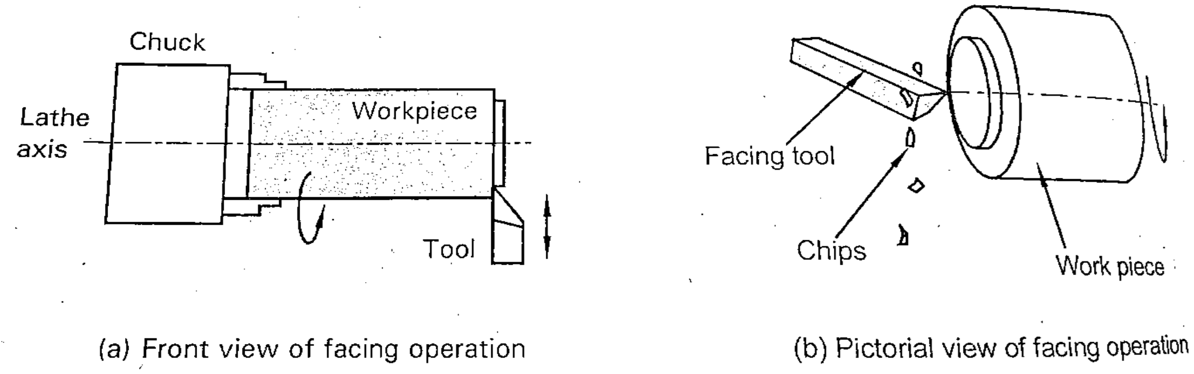


Fig. 5.5 Facing

Knurling: -

- Knurling is defined as an operation performed on the lathe to generate serrated surfaces or cross on workpieces by using a special tool called knurling tool which impresses its pattern on the workpiece. Fig. 5.6 shows the Knurling operation.

A typical knurling tool consists of one upper roller and one lower roller on which the desired impression pattern can be seen. The serration or impression pattern can be straight lines or diamond pattern.

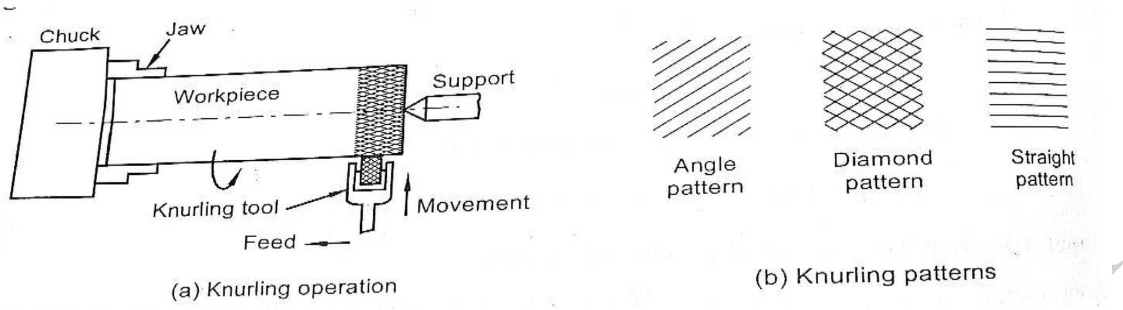


Fig. 5.6 Knurling

Thread Cutting:-

- A thread is a helical ridge formed on a cylindrical or conical rod. It is cut on a lathe when a tool ground to the shape of the thread, is moved longitudinally with uniform linear motion while the workpiece is rotating with uniform speed as shown in Fig 5.7.
- By maintaining an appropriate gear ratio between the spindle on which the workpiece is mounted, and the lead screw which enables the tool to move longitudinally at the appropriate linear speed, the screw thread of the required pitch can be cut.
- The pointed tool shown in Fig is employed to cut V-threads. When square threads are to be cut, the tool is ground to a squared end.

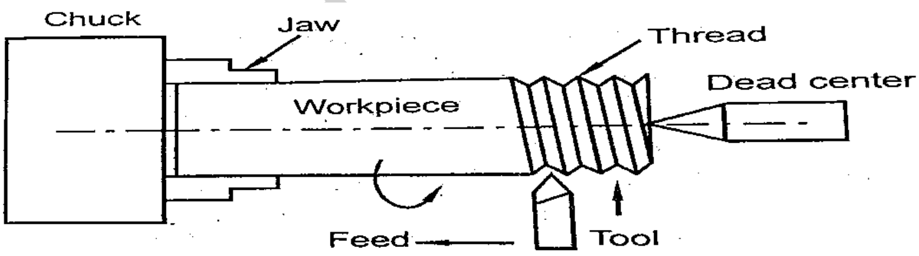


Fig. 5.7 Thread cutting

Drilling on lathe

Drilling is the operation of producing a cylinder hole by means of revolving tool called twist drill or drill bit. In operation, one end of the workpiece is held in a chuck, while the other end is left free (not fitted to the tailstock end). The tool is held in the tapered hole of the tailstock sleeve and is fed into the rotating workpiece with the help of rotating hand wheel of the tailstock. Drilling on the lathe he is limited to holes through the axis of rotation of the workpiece and from any of the ends only. Although drillings operation can be done on lathes, it is best performed on drilling machines.

Reaming

The size of the hole made by drilling may not be accurate and the internal surface will not be smooth. Reaming is an accurate way of sizing and finishing a hole which has been previously drilled by a multi-point cutting tool known as a reamer. The surface obtained by reaming will be smoother and the size accurate. The speed of the spindle is made half that of drilling. Reaming removes a very small amount of metal (approx. 0.375 mm). In order to finish a hole and bring it to the accurate size, the hole is drilled slightly undersize.

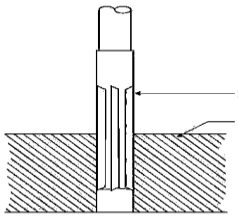


Fig. 5.8 Reaming

Boring

Boring is the operation enlarging the diameter of the previously made hole. It is done for the following reasons.

1. To enlarge a hole by means of an adjustable cutting tool. This is done when a suitable sized drill is not available or the hole diameter is so large that is cannot be ordinarily drilled.
2. To finish a hole accurately and bring it to the required size
3. To machine the internal surface of the hole already produced in a casting
4. To correct out of roundness of the hole
5. To correct the location of the hole as the boring tool follows an independent path with respect to the hole Boring tool is a tool with only one cutting edge. The tool is held in a boring bar which has a tapered shank to fit into the spindle or a socket.

For perfectly finishing a hole, the job is drilled undersize slightly. Boring operation in some precise drilling machine is performed to enlarge the holes to an accuracy of 0.00125mm. The spindle speed during boring should be adjusted to be lesser than that of reaming.

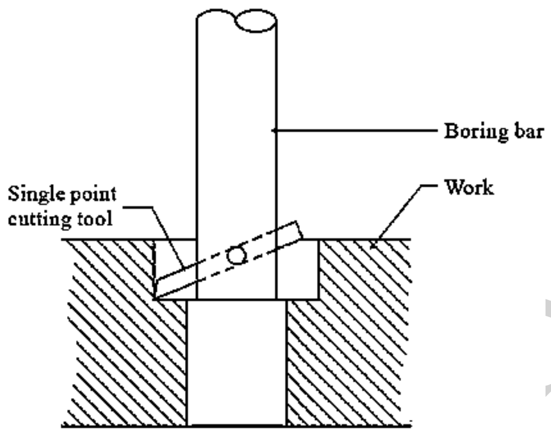


Fig. 5.9 Boring

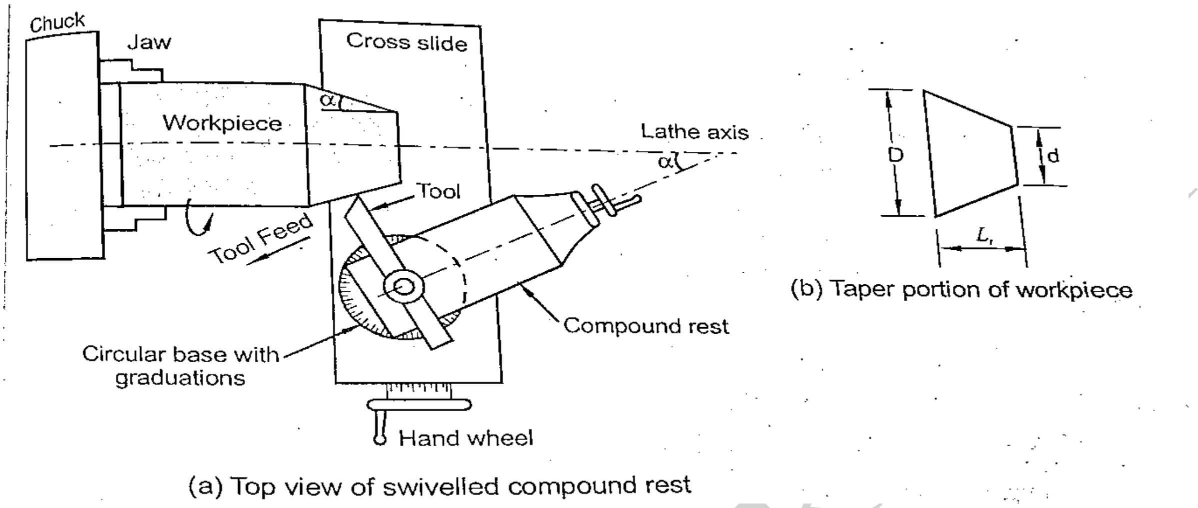
Taper turning: -

The taper is defined as a uniform increase or decrease in the diameter of a piece of work measured along its length. Taper turning is an operation on a lathe to produce a conical surface on the workpieces.

Methods of Taper Turning: -

1. Taper Turning by swiveling (Rotating) the Compound Tool Rest.
2. Taper Turning by off-setting the tailstock
3. Taper Turning by a Taper turning attachment.

Taper Turning by the Swiveling the Compound Tool Rest:



(a) Top view of swivelled compound rest

(b) Taper portion of workpiece

Fig. 5.10 Taper Turning by the Swiveling the Compound Tool Rest

Fig. 5.10 shows the Taper Turning by the Swiveling the Compound Tool Rest. It is more suitable for workpieces, which require steep taper for short lengths. The compound rest has a circular base graduated in degrees. The compound tool rest is swiveled to the required taper angle and then locked in the angular position. The carriage is also locked at that position. For taper turning, the compound tool rest is moved linearly at an angle so that the cutting tool produces the tapered surface on the workpiece. The rotation of the compound rest to the calculated taper angle (α), will cause the tool to be fed at that angle, thereby producing the corresponding taper on the workpiece. This method is more suitable for producing steep taper with a short length

The angle at which the compound rest to be swiveled is calculated using the equation given below

$$\tan \alpha = \frac{D-d}{2XL}$$

$$\alpha = \tan^{-1} \frac{D-d}{2XL}$$

Where D= Larger diameter of taper in mm

d=smaller diameter f taper in mm

L=Length of taper in mm

Taper turning by offsetting the tailstock (tailstock set over method)

In this method as shown in the Fig. 5.11, the taper is produced by shifting the axis of rotation of the workpiece at an angle to the lathe axis, and then the tool is moved parallel to the lathe axis. Refer figure. This is used for producing small taper on long workpieces. The angle at which the axis of rotation of the workpiece is shifted is equal to half-angle of the taper.

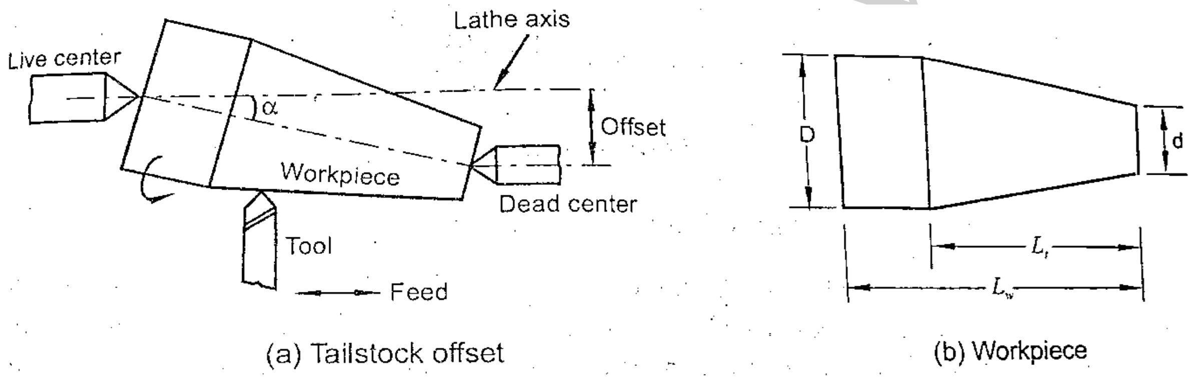


Fig. 5.11 Taper turning by offsetting the tailstock (tailstock set over method)

This is done by offsetting the body of the tailstock with respect to its base by an amount equal to

$$offset = \frac{(D-d)L_w}{2L_t}$$

Where D= Larger diameter of taper in mm

d=smaller diameter f taper in mm

L_t=Length of taper in mm

L_W=Length of the entire workpiece in mm

5.4 MILLING MACHINE

INTRODUCTION

Milling: -Milling is a manufacturing process in which the excess material from the workpiece is removed by a rotating multipoint cutting tool called milling cutter. The milling cutter is a multipoint cutting tool. The workpiece is mounted on a movable work table which will be fed against the revolving milling cutter to perform the cutting operation. **Milling machine: -** A milling machine is a power-operated machine tool in which the workpiece is mounted on the moving table is machined to various shapes when moved under a slow revolving serrated cutter.

Principle of Milling

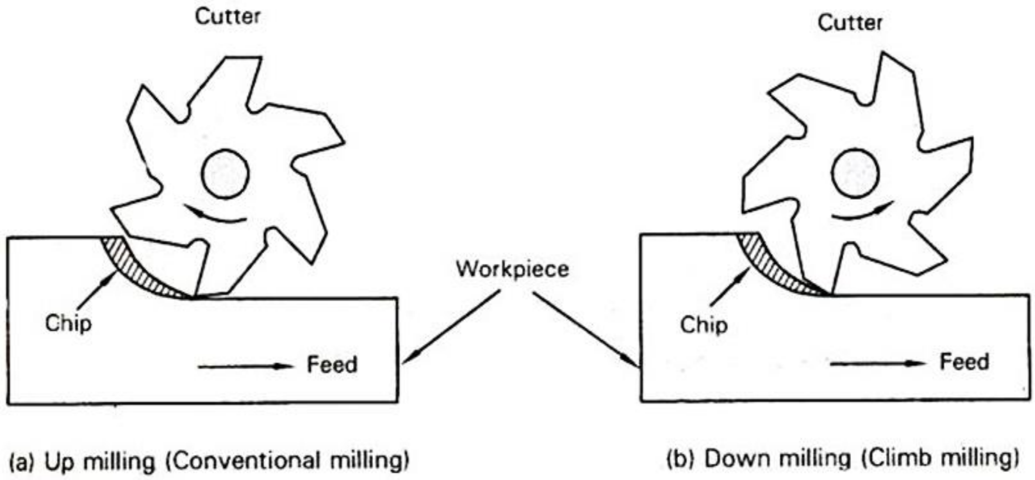


Fig. 5.12 milling operation

The above Fig. 5.12 shows the principle of the milling process that is up milling and down milling. The up milling is also called as conventional milling and down milling is called climb milling. The milling cutter is mounted on a rotating shaft known as an arbor. The workpiece which is mounted on the table can be fed either in the direction opposite to that of the rotating cutter as shown in the figure or in the same direction of the cutter as shown in the figure.

Types of milling machine

The different types of milling machines are listed as follows

1. Column and knee type milling machines
   a. Plain and knee type milling machines
   - Horizontal spindle type
   - Vertical spindle type

   b. Universal Column and knee type milling machine
2. Bed type milling machine
3. Planer type milling machine
4. Special type milling machines
   a) Tracer -controlled milling machine
   b) Thread milling machine
   c) CNC milling machine

Horizontal Spindle Column and Knee Milling Machine (Horizontal Milling Machine)

It is called a Horizontal milling machine, because of the horizontal position of the spindle. This type of machine is used to cut grooves, slots, keyways, gear teeth, etc. Fig. 5.13 shows the Horizontal Spindle Column and Knee Milling Machine.

a) The base is usually a strong and a hollow part, which forms the foundation of the machine and upon which all other parts are mounted. The base also serves as a sump for the cutting fluid. A pump and filtration system can be installed in the base. The hole provided in the center of the base houses the support for the elevating screw that raises and lower the knee.

b) Column is a vertical hollow casting and is usually combined with the base to form a single casting. The column houses the spindle and bearings as well as the drive units (gears, clutches, shafts and shifting mechanisms) for transmitting power from the electric motor to the spindle at desired speeds. The front face of the vertical column is provided with a square or dovetail type guideways on which knee slides up and down.

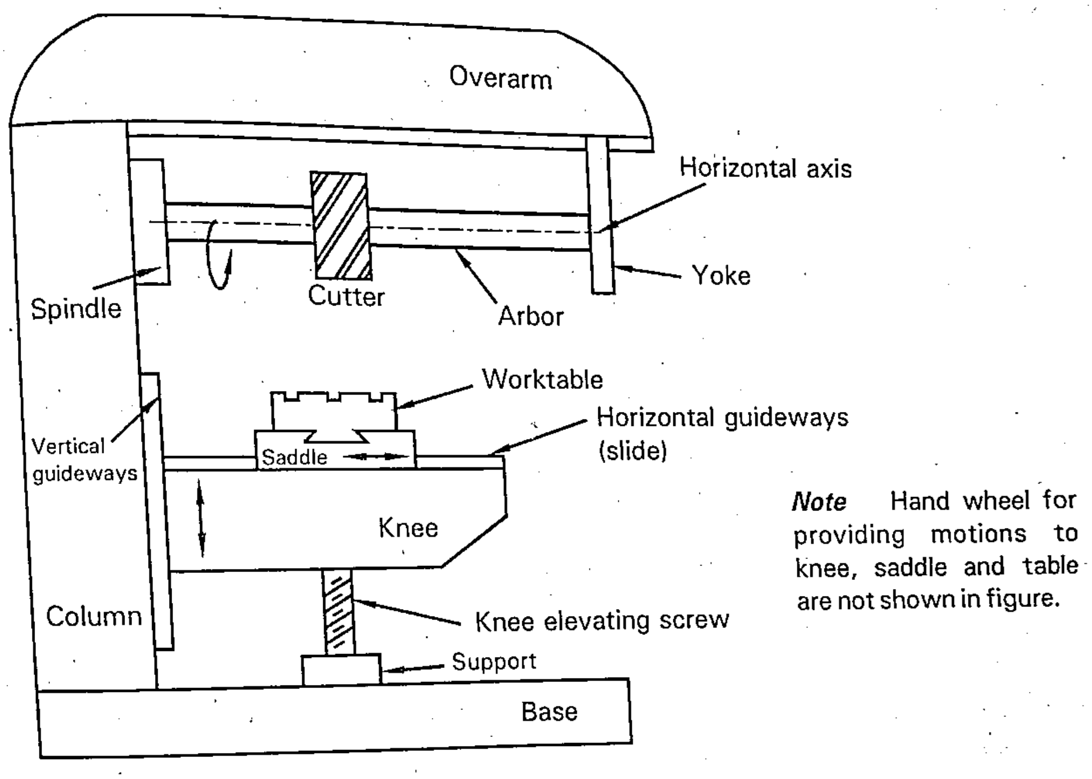
c) The spindle is a hollow shaft supported by the column with a suitable bearing that absorbs both radial and thrust loads. The spindle is made hollow and tapered inside to accept standard arbors, the spindle obtains power from the motor and transmits it to the arbor. The arbor carrying the cutter rotates about a horizontal axis.

d) Overarm mounted on the vertical column supports the yoke, this, in turn, supports the free end of the arbor.

e) Knee is a casting slide up and down on the vertical guide ways provided on the column by means of the elevating screw.

f) Saddle mounted on the knee is provided with two slides (guides ways) on its top and bottom surfaces, lower guide ways helps to facilitate horizontal movement of the saddle. The upper guideways on saddle help to facilitate the movement of the worktable.

g) Worktable is larger in size and rests on the saddle. This enables the workpiece to be clamped rigidly on the table. The worktable may be manually controlled or power fed. The work table is provided with T-slots all along its length of mounting vice.



(a) End view of a horizontal-spindle column and knee milling machine

Fig. 5.13 Horizontal Spindle Column and Knee Milling Machine

Vertical Spindle Column and Knee Milling Machine (Vertical Milling Machine) (swiveling type milling machine)

It is called a vertical milling machine, because of the vertical position of the spindle. This type of machines is used to perform end milling and face milling operations etc. Fig. 5.14 shows the vertical Spindle Column and Knee Milling Machine

a) The base is usually a strong and a hollow part, which forms the foundation of the machine and upon which all other parts are mounted. The base also serves as a sump for the cutting fluid. A pump and filtration system can be installed in the base. The hole provided in the center of the base houses the support for the elevating screw that raises and lower the knee.

b) Column is a vertical hollow casting and is usually combined with the base to form a single casting. The front face of the vertical column is provided with a square or dovetail type guideways on which knee slides up and down.

c) Spindle

- The spindle is located vertically, parallel to the face of the column, and perpendicular to the top of the work table,
- The spindle is mounted in the spindle head and carries the cutter at its end.
- The spindle head houses the motor and feeds controls and spindle head is a fixed type or swiveled type.
- The fixed type, the spindle head is fixed, and spindle remains vertical. The spindle can be adjusted up and down to perform operations like grooving, slotting, facing drilling and boring.

e) The knee is a casting slide up and down on the vertical guideways provided on the column by means of the elevating screw.

f) Saddle mounted on the knee is provided with two slides (guides ways) on its top and bottom surfaces, lower guide ways helps to facilitate the horizontal movement of the saddle. The upper guideways on saddle help to facilitate the movement of the worktable.

g) The worktable is larger in size and rests on the saddle. This enables the workpiece to be clamped rigidly on the table. The worktable may be manually controlled or power fed. The work table is provided with T-slots all along its length of mounting vice.

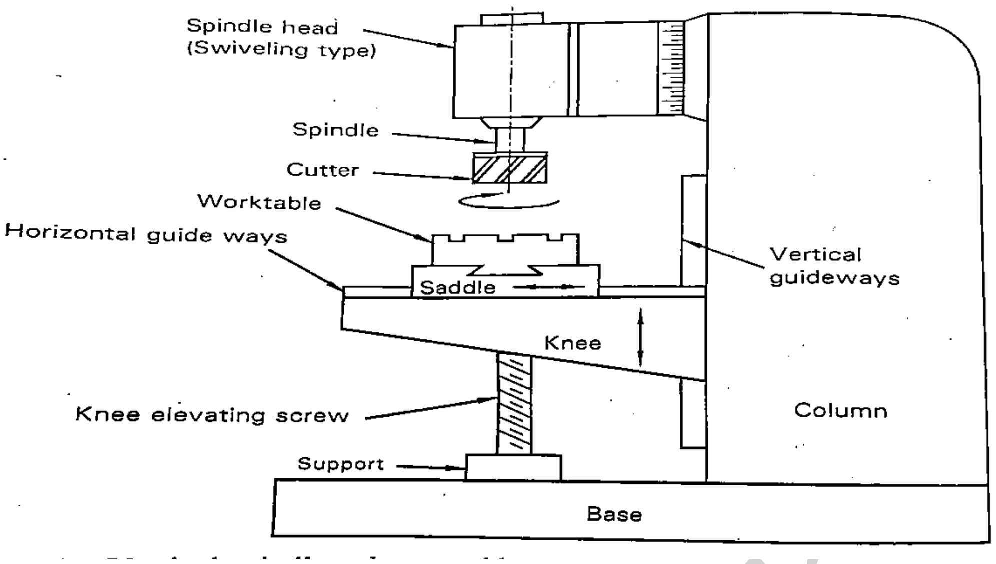


Fig. 5.14 Vertical Spindle Column and Knee Milling Machine

5.5 MILLING OPERATIONS OR PROCESSES:

The milling operations are given below.

1) Plain milling, Form milling, End milling, Straddle milling, Slot milling, Gang milling, Angular milling

Plain milling or Slab milling or surface milling: -The slab milling is the operation of producing flat, horizontal surface parallel to the axis of rotation of a slab-milling cutter. Slab milling is done to remove the material from the upper surface of the workpiece. The slab milling cutters are held in the arbor and it may have straight or helical teethes. Both cutters can be used to generate flat surfaces. The required depth of cut can be adjusted by raising the table or the knee and the feed is given by moving the saddle. Fig. 5.15 shows the plain milling processes.

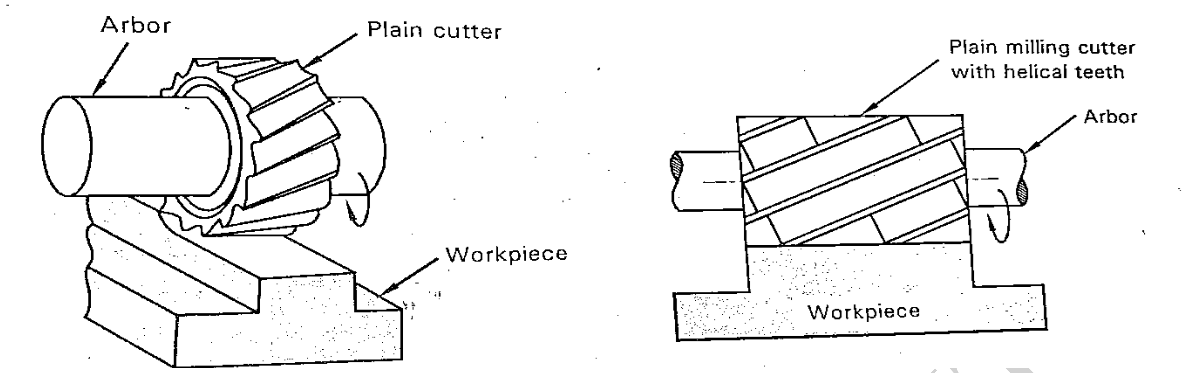


Fig. 5.15 Plain milling processes

End milling: -End milling is a process of milling that is used to mill slots, pockets, and keyways in such a way that the axis of the milling cutter is perpendicular to the surface of the workpiece. The milling operation when used for keyway cutting as shown in the figure. The advantage of the end milling operation is that we can achieve the depth of cut of nearly the diameter of the mill.

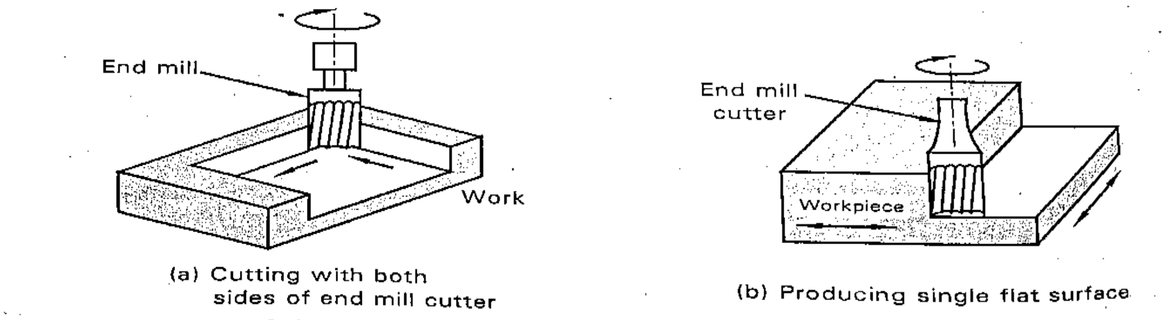


Fig. 5.16 End Milling processes

Slot milling: - Slot milling is the operation of producing slots like T-slots, plain slots, dovetail slots, etc., in worktable fixtures and other work holding devices. The operation may be performed using end milling cutter, T-slot cutter, dovetail cutter or side milling cutter.

The type of cutter selected depends on the shape of the slot to be produced.

- Two separate milling cutters are required for milling T-slots. Initially a side cutter or an end milling cutter is used to cut the throat (open slot) starting from one end of the workpiece to its other end. A T-slot milling cutter is then used to cut the headspace to the desired dimensions.

- A similar procedure is followed for cutting a dovetail slot, but a dovetail slot cutter is used in place of T-slot cutter.

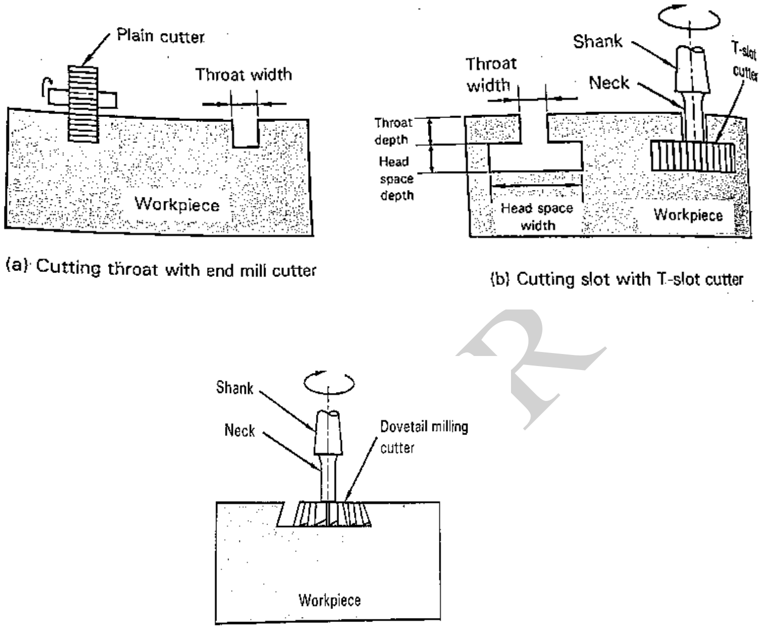


Fig. 5.17 Slot Milling processes

Angular Milling

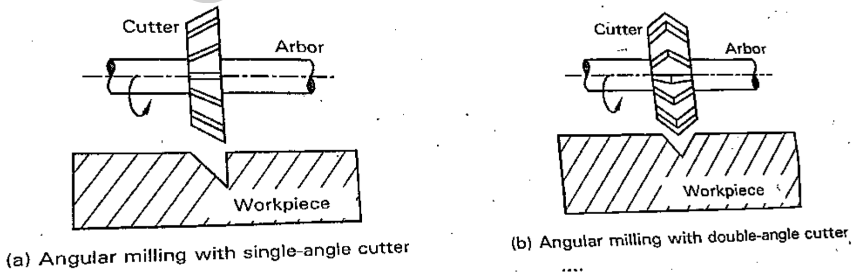


Fig. 5.18 Angular Milling processes

- Angular milling is the operation of producing all types of angular cuts like V-notches and grooves, serrations and other angular surfaces.

- The cutter, called angle milling cutter or angle cutter has peripheral teeth, which are neither parallel nor perpendicular to the cutter axis.
- The cutter may be either a single angle or double angle type or its selection depends on the surface to be machined.
- Single angle cutter is angled on one side to produce an angle or chamfer on the workpiece edge as shown in the figure.
- Double angle cutter is angled on both the sides of the cutter and hence can produce angle cuts as shown in the figure. Angle cutter may also be used to produce dovetail slots in workpieces.

Form Milling

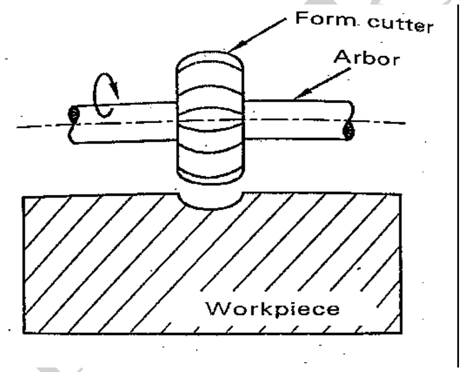


Fig. 5.19 Form Milling processes

- Form milling is the operation of producing curved profiles with a variety of shapes like concave, convex, spline, etc., using cutter whose edge is shaped to produce a special configuration on the surface of the workpiece.
- The cutter known as form mill has teeth on its periphery and is designed in various shapes to suit the type of surface being machined.
- One example of form mill is the gear tooth cutter, which is used to cut gear teeth on workpieces.

Straddle Milling

- Straddle milling is the operation in which a pair of the side milling cutter is used for machining two parallel vertical surfaces simultaneously as shown in the figure.

- The side milling cutter has a cutting edge on one or both sides as well as on the periphery.
- Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart at an exact spacing with the help of spacers, washers, and shims
- The distance between the cutting teeth of each cutter is exactly equal to the width of the workpiece area being machined

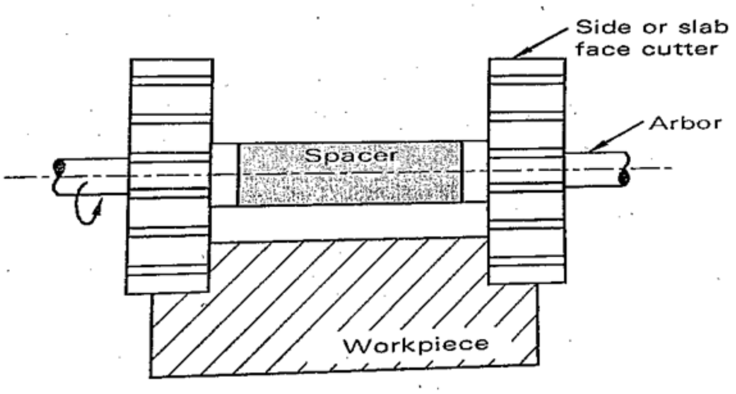


Fig. 5.20 Straddle Milling processes

Gang Milling

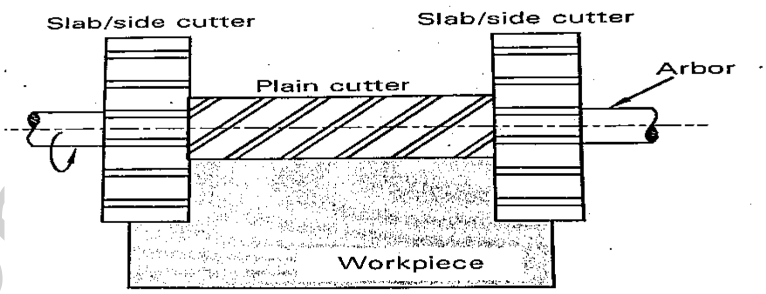


Fig. 5.21 Gang Milling processes

- Gang milling is the operation in which two or more cutters or mounted on the same arbor, so the different profiles required on the workpiece can be machined simultaneously in a single pass.
- All the cutters used may be of the same types depending on the types of the surface being

machined.

- ***Note*** the name gang is given in conjunction to the use of different types or a group of cutters.

5.6 Up Milling and Down Milling

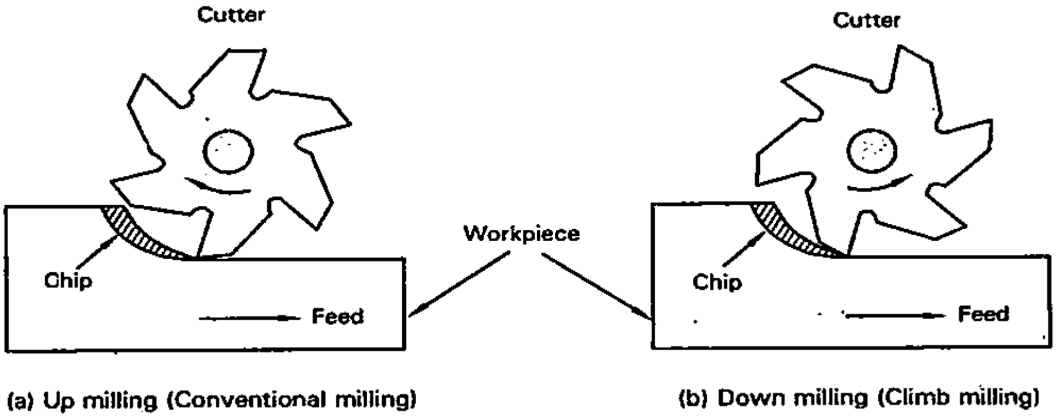


Fig. 5.22 Up and down Milling processes

	UP MILLING	DOWN MILLING
1	The workpiece is fed in the **direction opposite** to that rotating cutter.	The workpiece is fed in the **same direction** as that of the rotating cutter.
2	The thickness of the chip is **minimum** at the **beginning** of the cut and reaches to a ***maximum*** when the cut **ends**.	The thickness of the chip is **maximum** at the **beginning** of the cut and reaches to the **minimum** when the cut **ends**.
3	• Cutting force is directed up words that tend to lift the workpiece from the worktable. • Hence, a greater clamping force for the workpiece is necessary.	• Cutting force is directed down words, which tends to keep the workpiece firmly on the worktable, • Permitting lesser clamping forces.
4	• The chip gets accumulated at the cutting zone (Tool -work interface). • These chips interface with the rotating cutter thereby impairing the surface finish	• In down milling, the chips do not interfere with the revolving cutter, since they are disposed of easily by the cutter. • Hence, there is no damage to the surface

	on the work- surface.	finish of the workpiece.
5	It is difficult for efficient circulation of coolant. The cutter rotating cutter in the up word direction carries away the coolant from the cutting zone.	In down milling, the coolant can easily reach the cutting zone. Hence, efficient cooling of the tool and the workpiece can be achieved.
6	Up milling is preferred for rough cuts, especially for castings and forgings	Down milling produces a better surface finish

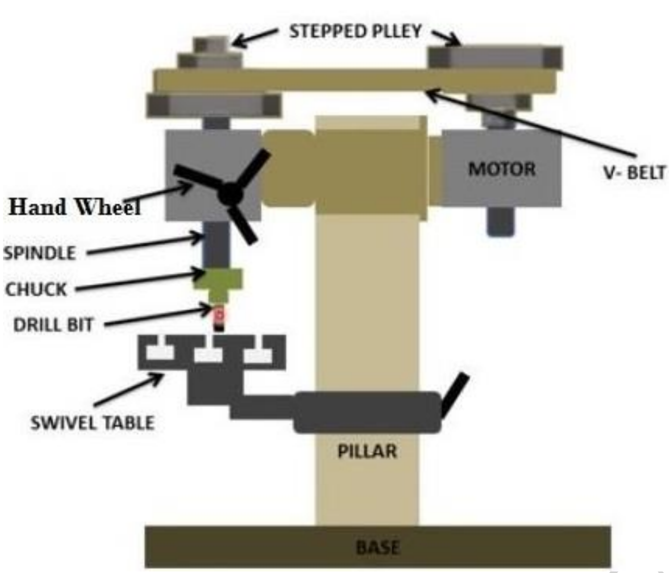
5.7 DRILLING MACHINE

Introduction

- Drilling machine is one of the most important machine tools in a workshop. It was designed to produce a cylindrical hole of required diameter and depth on metal workpieces (Fig.5.23). Though holes can be made by different machine tools in a shop, drilling machine is designed specifically to perform the operation of drilling and similar operations. Drilling can be done easily at a low cost in a shorter period of time in a drilling machine.
- Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill. The cutting tool known as drill is fitted into the spindle of the drilling machine. A mark of indentation is made at the required location with a centre punch. The rotating drill is pressed at the location and is fed into the work. The hole can be made upto a required depth.

Construction of a drilling machine

- The basic parts of a drilling machine are a base, column, drill head and spindle (Fig. 5.23). The base made of cast iron may rest on a bench, pedestal or floor depending upon the design. Larger and heavy duty machines are grounded on the floor. The column is mounted vertically upon the base. It is accurately machined and the table can be moved up and down on it. The drill spindle, an electric motor and the mechanism meant for driving the spindle at different speeds are mounted on the top of the column. Power is transmitted from the electric motor to the spindle through a flat belt or a 'V' belt.



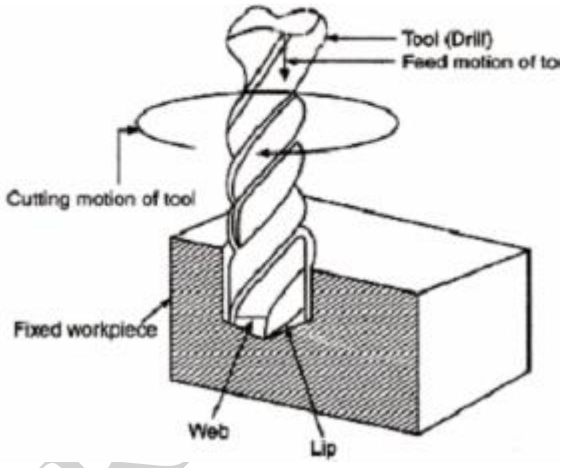


Fig. 5.23 Explains the drilling operation

Working principle of a drilling machine

- The When the power is given to the motor, the spindle rotates and thereby the stepped pulley attached to it also rotates. On the other end, one more stepped pulley is attached and that is inverted to increase or decrease the speed of the rotational motion. Now, a V-belt is placed in between the stepped pulleys so as to drive the power transmission. Here a V-belt is used instead of a flat belt, in order to increase the power efficiency. Now the drill bit also rotates which was placed in the chuck and which was in connection with the spindle. As the Pulleys rotates, the spindle also rotates which can rotate the drill bit. Now, by the rotation of hand-wheel, the spindle moves up and down in the vertical direction in order to give the necessary amount of feed to the work and this drill bit is used to make the holes on the component placed in the machine vice.

Though drilling is the primary operation performed in a drilling machine, a number of similar operations are also performed on holes using different tools. The different operations that can be performed in a drilling machine are: 1. Drilling 2. Reaming 3. Boring 4. Counter boring 5. Countersinking 6. Spot facing 7. Tapping 8. Trepanning

5.8 INTRODUCTION TO ADVANCED MANUFACTURING SYSTEMS

COMPUTER NUMERICAL CONTROL MACHINES:

Computer Numerical Control (CNC) is defined as an NC system who's MCU is based on a dedicated Microcomputer rather than on a hard-wired controller. The latest computer controllers for CNC feature high-speed processors, large memories, solid-state flash memory, improved servos, and bus architectures. Some controllers have the capability to control multiple machines.

Features of CNC:

Computer NC system includes additional features beyond what is feasible with conventional hard-wired NC.

The features, many of which are standard on most CNC MCUs, include the following.

1. **Storage of more than one part program.** With improvements in computer storage technology, newer CNC controllers have sufficient capacity to store multiple programs.

2. **Various forms of program input.** Whereas conventional (hard-wired) MCUs are limited to punched tape as the input medium for entering part programs, CNC controllers generally process multiple data entry capabilities, such as punched tape (if the machine stop still uses punched tape), magnetic tape, floppy diskettes, RS-232 communications with external computers, and manual data input (operator entry of program).

3. **Program editing at the machine tool.** CNC permits a part program to be edited while it resides in the MCU computer memory. Hence, a program can be tested and corrected entirely at the machine site, rather than being returned to the programming office for corrections.

4. **Diagnostics.** Many modern CNC systems possess a diagnostics capability that monitors

certain aspects of the machine tool to detect malfunctions or signs of impending malfunctions or to diagnose system breakdowns.

5. **Communication interface.** With the trend toward interfacing and networking in plants today, most modern CNC controllers are equipped with a standard RS-232 or other communications interface to link the machine to other computers and computer-driven devices.

Machine Control Unit for CNC

The MCU is the hardware that distinguishes CNC from conventional NC. The general configuration of the MCU in a CNC system is illustrated in Figure 8. The MCU consists of following components and subsystems: (1) central processing unit, (2) memory (3) I/O interface, (4) controls for machine tool axes and spindle speed, and (5) sequence controls for other machine tool functions.

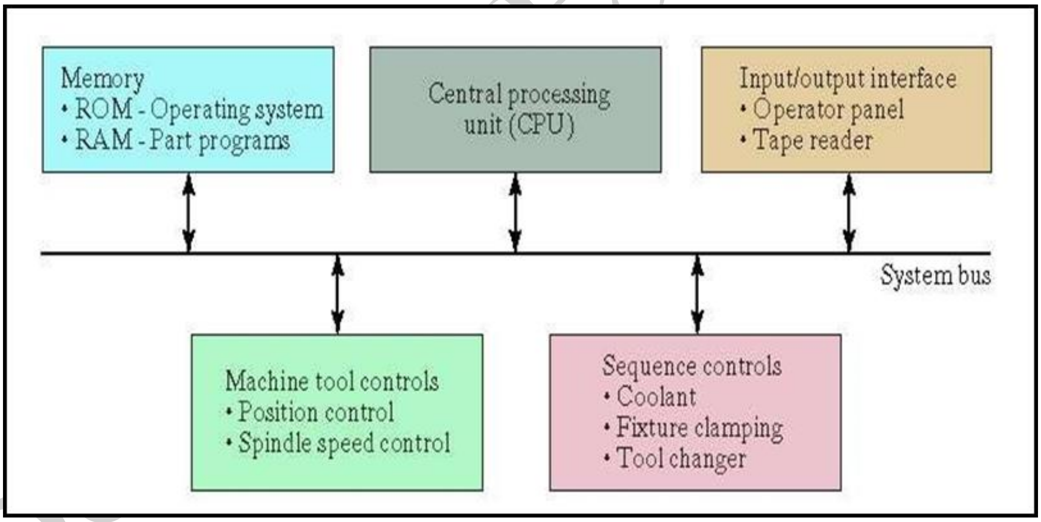


Fig. 5.24 Machine control unit

Central processing unit the central processing unit (CPU) is the brain of the MCU. It manages the other components in the MCU based on software contained in main memory. The CPU can be divided into three sections: (1) control section, (2) arithmetic-logic unit, and (3) intermediate access memory.

Memory The immediate access memory in the CPU is not intended for storing CNC software. Much greater storage capacity is required for the various programs and data needed to operate the CNC system.

Input/output interface The I/O interface provides communication between the various components of the CNC system, other computer systems, and the machine operator. As its name suggests, the I/O interface transmits and receives data and signals to and from external devices.

Controls for machine tool axes and spindle speed these are hardware components that control the position and velocity (feed rate) of each machine axis as well as the rotational speed of the machine tool spindle.

Sequence controls for other machine tool functions In addition to control of table position, feed rate, and spindle speed, several additional functions are accomplished under part program control. These auxiliary functions are generally on/off actuations, interlocks, and discrete numerical data. To avoid overloading of CPU, a programmable logic controller is sometimes used to manage the I/O interface for these auxiliary functions.

Major difference between NC and CNC machines as follows.

NC Machine	**CNC Machine**
punched tape is cycled through the reader for every workpiece in the batch	The program is entered once and then stored in computer memory
It has no additional flexibility and computational capability	It has additional flexibility and computational capability

The hardware NC controller unit is present	The conventional hardware NC control unit is replaced by microcomputer
We cannot easily refine. change and improve the part programming procedure	Use of computers refines, change and improves part programming procedure through interactive graphic techniques
Total factory automation with the help of NC machines not easily possible	Total factory automation is easily possible and is more compatible
Adaptive control and in-process compensation cannot be done with the help of NC machine	Use of adaptive control and in-process compensation optimize the working conditions

Advantages of CNC Machine:

- It eliminates human errors.
- Higher flexibility.
- High accuracy.
- Lower wastage.
- Suitable for batch production less space is required.
- Reduces inspection cost.
- More operational safety.
- Quality of product is high.

Disadvantages of CNC Machine

- The initial cost is high.
- It requires skilled programmers.
- It is not suitable for small scale production.
- Maintenance cost is more.

Concept of Smart Manufacturing:

- Smart manufacturing is the use of real-time data and technology when, where and in the forms that are needed by people and machines.
- According to the National Institute of Standards and Technology (NIST) SM systems that are “fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs.”
- The Smart Manufacturing Leadership Coalition (SMLC) defines SM as “the ability to solve existing and future problems via an open infrastructure that allows solutions to be implemented at the speed of business while creating advantaged value.”
- In the same way there are “microprocessors” that make it possible for smartphones to operate like mini-computers, there’s the “cloud” where an almost-unlimited amount of data can be stored and retrieved. Also, there are “apps” that can be downloaded to help us keep track of what we spend, track the location of people and devices, track how many steps we’ve walked, etc. SM utilizes all of the same components, addressing the complexities of security, interoperability and intellectual property for manufacturing. SM will create an open atmosphere where fact-based decisions can be made and decision makers will have the trusted data when it’s needed, where it’s needed and in the most useful form needed. Solving problems will be based on a total picture.
- The concept of a cloud-based open access SM platform allows manufacturers to integrate existing and future plant data, simulations and systems across manufacturing functions. What

does this mean? The cloud is basically a secure network of servers on the internet to store, manage and process systems data and analytics. Why is this important? This eliminates the need for companies to purchase and maintain a large IT infrastructure that requires support. Today, although many manufacturing processes rely on control contributions by computers, the systems and data on these computers exist in silos with little or no connectivity. The SM platform will allow processes to be integrated to support informed decision-making. In some cases, the integration of currently siloed processes may bring to light hidden inefficiencies and waste. Companies of all sizes will be able to gain easy, affordable access to run simulations and gain analytical data for their particular needs. Manufacturers will have the newfound ability to shop for applications through the Marketplace that cater to their organization's needs using ANY device with internet capability.

5.9 Smart Manufacturing Benefits:

This merger of the physical and virtual worlds (cyber physical systems - CPS) opens up new areas of innovation that will optimize the entire manufacturing industry to create higher quality products, improve productivity, increase energy efficiency, and sustain safer plant floors. Furthermore, smarter factories also offer the opportunity to boost employment 2-4 times over the current national manufacturing workforce of 12 million. As SM is adopted, new technology based manufacturing jobs will become available creating direct manufacturing and non-manufacturing positions. Creating smarter factories will allow the U.S. to remain competitive with manufacturing organizations abroad. New, overseas manufacturing facilities are being constructed with Smart Manufacturing technologies built-in. In order for the U.S. to remain competitive, it needs to embrace Smart Manufacturing with people who have the desire to get in on the ground floor.

Concept of Industrial IOT:

- The Internet of Things (IoT) is one of the most widely used phrases in modern computing developments. Although often referred to as a technology, it is more accurately a platform for connecting objects (via sensing) so that data gathered about them might be used to analyse, interpret, decide and act on that data and other associated information

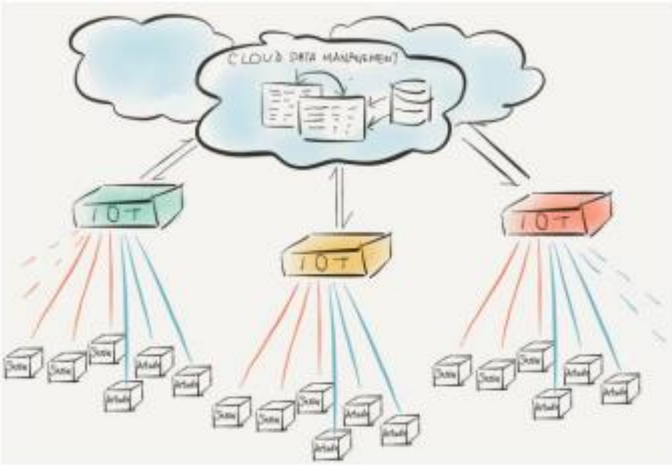


Fig. 5.25 Explain the concept of IOT

Conceptual of systematic IOT

- The Internet of Things, or IoT, is a system of interrelated computing devices (Fig. 5.25), mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
- In its simplest form, IoT is generally understood to comprise three key component levels:

1. Edge functionality – sensors (and actuators) connected to physical objects and machines.

2. Data Gateways – mechanisms for receiving sensed data from edge devices and transmitting to edge devices. Also capable of transmitting and receiving information from networked servers.

3. Data Management & Analysis – (cloud) server based collection, linking, analysis and use of data.

There are some common attributes of IOT as well as some misconceptions. These are summarized below:

IoT	Not IoT
• Enabling infrastructure • A means for connecting objects to other objects of machines • Extension of Internet (to include objects) • Enabling sensing, decisions and actions involving everyday objects	• An application or a service • A new separate network of objects • Just about getting object data from sensors • Mainly about big data • Mainly about data base coordination

Industrial IOT:

- Industrial Internet of Things (IIoT) is loosely interpreted as the industrial application developments associated with the Internet of Things (IoT).
- The application of Internet of Things developments to (create value for) industrial processes, supply chains, products and services
- This is because it explicitly includes the role of products and services within its scope, as well as industrial processes and operations
- Following the general IoT schematic in the Fig. 5.25 above, we note that in the specific context of industrial applications, the edge objects that would be expected to be connected within IoT infrastructure consist primarily of products / parts / materials being transformed or transported and resources / machines / equipment used in the transform or transport processes (see figure below – Fig.5.26)

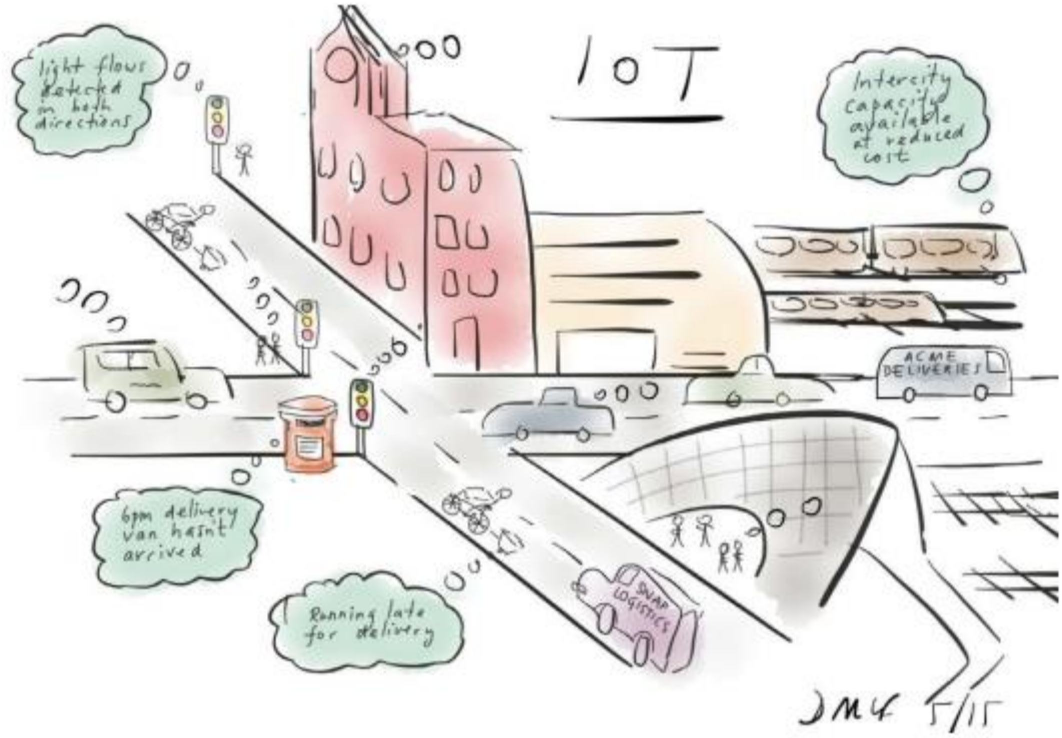


Fig. 5.26 Explain industrial IOT

Uses of Industrial IOT:

- In this section, two specific benefit areas of IoT in an industrial context are raised. These relate to areas of sensing that are not traditionally part of the factory information environment and are hence not typically integrated into production or asset management considerations. In a later section, the differences between existing industrial IT systems and the options that IoT can offer will be discussed.

  (i) Collecting Non-Production Data to Improve Industrial Operations:

  Industrial operations are extremely efficient at sensing production data to ensure best performance but generally less efficient at integrating data from maintenance, quality control and raw material supplies into considering production planning, scheduling and control issues. Part of the reason is the difficulty of integrating such data into the factory information & control environment. IoT can potentially help address this challenge by making this data accessible –

even if it originates from 3rd party data suppliers. Conversely the use of production data for non-production needs (maintenance, quality control etc.) can also be enabled by some of the evolving Industrial IoT offerings.

(ii) Collecting Product related Data to Improve Product Life Cycle Performance:
A second severe limitation of today's sensed data provision relates to product data and product-related process data as a product moves throughout its life cycle. Fragmented information relating to an industrial product lies in databases of suppliers, manufacturers, distributers, retailers and service providers etc. The work of the Auto ID Centre, EPC Global, GS1 and others over the last 15 years has been to create standards for the exchange of product data across multiple organizations. An industrial IoT framework in which product data could be seamlessly gathered and linked to a physical entity as it moves through its life cycle would address many of today's product life cycle management challenges. It might even enable self-managing products.

Industrial IoT will provide the best immediate impact are applications in:

- Integrating data from suppliers, logistics providers, customers
- Introducing data from new technology, peripherals, tools, equipment
- Distributed production requiring addition of new data sources, locations, owners Sensors on board raw materials, parts, products, orders passing through organisations

5.10 INTRODUCTION TO MECHATRONICS:

- Figure 5.27 - Mechatronics is the synergistic combination of mechanical and electrical engineering, computer science, and information technology, which includes the use of control systems as well as numerical methods to design products with built-in intelligence.

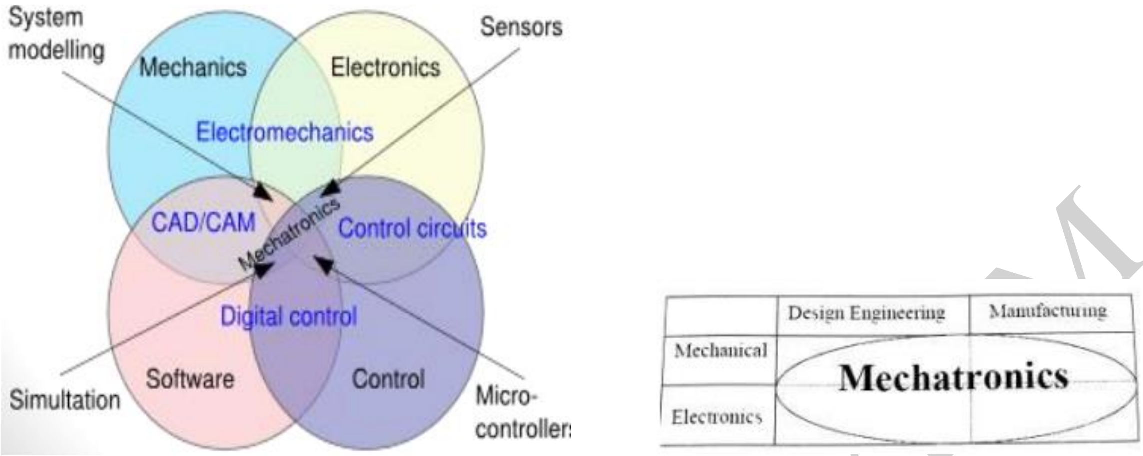


Fig. 5.27 Discuss the mechatronics concept

Basis of mechatronics: Always described as a combination of mechanical and electronic devices

- **Concept of mechatronics system:**

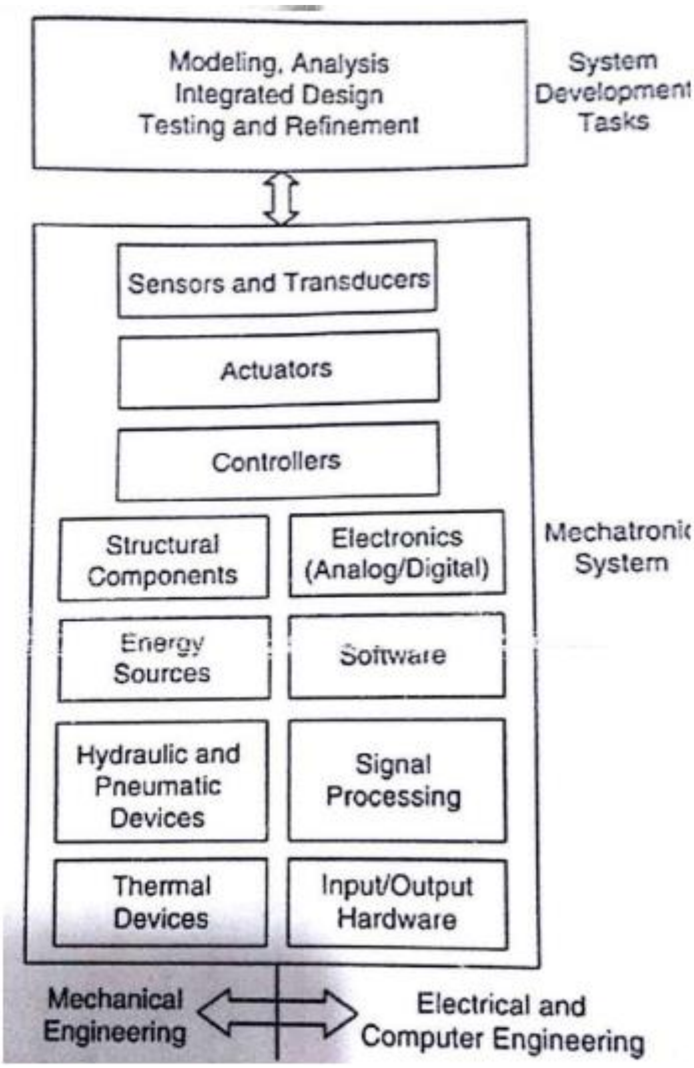


Fig. 5.28 Explain the concept of mechatronics

- **Typical components of mechatronic systems:**

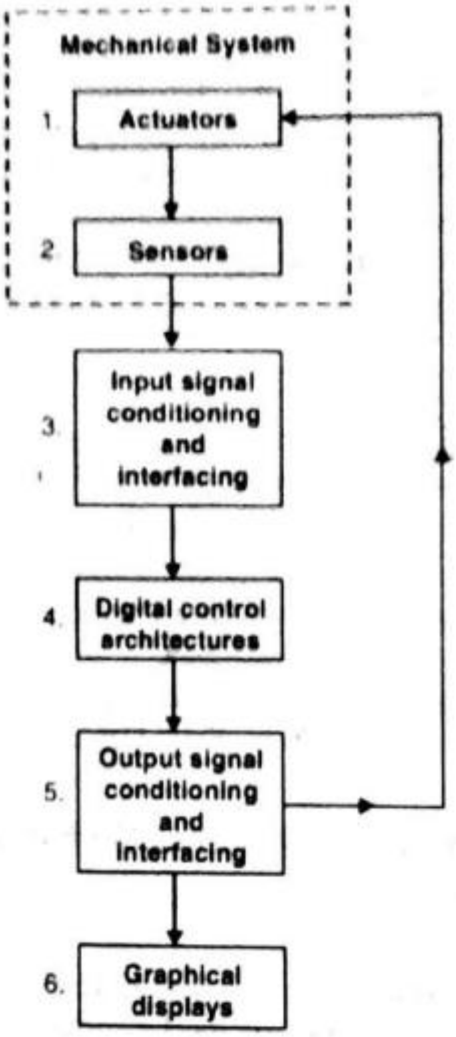


Fig. 5.28 Explain components of mechatronics system

- Some examples of mechatronic systems: Automotive Systems, Drive by Wire, Camless Engines, Robotics, Humanoids, Telemedicine/Remote Surgery, House Hold appliances, Washing Machine, Iron Box

Control System:

A control system is a collection of components that is designed to drive a given system (plant) with a given input to a desired output. In a control system there is an interconnection between the constituent components. These components may be electrical, mechanical, hydraulic, pneumatic, etc.

- Modification of the behaviour of a system such that a desired behaviour is achieved is called control.
- Controls are implemented by attaching a controller or compensator to the plant. The resulting combined system is called a control system.
- Control systems incorporate either human or machine controllers. When the controller is machine based, it is called automatic control.
- Within any control system there are variables and functions.
- Variables can be either constant or may vary with respect to some independent variable. Constant variables are called parameters.
- Varying variables are called signals.

Basic function of a control system are:

- To minimise the error between the actual and desired output.
- To minimise the time response to load changes in the system

CLASSIFICATION OF CONTROL SYSTEM:

Open loop control system:

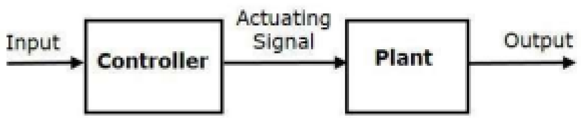


Fig. 5.29 Discuss open loop control system

The term open loop comes from the fact that the fact that the output only depends on the inputs. This is a complete system by itself. The control system takes the input from the controller in order to produce output by the action of the plant (Fig. 5.29). The relation between the input and output are mentioned in terms of transfer function, which is defined as the ratio between the Laplace transform of the output and the Laplace transform of the input. If the output is proportional to the input, the plant is called a linear system. In a basic open-loop control system the controller takes the reference input called setpoint and outputs a control signal to the plant or process. This configuration is also called feed-forward open-loop control system. The controller is designed and turned using accurate model of the plant. Any inaccuracy in the system model results discrepancy in the desired output response.

Closed loop control system:

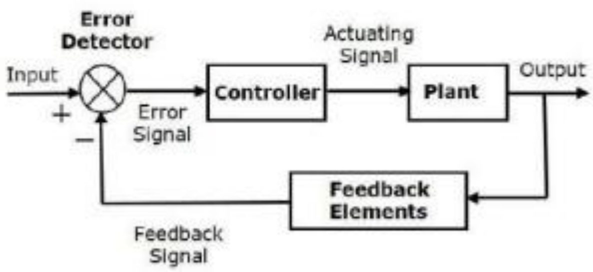


Fig. 5.30 Discuss closed loop control system

A closed loop control system, on the other hand, uses input as well as some portion of the output to regulate the output. Closed-loop systems are also called feedback control system. In feedback control the variable required to be controlled is measured. This measurement is compared with a given setpoint. If the error results, the controller takes this error and decides what action should be taken to compensate to remove the error. Errors occur when an operator changes the setpoint intentionally or when a process load changes the process variable accidentally. The error could be positive or negative.