MODULE-1
MACHINE TOOLS

LESSON CONTENTS:

Introduction, Classification, construction and specifications of lathe, drilling machine, milling machine, boring machine, broaching machine, shaping machine, planning machine, grinding machine.

OBJECTIVES:

- To study the constructional details of various machine tools and their specifications.

1.0 Introduction

Machining Process: Machining is an essential process of finishing by which work pieces are produced to the desired dimensions and surface finish by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tool(s) moved past the work surface(s).

Machine Tool: A machine tool is a non-portable power operated and reasonably valued device or system of devices in which energy is expended to produce jobs of desired size, shape and surface finish by removing excess material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surface(s).

1.1 Classification of Machine Tool:

Based on the principle of operation, the type of relative motion exists between the tool and the work surface etc., the machine tools are classified as,

1. **According to the direction of major axis:**
    a. Horizontal axis machine tools (Lathes, Horizontal milling machine, Boring machines, cylindrical grinding machines etc.,)
    b. Vertical axis machine Tools (Vertical Milling machines, Drilling machines etc.,)
    c. Inclined or multiple axis (CNC machine tools and Special purpose machines)

2. **According to the purpose of Use:**
    a. general purpose (center lathes, milling machines, drilling machines etc.)
    b. single purpose (facing lathe, roll turning lathe etc.)
    c. special purpose (for mass production.)
3. **According to the degree of automation:**
    a. non-automatic (center lathes, drilling machines etc.)
    b. semi-automatic (capstan lathe, turret lathe, hobbing machine etc.)
    c. automatic (single spindle automatic lathe, swiss type automatic lathe, CNC milling machine etc.)
4. **According to Size:**
    a. Heavy duty (heavy-duty lathes (e.g. ≥ 55 kW), boring mills, planning machine, horizontal boring machine etc.)
    b. Medium duty (lathes – 3.7 ~ 11 kW, column drilling machines, milling machines etc.)
    c. Small duty (table top lathes, drilling machines, milling machines.)
    d. Micro duty (micro-drilling machine etc)
5. **According to precision:**
    a. Ordinary (Conventional Machine tools)
    b. High Precision (CNC machines, Grinding machines, lapping machines)
6. **According to the type of automation:**
    a. Fixed automation (Single spindle and multi spindle)
    b. Flexible automation (CNC Milling Machines)

1.2 LATHE MACHINE TOOL

The lathe is a machine tool which holds the work piece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work. The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.

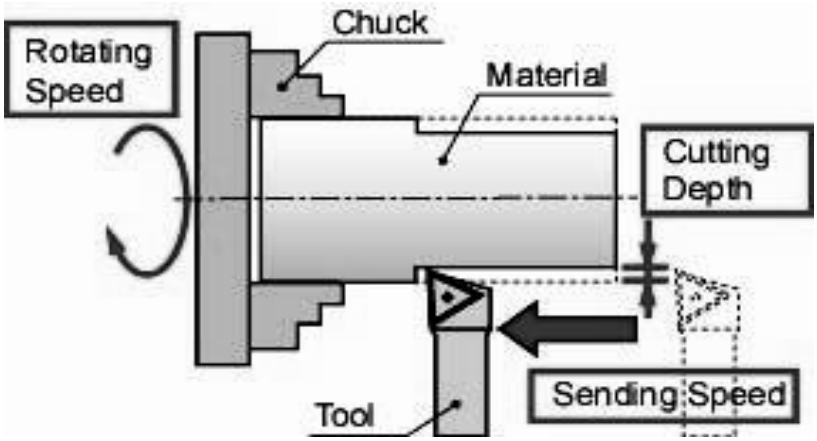


Fig: Principle of working of a lathe

1.2.1 Construction of Centre Lathe: The main parts of the lathe are the bed, headstock, quick changing gear box, carriage and tailstock.

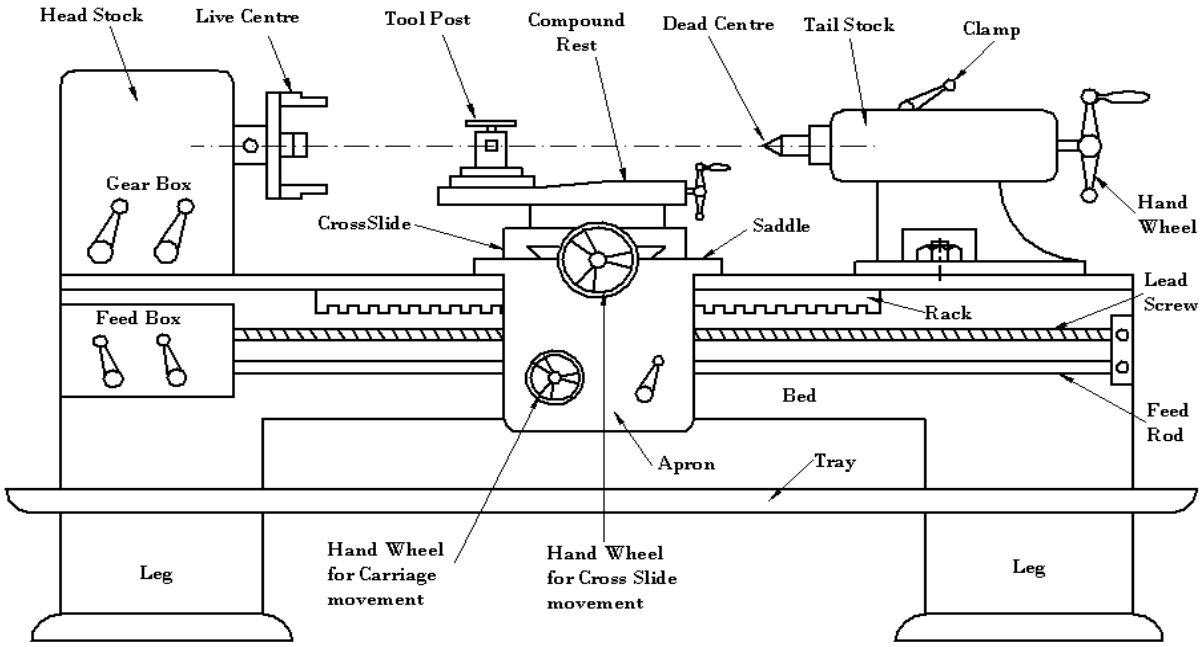


Fig: Parts of Lathe

- **Bed:** Usually made of cast iron. Provides a heavy rigid frame on which all the main components are mounted. It is the foundation part of a lathe and supports the remaining parts. The top of the bed is formed by precision-machined guide ways.
- **Guide Ways**: Inner and outer guide rails that are precision machined parallel to assure accuracy of movement.
- **Headstock:** mounted in a fixed position on the inner ways, usually at the left end. Using a chuck, it rotates the work. The housing comprising of the feed gearbox and the cone

pulley called headstock of the lathe. The main spindle projects out from the headstock. The motor drives the cone pulley drives the main spindle through belting. Spindle speeds can be further varied using beck gear mechanism.

- **Gearbox:** inside the headstock, providing multiple speeds with a geometric ratio by moving levers.
- **Spindle:** Hole through the headstock to which bar stock can be fed, which allows shafts that are up to 2 times the length between lathe centers to be worked on one end at a time.
- **Chuck:** allows the mounting of difficult work pieces that are not round, square or triangular. 3-jaw (self centering) or 4-jaw (independent) to clamp part being machined.
- **Tailstock:** Fits on the inner ways of the bed and can slide towards any position the headstock to fit the length of the work piece. Tail stock is the movable part of the lathe that carries the dead centre in it. The main function of the tailstock is to support the free end of the long work pieces. It is mounted loosely on the bed ways and can be moved in desired direction an optional taper turning attachment would be mounted to it.
- **Carriage Assembly**: Moves on the outer ways. Used for mounting and moving most the cutting tools. The carriage assembly consists of.
  - **Saddle**: is a H-shaped casting slides over the outer set of guide ways and serves as the base for the cross slide.
  - **Cross slide**: is mounted on the saddle and enables the movement of the cutting tool laterally across the lathe bed by means of cross-feed hand wheel.
  - **Compound Rest**: is mounted on the top of the cross slide and is swiveled to any angle in the horizontal plane to facilitate taper turning and thread cutting operations.
  - **Apron**: is mounted in front of the saddle beneath it and houses the carriage and cross slide mechanisms.
  - **Tool Post**: is mounted in the T-Slot of the compound rest and properly clamps the cutting tool.
- **Feed Rod:** Has a keyway, with two reversing pinion gears, either of which can be meshed with the mating bevel gear to forward or reverse the carriage using a clutch. is a stationary rod mounted in front of lathe bed and facilitates longitudinal movement of the carriage.
- **Lead Screw**: is the screw rod that runs longitudinally in front of the lathe bed. The gyration of the lead screw moves the carriage to and fro longitudinally during thread cutting operations.

1.2.2 Specification of Lathe:

The size of the lathe is specified in order to know the work holding capacity of the lathe. The specification of the lathe is shown in fig below.

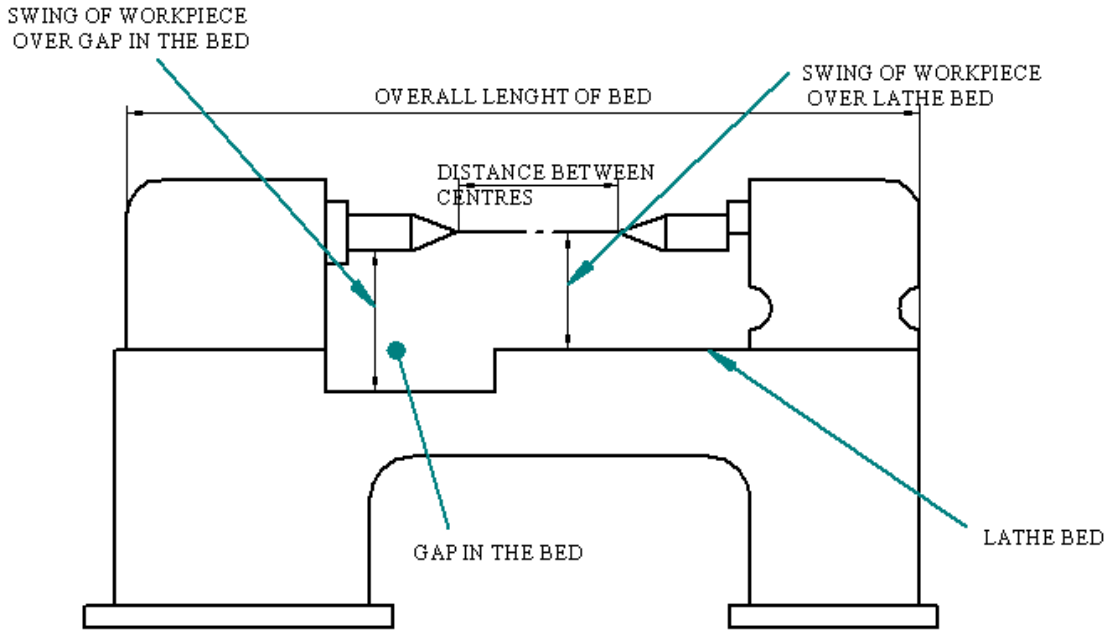


Fig: Specification of Lathe

1. **Distance between Centers:** The maximum length of the work pieces that can be held between the centers.
2. **Overall length of bed:** It is the total length of the lathe.
3. **Swing over lathe bed:** The Maximum diameter of the work piece that can be revolved over the lathe bed.
4. **Swing over the gap in bed:** The maximum diameter and width of the work piece that can be revolved over the lathe when the lathe has gap bed.

1.3 Drilling Machine Tool:

A power operated machine tool, which holds the drill in its spindle rotating at high speeds and when manually actuated to move linearly simultaneously against the work piece produces a hole is called drilling machine. In a drilling machine the holes can be produced to the sizes as small as thousandth of a centimetre and up to 7.5 cm diameter.

The different of types of drilling machines are:

- Portable drilling machine
- Bench Drilling Machine
- Pillar drilling Machine
- Radial Drilling Machine
- Gang Drilling Machine
- Multiple Drilling machine

1.3.1: Construction details of Portable/Upright Drilling Machine:

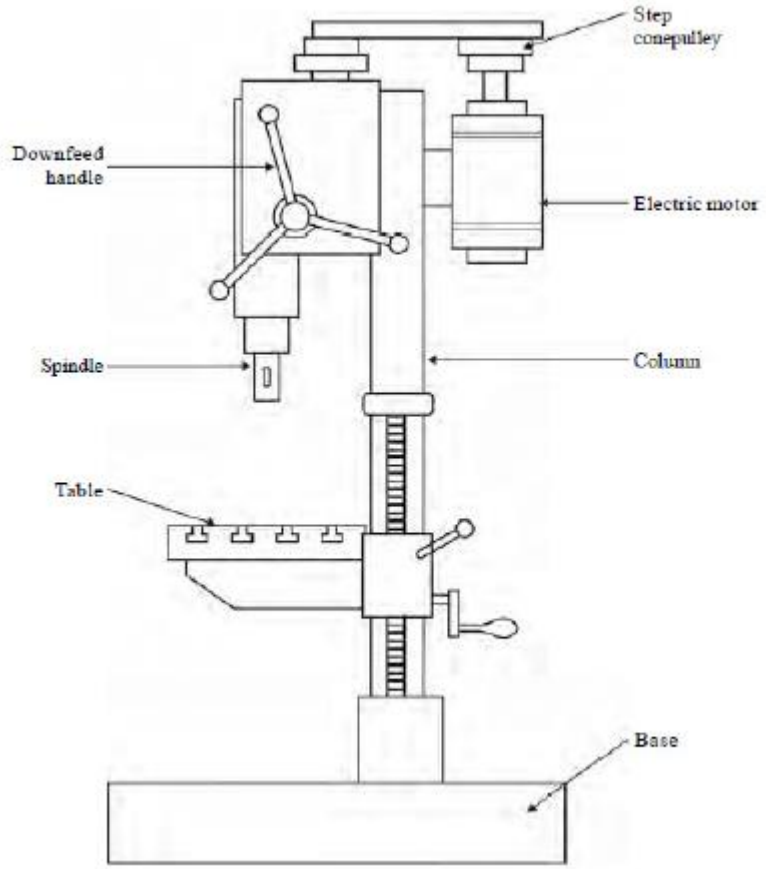


Fig: Upright Drilling Machine

The upright drilling machine is designed for handling medium sized workpieces. Though it looks like a sensitive drilling machine, it is larger and heavier than a sensitive drilling machine. Holes of diameter upto 50mm can be made with this type of machine. Besides, it is supplied with power feed arrangement. For drilling different types of work, the machine is provided with a number of spindle speeds and feed.

Base: The base is made of cast iron and so can withstand vibrations. It may be mounted on a bench or on the floor. It supports all the other parts of the machine on it.

Column: The column stands vertically on the base at one end. It supports the work table and the drill head. The drill head has drill spindle and the driving motor on either side of the column.

Table: The table is mounted on the vertical column and can be adjusted up and down on it. The table has 'T'-slots on it for holding the workpieces or to hold any other work holding device. The table can be adjusted vertically to accommodate workpieces of different heights and can be clamped at the required position.

Drill head: Drill head is mounted on the top side of the column. The drill spindle and the driving motor are connected by means of a V-belt and cone pulleys. The motion is transmitted to the spindle from the motor by the belt. The pinion attached to the handle meshes with the rack on the sleeve of the spindle for providing the drill the required down feed. There is no power feed arrangement in this machine. The spindle rotates at a speed ranging from 50 to 2000 r.p.m.

1.3.2: Radial Drilling Machine:

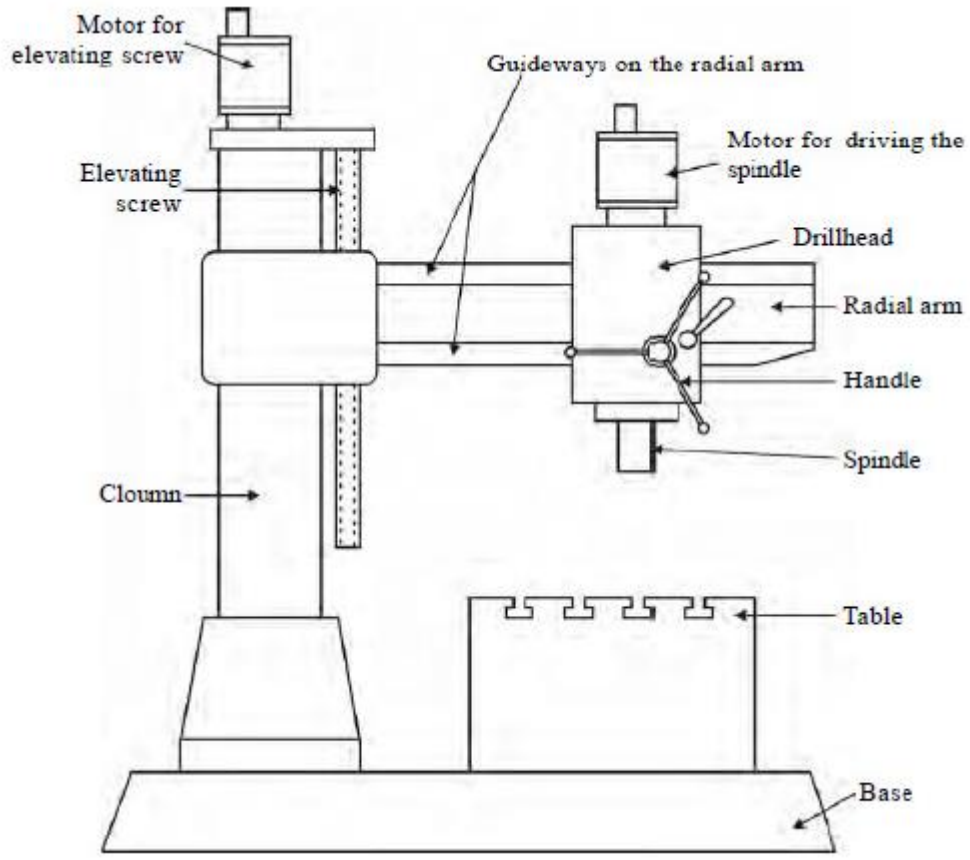


Fig: Radial Drilling Machine

The radial drilling machine is intended for drilling on medium to large and heavy workpieces. It has a heavy round column mounted on a large base. The column supports a radial arm, which can be raised or lowered to enable the table to accommodate workpieces of different heights. The arm, which has the drill head on it, can be swung around to any position. The drill head can be made toslide on the radial arm. The machine is named so because of this reason. It consists of parts like base, column, radial arm, drill head and driving mechanism.

1.3.3: Specification of Drilling Machine:

Drilling machines are specified according to their type.

To specify the machine completely the following factors are considered:

1. the maximum diameter of the drill that it can handle
2. the size of the largest workpiece that can be centred under the spindle
3. distance between the face of the column and the axis of the spindle
4. diameter of the table
5. maximum travel of the spindle
6. numbers and range of spindle speeds and feeds available
7. Morse taper number of the drill spindle
8. floor space required
9. weight of the machine
10. Power input is also needed to specify the machine completely.

1.4 Milling Machine Tool:

Milling is a metal cutting operation in which the cutting tool is a slow revolving cutter having cutting teeth formed on its periphery. The milling cutter is a multipoint cutting tool. The work piece is mounted on a movable worktable, which will be fed against the revolving milling cutter to perform the cutting operation.

1.4.1 Working Principle:

Figure shown above is the principle of cutting action of a milling cutter. The milling cutter is mounted on a rotating shaft known as arbor. The work piece which is mounted on the table can be fed either in the direction opposite to that of the rotating cutter as shown in above fig (a) or in the same direction to that of the cutter as shown in above fig (b).

Fig (a): Up Milling *(b): Down Milling*

1.4.2 Classification/ Types of Milling Machine:

Various types of milling machines are

1) Plain or horizontal type of milling machine.
2) Vertical Milling Machine
3) Universal Milling machine
4) Planer type milling machine
5) Profile cutting milling machine.

1.4.3 Horizontal/ Column & Knee type milling Machine:

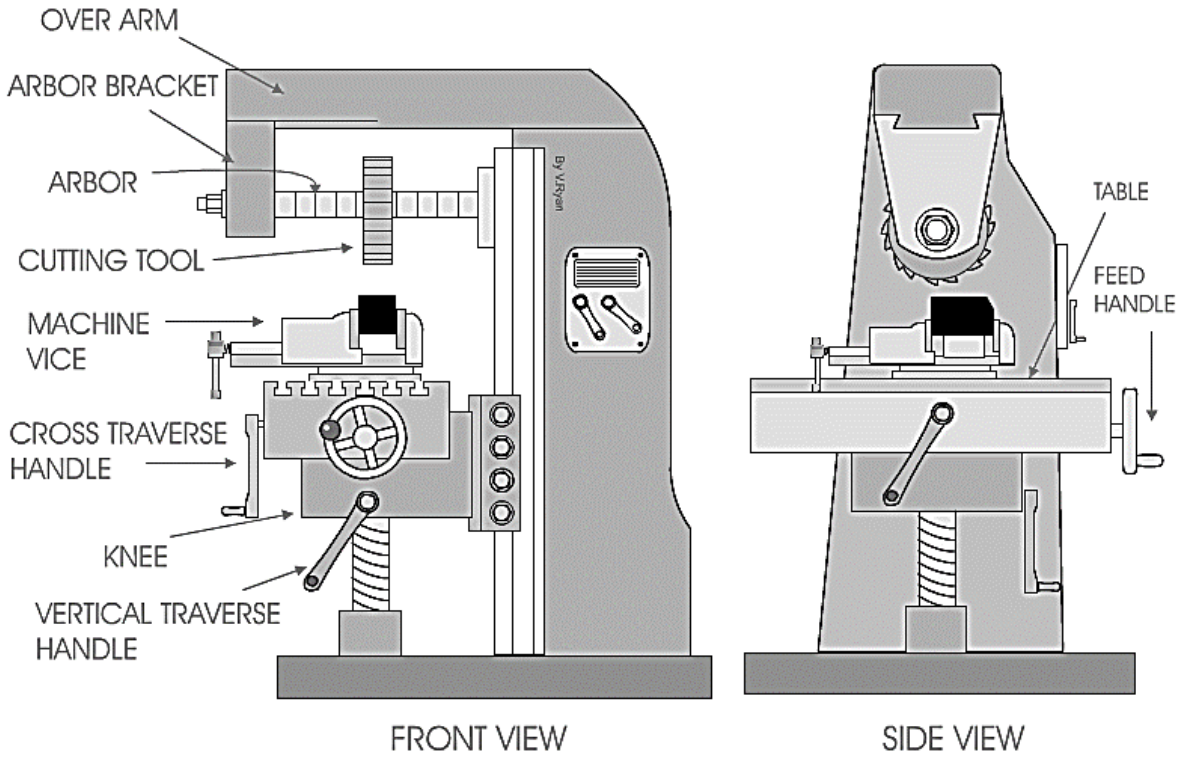


Fig: Horizontal Milling Machine

The main part of machine is base, Column, Knee, Saddle, Table, Overarm, Arbor Support and Elevating Screw.

1. Base: It gives support and rigidity to the machine and also acts as a reservoir for the cutting fluids.

2. Column: The column is the main supporting frame mounted vertically on the base. The column is box shaped, heavily ribbed inside and houses all the driving mechanisms for the spindle and table feed.

3. Knee: The knee is a rigid casting mounted on the front face of the column. The knee moves vertically along the guide ways and this movement enables to adjust the distance between the cutter and the job mounted on the table. The adjustment is obtained manually or automatically by operating the elevating screw provided below the knee.

4. Saddle: The saddle rests on the knee and constitutes the intermediate part between the knee and the table. The saddle moves transversely, i.e., crosswise (in or out) on guide ways provided on the knee.

5. Table: The table rests on guide ways in the saddle and provides support to the work. The table is made of cast iron, its top surface is accurately machined and carriers T-slots which accommodate the clamping bolt for fixing the work. The worktable and hence the job fitted on it is given motions in three directions:

a). Vertical (up and down) movement provided by raising or lowering the knee.

b). Cross (in or out) or transverse motion provided by moving the saddle in relation to knee.

c). Longitudinal (back and forth) motion provided by hand wheel fitted on the side of feed screw.

In addition to the above motions, the table of a universal milling machine can be swivelled 45° to either side of the centre line and thus fed at an angle to the spindle.

6. Overarm: The Overarm is mounted at the top of the column and is guided in perfect alignment by the machined surfaces. The Overarm is the support for the arbor.

7. Arbor support: The arbor support is fitted to the Overarm and can be clamped at any location on the Overarm. Its function is to align and support various arbors. The arbor is a machined shaft that holds and drives the cutters.

8. Elevating screw: The upward and downward movement to the knee and the table is given by the elevating screw that is operated by hand or an automatic feed.

1.4.4: Milling machine Specification:

a) Milling machines are usualy specified by the size of the table (lxb)

b) Along with the size of the table, milling machine is also specified by

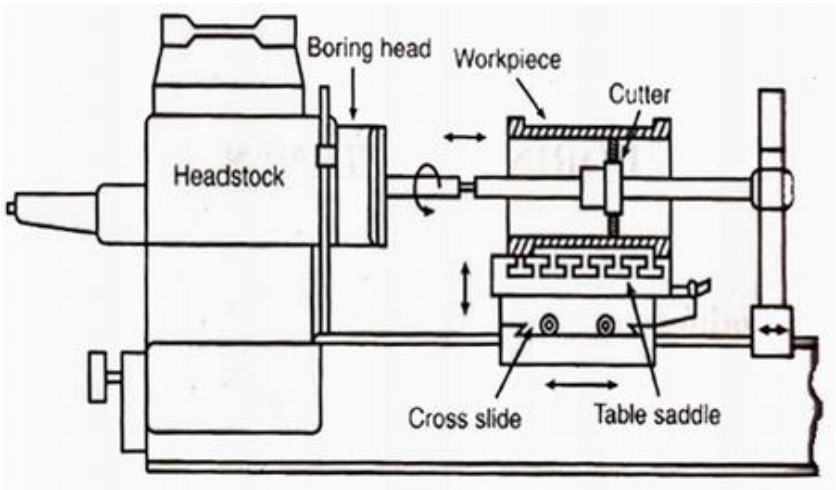
- Motor power required,
- Feed
- Floor space required
- Spindle speed
- Drives used

1.5 Boring Machine:

Boring is a process of producing circular internal profiles on a hole made by drilling or another process. It uses single point cutting tool called a boring bar. In boring, the boring bar can be rotated, or the work part can be rotated. Machine tools which rotate the boring bar against a stationary workpiece are called boring machines (also boring mills). Boring can be accomplished on a turning machine with a stationary boring bar positioned in the tool post and rotating workpiece held in the lathe chuck as illustrated in the figure. In this section, we will consider only boring on boring machines.

1.5.1 Boring Machine Tool:

Boring machines can be *horizontal* or *vertical* according to the orientation of the axis of rotation of the machine spindle. In *horizontal boring* operation, boring bar is mounted in a tool slide, which position is adjusted relative to the spindle face plate to machine different diameters. The boring bar must be supported on the other end when boring long and small-diameter holes.



A *vertical boring mill* is used for large, heavy workparts with diameters up to 12 m. The typical boring mill can position and feed several cutting tools simultaneously. The workpart is mounted on a rotating worktable.

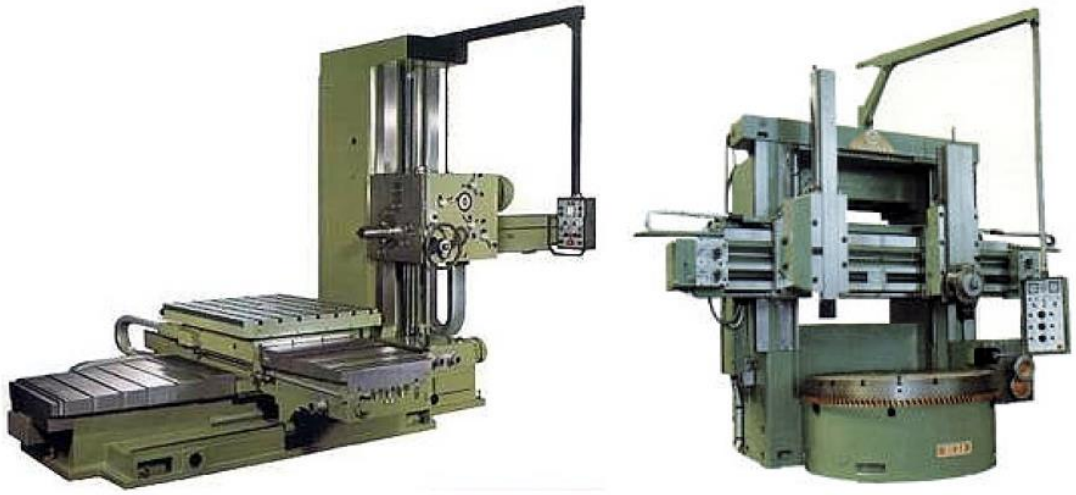


Fig: Horizontal boring machine (Left) and vertical boring mill (Right).

1.6 Broaching Machine:

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Figure. In shaping, attaining full depth requires a number of strokes to remove the material in thin layers step – by – step by gradually infeeding the single point tool. Whereas, broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach. The amount of tooth rise between the successive teeth of the broach is equivalent to the infeed given in shaping.

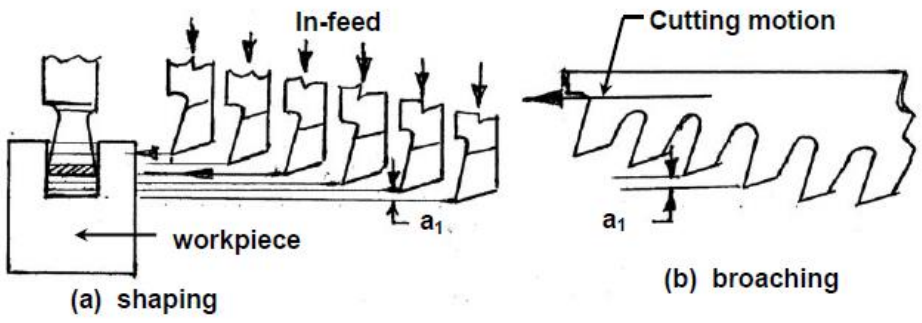


Figure: principle of Broaching

1.6.1 Broaching machine Tool:

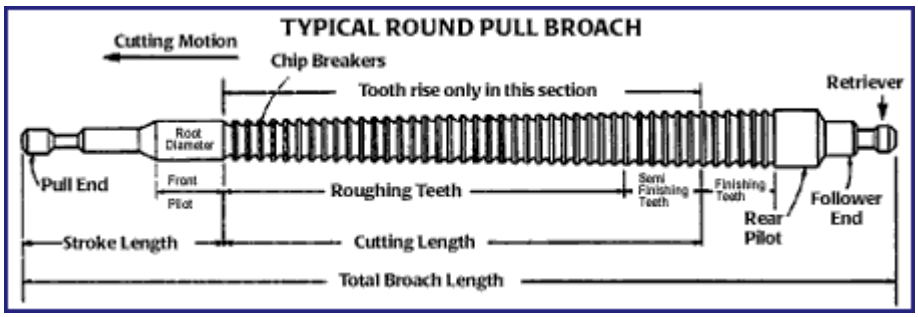


Fig: Horizontal broaching tool

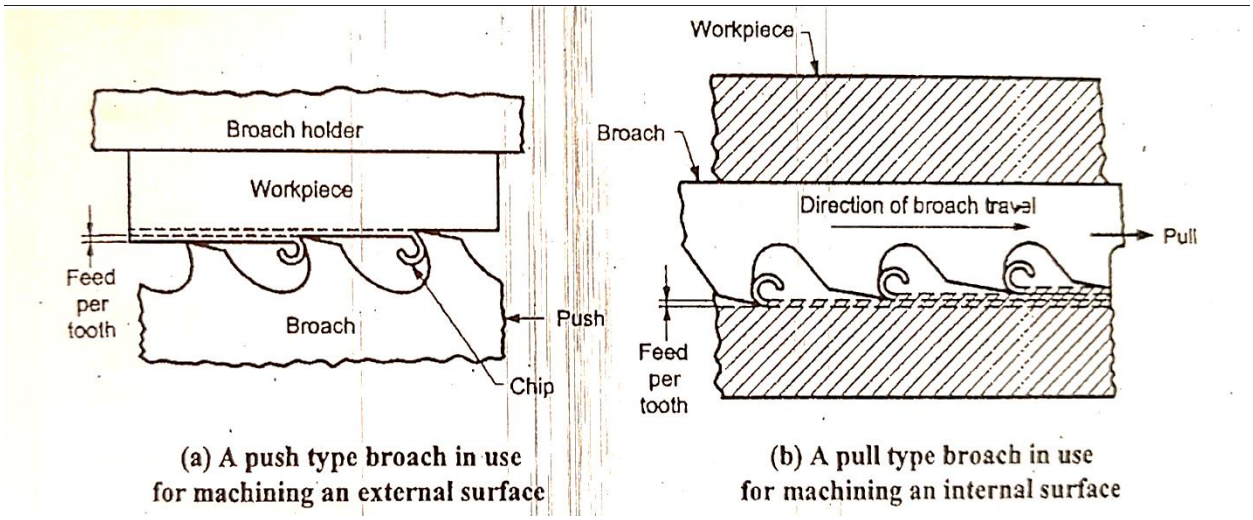


Fig: principle of broaching operation

a) Horizontal broaching machines are applicable for machining of both internal and external surfaces. Figure shows the principle operation of broaching for internal and external machining.
b) In operation either workpiece is kept stationary and broach is fed past on the workpiece or broach is kept stationary and workpiece is fed past on the broach.
c) Horizontal broaching machines have a bed similar to the lathe machine and the broach is moves like a tailstock on the bed ways.
d) Horizontal internal broaching machines range from 2 to 60 tons and stroke upto 3m, whereas horizontal externa broaching machine are available upto 100 tons and stroke upto 9m.
e) Horizontal internal broaching is generally used for producing internal splines in the boss od a gear.

1.7 Shaper machine Tool:

The shaper is a reciprocating type of machine tool intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical, or inclined. In general, the shaper can produce any surface composed of straight line elements. Modern shapers can generate contoured surface. The shaper is a machine tool used primarily for:

1. Producing a flat or plane surface which may be in a horizontal, a vertical or an angular plane.

2. Making slots, grooves and keyways

3. Producing contour of concave/convex or a combination of these

1.7.1 Working principle of Standard Shaper:

The job is rigidly fixed on the machine table. The single point cutting tool held properly in the tool post is mounted on a reciprocating ram. The reciprocating motion of the ram is obtained by a quick return motion mechanism. As the ram reciprocates, the tool cuts the material during its forward stroke. During return, there is no cutting action and this stroke is called the idle stroke. The forward and return strokes constitute one operating cycle of the shaper.

1.7.2 Construction details of Standard Shaper:

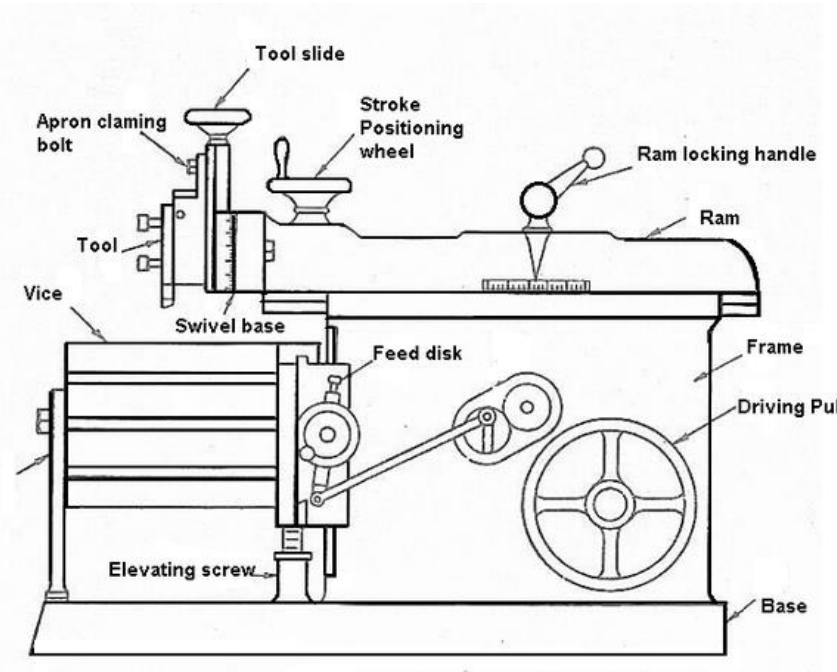


Fig: Standard Horizontal Shaper

Construction: The main parts of the Shaper machine is Base, Body (Pillar, Frame, Column), Cross rail, Ram and tool head (Tool Post, Tool Slide, Clamper Box Block).

Base: The base is a heavy cast iron casting which is fixed to the shop floor. It supports the body frame and the entire load of the machine. The base absorbs and withstands vibrations and other forces which are likely to be induced during the shaping operations.

Body (Pillar, Frame, Column): It is mounted on the base and houses the drive mechanism compressing the main drives, the gear box and the quick return mechanism for the ram movement. The top of the body provides guide ways for the ram and its front provides the guide ways for the cross rail.

Cross rail: The cross rail is mounted on the front of the body frame and can be moved up and down. The vertical movement of the cross rail permits jobs of different heights to be accommodated below the tool. Sliding along the cross rail is a saddle which carries the work table.

Ram and tool head: The ram is driven back and forth in its slides by the slotted link mechanism. The back and forth movement of ram is called stroke and it can be adjusted according to the length of the workpiece to be-machined.

1.7.3 Specification of Standard Shaper:

a) The size of the shaper is specified by the strike length or maximum length of cut
b) Shapers are made with wide variety of sizes depending upon their stroke length. It is uasually from 175mm to 900mm.
c) Along with the length the stroke number other details are required specify shaper
    - Type of drive
    - Type of speed reduction
    - Power in-put
    - Maximum momnet of tool, table
    - Cutting to return stroke ratio
    - Type of feed (manual or Automatic)
    - Total floor space required

1.8 Planer machine Tool:

The planer is a machine tool designed to produce plane and flat surface on a workpiece which is too large or too heavy. The workpiece is securely fixed on a table called platen, and it reciprocates horizontally against a single edged cutting tool. The surface machined may be horizontal, vertical or at an angle.

The planer is used for:

1. Planing flat horizontal, vertical and curved surfaces.

2. Planing at an angle and machining dovetails.

3. Planing slots and grooves.

The planer is available in different types for doing different types and sizes of job; the most common being the standard and double housing planer.

1.8.1 Types of Planner machines:

1 Standard or double housing planer.
2 Open side planer.
3 Pit planer.
4 Edge or plate planer.
5 Divided or latching table planer.

1.8.2 standard Double Housing Planner:

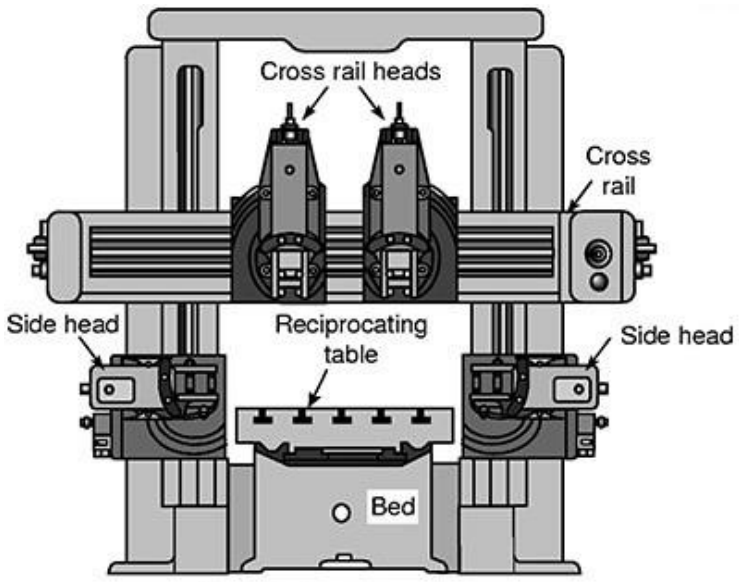


Fig: Double housing Planner

Construction: The main parts of the double Housing Planer machine is Bed and table, Housings, Cross rail, Tool heads, Driving and feed mechanism.

Bed and table: The bed is a long heavy base and table made of cast iron. Its top surface is flat and machined accurately. The flat top surface has slots in which the workpiece can be securely clamped. The workpiece needs rigid fixing so that it does not shift out of its position. The standard clamping devices used on planer machine are: Heavy duty vice, T-holders and clamps, angle plate, planer jack, step blocks and stop. The table movement may be actuated by a variable speed drive through a rack and pinion arrangement, or a hydraulic system.

Housings: The housings are the rigid and upright column like castings. These are located near the centre on each side of the base.

Cross rail: The cross rail is a horizontal member supported on the machined ways of the upright columns. Guide ways are provided on vertical face of each column and that enables up and vertical movement of the cross rail. The vertical movement of the cross rail allows to accommodate workpiece of different heights. Since the cross rail is supported at both the ends, this type of planer machine is rigid in construction.

Tool heads: Generally, two tool heads are mounted in the horizontal cross rail and one on each of the vertical housing. Tool heads may be swivelled so that angular cuts can be made.

Driving and feed mechanism: The tool heads may be fed either by hand or by power in crosswise or vertical direction. The motor drive is usually at one side of the planer near the centre and drive mechanism is located under the table.

The size of the planer is specified by the maximum length of the stroke, and also by the size of the largest rectangular solid that can be machined on it.

1.8.3 Specification of a planner machine:

The planer is specified by the following parameters:

- Radial distance between the top of the table and the bottom most position of the cross rail.
- Maximum length of the table and maximum stroke length of table.
- Power of the motor.
- Range of speeds and feeds available.
- Type of feed and type of drives required.

- Horizontal distance between two vertical housings. Net weight of machine and Floor area required.

1.9 Grinding Machine:

Grinding, also called abrasive machining, is a process in which the material is removed in form of fine chips, almost as dust particles by the abrasive action using some kind of abrasive materials. Generally, grinding is employed when a thick layer of material is to be removed in general classes of work, where the surface finish is not that important, and for finishing and polishing works on the parts already machined by some other machining processes.

1.9.1 Grinding Machines:

The different methods of grinding are:
1. Surface Grinding,
2. Cylindrical Grinding and
3. Centre less Grinding.

1.9.2 Surface Grinding Machine:

In the surface grinding process, the grinding wheel revolves on a spindle and the work-piece mounted on a reciprocating table as shown in Figure, is brought into contact with the grinding wheel. Flat, angular and irregular surfaces may be produced by surface grinding.

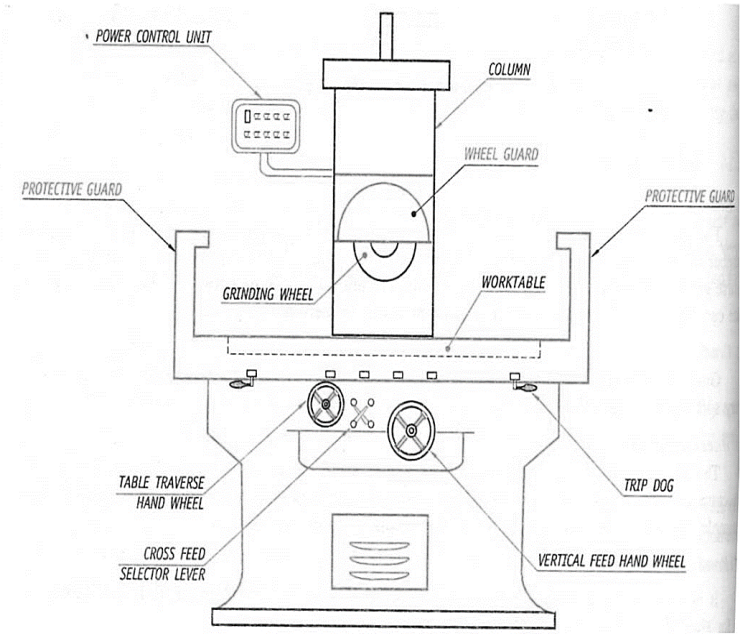


Fig: Horizontal Surface grinding machine

The Surface Grinding Machine is used to grind flat surfaces. Here, the job is mounted on a rectangular table which moves longitudinally as well as in the transverse direction below the rotating grinding wheel. The longitudinal and transverse feed movements can be accomplished either by manual feed or through power feed arrangement. The work-piece can be clamped in two ways; one is by clamping it to the work table by means of clamping elements; the other way is by using a magnetic chuck, which holds the work-piece through its strong magnetic field. There is an internal pump and a piping arrangement to take care of automatic application and recirculation of the coolant. There is a protective safety guard at the end of the table to prevent the wheel from hitting any person or object.

1.9.3 Cylindrical Grinding Machine:

Cylindrical grinding is the process of grinding the curved surfaces of cylindrical pieces. These surfaces may be straight, tapered or contoured. Fig. 8.3 shows the basic principle of the cylindrical grinding. Fig 8.3 shows a typical cylindrical grinding machine. The work-piece is mounted on the two centres, one is the tail stock centre and the other is the headstock centre. The tail stock centre is the dead centre and the headstock centre mayor may not revolve during grinding. When high accuracy is required the two supporting canters must remain stationary when the work-piece revolves.

When both canters are dead, precision sizes and good finish can be obtained, because there is no possibility of run out from the headstock spindle. As the work-piece revolves, the grinding wheel rotating much faster in the opposite direction is brought into contact with the work-piece. The work-piece and the table reciprocate while the grinding wheel in contact with the work-piece removes the material.

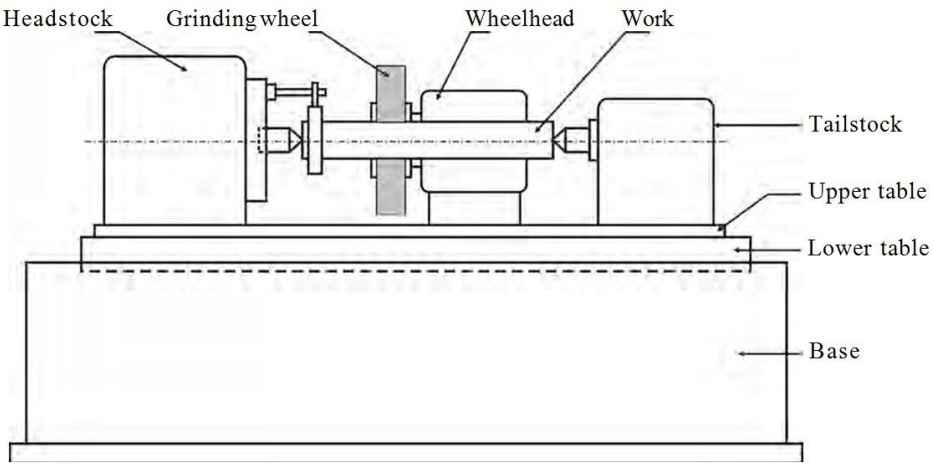
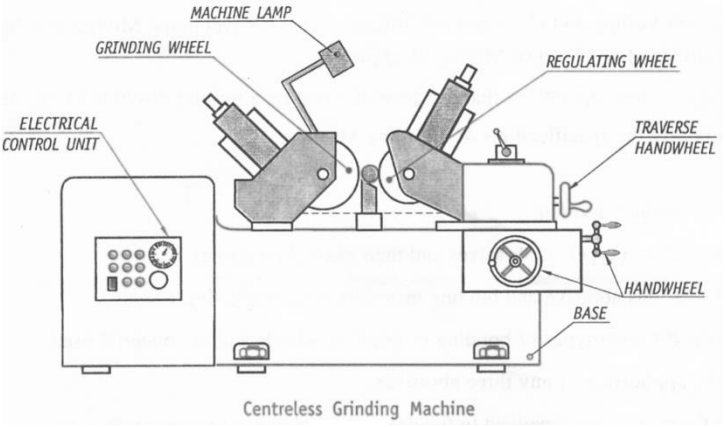


Fig: Cylindrical Grinding Machine

1.9.4 Centreless Grinding Machine:

Centre less grinding method also employed for grinding the curved surfaces of long slender rods which cannot be ground by cylindrical grinding due to the lateral thrust of the wheel on the work-piece. In the centre less grinding, shown in Figure the work-piece rests on a work-rest blade and is backed up by a second wheel, called the regulating wheel. The rotation of the grinding wheel pushes the work-piece down on the work-rest blade and against the regulating wheel. The regulating wheel, usually made up of a rubber bonded abrasive, rotates in the same direction as the grinding wheel and controls the longitudinal feed of the work-piece. A typical centre less grinding machine is shown in Figure.



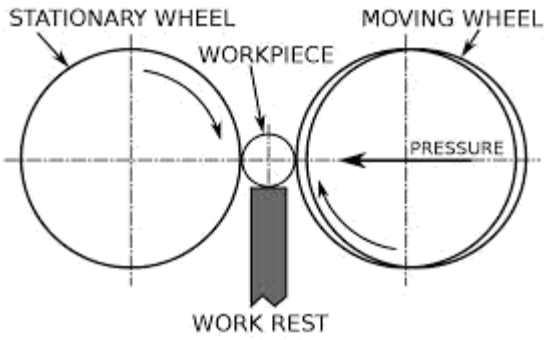


Figure: (a) centreless Grinding machine (b) Principle of centreless grinding operations

OUTCOMES:

- Students will bale to explain the construction & specification of various machine tools.

QUESTIONS:

1. Explain the principle of working of a lathe with the help of a neat sketch
2. What factors govern the specification of lathe?
3. What is meant by machine tool? Give the classification of machine tools.
4. What are the basic elements of drilling machine? Explain the construction of upright drilling machine.
5. Explain the principle of broaching.
6. With the help of a neat sketch explain column and knee type milling machine.
7. Give a constructional details of surface grinding machine.
8. Define centre less grinding. Briefly explain the construction of it.

Further Reading

1. "Metal cutting principles", Milton C. Shaw, Oxford University Press, Second Edition,2005.
2. "Manufacturing Technology", Vol 2, P N Rao, McGraw Hill Education, 3rd Edition

3. "Workshop Technology, Vol-II", by Hazara Chowdary