<table>
<thead>
<tr>
<th>Chapter</th>
<th>Name of the Topic</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td><strong>5 BASIC MACHINE TOOLS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific Objectives :</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ To understand basic concept of Conventional Machine tools</td>
<td></td>
</tr>
<tr>
<td>5.1 Lathe:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Classification of lathes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Major parts of Centre lathe machine with block diagram.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lathe specifications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Accessories used on lathe.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Operations performed on lathe – Turning, Taper turning by swiveling compound rest, Facing, Knurling and Threading.</td>
<td></td>
</tr>
<tr>
<td>5.2 Drilling:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Classification of drilling machines.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Major parts of bench drilling machine with block diagram</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Operations performed on drilling machines – drilling, reaming.</td>
<td></td>
</tr>
<tr>
<td>5.3 Milling:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Classification of milling machines.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Major parts of column and knee type universal milling machine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Standard milling cutters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milling operations like face milling, Gang milling, Key-way milling and End milling</td>
<td></td>
</tr>
</tbody>
</table>
5.1 LATHE

INTRODUCTION

1) The lathe is one of the most important machines in any workshop.
2) Its main objective is to remove material from outside by rotating the work against a cutting tool.
3) Though a lathe is used to produce cylindrical work, yet it may also be used for many other purposes such as drilling, threading, grinding, milling, turning, boring, reaming, knurling, etc.
4) In addition to it, with help special attachments, operations like key-way cutting, cam & gear cutting, shaping, fluting can be carried out.

Working Principle of a Lathe

The working principle of a lathe is shown in Fig.5.1

1) In a lathe, the workpiece is held in a chuck or between centres and rotated about its axis at a uniform speed.
2) The cutting tool held in the tool post is fed into the workpiece for a desired depth and in the desired direction (i.e., in the linear, transverse or lateral direction).
3) Since there exists a relative motion between the workpiece and the cutting tool therefore the material is removed in the form of chips and the desired shape is obtained.
LATHE BLOCK DIAGRAM

Lathes are classified according to
1) The design,
2) Type of drive,
3) Arrangement of gears and
4) Purpose.

The following are important types of lathe:

1. **Speed lathe.**

   a) It is one of the simplest types of all types all lathes.
   b) It is driven by power and consists of a bed, a headstock, a tailstock and an adjustable slide for supporting the tool.
   c) Since the tool is fed into the work by hands and cuts are very small, therefore this type of lathe is driven at high speeds usually from 1200 to 3600 r.p.m.
   d) The work may be held between centres or attached to a face plate on the headstock.
   e) The speed lathe is used mainly for wood working, centering, metal spinning, polishing etc.
2. **Engine or centre lathe.**
   a) It is a general purpose lathe and is widely used in workshops.
   b) It differs from a speed lathe that it has additional mechanism for controlling the spindle speed and for supporting and controlling the feed of the fixed cutting tool.
   c) The cutting tool may be led both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage.

3. **Bench lathe.**
   a) The bench lathe is so small that it can be mounted on a bench.
   b) All the types of operation can be performed on this lathe that may be done on an ordinary speed or engine lathe.
   c) This is used for small work usually requiring considerable accuracy such as in the production of gauges, punches and beds for press tools.

4. **Tool room lathe.**
   a) The tool room lathe is similar to an engine lathe and is equipped with all accessories needed for accurate tool work.
   b) It has an individually driven geared headstock with a wide range of spindle speeds.
   c) Since this lathe is used for precision work on tools, gauges, dies, jigs and other small parts, therefore greater skill is needed to operate the lathe.

5. **Capstan and turret lathe.**
   a) The capstan and turret lathes are the modification of engine lathes and is particularly used for mass production of identical parts in the minimum time.
   b) These lathes are semi-automatic and are fitted with multi tool holding devices, called capstan and turret heads.
   c) The advantage of capstan and turret lathe is that several different types of operations can be performed on a workpiece without resetting of work or tools.
6. Automatic lathes.

a) The automatic lathe are so designed that the tools are automatically fed to the work and withdrawn after all the operations are complete to finish the work.
b) Since the entire operation is automatic, these lathes require little attention of the operator.
c) These lathes are used for mass production of identical parts.

7. Special purpose lathes.

a) The work which can not be conveniently accommodated or machined on a standard lathe, the special purpose lathes are used.
b) The Gap bed lathe which has a removable section in the bed in front of the headstock to provide a space or gap is used to swing extra large diameter jobs.
c) The Wheel lathe is made for finishing the journals and turning the tread on railroad car and locomotive wheels.

- LATHE SPECIFICATION OR SIZE OF LATHE

The size of a lathe is generally specified by the following means:

(a) Swing or maximum diameter that can be rotated over the bed ways
(b) Maximum length of the job that can be held between head stock and tailstock centres
(c) Bed length, which may include head stock length also
(d) Maximum diameter of the bar that can pass through spindle or collect chuck of capstan lathe.

Fig. 5.3 illustrates the elements involved in specifications of a lathe. The following data also contributes to specify a common lathe machine.
PARTS OF LATHE

Fig. illustrates the basic parts of a geared head lathe. Following are the principal parts: Bed, Headstock, Tailstock, Carriage, Feed mechanism and Screw cutting mechanism.

THE BED

The lathe bed forms the base of the machine. The headstock and the tailstock are located at either end of the bed and the carriage rests over the lathe bed and slides on it.
The lathe bed being the main guiding member of the tool, for accurate machining work, must satisfy the following conditions:

1. It should be sufficiently rigid to prevent deflection under tremendous cutting pressure transmitted through the tool-post and carriage to the lathe bed.
2. It must be massive with sufficient depth and width to absorb vibration.

THE HEADSTOCK

The headstock is secured permanently on the inner ways at the left hand end of the lathe bed, and it provides mechanical means of rotating the work at multiple speeds. It comprises essentially a hollow spindle and mechanism for driving and altering the spindle speed. All the parts are housed within the headstock casting.

The spindle of the headstock, illustrated in Fig. 5.5, is made of carbon or nickel-chrome steel.
This is usually of a large diameter to resist bending and it should be perfectly aligned with the lathe axis and accurately machined for producing true work surface.

**TAILSTOCK OR LOOSE HEADSTOCK**

The tailstock is located on the inner ways at the right hand end of the bed. This has two main uses: (1) it supports the other end of the work when it is being machined between centres, and (2) it holds a tool for performing operations such as drilling, reaming, tapping, etc. To accommodate different lengths of work, the body of the tailstock can be adjusted along the ways chiefly by sliding it to the desired position where it can be clamped by bolts and plates.

**CARRIAGE**

The carriage of a lathe has several parts that serve to support, move and control the cutting tool.

It consists of the following parts: (1) saddle, (2) cross-slide, (3) compound slide or compound rest, (4) tool post, and (5) apron.
**Saddle:** The saddle is an H-shaped casting that fits over the bed and slides along the ways. It carries the cross slide and tool post.

**The cross-slide:** The cross-slide comprises a casting, machined on the underside for attachment to the saddle and carries locations on the upper face for the tool post or **compound rest:** The compound rest or compound slide is mounted on the top of the cross-slide and has a circular base graduated in degrees. It is used for obtaining angular cuts and short tapers as well as convenient positioning of the tool to the work.

**The tool post:** This is located on the top of the compound rest to hold the tool and to enable it to be adjusted to a convenient working position. The type and mounting of the tool post depends upon the class of work for which it is to be used.

**The apron:** The apron is fastened to the saddle and hangs over the front of the bed. It contains gears, clutches and levers for operating the carriage by hand and power feeds.

**FEED MECHANISM**

The movement of the tool relative to the work is termed as feed. A lathe tool has three types of feed – longitudinal, cross and angular. When the tool moves parallel to the lathe axis, the movement is a longitudinal feed. When the tool moves to the right angle to the lathe axis is a cross feed. When compound slide is swiveled at an angle to the lathe axis is termed as angular feed.

**THREAD CUTTING MECHANISM**

The rotation of the lead screw is used to transverse the tool along the work to produce screw thread. The half-nut mechanism makes the carriage to engage or disengage with the lead screw. It comprises a pair of half nuts capable of moving in or out of mesh with the lead screw. The two halves of the nut are connected in the cam slots in a circular disc by two pins. When the disc is rotated by a hand lever attached to it, the pins being guided in the cam slots serve to open or close the split nuts and thus engages or disengages with the lead screw.
• **LATHE ACCESSORIES**

The lathe accessories are used for holding and supporting the work or for holding the cutting the various lathe accessories are discussed as follows

1. **Centres.**
   
   a) There are two types of centres i.e., live centre and dead centre.
   
   b) A centre which fits into the headstock spindle and revolves with the work is called live centre.
   
   c) The centre which is used in a tailstock spindle and does not revolve is called dead centre.

   ![Standard centre and Half centre](image)

2. **Chucks.**
   
   a) It is an important device used for holding and rotating the workpiece in lathes.
   
   b) The work pieces which are too short to be held between centres are clamped in a chuck.
   
   c) It is attached to the lathe spindle by means of two bolts with the back plate screwed on to the spindle nose.
   
   d) There are many types of the chuck, but the following two are commonly used.

   i) **Three jaw universal chuck.**
      
      The three jaw universal chuck, as shown in Fig.5.7 (a) is also called self centering chuck or scroll chuck. Thus chuck is used for holding round and hexagonal work.
ii) Four jaw independent chuck.
1. The four jaw independent chuck, as shown in Fig.5.7 (b) has four reversible jaws, each of which may be independently adjusted to accommodate the work it supports.
2. This type of chuck can hold square, round and irregular shape of work in either a concentric or eccentric position.

The other types of the chucks are:
iii) combination chucks, iv) magnetic chuck, v) collect chuck, vi) drill chuck, and vii) air or hydraulic chuck

3. Lathe dog or carrier
a) The work placed on a mandrel or held between centres is rotated positively by clamping the dog or carrier to the end of the work.
b) This is engaged with a pin attached to the drive plate or face plate.
c) The lathe dog or carrier may be of straight type or bent type as shown in Fig.5.8 (a) and (b) respectively.
4. Drive plate

a) The drive plate, as shown in Fig. 5.9 is a circular plate which is bored out and threaded so that it can be attached to the spindle nose.

b) It also carries a hole for the pin which is used only when the work is held in a lathe dog having straight tail. When bent-tail dog is used, this pin is taken out and the bent portion of the tail is inserted into the hole.

![Drive plate](image)

5. Faceplate.

c) The face plate, as shown in Fig. 5.10 is similar to drive plate except that it is larger in diameter.

d) It contains more open slots or T-slots so that bolts may be used to clamp the workpiece to the face of the plate.

e) The face plate is used for holding work pieces which can not be conveniently held in a chuck.

6. Angle plate.

a) An angle plate is simply a cast iron plate with to faces planed at right angles to each other and having slots in various positions for the clamping bolts.

b) It is always used with the face plate for holding such parts which can not be clamped against the vertical surface of the face plate.

7. Mandrels.

a) The lathe mandrel is a cylindrical bar with centre hole at each end. It is used to hold hollow work pieces to machine their external surface.
b) The work revolves with the mandrel which is mounted between the centres of the lathe. The various types of mandrels used for different classes of work are shown in Fig.5.11

Plain mandrel, Step mandrel and Collar mandrel

- **LATHE TOOLS**
  a) The tool used in a lathe, for general purpose work, is a single point tool, but for special operations multi-point tools may be used.
  b) The material used for lathe tools should have hardness, toughness, heat resistance and low wear.
  c) The commonly used materials are high carbon steel; high speed steel, cemented carbides, diamond tips and ceramics.
The lathe tools, depending upon the nature of operation done by the tool, are classified as follows:

1) Turning tool (left hand or right hand),
2) Facing tool (left hand or right hand),
3) Chamfering tool (left hand or right hand),
4) Form or profile tool,
5) Parting or necking tool,
6) External threading tool,
7) Internal threading tool,
8) Boring tool, and
9) Knurling tool.

Different kinds of tools used for external surfaces:
Different kinds of tools used for internal surfaces

- **LATHE OPERATIONS**
  The most common operations which can be carried out on a lathe are
  1) Facing,
  2) Plain turning,
  3) Step turning,
  4) Taper turning,
  5) Drilling,
  6) Reaming,
  7) Boring,
  8) Undercutting,
  9) Threading,
  10) Knurling.

These operations are discussed as follows;
1) **Facing**

This operation is almost essential for all works. In this operation, as shown in Fig. the workpiece is held in the chuck and the facing tool is fed from the centre of the workpiece towards the outer surface or from the outer surface to the centre, with the help of a cross-slide.

2) **Plain turning**

It is an operation of removing excess amount of material from the surface of the cylindrical workpiece. In this operation, as shown in Fig. the work is held either in (lie chuck or between centres and the longitudinal feed is given to the tool either by hand or power.

3) **Step turning**

It is an operation of producing various steps of different diameters in the workpiece, as shown in Fig. This operation is carried out in the similar way as plain turning.

4) **Taper turning**

It is an operation of producing an external conical surface on a workpiece. A small taper may be produced with the help of a forming tool or chamfering tool, but the larger tapers are produced by swiveling the compound rest, as shown in Fig.5.17 at the required angle or by offsetting the tailstock or by taper turning attachment.
5) **Drilling**

It is an operation of making a hole in a workpiece with the help of a drill. In this operation, as shown in Fig.5.18 the workpiece is held in a chuck and the drill is held in the tailstock. The drill is fed manually, into the rotating workpiece, by rotating the tailstock hand wheel.

6) **Reaming**

It is an operation of finishing the previously drilled hole. In this operation, as shown in Fig.5.19 a reamer is held in the tailstock and it is fed into the hole in the similar way as for drilling.
7) Boring

It is an operation of enlarging of a hole already made in a workpiece. In this operation, as shown in Fig.5.20 a boring tool or a bit mounted on a rigid bar is held in the tool post and fed into the work by hand or power in the similar way as for turning.

8) Undercutting or Grooving

It is an operation of reducing the diameter of a workpiece over a very narrow surface. In this operation, as shown in Fig.5.21 a tool of appropriate shape is fed into the revolving work up to the desired depth at right angles to the centre line of the workpiece.

9) Threading

It is an operation of cutting helical grooves on the external cylindrical surface of workpiece. In this operation, as shown in Fig.5.22 the work is held in a chuck or between centres and the threading is fed longitudinally to the revolving work. The longitudinal feed is equal to the pitch of the thread be cut.
10) **Knurling**

It is an operation of providing knurled surface on the workpiece. In this operation, as shown in Fig.5.23 a knurled tool is moved longitudinally to a revolving workpiece surface. The projections on the knurled tool reproduce depressions on the work surface.

- **SPEED, FEED AND DEPTH OF CUT FOR LATHE**

The following terms are commonly used while machining a workpiece on lathe.

1. **Cutting speed.**

   It is defined as the speed at which the metal is removed by the tool from the workpiece. In other words, it is the peripheral speed of the work past the cutting tool. It is usually expressed in meters per minute.

2. **Feed.**

   It is defined as the distance which the tool advances for each revolution of the work. It is usually expressed in millimeters.

3. **Depth of cut.**

   It is defined as the depth of penetration of the tool into the workpiece during machining. In other words, it is the perpendicular distance measured from the machined surface to the unmachined surface of the workpiece. It is usually expressed in millimeters.
5.2 DRILLING

INTRODUCTION

The drilling machine is one of the most important machine tools in a workshop. It was primarily designed to originate a hole but it can perform a number of similar operations.

1. The basic purpose of a drilling machine is to drill cylindrical holes in workpieces. (Metallic and non-metallic materials).
2. The holes are cut out of the material with a cutting tool, which is known as drill. The drill is fixed in a rotating spindle and can be fed towards the workpiece which may be fixed to the table or to the base of the machine.
3. The speed of the spindle and the feed can be adjusted according to the workpiece.
• **TYPES OF DRILLING MACHINE**
  1. Portable drilling machine
  2. Sensitive drilling machine
  3. Upright or column drilling machine
  4. Radial drilling machine
  5. Gang drilling machine
  6. Multi-spindle drilling machine
  7. Vertical drilling machine
  8. Automatic drilling machine
  9. Deep hole drilling machine

• **SPECIFICATION OF THE DRILLING MACHINE**

A heavy duty drilling machine is specified by following parameters.

1) Drilling capacity,
2) Taper in spindle (Morse no.),
3) Distance between spindle and column (maximum and minimum) in case of radial drilling machine,
4) Transverse of spindle,
5) Minimum distance between spindle and table,
6) Minimum distance between spindle and base plate,
7) Working surface of table (i.e., diameter),
8) Range of spindle speeds,
9) Range of power feed per revolution,
10) Motor speed, and
11) Motor power.

• **DRILLING OPERATIONS**

1) **Drilling.** It is an operation of producing a circular hole in a work piece by forcing a drill against it.
2) **Boring.** It is an operation of enlarging a hole that has already been drilled by a single point tool, so as to make it true to required size.

3) **Reaming.** It is an operation of slightly enlarging a machined hole to proper size with a smooth finish. The reamer is an accurate tool and is not designed to remove much metal. The reaming allowance is usually 0.2 mm only.

4) **Tapping.** It is an operation of producing internal threads in a hole by means of a tool called tap.

5) **Counter boring.** It is an operation of enlarging the mouth of a drilled hole to set bolt heads and nuts below the surface so that they may not project out from the surface level.
6) **Spot facing.** It is an operation to finish off a small portion of rough surface around a drilled hole to provide smooth seat for bolt head. Spot facing tool is a single blade; ground to give two cutting edges and is guided by a stem which runs in a pilot hole.

7) **Counter-sinking.** It is an operation to bevel the top of a drilled hole for making a conical seat for a flat head screw. Ordinary flat drill ground to correct angle is used for countersinking holes.

![Related drilling operations](image)

**Related drilling operations**

- Drill multiple diameters
- Multiple drill countersink and counterbore
- Drill and countersink
- Drill and counterbore
- Drill and chamfer
- Drill, countersink, and counterbore
• NOMENCLATURE OF THE DRILLING TOOL (DRILL)
• TYPES OF TOOLS USED ON THE DRILLING MACHINE

Work holding devices on the drilling machine.

1. T- bolts and clamps
2. Drill press vice
3. Step block
4. V- block
5. Angle plate
6. Drill jigs

Tool holding devices on the drilling machine.

The different methods used for holding tools in a drill spindle are:

1. By directly fitting in the spindle
2. By a sleeve
3. By a socket
4. By chucks
5.3 MILLING

- WORKING PRINCIPLE

Milling is a basic machining process by which a surface is generated by progressive chip removal. The workpiece is fed into a rotating cutting tool. Sometimes the workpiece remains stationary, and the cutter is fed to the work. In nearly all cases, a multiple-tooth cutter is used so that the material removal rate is high. Often the desired surface is obtained in a single pass of the cutter or work and, because very good surface finish can be obtained, milling is particularly well suited and widely used for mass-production work. Many types of milling machines are used, ranging from relatively simple and versatile machines that are used for general-purpose machining in job shops and tool and die work (these are NC or CNC machines) to highly specialized machines for mass production. Unquestionably, more flat surfaces are produced by milling than by any other machining process.

- CLASSIFICATION OF MILLING MACHINE

The four most common types of manually controlled milling machines are listed below in order of increasing power (and therefore metal removal capability):

1. Ram-type milling machines
2. Column-and-knee-type milling machines
   a. Horizontal spindle
   b. Vertical spindle
3. Fixed-bed-type milling machines
4. Planer-type milling machines

Milling machines whose motions are electronically controlled are listed in order of increasing production capacity and decreasing flexibility:

1. Manual data input milling machines
2. Programmable CNC milling machines
3. Machining centers (tool changer and pallet exchange capability)
4. Flexible Manufacturing Cell and Flexible Manufacturing System
5. Transfer lines
• **MAJOR PARTS OF COLUMN & KNEE TYPE UNIVERSAL MILLING MACHINE**

One of the features of the knee-and-column milling machine that makes it so versatile is its capability for worktable feed movement in any of the x–y–z axes. The worktable can be moved in the x-direction, the saddle can be moved in the y-direction and the knee can be moved vertically to achieve the z-movement.

The special knee-and-column machine is shown here i.e. The universal milling machine, which has a table that can be swiveled in a horizontal plane (about a vertical axis) to any specified angle. This facilitates the cutting of angular shapes and helixes on workparts.

• **TYPES OF MILLING CUTTERS**

Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

(1) Plain milling cutters,
(2) Side milling cutters,
(3) Face milling cutter,
(4) Angle milling cutters,
(5) End milling cutter,
(6) Fly cutter,
(7) T-slot milling cutter,
(8) Formed cutters,
(9) Metal slitting saw,

Milling cutters may have teeth on the periphery or ends only, or on both the periphery and ends. Peripheral teeth may be straight or parallel to the cutter axis, or they may be helical, sometimes referred as spiral teeth.
• MILLING OPERATIONS

Face Milling
In face milling, the axis of the cutter is perpendicular to the surface being milled and machining is performed by cutting edges on both the end and outside periphery of the cutter.

Gang milling
Fig. illustrates the gang milling operation. It is a method of milling by means of two or more cutters simultaneously having same or different diameters mounted on the arbor of the milling machine.
**Key way milling**

Fig. illustrates keyway milling operation.

**End milling**

End milling, in which the cutter diameter is less than the work width, so as lot is cut into the part. It is a method of milling slots, flat surfaces and profiles by end mills.