PET ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

MANUFACTURING TECHNOLOGY

UNIT III

Shaper Milling and Gear Cutting Machines

PART A

1. **What is shaper?**

The machine which is having a reciprocating type of machine tool with single point cutting tool used to produce flat surface called shaper.

2. **List any four important parts of a shaper.**

   i. Table
   ii. Tool head
   iii. Ram
   iv. Cross-rail

3. **Define cutting ratio in a shaper.**

The ratio between cutting stroke time to return stroke time,

$$m = \frac{cutting\ stroke\ time}{return\ stroke\ time}$$

4. **List any two types of quick return mechanisms.**

   (i) Hydraulic drive mechanism
   (ii) Crank and slotted lever mechanism

5. **Write the Classification of the shaper.**

Classification of the shaper according to the reciprocating of ram:

   i. Crank type
   ii. Hydraulic type
   iii. Geared type.

Classification of the shaper according to the travel and position of the ram:

- Horizontal type,
- Vertical type
- Traveling head type.

Classification of the shaper according to the design of table:

- Standard type
- Universal type.

Classification of the shaper according to the type of cutting stroke:

- Push type
- Draw type

6. **How are shaping machines specified.(May/June 2012) (May /June 2013)**

Generally, a shaper may be specified by its maximum length of stroke.

The other specifications are:

1. Type of drive (Mechanical or hydraulic)
2. Power of motor-3 HP
3. Speed and feed available.
4. Ratio of cutting stroke time and return stroke time-2:1
5. Floor area required – 1981 mm x 1067 mm.
6. Net weight. Approximately-1750 kg.
7. Maximum vertical travel of table – 475 mm
8. Maximum horizontal travel of table-450 mm.

9. Size of side table-473 mm x 330 mm.
10. Maximum vertical travel of tool slide-150 mm.

7. Mention the differences between shaper and planer. (Apr/May 2011)

S.No	SHAPER	PLANER
1.	Cutting stroke is slower than inactive /idle stroke.	Cutting stroke is slower here also.
2.	Shaper machine is use for small workings.	Meant for much larger jobs. Jobs as large as 6 meter wide and twice as long can be machined..
3.	A single cutting tool is used for machining at a time.	Two or extra cutting tools are used for machining at a time.
4.	The work is held stationary and the tool on the ram is moved back and forth across the work.	The tool is stationary and the work piece on the table travels back and forth under the tool.
5.	Stroke length is small.	Stroke length is considerably bigger than that of a shaper.

8. State the differences between a vertical shaper and slotter. (Nov/Dec 2008)

A vertical shaper and a slotter are almost similar to each other as regards to their construction, operation, and use. The only difference being in the case of a vertical shaper, the ram holding the tool may also reciprocate at an angle to the horizontal table in addition to the vertical stroke.

9. Mention the operations performed by a shaper.

1. Machining horizontal surface.
2. Machining vertical surface.
3. Machining angular surface.
4. Machining irregular surface.

10. Compare hydraulic shaper and mechanical shaper.

S.No	Hydraulic shaper	Mechanical shaper
1.	The reciprocating movement is obtained by using cylinders and pistons in a hydraulic system.	The reciprocating movement is obtained by using crank mechanism (Bull gear) or geared mechanism (rack and pinion arrangement).
2.	Hydraulic power namely oil is used.	Power is obtained either from an individual motor or from an overhead line shaft if it is a belt driven shaper.
3.	Cutting speed and force of the ram drive are constant from the very beginning to the end of the cut.	Cutting speed and force of the ram drive is not constant or uniform.
4.	It offers great flexibility of speed and feed control.	No great flexibility of speed and feed control.

11. List the different parts involved in the shaper.

The main parts of horizontal shaper are as below:

1. Ram
2. Table
3. Clapper box
4. Tool head
5. Column
6. Cross Rail
7. Stroke Adjustment
8. Table supports
9. Base

12. List the parts in tool head.

The parts in tool head:

- Swivel base
- Vertical slide
- Apron
- Tool post

13. List the parts in apron.

- Clapper box
- Clapper block
- Tool post

14. What are the different types of mechanism used in shaper?

a. Crank and slotted Mechanism
b. Whit worth mechanism
c. Hydraulic shaper mechanism

15. List the two blocks used in the Crank and slotted Mechanism.

a. Bull gear sliding block
b. Rocker arm sliding block.

16. Define slot milling.

- It is also a type of milling operation, also called as slot milling operation. In this case width of the cutter is less than the width of work piece. It is used to make slot in the work piece.
- Thin slots can be made by using very thin milling cutters.
- The work piece can be cut into two pieces by making a very thin slot throughout the depth of work piece. Cutting the work piece this way be slot milling is called saw milling.

17. How are work pieces held in a shaper? (April /May 2010)

The work may be supported on the table by the following methods depending on the nature of the work piece.

1. Clamped in a vise
2. Clamped on the table
3. Clamped to the angle plate
4. Clamped on a V- block
5. Held between shaper index centre

18. What are the devices used to hold the work on the shaper table?

a. T bolt and clamps
b. Stop pins

c. Stop pins and toe dogs
d. Strip and stop pins

19. What is planer?

A planer is a type of metalworking machine tool that uses linear relative motion between the work piece and a single-point cutting tool to machine a linear tool path. Its cut is analogous tothat of a lathe, except that it is (archetypally) linear instead of helical..

20. Define feed and depth of cut in a shaper.

Feed(s) is the relative movement of the tool or work in a direction perpendicular to the axis of reciprocation of the ram per double stroke and is expressed in mm. The feed is always given at the end of return stroke when the tool is not cutting the metal. The selection of feed is dependent upon the kind of metal, type of job, etc.

Depth of cut:

Depth of cut (t) is the thickness of metal that is removed in one cut. It is the perpendicular distance measured between machined surface and non-machined surface of the work piece.

21. What is the difference between shaper and slotter?

S.No	SHAPER	SLOTTER
1	The work is stationary and the tool on the ram is moved back forth(horizontal axis) across the work	The work is held stationary and the tool on the ram is moved up and down (vertical axis) across the work.
2	Used for shaping much smaller jobs.	It is used for making slots in smaller jobs.
3	Is a light machine	Slotting is light machine
4	Can employ light cuts and finer feed	Can employ light cuts and finer feed.
5	Uses one cutting tool at a time	Slotter uses one cutting tool at a time
6	Driven using quick- return link Mechanism	The rams are either crank-driven or Hydraulically driven
7	It is less rigid and less robust	It is less rigid and less robust

22. What is the difference between planner and slotter?

S.No	PLANER	SLOTTER
1	It can use heavier use and coarse feed	Its can use light cuts and improved feed
2	Some tools can cut at the same time	Shaper uses single cutting tool at a time
3	It is heavy weight machine	It is light machine
4	Drive a planner table is too by gears or by hydraulic means	The ram are also crank driven or hydraulically drive.
5	Job as big like six meter wide and twice as long can be machined	It use for make slots in small jobs.

23. What is meant my drilling?

Drilling is the process of producing hole on the workpiece by using a rotating cutter called drill.

24. List the types of drilling machines.

Types of drilling machines:

1. Portable drilling machine.
2. Sensitive drilling machine.
   a) Bench mounting b) Floor mounting
3. Upright drilling machine.
   a) Round column section b) Box column section

4. Radial drilling machine

   a) Plain b)Semi -universal c)Universal

5. Gang drilling machine.
6. Multiple spindle drilling machines.
7. Automatic drilling machine.
8. Deep hole drilling machine.

   a)Vertical b)Horizontal

25. List the parts involved in the upright drilling machine.

1. Base
2. Column
3. Table
4. Head
5. Spindle
6. quill
7. Drill head assembly.

26. List the parts involved in the radial drilling machine.

1. Base
2. Column
3. Radial arm
4. Drill head

27. What are the different operations performed in drilling machine?

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Counter sinking
6. Spot facing
7. Tapping
8. Lapping
9. Grinding.

28. Define the cutting speed, feed and machining time for drilling. (Nov/Dec 2010)

cutting speed

It is the peripheral speed of a point on the surface of the drill in contact with the work piece. The cutting speed (v) may be calculated as:

$$V = \frac{\pi \times d \times n}{1000} \text{ m/min}$$

Where, d is the diameter of the drill in mm

N is the r.p.m. of the frill spindle.

<u>Feed</u>:

The feed of a drill is the distance the drill moves into the work at each revolution of the spindle. It is expressed in millimeter or may also be expressed as feed per minute. The feed (s_m) per minute may be calculated as:

$$S_m = s_r \times n$$

Where Sm = Feed per minute in mm.

S_r = Feed per revolution in mm.

N = r.p.m. of the drill.

<u>Machining time:</u>

Time taken to complete the machining process without considering the idle time of machine is called machining time. The machining time can be calculated by using the following relation

$$\text{Machining time, T} = \frac{length\ of\ the\ tool\ travel\ in\ mm}{feed\ in \frac{mm}{rev} \times rpm\ of\ the\ spindle}$$

Where, n = r.p.m. of the drill

s_r = Feed per revolution of the drill in mm/rev

L =Length of travel of the drill in mm

And T =Machining time in min.

$L = l_1 + l_2 + l3 + l_4$

Where l1 = length of the work piece

l_2 = approach of the drill

l_3 = length of the drill point

l_4 = over travel

29. What do you know about straight fluted drill and fluted drill? (Nov/Dec 2009)

Straight Fluted drill:

The reamer with helical flutes provides a smooth provides a smooth shear cutting action and it provides a better surface finish. The pitch of the flutes is made uneven to reduce vibration.

Fluted drill:

Most drill bits for drilling wood, metal or masonry incorporate some type of flute in the design. The flute is a deep groove that typically twists around the bit, giving the waste material a path out of the hole.

30. What is heel, Flank and Lip in a drill?

Heel:

The edge is formed by the intersection of the flute surface and body clearance in a drill .

Flank:

The surface on a drill point which extends behind the lip to the following flute.

Lip (cutting edge):

The edge formed by the intersection of the flank and face. The requirements of the drill lip are

1. Both lips should be at the same angle of inclination with the drill axis, 59° for general work.
2. Both should be of equal length.
3. Both lips should be provided with the correct clearance.

31. What are the advantages of using diamond drill bit?

1 - Cuts through Tougher Materials

2 - Speed

3 - Metal Bonded Bits

4 - Prevents Chips and Cracks

5 - Minimal Noise.

32. What is reaming?

Reaming is the process of sizing and finishing the existing drilled hole. The tool used for reaming is known as reamer.

33. What is tapping?

Tapping as shown in the figure is the operation of cutting internal threads by means of a cutting tool called a tap. A tap may be considered as a bolt with accurate threads cut on it. The threads act as cutting edges which ate hardened and ground. When the tap is screwed into the hole it removes metal and cuts internal threads which will fit into external threads of the same size.

34. Write the differences between drilling and tapping. (Nov/Dec 2008)

Drilling:

Drilling is the process of producing hole on the workpiece by using a rotating cutter called drill. The different shapes of holes can be made.

Tapping:

Tapping is the process used for making internal threads in a machine component by a tool called tap. Internal thread can be cut in existing drilled holes.

35. What are the differences between drilling and reaming? (Apr/May 2011)

Drilling:

This is an operation of creating a circular hole by removing a volume of metal from a job by rotating a cutting tool called drill. Drilling removes solid metal to create a round hole.

Reaming:

Drilled hole is constantly bigger than diameter of drill. While a round hole by straight with flat walls is required reaming is done. It is a process of sizing, aligning and smooth a drilled hole through use of a reamer.

36. What is boring?

Boring is a process of enlarge and locating previously drilled holes with a single point cutting tool.

37. What are applications of boring?

The boring machine is designed for machining large and heavy workpiece in mass production work of engine frame, cylinder, machine housing.

38. What is a milling machine?

Milling is the process of removing metal by feeding the work past against a rotating multipoint cutter.

39. What are the types of milling machines?

1. Column and knee type milling machine
    a. Hand milling machine
    b. Plain milling machine
    c. Universal milling machine
    d. Omniversal milling machine
    e. Vertical milling machine
2. Manufacturing of fixed bed type.
    a. Simplex milling machine
    b. Duplex milling machine
    c. Triplex milling machine
3. Planer type
4. Special type.
    a. Rotary table milling machine
    b. Drum milling machine

40. What is the difference between a plain milling machine and an universal milling machine? (Nov/Dec 2012)

S.No	Plain milling	Universal milling
1.	Plain milling is provided with three table movements: longitudinal, cross and vertical.	A universal milling machine has a fourth movement of the table in addition to the three movements in plain milling machine.
2.	Plain milling machine is not provided with auxiliary's equipment.	Universal milling machine is provided with auxiliaries such as dividing head equipment, vertical milling attachment, rotary table, etc.
3.	Plain milling machine is more rigid and heavier in construction.	Universal milling machine is not that rigid and is lighter.
4.	Plain milling is adapted for manufacturing operations.	Universal milling machine is intended more for tool room work and for special machining operations.

41. What are the special attachments made in the universal milling machine?

1. Dividing head or Index head
2. Vertical milling attachment
3. Rotary attachment
4. Slotting attachment

42. What is vertical milling machine?

In vertical milling machine the spindle is mounted vertical or perpendicular to the table. The machine may be plain or universal type and has all the movements of the table for proper setting and feeding the work.

43. What are the parts used in the column and knee type milling machine?

1. Base 2. Column
3. Knee 4. Table
5. over hanging arm 6. Front brace
7. Arbor

44. State the differences between up milling and down milling. (Nov/Dec 2013) (Apr/May 2010) (Apr/May 2011)

S.No	Event of operation	Up Milling	Down Milling
i.	Direction of travel	The cutter rotates against the direction of travel of workpiece	The cutter rotates in the same direction of travel of workpiece
ii.	Chip thickness	Minimum at the beginning of cut reaches maximum when the cut terminates	Maximum at the beginning reaches minimum at terminates
iii.	Cutting forces	It increases from zero to maximum per tooth	It decreases from zero to maximum per tooth

45. What are the various milling operations?

Different operations can be performing on milling machine:

1. Face Milling Operation 2. Straddle Milling Operation
3. Side Milling Operation 4. Plain Milling Operation

5. Angular Milling Operation
6. Gang Milling Operation
7. Profile Milling Operation
8. Form Milling Operation
9. End Milling Operation
10. Slot Milling Operation
11. Gear Cutting Operation
12. Saw Milling Operation
13. Cam Milling Operation
14. Thread Milling Operation
15. Helical Milling Operation

46. What is meant by up milling and down milling? (Nov/Dec 2008)

In up milling process, the cutter rotates opposite to the direction of feed of the workpiece whereas in down milling, the cutting rotates in the same direction of travel of the workpiece.

47. What is the difference between face milling and end milling?

Face milling:

Face milling makes use of a cutter that machines a surface at right angles to the spindle axis and parallel to the face of the tool.

End Milling:

End milling is the operation of machining flat surfaces, either horizontal, vertical, or at an angle, using an end mill as a cutter. These cutters have teeth on the end face as well as on the periphery.

48. How do you classify milling cutters? (Nov/Dec 2009, April/May 2010)

There are many different types of standard milling cutters. They are classified as :

1. Plain milling cutter
   - A) Light duty plain milling cutter
   - b) Heavy duty plain milling cutter
   - c) Helical plain milling cutter
2. Side milling cutter
   - a) Plain Side milling cutter
   - b) Staggered teeth Side milling cutter
   - c) Half Side milling cutter
   - d) Interlocking Side milling cutter
3. Metal slitting saw
   - a) Plain metal slitting saw
   - b) Staggered teeth metal slitting saw
4. Angle milling cutter
   - a) Single Angle milling cutter
   - b) Double Angle milling cutter
5. End mill
   - a)Taper shank end mill
   - b) Straight shank end mill
   - c) Shell end mill

49. What is a shell mill? (Nov/Dec 2007).

The shell mill is a large type of face or end mill that mounts onto an arbor, rather than having an integral shank. Typically, there is a hollow or recess in the centre of the shell mill for mounting hardware onto a separate arbor.

50. What are the various types of end mills used in milling? (AU April / May 2010)

1. Taper shank end mill
2. Straight shank end mill
3. Shell end mill

51. How are gears manufactured?

Gears are manufactured by various processes. They are:

- ✓ Casting

- ✓ Stamping
- ✓ Rolling
- ✓ Extruding
- ✓ Powder Metallurgy
- ✓ Machining

52. Write how the gear teeth produced by machining.

Gear teeth are produced by machining based on:

- ➢ Forming – where the profile of the teeth are obtained as the replica of the form of the cutting tool (edge); e.g., milling, broaching etc.
- ➢ Generation – where the complicated tooth profile are provided by much simpler form cutting tool (edges) through rolling type, tool – work motions, e.g., hobbing, gear shaping etc.

53. How are gears formed by disc cutter?

The disc cutter shape conforms to the gear tooth space. Each gear needs a separate cutter. However, with 8 to 10 standard cutters, gears from 12 to 120 teeth can be cut with fair accuracy. Tooth is cut one by one by plunging the rotating cutter into the blank.

54. What is indexing?

Indexing is an operation of dividing the periphery of a piece of work into any number of equal parts.

55. What are the different methods of indexing?

1. Direct Indexing
2. Simple Indexing
3. Compound Indexing
4. Differential Indexing

56. What is gear finishing?

For smooth running, good performance and long service life, the gears need

- to be accurate in dimensions and forms
- to have high surface finish and
- to be hard and wear resistive at their tooth flanks

57. List the gear finishing methods.

Common methods of gear teeth finishing

Gear teeth, after preforming and machining, are finished generally by;

- For soft and unhardened gears
  - ❖ Gear shaving
  - ❖ Gear rolling or burnishing
- For hard and hardened gears
  - ❖ Grinding
  - ❖ Lapping

58. How are spur gears manufactured?

Cutting of a Spur Gear on a Milling Machine involves the following steps:

1. To determine the important dimensions and proportions of the gear tooth element.
2. Mounting the cutter and the job on the machine.
3. Adjust the position of the table to the starting position.
4. Indexing.
5. Repeat the operation till the gear is complete.

59. Define hobbing.

The process of generating a gear by means of a rotating cutter call hob is known as hobbing.

60. What is lapping and honing?

- Lapping and honing both employ an abrasive-impregnated gear or gear-shapedtool that is run against the gear to abrade the surface.
- In both cases, the abrasive tool drives the gear in what amounts to an acceleratedand controlled run-in to improve surface finish and the accuracy.

PART – B

1. Describe the principle of operation of a shaper with a neat sketch. (Nov/Dec 2010) (April/May 2016)

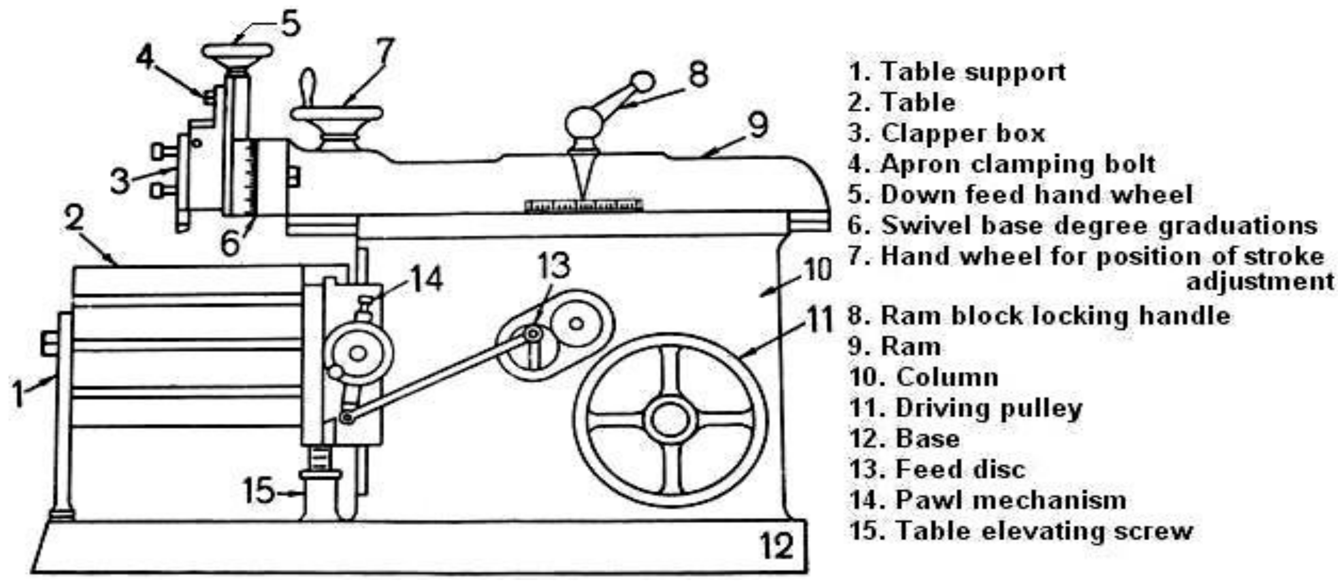


Fig. Schematic view of a standard shaper

Base

- It is rigidly bolted to the shop floor. All parts are mounted on the base.
- It is made up of cast iron to resist vibration and take up high compressive load.
- It takes the entire load of the machine and the forces set up by the cutting tool during machining.

Column

- Two accurately machined guide ways are provided on the top of the column on which the ram reciprocates.
- The front vertical face of the column which serves as the guide ways for the cross rail is also accurately machined.

Cross rail

- It is mounted on the front vertical guide ways of the column. It has two parallel guide ways on its top in the vertical plane that is perpendicular to the ram axis.
- The table may be raised or lowered to accommodate different sizes of jobs by rotating an elevating screw which causes the cross rail to slide up and down on the vertical face of the column.

Saddle

- It is mounted on the cross rail which holds the table firmly on its top. Crosswise movement of the saddle by rotating the cross feed screw by hand or power causes the table to move sideways.

Table

- It is bolted to the saddle receives crosswise and vertical movements from the saddle and cross rail. It is a box like casting having T-slots both on the top and sides for clamping the work.
- In a universal shaper the table may be swiveled on a horizontal axis and the upper part of the table may be tilted up or down.

Ram

- It holds and imparts cutting motion to the tool through reciprocation. It is connected to the reciprocating mechanism contained within the column.
- It is semi cylindrical in form and heavily ribbed inside to make it more rigid. It houses a screwed shaft for altering the position of the ram with respect to the work and holds the tool head at the extreme forward end.

Tool head

- It holds the tool rigidly, provides the feed movement of the tool and allows the tool to have an automatic relief during its return stroke.
- The vertical slide of the tool head has a swivel base which is held on a circular seat on the ram. So the vertical slide may be set at any desired angle.
- By rotating the down feed screw handle, the vertical slide carrying the tool executes the feed or depth of cut. The amount of feed or depth of cut may be adjusted by a micrometer dial on the topof the down feed screw.
- Apron consisting of clapper box, clapper block and tool post is clamped upon the vertical slide by a screw. By releasing the clamping screw, the apron may be swiveled upon the apron swivel pin with respect to the vertical slide.

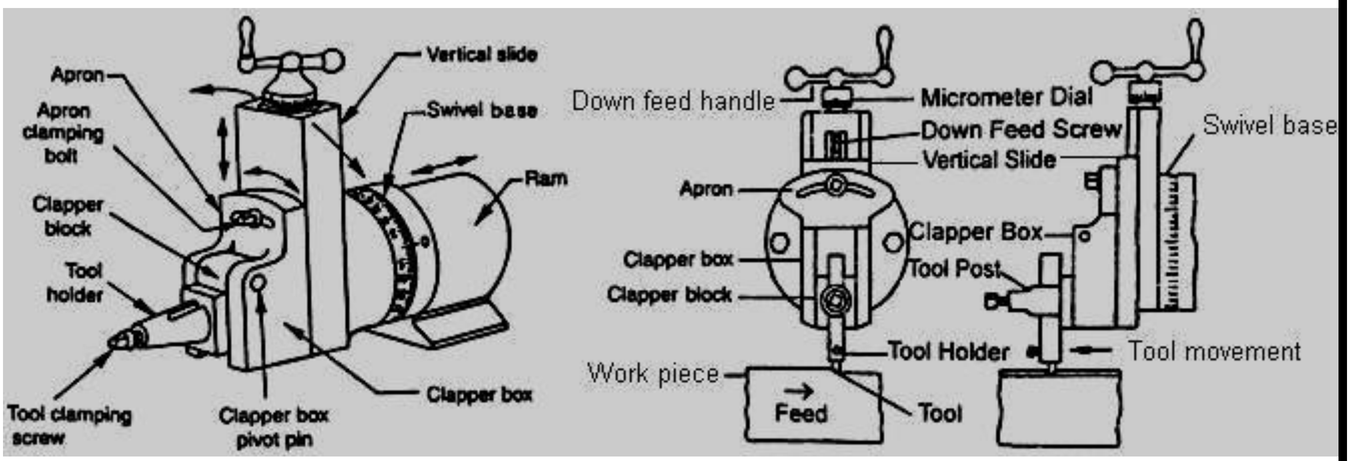


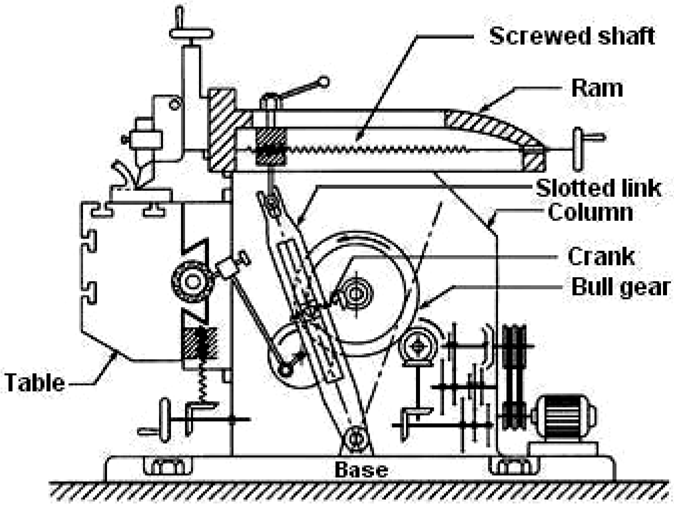
Fig. Tool head of a shaper

- This arrangement is necessary to provide relief to the tool while making vertical or angular cuts. The two vertical walls on the apron called clapper box houses the clapper block which is connected to it by means of a hinge pin.
- The tool post is mounted upon the clapper block. On the forward cutting stroke the clapper block fits securely to the clapper box to make a rigid tool support.

Working principle:

- The bull gear receives its rotation from the motor through the pinion.
- The rotation of the crank causes oscillation of the link and thereby reciprocation of the ram and hence the tool in straight path.
- The cutting motion provided by the reciprocating tool and the intermittent feed motion provided by the slow transverse motion of the work at different rate by using the ratchet - pawl system along with the saddle result in producing a flat surface by gradual removal of excess material layer by layer in the form of chips.
- The vertical in feed is given either by descending the tool holder or raising the cross rail or both.
- Straight grooves of various curved sections are also made in shaper by using specific form tools.

- The single point straight or form tool is clamped in the vertical slide of the tool head, which is mounted at the front face of the reciprocating ram.
- The work piece is clamped directly on the table or clamped in a vice which is mounted on the table.



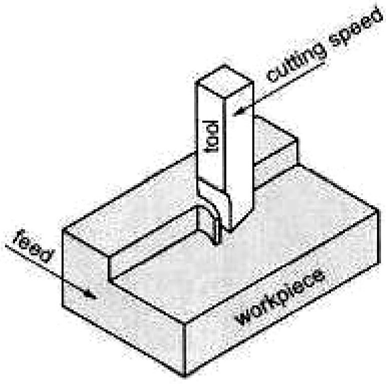


Fig. 3 (a) Kinematic system of a shaper **Fig. 3 (b) Principle of producing flat surface**

The changes in length of stroke and position of the stroke required for different machining are accomplished respectively by:

- Adjusting the crank length by rotating the bevel gear mounted coaxially with the bull gear.
- Shifting the ram block nut by rotating the lead screw.

TYPE OF DRIVE MECHANISM

The following are three type of drive mechanism are:

1. Crank and slotted link quick return mechanism
2. Whitworth quick return mechanism
3. Hydraulic drive

2. Describe the working of a crank and slotted link mechanism. (Nov/ Dec 2003 & 2010)

- This mechanism has a bull gear mounted within the column. The motion or power is transmitted to the bull gear through a pinion which receives its motion from an individual motor.
- A radial slide is bolted to the centre of the bull gear. This radial slide carries a bull gear sliding block into which the crank pin is fitted.
- Rotation of the bull gear will cause the crank pin to revolve at a constant speed about the centre of the bull gear.
- Rocker arm sliding block is mounted upon the crank pin and is free to rotate about the pin. The rocker arm sliding block is fitted within the slotted link and can slide along the slot in the slotted link (rocker arm).
- The bottom end of the rocker arm is pivoted to the frame of the column. The upper end is forked and connected to the ram block by a pin which can slide in the forked end.
- As the bull gear rotates causing the crank pin to rotate, the rocker arm sliding block fastened to the crank pin will rotate on the crank pin circle, and at the same time will move up and down in the slot provided in the slotted link.
- This up and down movement will give rocking motion (oscillatory motion) to the slotted link (rocker arm), which communicated to the ram. Thus the rotary motion of the bull gear is converted into reciprocating movement of the ram.

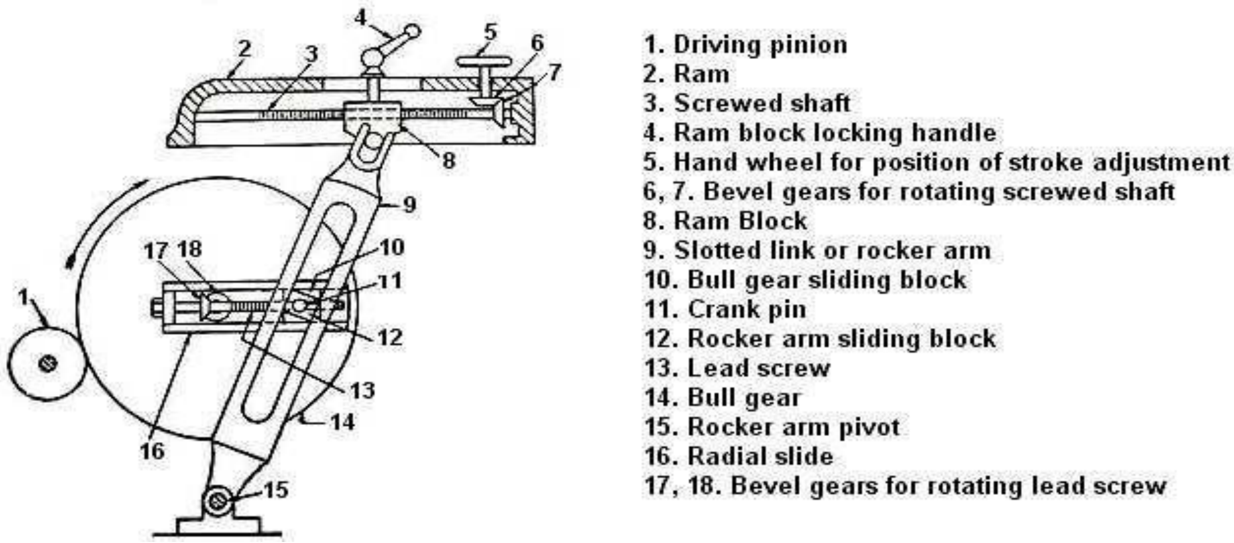


Fig. 4 Crank and slotted link quick return mechanism

Quick return principle

- When the slotted link is in the position PA_1, the ram will be at the extreme backward position of its stroke.
- When the slotted link is in the position PA_2, the ram will be at the extreme forward position of its stroke. PA_1 and PA_2 are shown tangent to the crank pin circle.
- Therefore the forward cutting stroke takes place when the crank pin rotates through the angle C_1KC_2 (α) and the return stroke takes place when the crank pin rotates through the angle C_2LC_1 (β).
- It is clear that the angle α made by the forward or cutting stroke is greater than that the angle β described by the return stroke.
- The angular velocity of the crank pin being constant, therefore the return stroke is completed within a shorter time for which it is known as quick return motion.
- The only disadvantage of this mechanism is that the linear velocity of the ram is not constant throughout the stroke. The velocity is minimum, when the rocker arm is at the two extremities and the velocity is maximum when the rocker arm is vertical.

Adjusting the length of stroke

- The crank pin is fastened to the bull gear sliding block which can be adjusted and the radius of its travel may be varied. The bevel gear 18 placed at the centre of the bull gear may be rotated by a handle causing the bevel gear 17 to rotate.
- The bevel gear 17 is mounted upon the small lead screw which passes through the bull gear sliding block.

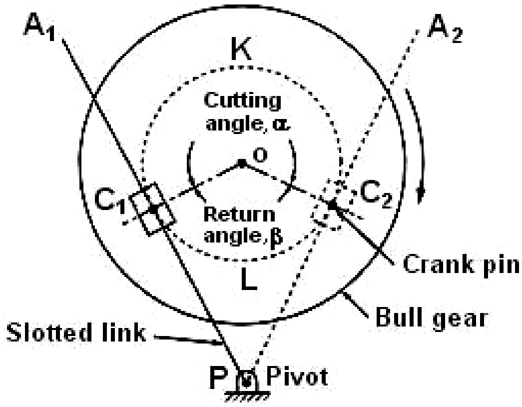


Fig. Principle of quick return motion

- Thus rotation of the bevel gear will cause the bull gear sliding block carrying the crank pin to be brought inwards or outwards with respect to the centre of the bull gear.
- The sketch has been drawn without the rocker arm in position.

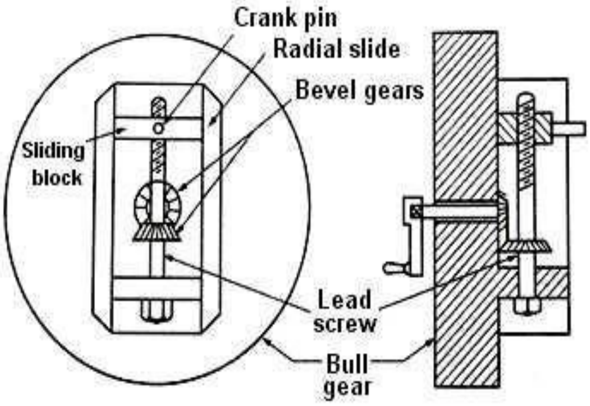


Fig. (a) Arrangement of bull gear sliding block

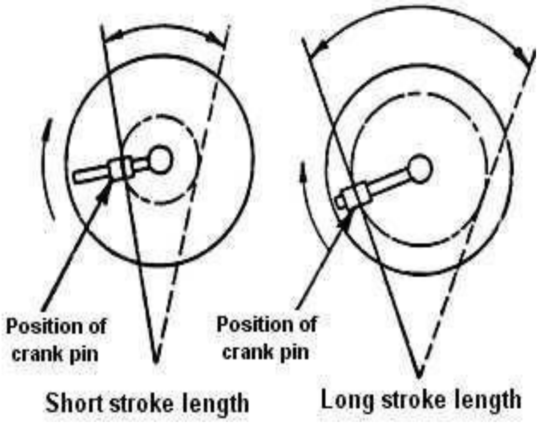


Fig. (b) Short and long stroke length

Adjusting the position of stroke

- The position of the ram relative to the work can also be adjusted. *Referring to the Fig. 4,* byrotating the hand wheel 5 the screwed shaft fitted in the ram may be made to rotate through two bevel gears 6 and 7.
- The ram block which is mounted upon the screwed shaft acts as a nut. The nut remaining fixed in position, rotation of the screwed shaft will cause the ram to move forward or backward with respect to the ram block according to the direction of rotation of the hand wheel.
- Thus the position of ram may be adjusted with respect to the work piece. The ram block locking handle 4 must be tightened after the adjustment has been made.

3. Describe with neat sketch whit worth quick return mechanism used in a shaper. (May/ June 2006)

- The bull gear is mounted on a large fixed pin A upon which it is free to rotate. The motion or power is transmitted to the bull gear through a pinion which receives its motion from an individual motor.
- The crank plate is pivoted eccentrically upon the fixed pin at 5. The crank pin is fitted on the face of the bull gear. The crank plate sliding block is mounted upon the crank pin and it fits into the slot provided on the crank plate. The crank plate sliding block can slide inside the slot.

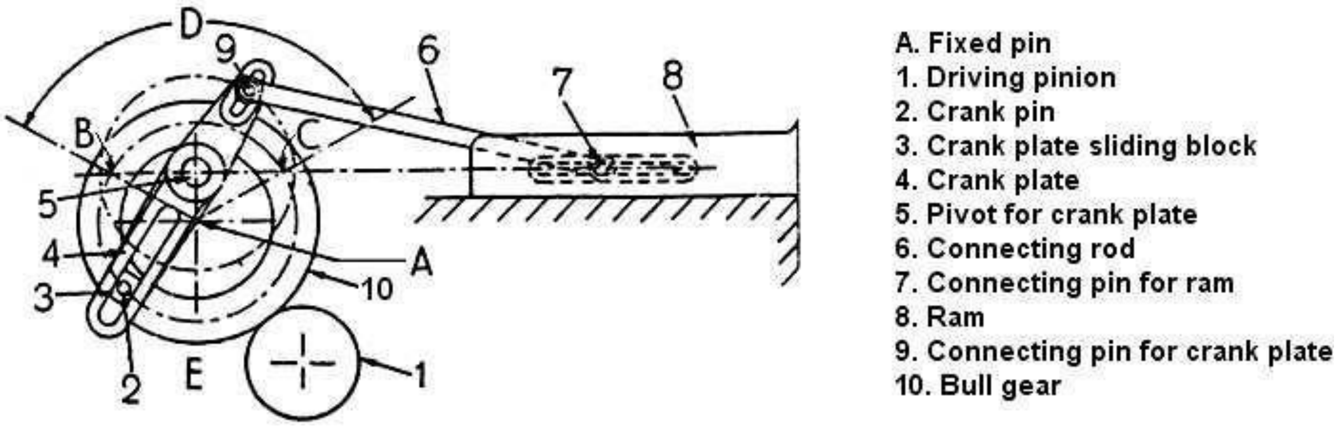


Fig. 7 Whitworth quick return mechanism

- At the other end of the crank plate, a connecting rod connects the crank plate and the ram by two pin 9 and 7. When bull gear will rotate at a constant speed the crank pin with the sliding block will rotate on a crank circle of radius A and the sliding block will cause the crank plate to rotate about the point 5 with a variable angular velocity.

- When the crank pin 2 is at the point C the ram will be at the extreme backward position of its stroke. When the crank pin 2 is at the point B the ram will be at the extreme forward positionof its stroke.
- Therefore the forward cutting stroke takes place when the crank pin rotates through the angle CEB (α) and the return stroke takes place when the crank pin rotates through the angle BDC (β).
- It is clear that the angle α made by the forward or cutting stroke is greater than the angle β described by the return stroke.
- The angular velocity of the crank pin being constant, therefore the return stroke is completed within a shorter time for which it is known as quick return motion. The length of stroke of the ram may be changed by shifting the position of pin 9 closer or away from the pivot 5.
- The position of stroke may be altered by shifting the position of pin 7 on the ram.

4. Explain the hydraulic drive quick return mechanism of a horizontal shaper with a neat sketch. (May/ June 2014)

- A constant speed motor drives a hydraulic pump which delivers oil at a constant pressure to the line.
- A regulating valve admits oil under pressure to each end on the piston alternately, at the same time allowing oil from the opposite end of the piston to return to the reservoir.
- The piston is pushed by the oil and, being connected to the ram by the piston rod, pushes the ram carrying the tool. The admission of oil to each end of the piston, alternately, is accomplished with the help of trip dogs and pilot valve.
- As the ram moves and completes its stroke (forward or return) a trip dog will trip the pilot valve which operates the regulating valve.
- The regulating valve will admit the oil to the other side of the piston and the motion of the ram will get reversed. It is clear that the length of the ram stroke will depend upon the position of the trip dogs.
- The length of the ram stroke can be changed by unclamping and moving the trip dogs to the desired positions. The above system is a constant pressure system.
- The velocity of the ram travel will be directly proportional to the oil pressure and the piston areato which it is applied.
- The return stroke is quicker, since the piston area on which the oil pressure acts is greater as compared to the other end for which it gets reduced because of the piston rod.
- Another oil line is connected to a smaller feed cylinder to change the hydraulic power to mechanical power for feeding the work past the tool.

Advantages of Hydraulic drive

- Does not make any noise and operates very quietly.
- Ability to stall against an obstruction without damage to the tool or the machine.
- Ability to change length and position of stroke or speed while the machine is running.
- The cutting and return speeds are practically constant throughout the stroke. This permits the cutting tool to work uniformly during cutting stroke.

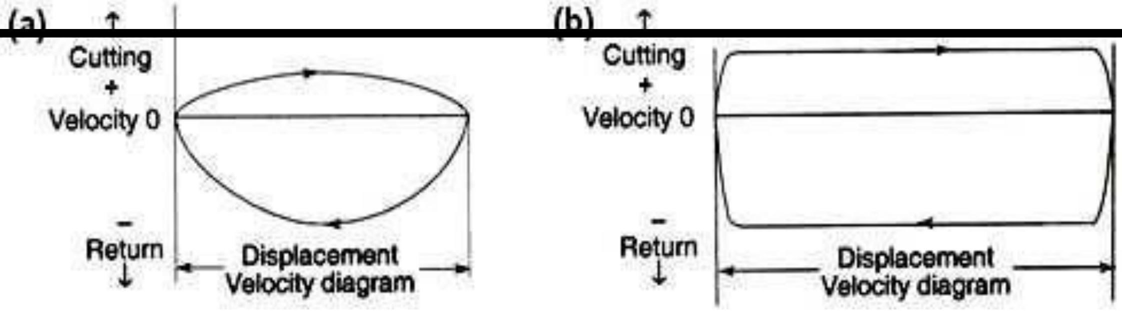


Fig. Velocity diagram of (a) Crank shaper and (b) Hydraulic shaper

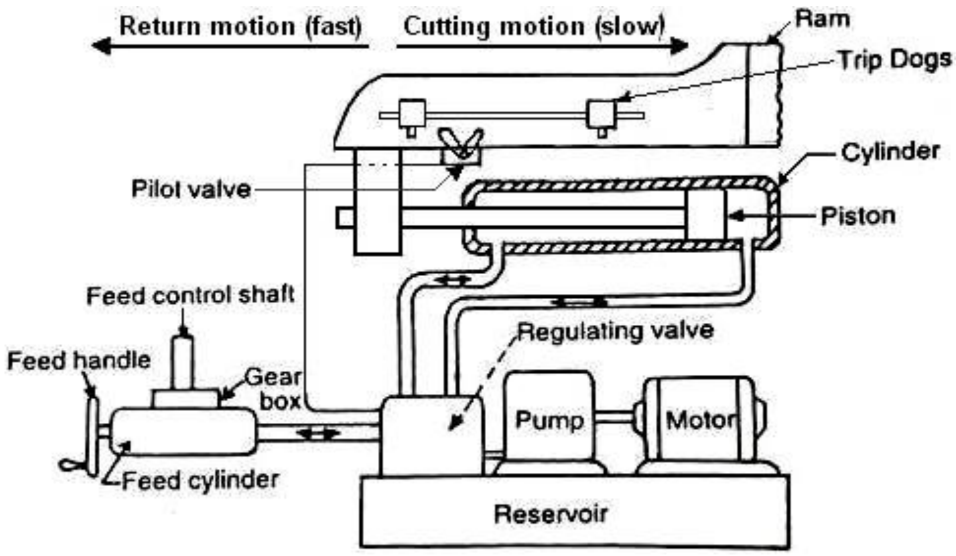


Fig. Hydraulic drive for horizontal shaper

On the other hand, a mechanical shaper has the following plus points: Lower first cost and simpler in operation. The cutting stroke has a definite stopping point.

5. Explain in detail the three types of feed mechanism.

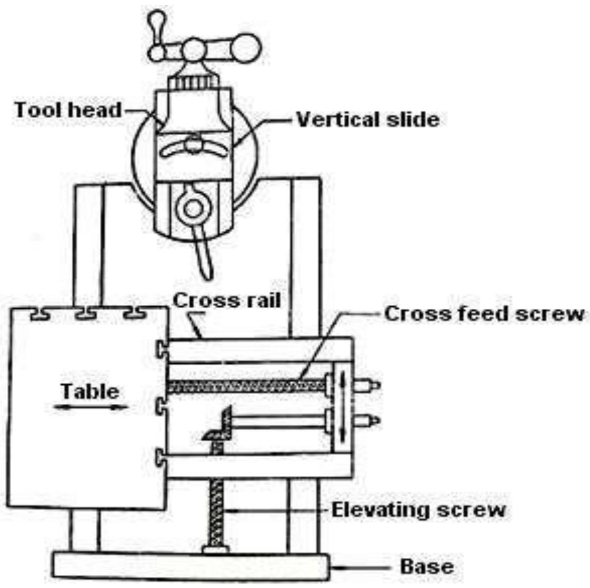


Fig. Down feed and cross feed mechanism

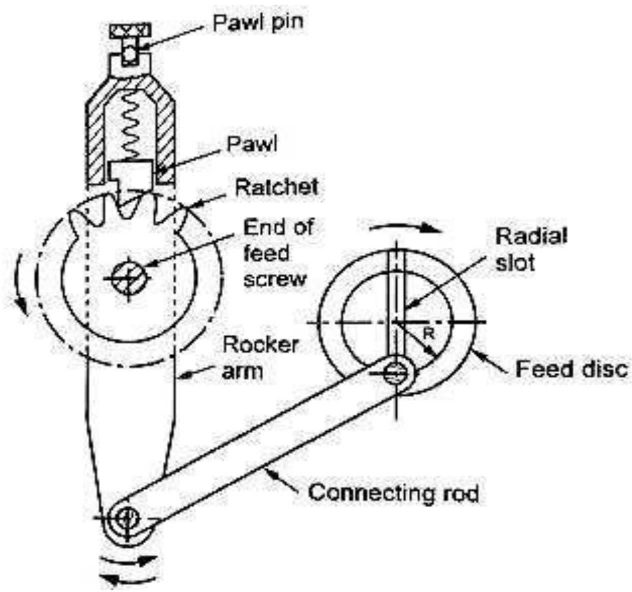


Fig. Automatic feed mechanism

The feed mechanism in which the feed is given at the end of each return stroke is known as **feed mechanism.**

1. Hand feed

- The table is moved perpendicular to the ram movement it is called as cross feed. It is given by rotating the hand wheel of the cross feed screws on the tool head.
- The vertical adjustment is made by rotating the elevating screw through the horizontal rod to hold the work piece at various heights.
- Both vertical and angular feeds are given by the tool head. But the only difference in angular feed is that the feed will be given after setting the work to its required angle.

2. Automatic feed mechanism of a shaper

- In this mechanism, a ratchet wheel is keyed to the end of the cross feed screw. A rocker arm is pivoted at the centre of the ratchet wheel.
- The rocker arm houses a spring loaded pawl at its top. The spring pushes against the pawl to keep it in contact with the ratchet wheel.
- The pawl is straight on one side and bevel on the other side. So the pawl moves the ratchet wheel in one direction only.
- The rocker arm is connected to the driving disc or feed disc by a connecting rod. The driving disc has a T-slot on its face along its diameter. The driving pin or crank pin fits into this slot. One end of the connecting rod is attached to this crank pin.
- We know that the table feed is intermittent and is accomplished on the return stroke when the tool has cleared the work piece.
- The driving disc is driven from the bull gear through a spur gear drive and rotates at the same speed as the bull gear. As the driving disc rotates, the connecting rod oscillates the rocker arm about the cross feed screw.
- During the forward stroke of the ram, the rocker arm moves in the clockwise direction. As bevel side of the pawl fits on the right side, the pawl slips over the teeth of the ratchet wheel. It gives no movement to the table.
- During the return stroke of the ram, the rocker arm moves in the counter clockwise direction. The left side of the pawl being straight; so that it moves the ratchet wheel by engaging with it and hence rotates the cross feed screw which moves the table.
- A knob at the top of the pawl enables the operator to rotate it 180^0 to reverse the direction of feed or 90^0 to stop it altogether. The rate of feed is controlled by adjusting the eccentricity or offset of the crank pin in the driving disc.

6. With neat sketch and explain in detail of work holding devices in shaper.

WORK HOLDING DEVICES USED IN A SHAPER

The top and side of the table of a shaper have T-slots for clamping the work piece. The work piece may be supported on the shaper table by using any one of the following work holding devices depending upon the geometry of the work piece and nature of the operation to be performed.

- Machine vise.
- Clamping work on the table.
- Angle plate.
- V-blocks.
- Shaper Centre

A vise is a quick method of holding and locating small and regular shaped work pieces. It consists of a base, screw, fixed jaw and movable jaw. The work piece is clamped between fixed and movable jaws by rotating the screw. Types of machine vise are plain vise, swivel vise and universal vise.

- A **plain vise** is the most simple of all the types. The vise may have a single screw or double screws for actuating the movable jaw. The double screws add gripping strength while taking deeper cuts or handling heavier jobs.
- In a **swivel vise** the base is graduated in degrees, and the body of the vise may be swiveled at any desired angle on a horizontal plane. The swiveling arrangement is useful in beveling the end of work piece.
- A **universal vise** may be swiveled like a swivel vise. In addition to that, the body may be tilted in a vertical plane up to 90 degrees from the horizontal. An inclined surface may be machined by a universal vise.

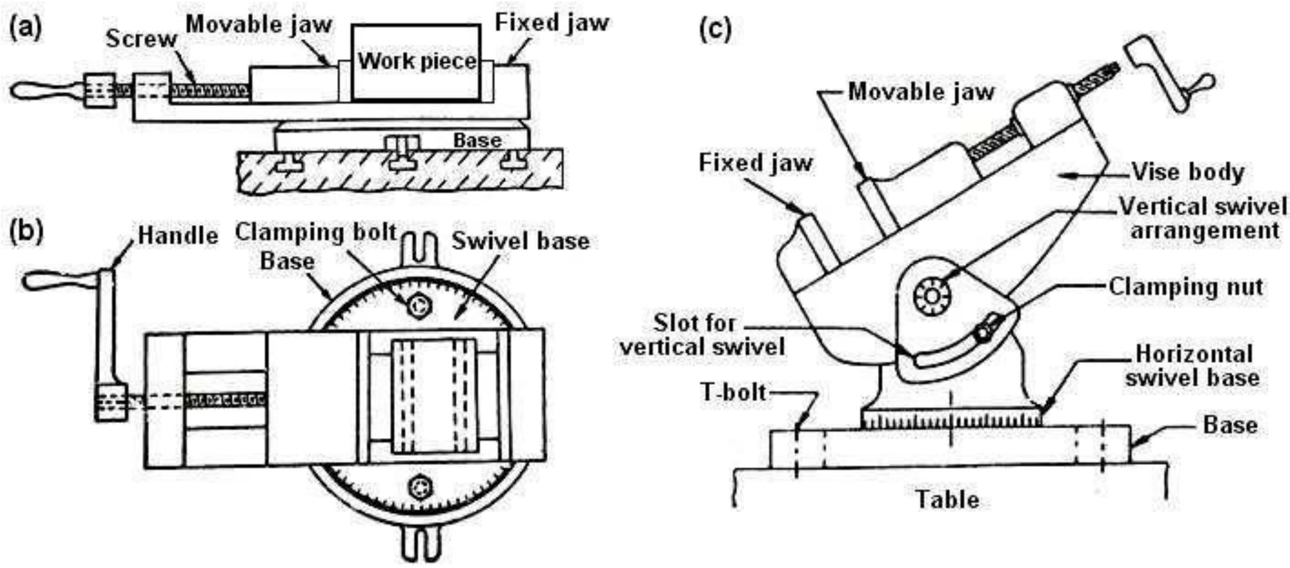


Fig. Machine vise (a) Plain vise (b) Swivel vise and (c) Universal vise

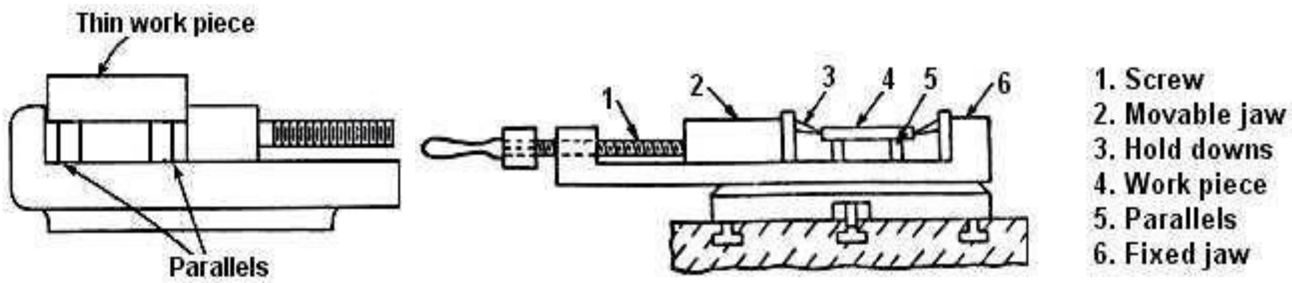


Fig. Use of parallels

Parallels

- When the height of the job is less than the height of the jaws of the vise, parallels are used to raise and seat the work piece above the vise jaws and parallel with the vise bottom. Parallels are square or rectangular hardened bars of steel or cast iron.

Hold downs

- Hold downs or grippers are used for holding thin pieces of work in a shaper vise. These are also used for holding work of smaller height than the vise jaws. These are hardened wedge shaped piece with a taper angle of 5^0.
- These are placed between two jaws of the vise and the work piece. When the screw is tightened the typical shape of the hold down exerts downward pressure on the work to hold it tight on the parallels or on the vise table.

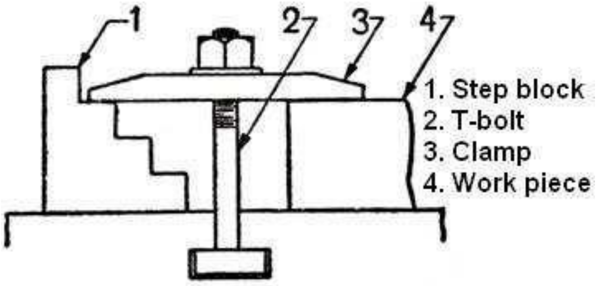
Clamping work on the table

When the work piece is too large to be held in a vise it must be fastened directly on the shaper table. The different methods employed to clamp different types of work on a shaper table are:

- T-bolts, step blocks and clamps.
- Stop pins.
- Stop pins and toe dogs.
- Strip and stop pins.

T-bolts, step blocks and clamps

- T-bolt having T-head is fitted in the T-slot of the table. The length of the threaded portion is sufficiently long in order to accommodate different heights of work.
- One end of the clamp rests on the side of the work while the other end rests on a fulcrum block or step block. The fulcrum block should be of the same height as the part being clamped.
- To hold a large work on the table a series of clamps and T- bolts are used all round the work.



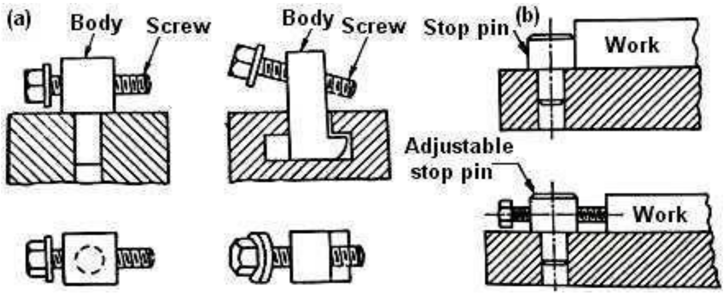


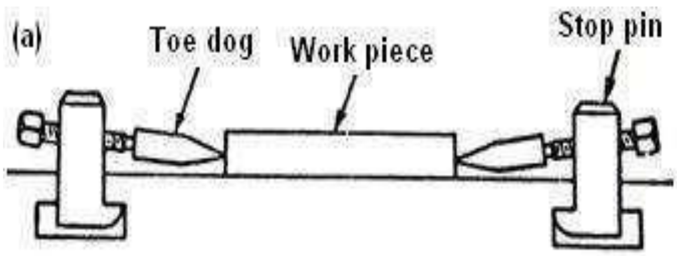
Fig. Use of T-bolt, step block and clamp **Fig. (a) Stop pins and (b) Use of stop pins**

Stop pins

- A stop pin is a one-leg screw clamp. Stop pins are used to prevent the work piece from coming out of position during the cutting stroke. The body of the stop pin is fitted in the slot on the table and the screw is tightened till it forces against the work.

Stop pins and toe dogs

- While holding thin work on the table stop pins in conjunction with toe dogs are used. A toe dog is similar in shape to that of a centre punch or a cold chisel.
- When screw of the stop pin is tightened, the work is gripped down on the table.



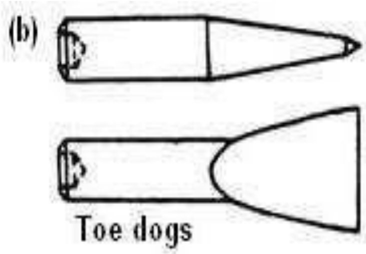


Fig. (a) Use of stop pins and toe dogs **Fig. (b) Toe dogs**

Strip and stop pin

Work having sufficient thickness is held on the table by strip and stop pin. A strip is a long bar having a tongue with holes for fitting the T-bolts. The strip with bolts is fitted in the T-slot of the table.

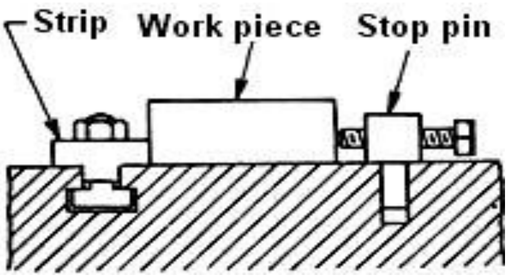


Fig. 18 Use of strip and stop pin

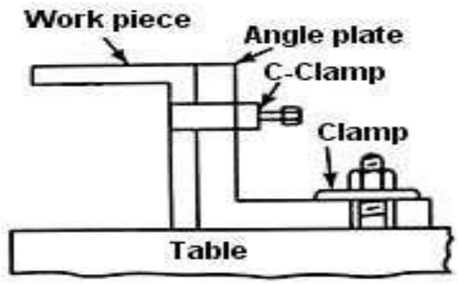


Fig. 19 Use of angle plate

Angle plate

- For holding “L” shaped work piece, angle plate is used. Angle plate is made of cast iron and is accurately planed on two sides at right angles.
- One of the sides is clamped to the table by T-bolts while the other side holds the work by clamps.

V- blocks

- V-blocks are used for holding round rods. Work piece may be supported on two V-blocks at its two ends and is clamped to the table by T-bolts and clamps.
- V-blocks are made of cast iron or steel and are accurately machined.

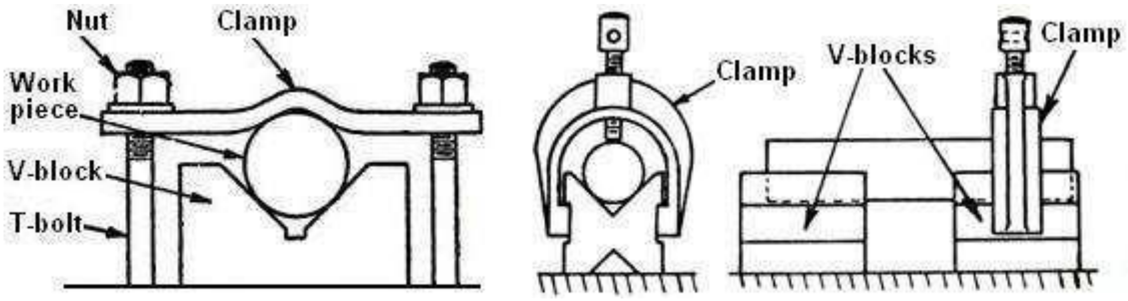
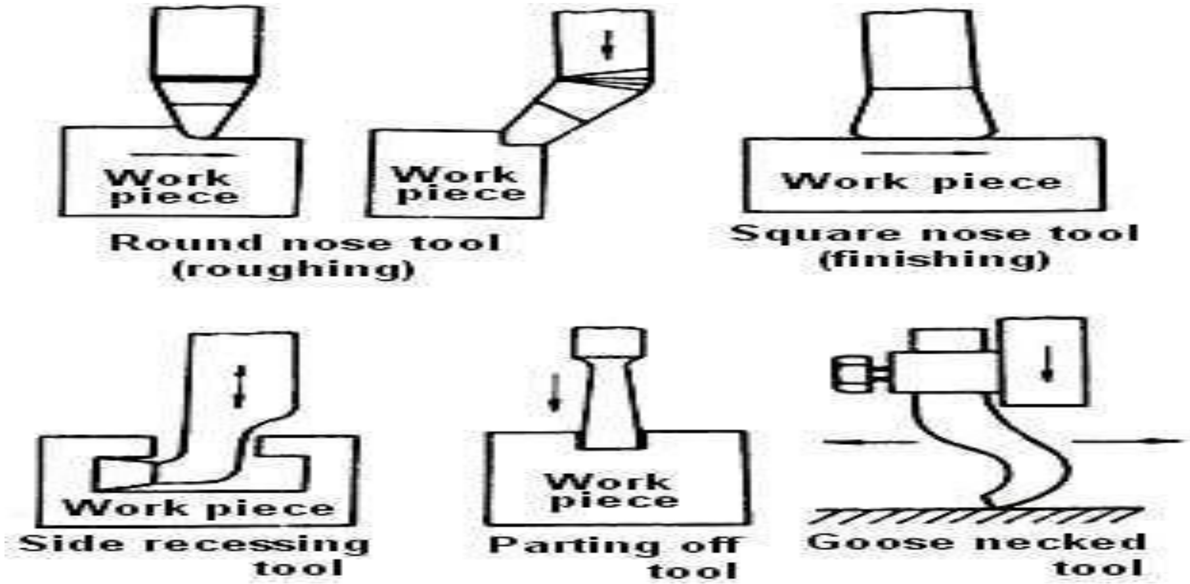


Fig. Use of V-block

7. Write the classification of shaper.

SHAPER TOOLS

- The cutting tool used in a shaper is a single point cutting tool having rake, clearance and other tool angles similar to a lathe tool. It differs from a lathe tool in tool angles.
- Shaper tools are much more rigid and heavier to withstand shock experienced by the cutting tool at the commencement of each cutting stroke.
- In a shaper tool the amount of side clearance angle is only 2^0 to 3^0 and the front clearance angle is 4^0 for cast iron and steel. Small clearance angle adds strength to the cutting edge.



Classification of shaper tools

The shaper tools are classified as follows:

According to the shape:

- Straight tool.
- Cranked tool.
- Goose necked tool.

According to the direction of cutting:

- Left hand tool.
- Right hand tool.

According to the finish required:

- Roughing tool.
- Finishing tool.

According to the type of operation:

- Down cutting tool.
- Parting off tool.
- Squaring tool.
- Side recessing tool.

According to the shape of the cutting edge:

- Round nose tool.
- Square nose tool

Round nose tool:

- This is used for roughing operations. The tool has no top rake. It has side rake angle, in between 10 to 20^0. Round tool is of two types - plain and bent types.
- The plain straight type is used for rough machining of horizontal surface. Round nose tool can be left handed or right handed.
- Another type of round nose tool which is cranked or bent is used for machining vertical surfaces. It is known as round nose cutting down tool.

Square nose tool:

- This tool is used for finishing operations. The cutting edge may have different widths. It is also used to machine the bottom surfaces of key ways and grooves.

Side recessing tool:

- ❖ This is a special tool used for machining T-slots and narrow vertical surfaces. This tool can be both left handed and right handed.

Parting off tool:

- ❖ This is used for parting off operation. It is also used for cutting narrow slots. It has no side rake angle. It has front and side clearance angle of 3^0.

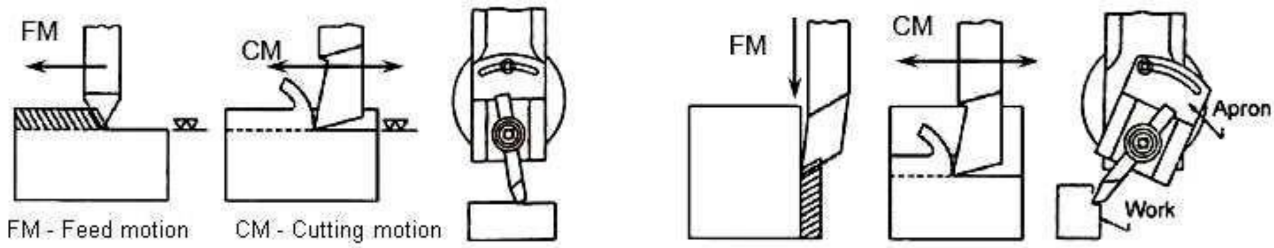
Goose necked tool:

- ❖ This is also known as spring tool. The special shape of tool reduces chatter and prevents digging of tool into the work piece. This tool is generally used for finishing cast iron.

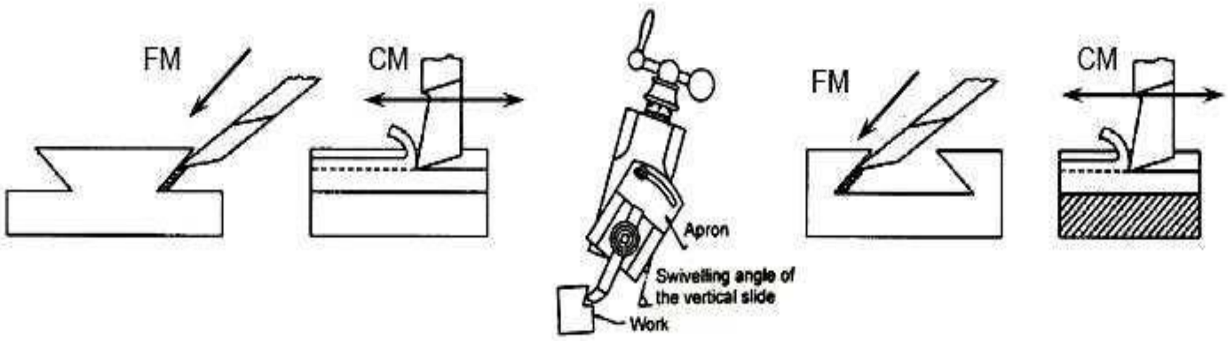
8. Write short notes on shaper operations.

- ❖ A shaper is a versatile machine tool primarily designed to generate a flat surface by a single point cutting tool. But it may also be used to perform many other operations. The different operations which a shaper can perform are as follows:

Machining flat surfaces in different planes



(a) Horizontal surface **(b) Vertical surface**



(a)

(c) Inclined surfaces (dovetail slides and guides)

Fig. Machining of flat surfaces in a shaper

Making features like slots, steps etc. which are also bounded by flat surfaces

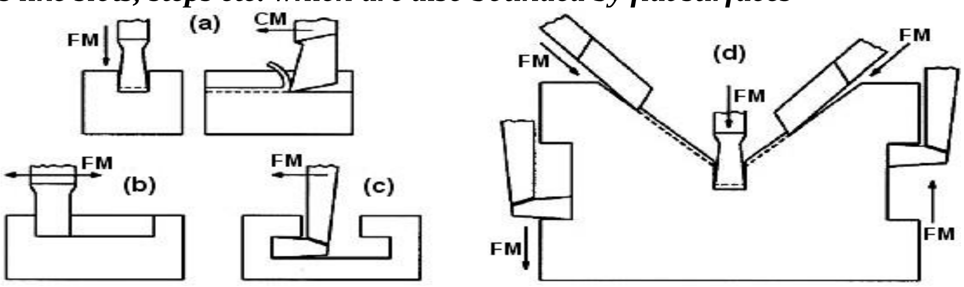


Fig. Machining (a) Slot (b) Pocket (c) T-slot and (d) V-block in a shaper

Forming grooves bounded by short width curved surfaces

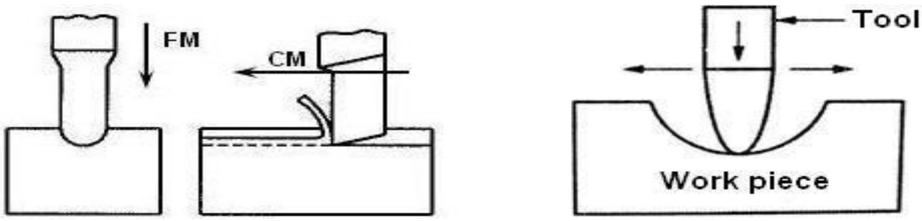


Fig. Making grooves in a shaper by form tools

Cutting external and internal keyways

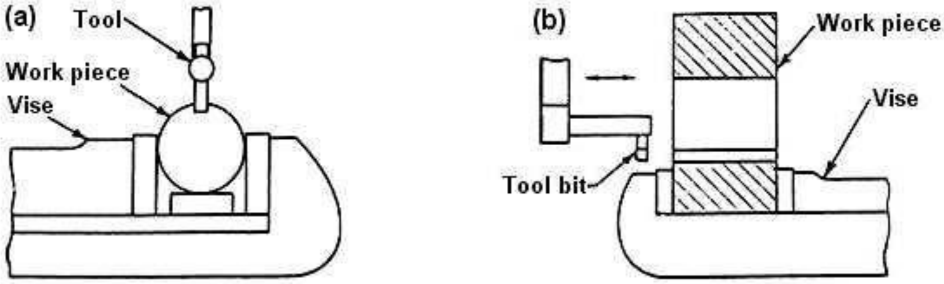


Fig. Machining of (a) External keyway and (b) Internal keyway in a shaper

The methods of machining (a) External keyway and (b) Internal keyway in a shaper by using single point tools.

Machining of external gears, external and internal spline

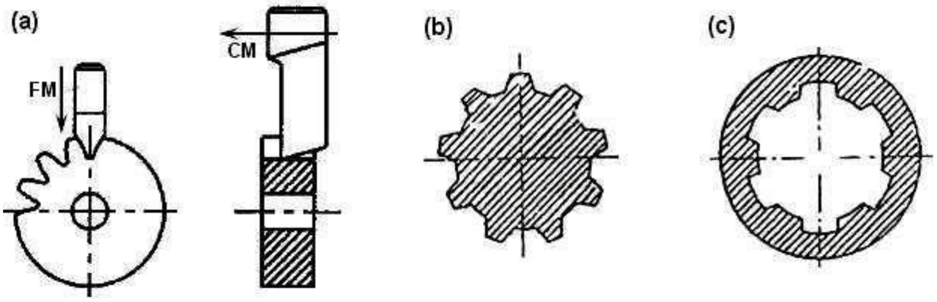


Fig. Machining of (a) External gear (b) External splines and (c) Internal splines in a shaper

Some other machining applications of shaper are smooth slitting or parting, cutting teeth of rack for repair etc. using simple or form type single point cutting tools. Some unusual work can also be done, if needed, by developing and using special attachments. However, due to very low productivity, less versatility and poor process capability, shapers are not employed for lot and batch production.

DRILLING

Drilling is the process of originating holes in the work piece by using a rotating cutter called drill. The machine used for this purpose is called drilling machine. Although it was primarily designed to originate a hole, it can perform a number of similar operations. In a drilling machine holes may be drilled quickly and at a low cost. As the machine tool exerts vertical pressure to originate a hole it is also called drill press. Holes were drilled by the Egyptians in 1200 B.C. by bow drills. The bow drill is the mother of present day metal cutting drilling machine

Types of drilling machine

The different types of drilling machine which are most commonly used are:

- Portable drilling machine.
- Sensitive drilling machine (Bench mounting or table top and Floor mounting).
- Upright drilling machine (Pillar or Round column section and Box column section).
- Radial drilling machine (Plain, Semi-universal and Universal).
- Gang drilling machine.
- Multiple spindle drilling machine.
- Deep hole drilling machine.
- Turret type drilling machine

But in working principle all are more or less the same.

1. Portable drilling machine or hand drilling machine

Unlike the mounted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled. The small and reasonably light hand drilling machines are run by a high speed electric motor. In fire hazardous areas the hand drilling machine is often rotated by compressed air. The maximum size of the drill that it can accommodate is not more than 12 to 18 mm.

2. Bench mounting or table top sensitive drilling machine

This small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machine is mounted on rigid table and manually operated using usually small size (φ ≤ 10 mm) drills.

9. Sketch and explain the working principle of floor mounting sensitive drilling machine.

3. Floor mounting sensitive drilling machine

- The floor mounting sensitive drilling machine is a small machine designed for drilling small holes at high speed in light jobs. The base of the machine is mounted on the floor.
- It consists of a vertical column, a horizontal table, a head supporting the motor and driving mechanism, and a vertical spindle for driving and rotating the drill.
- There is no arrangement for any automatic feed of the drill spindle. The drill is fed into the work by purely hand control.

Fig. Hand drilling machine **Fig. Table top sensitive drilling machine**

- High speed is necessary for drilling small holes. High speeds are necessary to attain required cutting speed by small diameter drill.
- Hand feed permits the operator to feel or sense the progress of the drill into the work, so that if the

drill becomes worn out or jams on any account, the pressure on the drill may be released immediately to prevent it from breaking.

- ❖ As the operator senses the cutting action, at any instant, it is called sensitive drilling machine. Sensitive drilling machines are capable of rotating drills of diameter from 1.5 to 15.5 mm.
- ❖ Super sensitive drilling machines are designed to drill holes as small as 0.35 mm in diameter and the machine is rotated at a high speed of 20,000 r.p.m. or above.

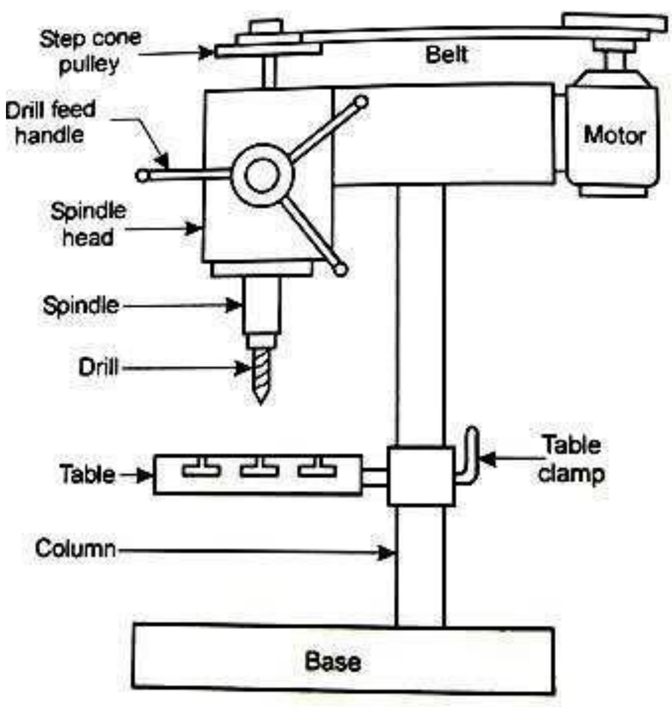


Fig. Floor mounting sensitive drilling machine

Fig. Pillar drilling machine

10. Sketch and explain the working principle of upright drilling machine. (Nov/Dec 2006)

- ❖ This machine is usually called pillar drilling machine. It is quite similar to the table top drilling machine but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are mounted on the floor.
- ❖ In this machine the drill feed and the work table movements are done manually. This low cost drilling machine has a base, a tall tubular column, an arm supporting the table and a drill head assembly.
- ❖ The arm may be moved up and down on the column and also be moved in an arc up to 180^0 around the column. The table may be rotated 360^0 about its own centre independent of the position of the arm.
- ❖ It is generally used for small jobs and light drilling. The maximum size of holes that can be drilled is not more than 50 mm.

5. Box column section upright drilling machine

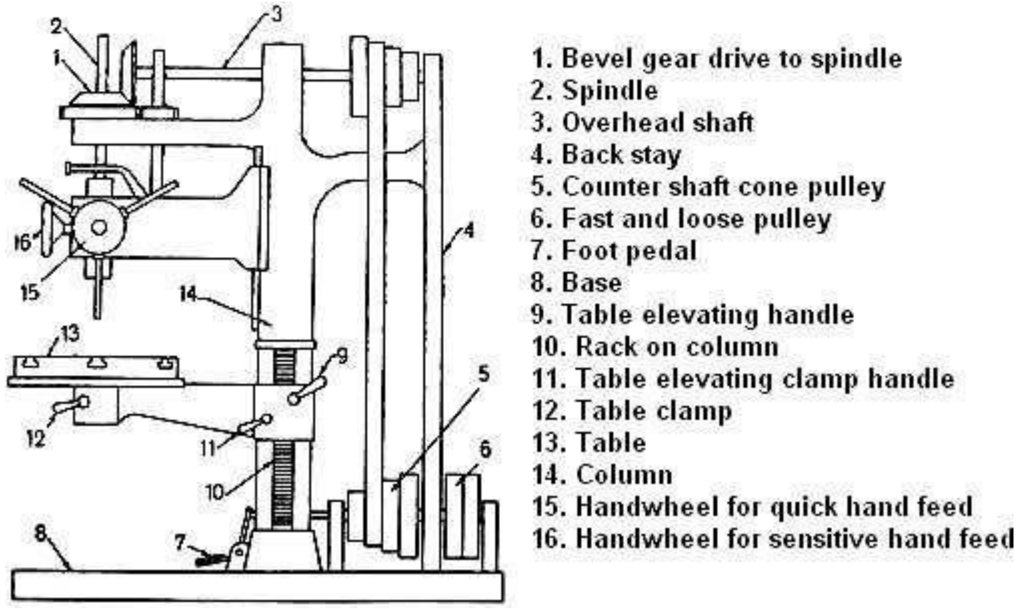
The major parts are:

Base: It is a part of the machine on which vertical column is mounted. The top of the base is accurately machined and has T-slots on it so that large work pieces and work holding devices may be set up and bolted to it.

Drill head: It is mounted on the top of the column and houses the driving and feeding mechanism for the spindle. In some of the machines the drill head may be adjusted up or down for accommodating different heights of work in addition to the table adjustment.

Spindle: Holds the drill and transmits rotation and axial translation to the tool for providing cutting motion and feed motion - both to the drill.

Fig. Box column section upright drilling machine



11. With a line diagram, describe the construction of radial drilling machine. (Nov/ Dec 2006).

The major parts are:

Base: It is a large rectangular casting that is finished on its top to support a column on its one end and to hold the work table at the other end. In some machines T-slots are provided on the base for clamping work when it serves as a table.

Column: The column is a cylindrical casting that is mounted vertically at one end of the base. It supports the radial arm which may slide up or down on its face.

An electric motor is mounted on the top of the column which imparts vertical adjustment of the arm by rotating a screw passing through a nut attached to the arm.

Radial arm: The radial arm that is mounted on the column extends horizontally over the base. It is a massive casting with its front vertical face accurately machined to provide guide ways on which the drill head may be made to slide. The arm may be swung round the column. In some machines this movement is controlled by a separate motor.

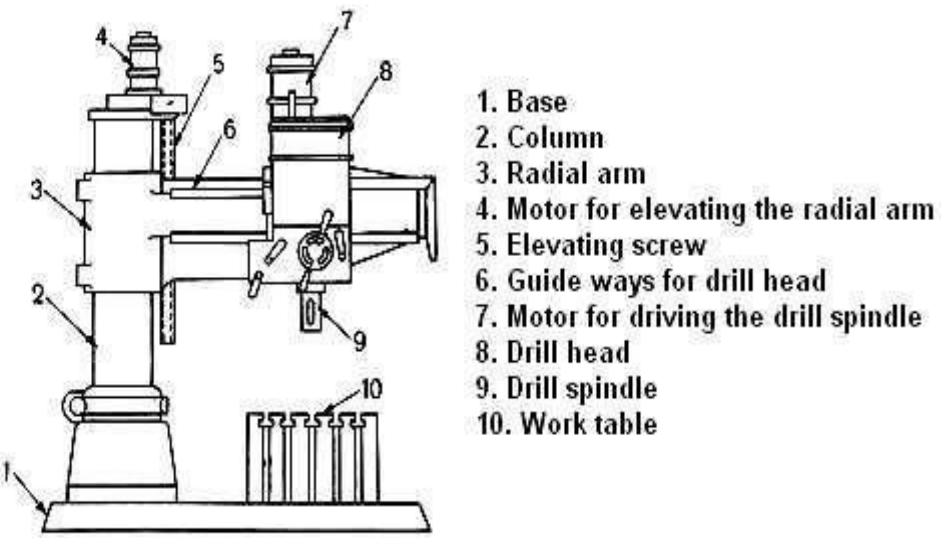


Fig. Radial drilling machine

Drill head: The drill head is mounted on the radial arm and drives the drill spindle. It encloses all the mechanism for driving the drill at multiple speeds and at different feed. All the mechanisms and controls are housed within a small drill head which may be made to slide on the guide ways of the arm for adjusting the position of drill spindle with respect to the work.

Spindle drive and feed mechanism:

There are two common methods of driving the spindle. A constant speed motor is mounted at the extreme end of the radial arm. The motor drives a horizontal spindle which runs along the length of the arm and the motion is transmitted to the drill head through bevel gears. By the gear train within the drill head, the speed of the spindle may be varied. Through another gear train within the drill head, different feeds of the spindle are obtained. In some machines, a vertical motor is fitted directly on the drill head and through gear box multiple speed and the feed of the spindle can be obtained.

Working principle

- The work is mounted on the table or when the work is very large it may be placed on the floor or in a pit.
- Then the position of the arm and the drill head is altered so that the drill may be pointed exactly on the location where the hole is to be drilled.
- When several holes are drilled on a large work piece, the drill head is moved from one position to the other after drilling the hole without altering the setting of the work.
- This versatility of the machine allows it to work on large work pieces. There are some more machines where the drill spindle can be additionally swiveled and / or tilted.

7. Gang drilling machine

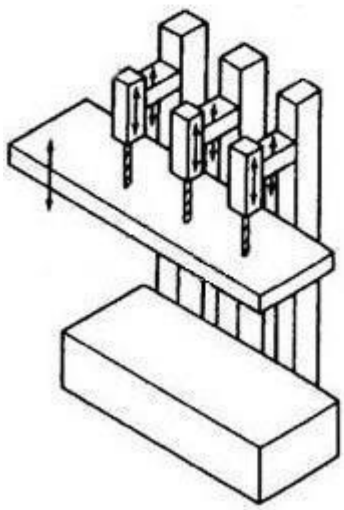


Fig. Gang drilling machine

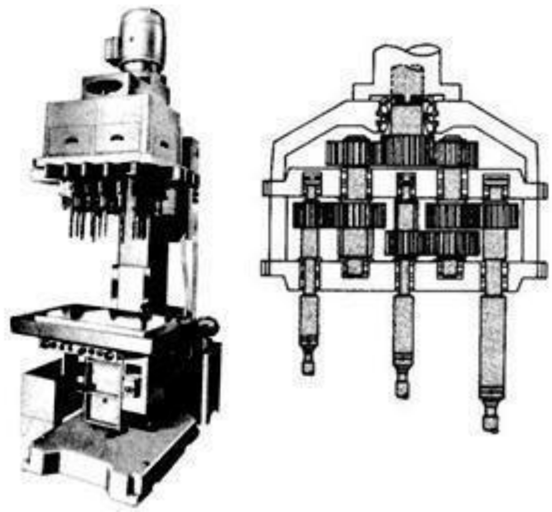


Fig. Multiple spindle drilling machines

In this almost single purpose and more productive drilling machine a number of spindles (2 to 6) with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig.

8. Multiple spindle drilling machine

- In this high production machine a large number of drills work concurrently on a blank through ajig specially made for the particular work.
- The entire drilling head works repeatedly using the same jig for batch or lot production.
- The rotations of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear and the corresponding flexible shafts.
- The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job.
- Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length.

- In some heavy duty multi spindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.

12. Write short notes on deep hole drilling. (Nov/ Dec 2013 & April/ May 2014)

- Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles, oil holes in shafts, bearings, connecting rods etc, are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal.
- Such drilling cannot be done in ordinary drilling machines and by using ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis or vertical axis.

- These machines are provided with:

  a. High spindle speed.
  b. High rigidity.
  c. Tool guide.

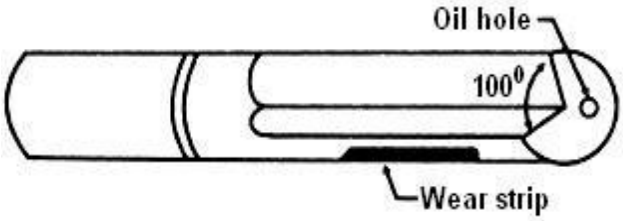


Fig. Deep hole drill

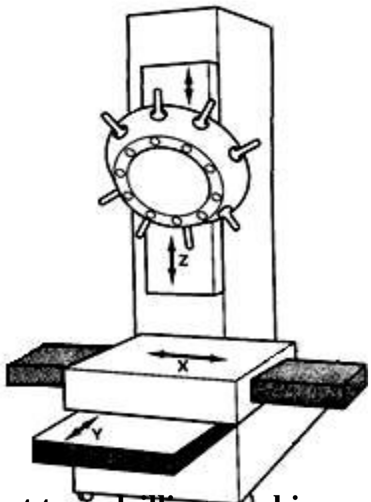


Fig. Turret type drilling machine

Turret type drilling machine

Turret drilling machine is structurally rigid column type drilling machine but is more productive like gang drill machine by having a pentagon or hexagon turret. The turret holds a number of drills and similar tools, is indexed and moved up and down to perform quickly the desired series of operations progressively. These drilling machines are available with varying degree of automation both fixed and flexible type.

13. a. Explain the feed mechanism in lathe.

In a drilling machine, the feed is effect by the vertical movement of the drill into the work. The feed movement of the drill may be controlled by hand or power.

The hand feed may be applied by two methods:

- Quick traverse hand feed.
- Sensitive hand feed.

The quick traverse feed is used to bring the cutting tool rapidly to the hole location or for withdrawing the drill when the operation is completed. Quick hand feed is obtained by rotating the hand wheel pivoted to the pinion. One turn of the hand wheel will cause the pinion to rotate through one complete revolution giving quick hand feed movement of the spindle.

The sensitive hand feed is applied for trial cut and for drilling small holes. The sensitive feed hand wheel is attached to the rear end of the worm shaft. Rotation of the hand wheel will cause the worm and worm gear to rotate and a slow but sensitive feed is obtained.

The automatic feed is applied while drilling larger diameter holes as the cutting pressure required is sufficiently great. The gear A rotates with the spindle as the spindle passes through it. Gear B is connected with gear A, so it also rotates. The shaft S rotates with the gear B as it connected to it.

At a suitable distance under the shaft, there is a worm which drives a pinion. The pinion is connected with the rack on the non-rotating sleeve (quill) fitted over the spindle. The rotation of the worm rotates the pinion.

The rotation of the pinion moves the quill up and down through the rack cut on it. The quill moves the drill spindle up and down. Thus the automatic feed of the drill spindle is achieved. Different ranges of feed can be obtained by means of feed gearbox.

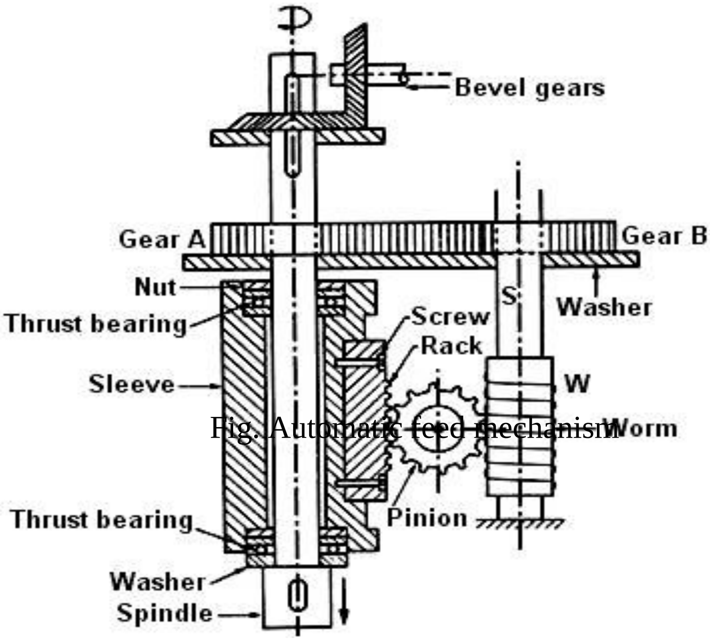


Fig. Automatic feed mechanism

13. b. Classify the drilling tools based on various applications.

Different types of drills are properly used for various applications depending upon work material, tool material, depth and diameter of the holes. General purpose drills may be classified as:

According to material:

- High speed steel - most common.
- Cemented carbides.
- Without or with coating.
- In the form of brazed, clamped or solid.

According to size:

- Large twist drills of diameter around 40 mm.
- Micro drills of diameter 25 µm to 500 µm.
- Medium range diameter ranges between 3 mm to 25 mm (most widely used).

According to number of flutes:

- Two fluted - most common.
- Single flute - e.g., gun drill (robust).
- Three or four flutes - called slot drill.
-

According to helix angle of the flutes:

- Usual: 20^0 to 35^0 - most common.
- Large helix: 45^0 to 60^0 - suitable for deep holes and softer work materials.

- Small helix: for harder / stronger materials.
- Zero helix: spade drills for high production drilling micro-drilling and hard work materials.

According to length to diameter ratio:

- Deep hole drill; e.g. crank shaft drill, gun drill etc.
- General type: L/φ ≅ 6 to 10.
- Small length: e.g. centre drill.

According to shank:

- Straight shank - small size drill being held in drill chuck.
- Taper shank - medium to large size drills being fitted into the spindle nose directly or through taper sockets and sleeves.

According to specific applications:

- Centre drill for small axial holes with 60^0 taper ends to hold the lathe centre.
- Step drill and sub land drill for small holes with 2 or 3 steps.
- Half round drill, gun drill and crank shaft drill for making oil holes.
- Ejector drill for high speed drilling of large diameter holes.
- Taper drill for batch production.

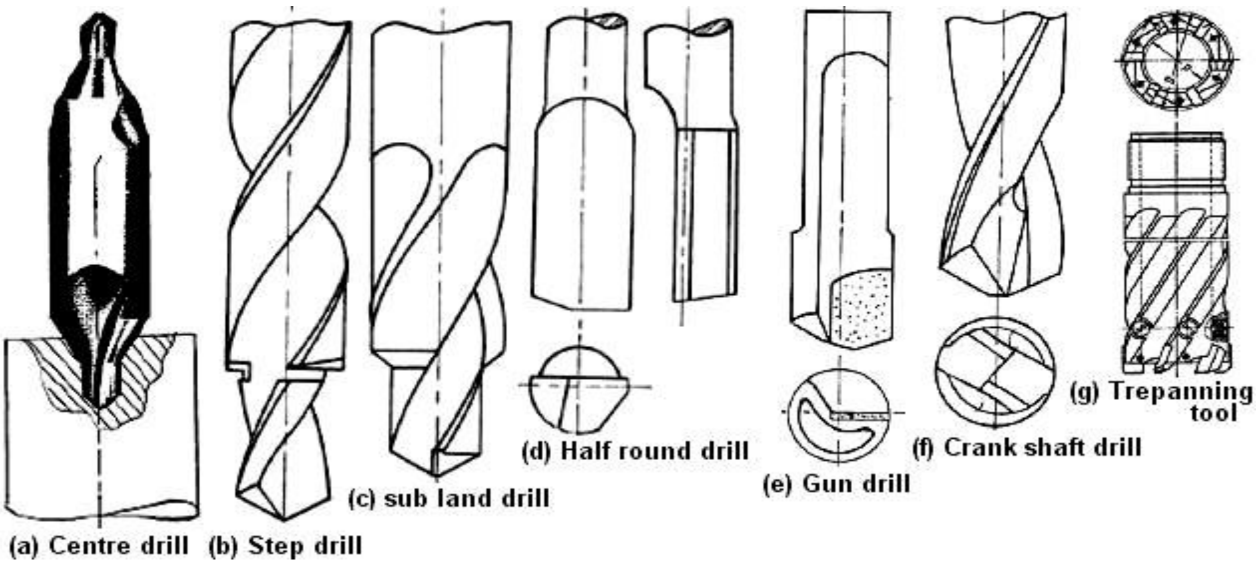


Fig. Different types of drills used in various applications

13. Explain the twist drill nomenclature and define various elements of twist drill. (April/May 2004, Nov/ Dec 2008 & May/June 2009)

Twist drill elements

Axis: The longitudinal centre line of the drill.

Body: That portion of the drill extending from its extreme point to the commencement of the neck, if present, otherwise extending to the commencement of the shank.

Body clearance: That portion of the body surface which is reduced in diameter to provide diametral clearance.

Chisel edge: The edge formed by the intersection of the flanks. The chisel edge is also sometimes called dead centre.

Chisel edge corner: The corner formed by the intersection of a lip and the chisel edge.

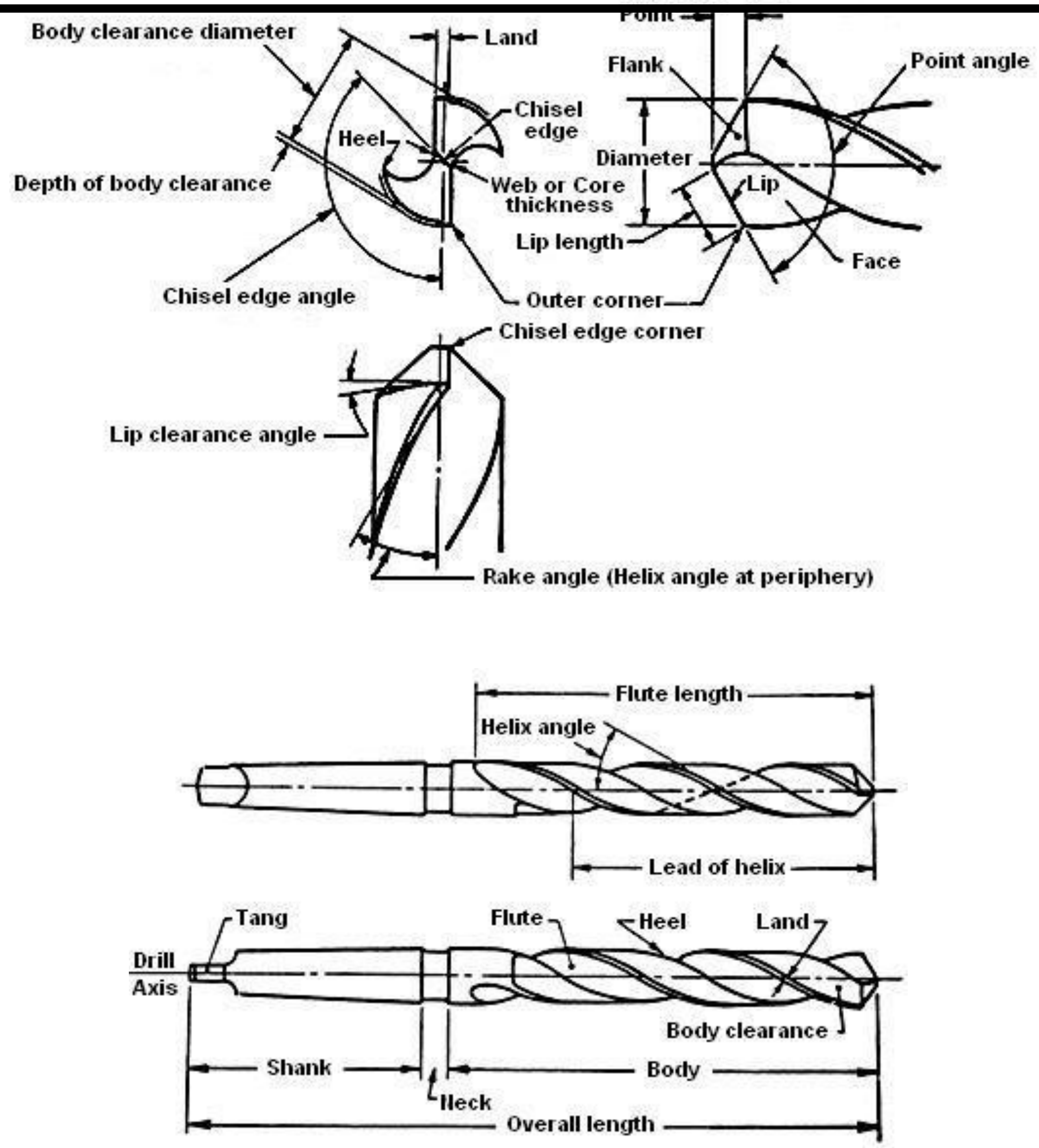


Fig. Twist drill nomenclature

Face: The portion of the flute surface adjacent to the lip on which the chip impinges as it is cut from the work.

Flank: That surface on a drill point which extends behind the lip to the following flute.

Flutes: The groove in the body of the drill which provides lip.

The functions of the flutes are:

- ⇨ To form the cutting edges.
- ⇨ To allow the chips to escape.
- ⇨ To cause the chips to curl.
- ⇨ To permit the cutting fluid to reach the cutting edges.

Heel: The edge formed by the intersection of the flute surface and the body clearance.

Lands: The cylindrically ground surface on the leading edges of the drill flutes. The width of the land is measured at right angles to the flute helix.

Lip (cutting edge) The edge formed by the intersections of the flank and face.

The requirements of the drill lip are:

- ⇨ Both lips should be at the same angle of inclination (59^0) with the drill axis.

- ⇨ Both lips should be of equal length.
- ⇨ Both lips should be provided with the correct clearance.

Neck: The diametrically undercut portion between the body and the shank of the drill.Diameter and other particulars of the drill are engraved at the neck.

Outer corner: The corner formed by the intersection of the flank and face.

Point: The sharpened end of the drill, which is shaped to produce lips, faces, flanks and chisel edge.

Shank: That part of the drill by which it is held and driven. The most common types of shank are the taper shank and the straight shank.

Tang: The flattened end of the taper shank intended to fit into a drift slot in the spindle, socket or drill holder. The tang ensures positive drive of the drill from the spindle.

Web: The central portion of the drill situated between the roots of the flutes and extending from the point toward the shank; the point end of the web or core forms the chisel edge.

Linear dimensions

Back taper (longitudinal clearance) It is the reduction in diameter of the drill from the point towards the shank. This permits all parts of the drill behind the point to clear and not rub against the sides of the hole being drilled. The taper varies from 1:4000 for small diameter drills to 1:700 for larger diameters.

Body clearance diameter: The diameter over the surface of the drill body which is situated behind the lands.

Depth of body clearance: The amount of radial reduction on each side to provide body clearance.

Diameter: The measurement across the cylindrical lands at the outer corners of the drill.

Flute length: The axial length from the extreme end of the point to the termination of the flute at the shank end of the body.

Lead of helix The distance measured parallel to the drill axis between the corresponding points on the leading edge of the flute in one complete turn of the flute.

Lip length: The minimum distance between the outer corner and the chisel edge corner of the lip.

Overall length: The length over the extreme ends of the point and the shank of the drill.

Web (core) taper: The increase in the web or core thickness from the point of the drill to the shank end of the flute. This increasing thickness gives additional rigidity to the drill and reduces the cutting pressure at the point end.

Web thickness: The minimum dimension of the web or core measured at the point end of the drill.

DRILL ANGLES

The obtuse angle included between the chisel edge and the lip as viewed from the end of the drill.

Helix angle or rake angle: This is the angle formed by the leading edge of the land with a plane having the axis of the drill.

Point angle: This is the angle included between the two lips.

Lip clearance angle: The angle formed by the flank and a plane at right angles to the drill axis.

14. Sketch the following operations performed in drilling machine.

1. Drilling 2. Reaming 3. Boring 4. Counter boring 5. Counter sinking 6. Tapping (April/May 2010 & 12)

Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing holes:

- Of different diameters up to 40 mm.
- Of varying length depending upon the requirement and the diameter of the drill.
- In different materials excepting very hard or very soft materials like rubber, polythene etc.
- Originating stepped cylindrical holes of different diameter and depth.
- Making rectangular section slots by using slot drills having 3 or 4 flutes and 180^0 cone angle.
- Boring, after drilling, for accuracy and finish or prior to reaming
- Counter boring, countersinking, chamfering or combination using suitable tools.
- Spot facing by flat end tools.
- Trepanning for making large through holes and or getting cylindrical solid core.

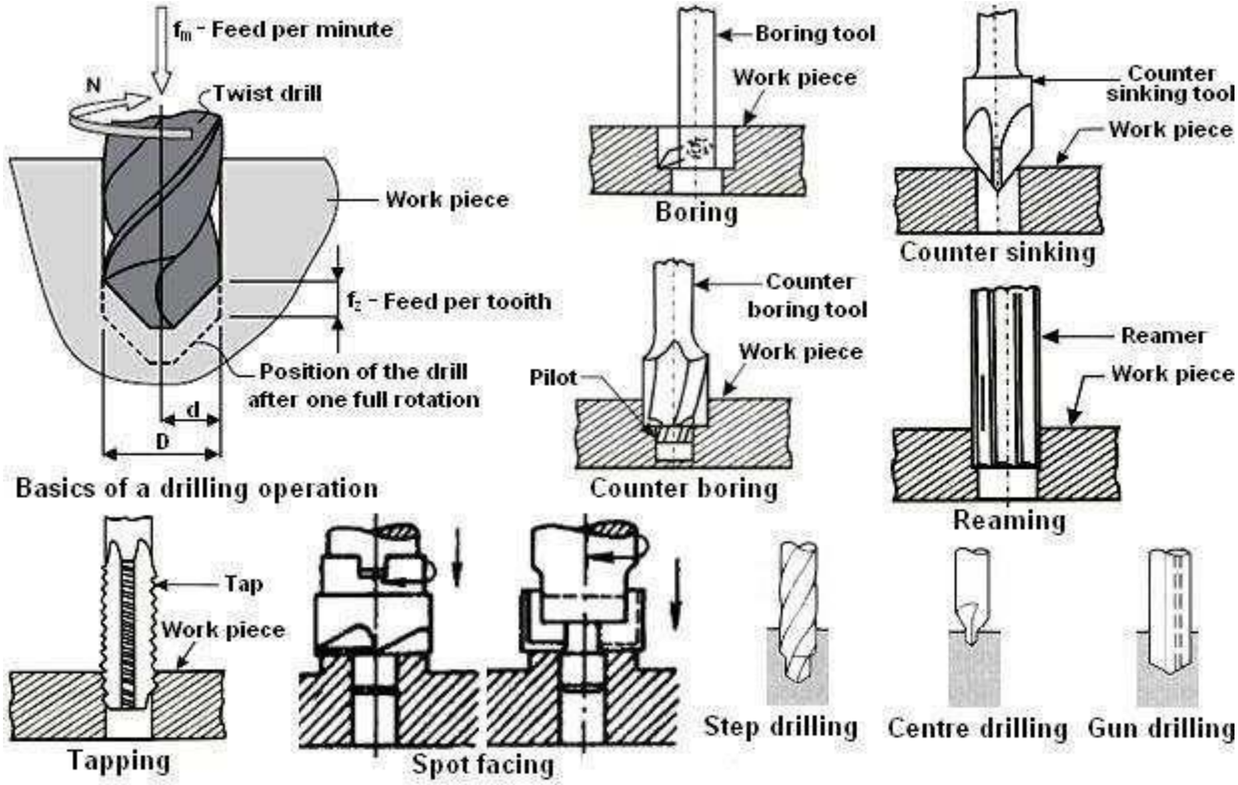
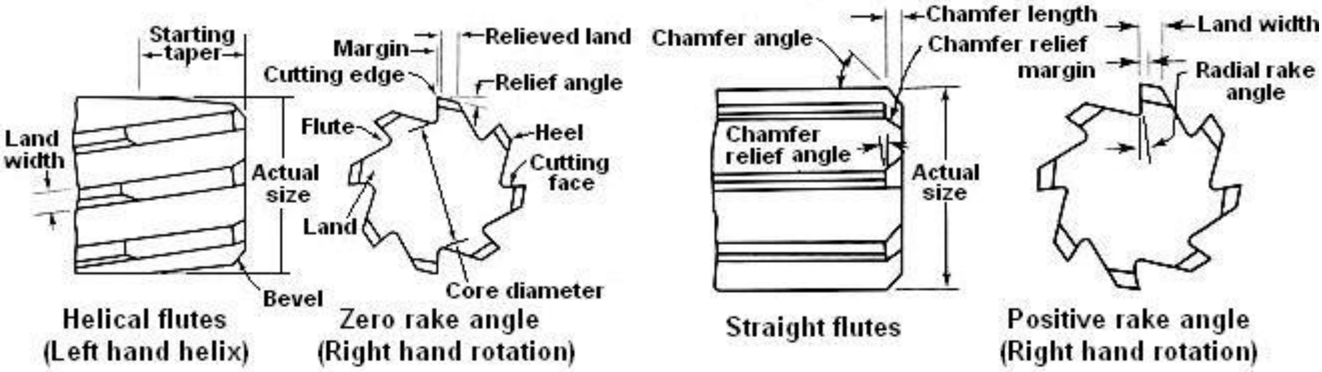


Fig. Different operations performed in a drilling machine

15. Write short notes on reaming operation. (Nov/Dec 2008 & April/May 2014)

Reaming is an operation of finishing a hole previously drilled to give a good surface finish and an accurate dimension. A reamer is a multi- tooth cutter which rotates and moves axially into the hole. The reamer removes relatively small amount of material. Generally the reamer follows the already existing hole and therefore will not be able to correct the hole misalignment.



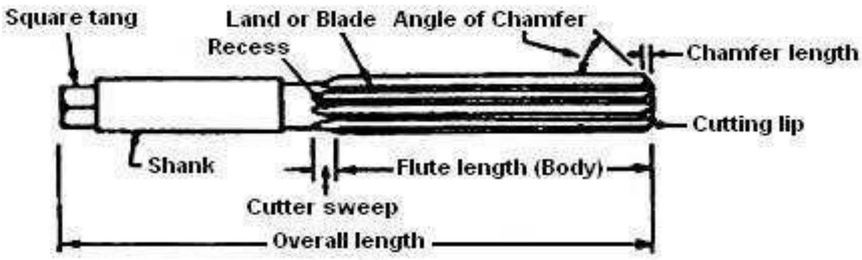


Fig. Elements of a reamer

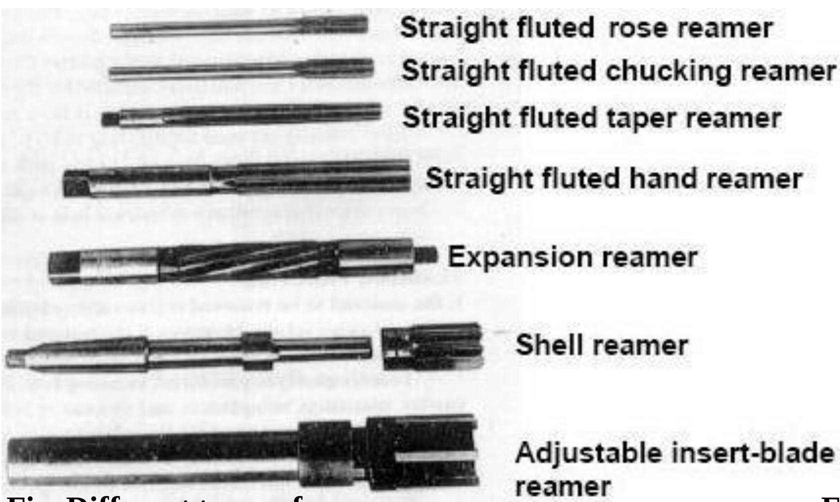


Fig. Different types of reamers

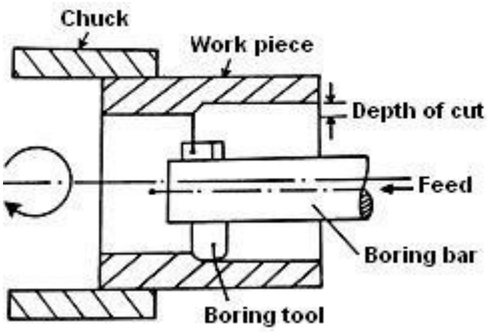


Fig. Principle of boring operation

16. Write short notes on boring machine. (Nov/ Dec 2008)

Boring is an operation of enlarging and locating previously drilled holes with a single point cutting tool. The machine used for this purpose is called boring machine. The boring machine is one ofthe most versatile machine tools used to bore holes in large and heavy parts such as engine frames, steam engine cylinders, machine housings etc. Drilling, milling and facing operations also can be performed in this machine.

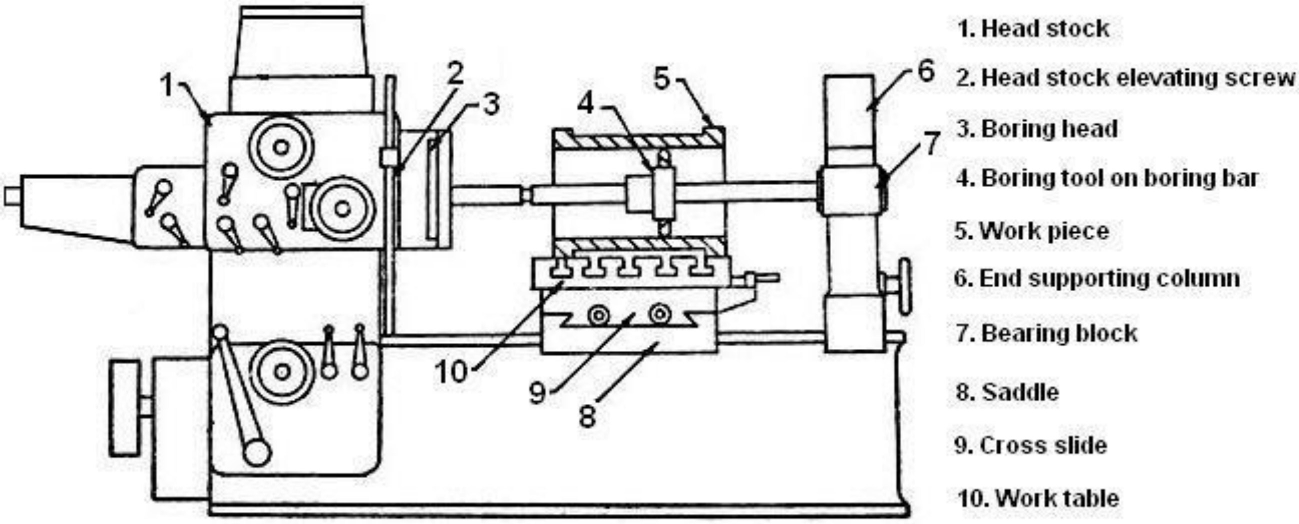


Fig. Basic configuration of a horizontal boring machine

Horizontal boring machines

- ❖ In horizontal boring machine, the tool revolves and the work is stationary. A horizontal boring machine can perform boring, reaming, turning, threading, facing, milling, grooving, recessing and many other operations with suitable tools.
- ❖ Work pieces which are heavy, irregular, unsymmetrical or bulky can be conveniently held and machined. This machine has two vertical columns. A headstock slides up and down in one column. It may be adjusted to any desired height and clamped.
- ❖ The headstock holds the cutting tool. The cutting tool revolves in the headstock in horizontal axis. A sliding type bearing block is provided in the other vertical column.
- ❖ It is used to support the boring bar. The work piece is mounted on the table and is clamped with ordinary strap clamps, T-slot bolts and nuts, or it is held in a special fixture if so required.
- ❖ Various types of rotary and universal swiveling attachments can be installed on the horizontal boring machines table to bore holes at various angles in horizontal and vertical planes.

Types of horizontal boring machine

Different types of horizontal boring machines have been designed to suit different purposes. They are:

1. **Table type horizontal boring machine**

   The work is held stationary on a coordinate work table having in and out as well as back and forth movements that is perpendicular and parallel to the spindle axis. The spindle carrying the tool can be fed axially. Alternatively, the table travels parallel to the spindle axis (longitudinal feed). This method of boring with longitudinal feed of the table is employed when holes are of considerable length and being bending of the boring bar is possible.

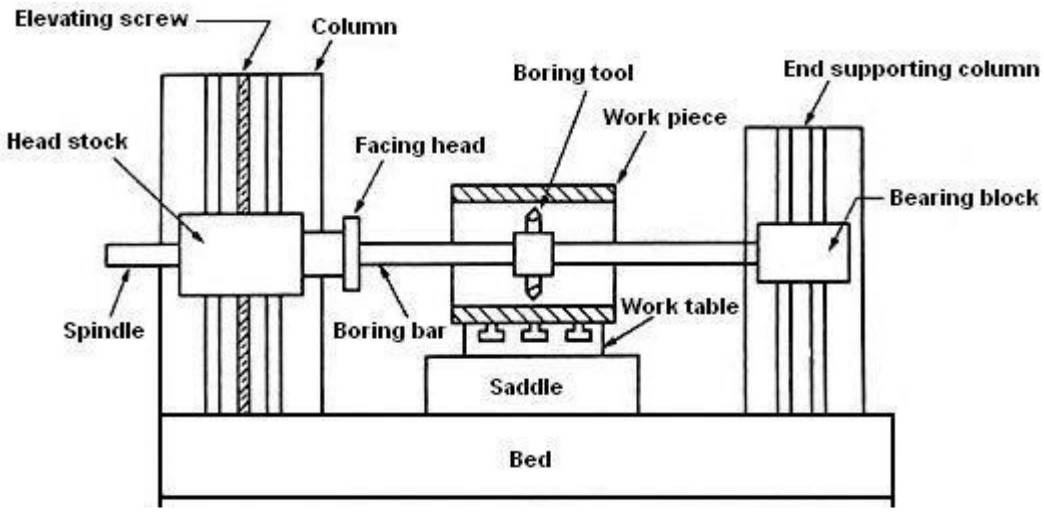


Fig. Table type horizontal boring machine

2. Planer type horizontal boring machine

This machine is similar to the table type horizontal boring machine except that the work table has only in and out movements that is perpendicular to the spindle axis. Other features and applications of this machine are similar to the table type horizontal boring machine. This type of machine is suitable for supporting a long work.

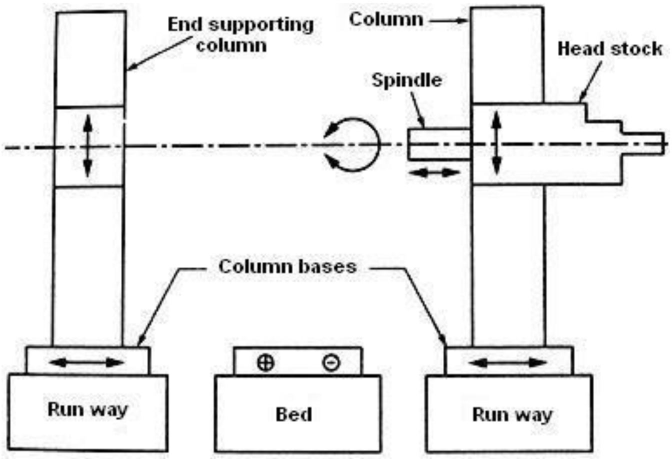


Fig. Planer type horizontal boring machine

3. Floor type horizontal boring machine

There is no work table and the job is mounted on a stationary T-slotted floor plate. This design is used when large and heavy jobs cannot be mounted and adjusted on the work table. Horizontal movement perpendicular to the spindle axis is obtained by traversing the column carrying the head stock, on guide ways.

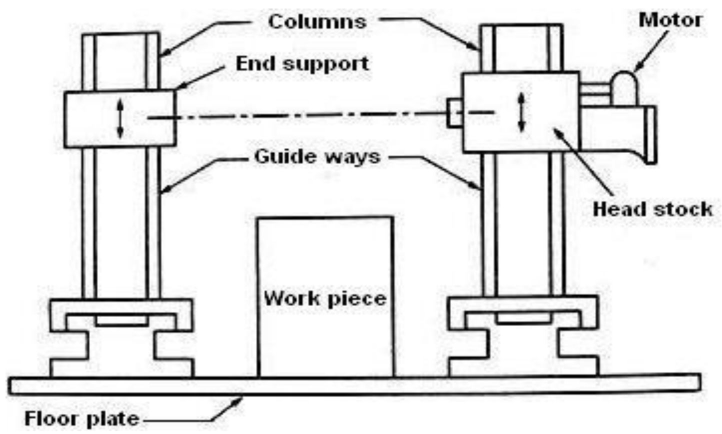


Fig. Floor type horizontal boring machine

4 Multiple head type horizontal boring machine

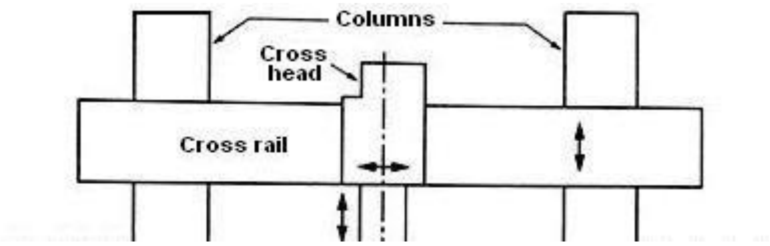


Fig. Multiple head type horizontal boring machine

The machine resembles a double housing planer or a Plano-miller and is used for boring holes of large diameter is mass production. The machine may have two, three or four headstocks. This type of machine may be used both as a horizontal and vertical machine

17. With neat sketches, explain the working of Vertical boring machines. (April/May 2004 & April/May 2013)

- ❖ For convenience, parts whose length or height is less than the diameter are machined on vertical boring machines.
- ❖ The typical works are: Large gear blanks, locomotive and rolling stock tires, fly wheels, large flanges, steam and water turbine castings etc.
- ❖ On a vertical boring machine, the work is fastened on a horizontal revolving table, and the cutting tool(s) which are stationary, advance vertically into it are as the table revolves.
- ❖ There are two types of vertical boring machine: Single column vertical boring machine and double column vertical boring machine. The single column vertical boring machine looks like a drilling machine or a knee type vertical milling machine.
- ❖ Guide ways are employed on the column to support the spindle head in the vertical direction. The work is accommodated on the horizontal revolving table at the front of the machine.
- ❖ The circular work can be clamped on to the table with the help of jaw chucks whereas the T-slots can be used with bolts and clamps for setting up and holding irregular work.
- ❖ A horizontal cross rail is carried on vertical slide ways and carries the tool holder slide(s). On

machines designed for working on large batches of identical parts, a single slide with turret may be employed.

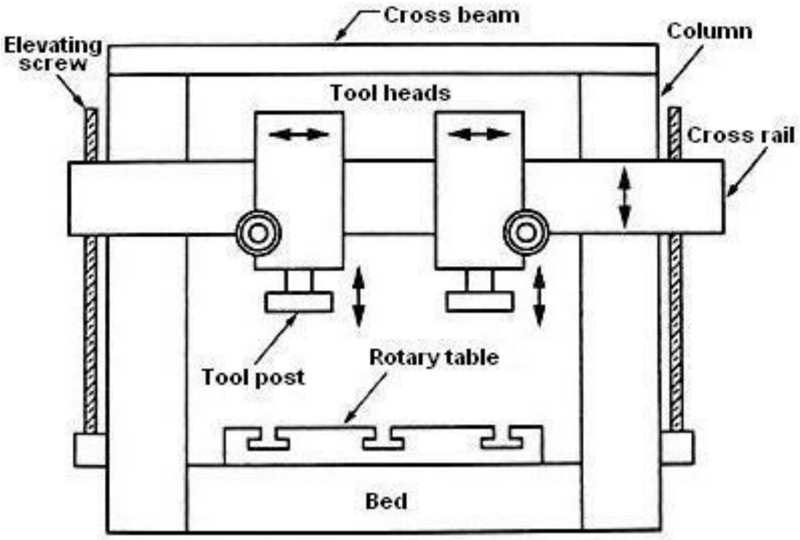


Fig. Double column vertical boring machine

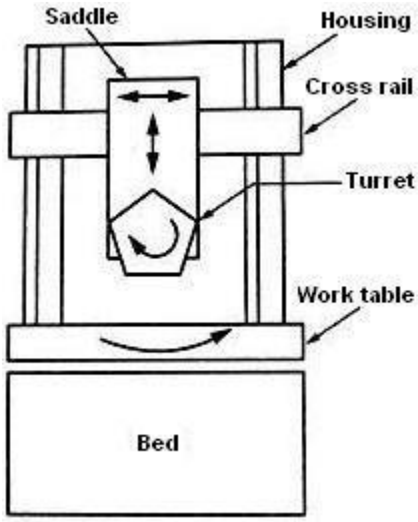


Fig. Turret boring machine

18. With neat sketches, explain the working of a Jig boring machine. (April/May 2004 & April/May 2013)

- It is very precise vertical type boring machine. The spindle and spindle bearings are constructed with very high precision. The table can be moved precisely in two mutually perpendicular directions in a plane normal to the spindle axis.
- The coordinate method for locating holes is employed. Holes can be located to within tolerances of 0.0025 mm. Jig boring machines are relatively costlier. Hence, they are found only in the large machine shops, where a sufficient amount of accurate hole locating is done.
- Jig boring machines are basically designed for use in the making jigs, fixtures and other special tooling.
- A boring tool consists of a single point cutting tool (boring bit) held in a tool holder known as boring bar. The boring bit is held in a cross hole at the end of the boring bar. The boring bit is adjusted and held in position with the help of set screws.
- The material of the boring bit can be: Solid HSS, solid carbide, brazed carbide, disposable carbide tips or diamond tips. Boring tools are of two types: fixed type and rotating type.

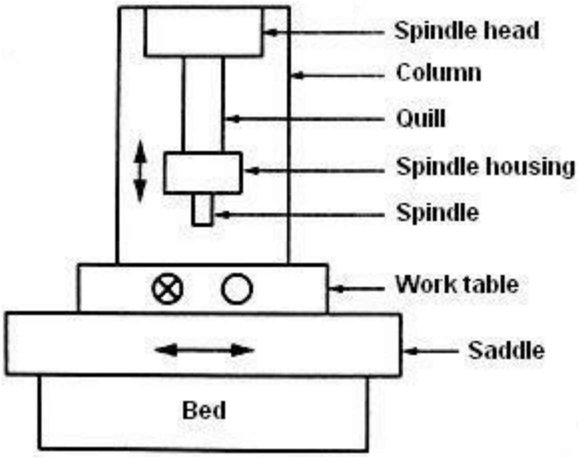


Fig. Block diagram of a jig boring machine

- Fixed type boring tools are used on working rotating machines such as lathes, whereas rotating type boring tools are used on tool rotating machines such as drilling machines, milling machines and boring machines.

20. Explain tapping process.

Tapping is the faster way of producing internal threads. A tap is a multi-fluted cutting tool with cutting edges on each blade resembling the shape of threads to be cut. A tap is used after carrying out the pre drilling operation corresponding to the required size.

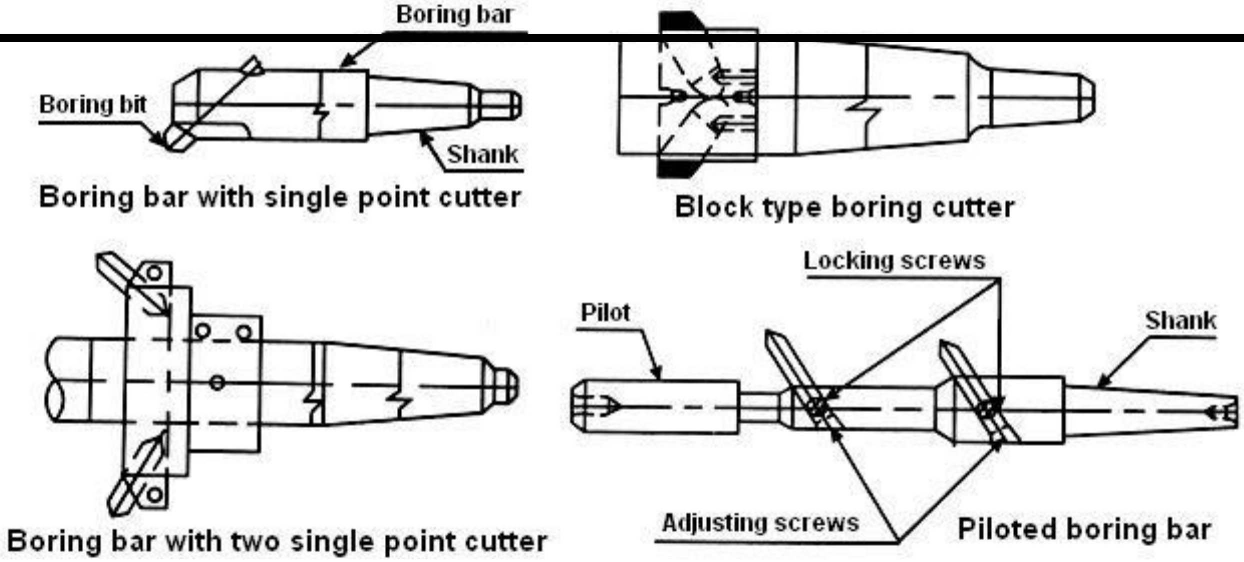


Fig. Different types of boring tools (bars)

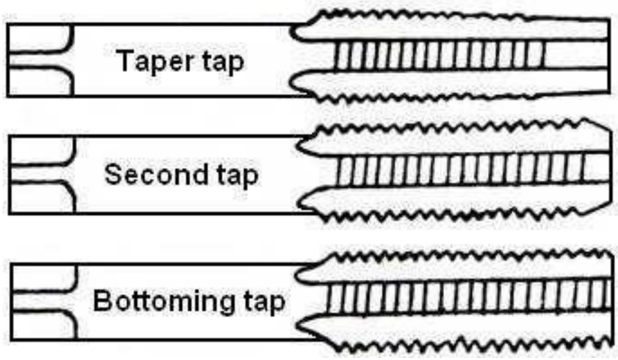


Fig. Hand (solid) taps

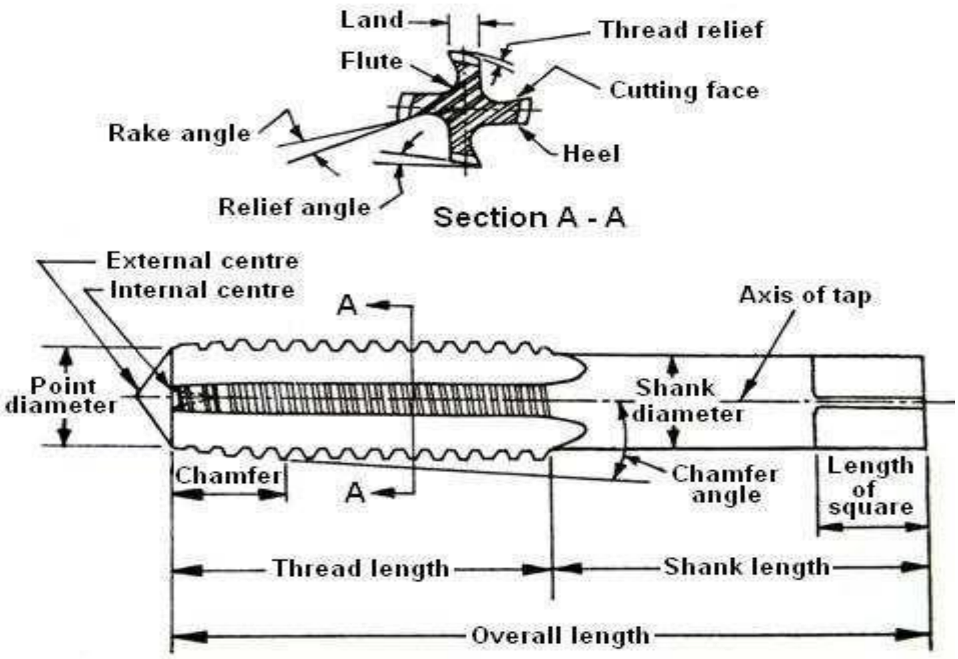


Fig. Elements of a solid tap

19. Describe the universal and omniversal type milling machine with a suitable sketch.

Universal milling machine

- It is so named because it may be adapted to a very wide range of milling operations. It can be distinguished from a plain milling machine in that the table of a universal milling machine is mounted on a circular swiveling base which has degree graduations, and the table can be swiveledto any angle up to 45^0 on either side of the normal position.
- Thus in a universal milling machine, in addition to the three movements as incorporated in a plain milling machine, the table have a fourth movement when it is fed at an angle to the milling cutter.
- This additional feature enables it to perform helical milling operation which cannot be done on a plain milling machine unless a spiral milling attachment is used.
- The capacity of a universal milling machine is considerably increased by the use of special attachments such as dividing head or index head, vertical milling attachment, rotary attachment, slotting attachment, etc.
- The machine can produce spur, spiral, bevel gears, twist drills, reamers, milling cutters, etc. besides doing all conventional milling operations.

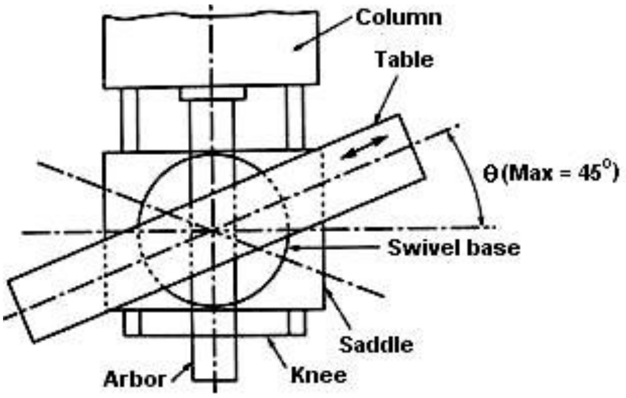


Fig. Universal milling machine

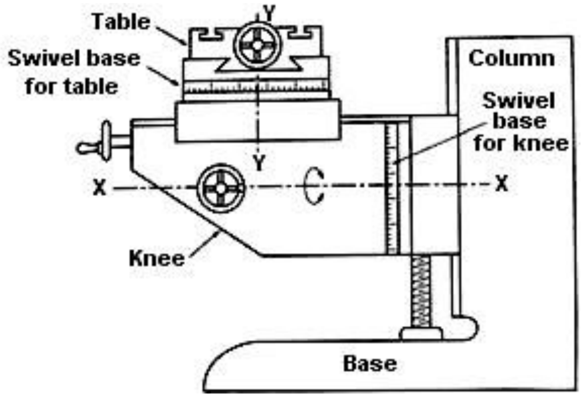
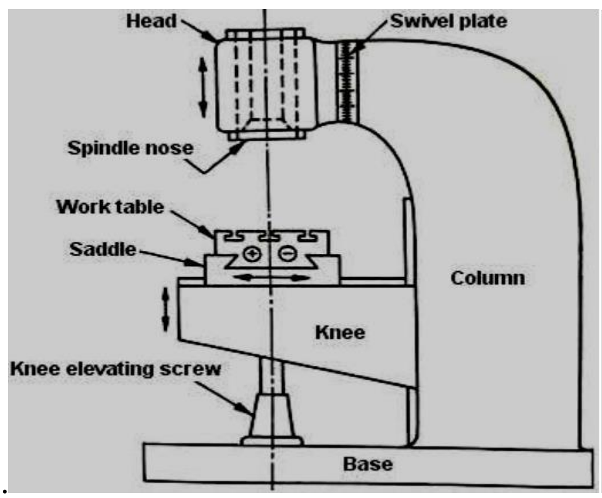


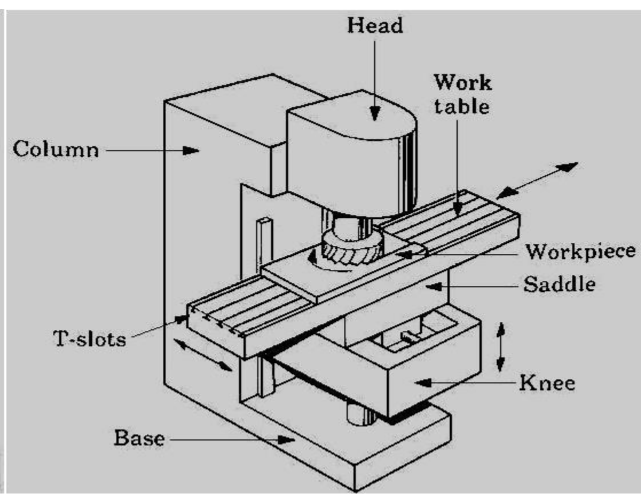
Fig. Omniversal milling machine**4.**

Omniversal milling machine

- In this machine, the table besides having all the movements of a universal milling machine can be tilted in a vertical plane by providing a swivel arrangement at the knee. Also the entire knee assembly is mounted in such a way that it may be fed in a longitudinal direction horizontally.
- The additional swiveling arrangement of the table enables it to machine taper spiral grooves in reamers, bevel gears, etc. It is essentially a tool room and experimental shop machine.

Vertical milling machine





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- This machine is very similar to a horizontal milling machine. The only difference is the spindle is vertical. The work table may or may not have swiveling features.
- The spindle head may be swiveled at an angle, permitting the milling cutter to work on angular surfaces.
- In some machines, the spindle can also be adjusted up or down relative to the work piece. This machine works using end milling and face milling cutters. This machine is adapted for machining grooves, slots and flat surfaces

20. Describe the bed type milling machine with a suitable sketch

- The fixed bed type milling machines are comparatively large, heavy, and rigid and differ radically from column and knee type milling machines by the construction of its table mounting. The table is mounted directly on the guide ways of the fixed bed.
- The table movement is restricted to reciprocation at right angles to the spindle axis with no provision for cross or vertical adjustment.
- The cutter mounted on the spindle head may be moved vertically on the column, and the spindle may be adjusted horizontally to provide cross adjustment.
- The name simplex, duplex and triplex indicates that the machine is provided with single, double and triple spindle heads respectively. In a duplex machine, the spindle heads are arranged one on each side of the table. In triplex type the third spindle (vertical) is mounted on a cross rail.
- The usual feature of these machines is the automatic cycle of operation for feeding the table, which is repeated in a regular sequence.
- The feed cycle of the table includes the following: Start, rapid approach, slow feed for cutting, rapid traverse to the next work piece, quick return and stop.
- This automatic control of the machine enables it to be used with advantage in repetitive types of work.

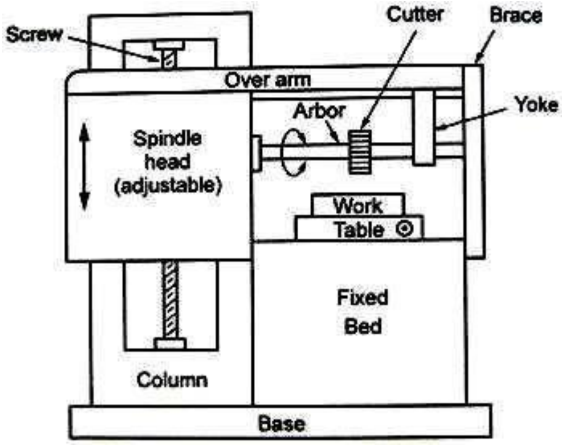


Fig. (a) Simplex milling machine

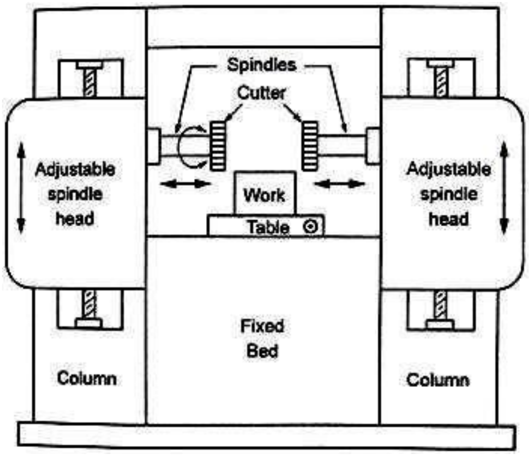
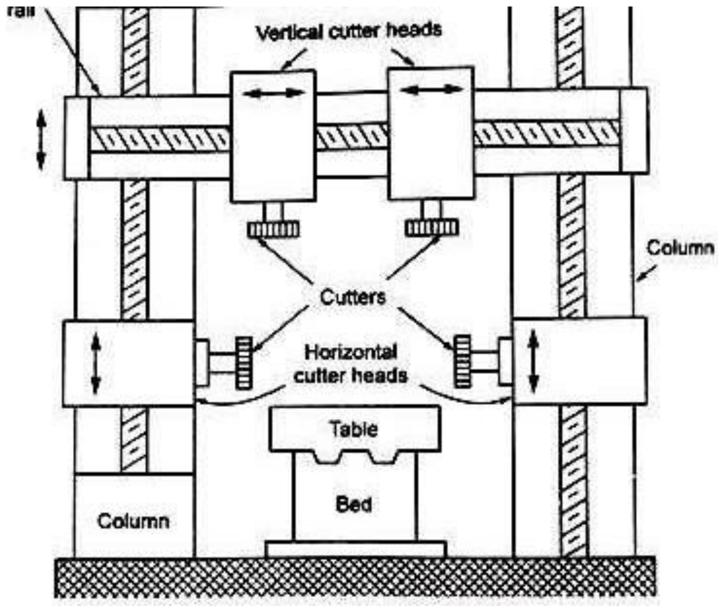
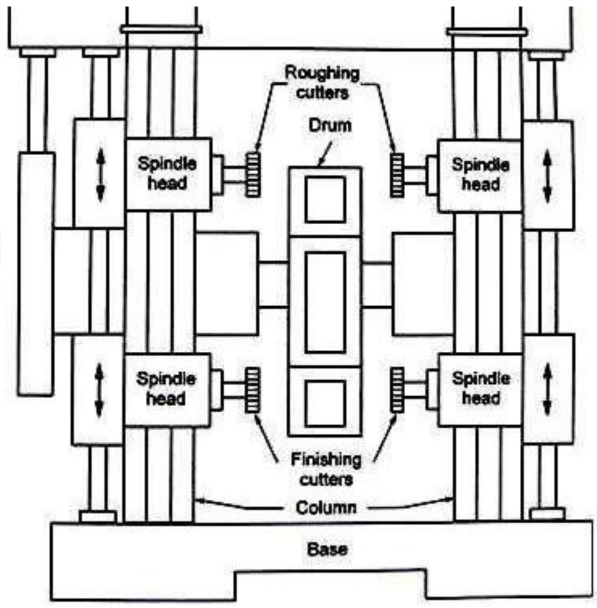


Fig. (b) Duplex milling machine

Planer type milling machine

This heavy duty large machine, called Plano-miller, look like planer where the single point tools are replaced by one or a number of milling heads. This is generally used for machining a number of longitudinal flat surfaces simultaneously, such as lathe beds, table and bed of planer etc. Modern Plano-millers are provided with high power driven spindles powered to the extent of 100 hp. and the rate of metal removal is tremendous. The use of this machine is limited to production work only and is considered ultimate in metal removing capacity.





SPECIAL TYPE MILLING MACHINES

1. Drum milling machine

These machines are of the continuous- operation type. They are mostly found in large-lot and mass production shops for production of large parts such as motor blocks, gear cases, and clutch housings. Two flat surfaces of the work piece can be milled simultaneously.

A square drum (sometimes it may be a regular pentagon or hexagon), is mounted on a shaft passing through the frame. Parts are carried in fixtures mounted on the drum faces. The drum rotates continuously in a horizontal axis, carrying the parts between face milling cutters. The milling cutters are mounted on three or four spindle heads and rotates in a horizontal axis.

2. Rotary table milling machine

The construction of this machine is the modification of a vertical milling machine and is adapted for machining flat surfaces. Such open or closed ended high production milling machines possess one large rotary work table rotates about a vertical axis and one or two vertical spindles. The positions of the work piece(s) and the milling head are adjusted according to the size and shape of the work piece. A continuous loading and unloading of work pieces may be carried out by the operator while the milling is in progress.

3. Profile milling machine

This machine duplicates the full size of the template attached to the machine. This is practically a vertical milling machine of bed type in which the spindle can be adjusted vertically and the cutter head horizontally across the table. The movement of the cutter is regulated by a hardened guide pin. The pin is held against and follows outline or profile of a template mounted on the table at the side of the work piece. The longitudinal movement of the table and crosswise movement of the cutter head follow the movements of the guide pin on the template.

4. Planetary milling machine

In this machine, the work is held stationary while the revolving cutter(s) move in a planetary path to finish a cylindrical surface on the work either internally or externally or simultaneously. This machine is particularly adapted, for milling internal or external threads of different pitches.

5. Major parts of a column and knee type milling machine

The major parts are:

Base: It is accurately machined on its top and bottom surface and serves as a foundation member for all other parts. It carries the column at its one end. In some machines, the base is hollow and serves as a reservoir for cutting fluid.

Column: It 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. The front vertical face of the column is accurately machined and is provided with dovetail guide ways for supporting the knee. The top of the column is finished to hold an over arm that extends outward at the front of the machine.

Knee: It slides up and down on the vertical guide ways of the column face. The adjustment of height is effected by an elevating screw mounted on the base that also supports the knee.

The knee houses the feed mechanism of the table, and different controls to operate it. The top face of the knee forms a slide ways for the saddle to provide cross travel of the table.

Table: The table rests on ways on the saddle and travels longitudinally. The top of the table is accurately finished and T-slots are provided for clamping the work and other fixtures on it. A lead screw under the table engages a nut on the saddle to move the table horizontally by hand or power. The longitudinal travel of the table may be limited by fixing trip dogs on the side of the table. in universal machines, the table may also be swiveled horizontally.

Overhanging arm: The overhanging arm that is mounted on the top of the column extends beyond the column face and serves as a bearing support for the other end of the arbor. The arm is adjustable so that the bearing support may be provided nearest to the cutter.

Front brace: The front brace is and extra support that is fitted between the knee and the over arm to ensure further rigidity to the arbor and the knee. The front brace is slotted to allow for the adjustment of the height of the knee relative to the over arm.

Spindle: The spindle of the machine is located in the upper part of the column and receives power from the motor through belts, gears, clutches and transmits it to the arbor. The front end of the spindle just projects from the column face and is provided with a tapered hole into which various cutting tools and arbors may be inserted. The accuracy in metal machining by the cutter depends primarily on the accuracy, strength, and rigidity of the spindle.

Arbor: It may be considered as an extension of the machine spindle on which milling cutters are securely mounted and rotated. The arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The arbor may be supported at the farthest end fromthe overhanging arm or may be of cantilever type which is called stub arbor.

Working principle of a column and knee type milling machine

- ❖ The kinematic system comprising of several mechanisms enables transmission of motion and power from the motor to the cutting tool for its rotation at varying speeds and to the work table for its slow feed motions along X, Y and Z directions.
- ❖ The milling cutter mounted on the horizontal milling arbor, receives its rotary motion at different speeds from the main motor through the speed gear box.

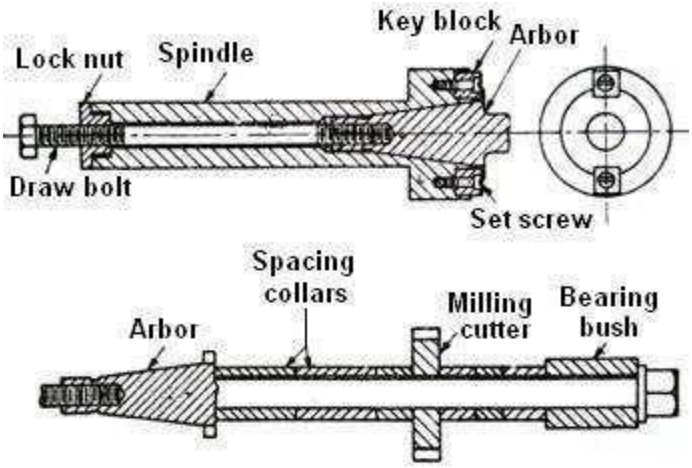


Fig. Arbor assembly

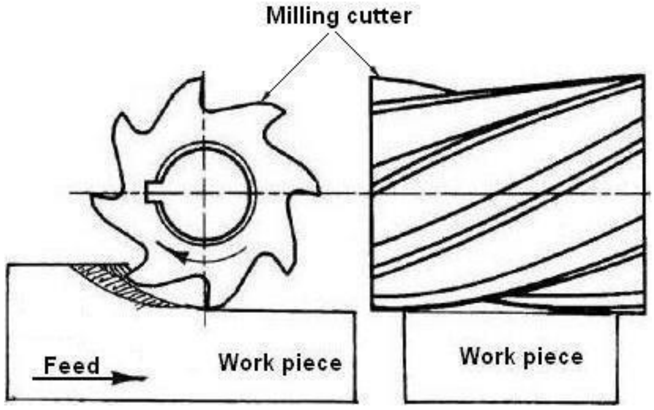


Fig. Principle of producing flat surface

- The feeds of the work piece can be given by manually or automatically by rotating the respective wheels by hand or by power. The work piece is clamped on the work table by a work holding device.
- Then the work piece is fed against the rotating multipoint cutter to remove the excess material at a very fast rate.

22. Explain with neat sketches in work holding devices used in milling.

It is necessary that the work piece should be properly and securely held on the milling machine table for effective machining operations. The work piece may be supported on the milling machine table by using any one of the following work holding devices depending upon the geometry of the work piece and nature of the operation to be performed.

- T-bolts and clamps.
- Angle plate.
- V-blocks.
- Vises.
- Special fixtures.
- Dividing heads.

T-bolts and clamps Bulky work pieces of irregular shapes are clamped directly on the milling machine table by using T-bolts and clamps. Different designs of clamps are used for different patterns of work.

Angle plate: Sometimes a titling type angle plate in which one face can be adjusted relative to another face for milling at a required angle is also used.

V-blocks: This is used for holding shafts on the table in which keyways, slots and flats are to be milled.

Vises: Vises are the most common appliances for holding work on milling machine table due to its quick loading and unloading arrangement.

Special fixtures: The fixtures are special devices designed to hold work for specific operations more efficiently than standard work holding devices.
Fixtures are especially useful when large numbers of identical parts are being produced. By using fixtures loading, locating, clamping and unloading time is greatly minimized.

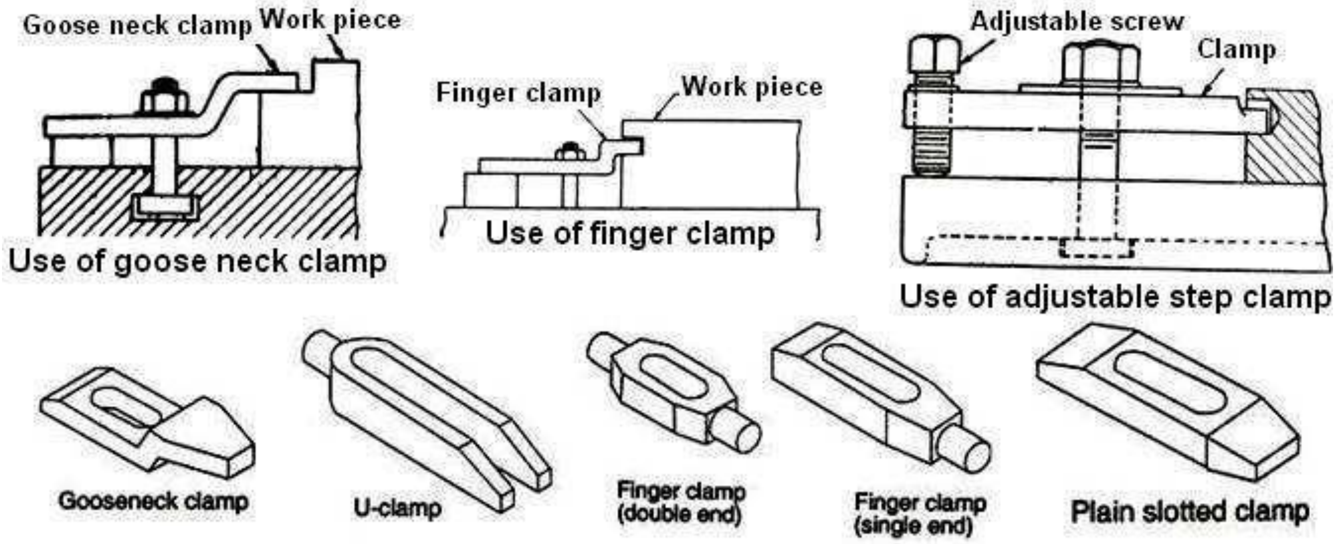


Fig. Different types of clamps

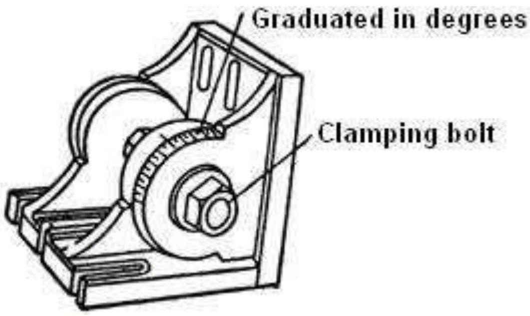


Fig. Tilting type angle plate

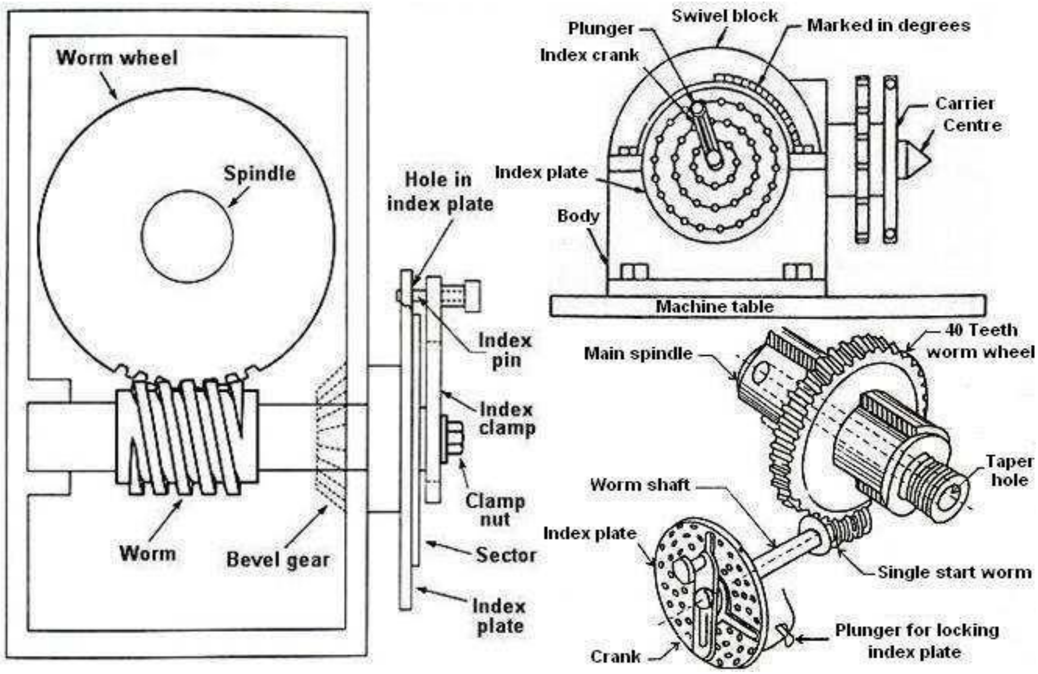
23. Explain the indexing mechanism of a dividing head on milling machine. (Anna Univ..May 14).

Describe the working mechanism of a universal dividing head, with neat diagrams. (Anna Univ..Apr 04 & June 06).

Explain the simple indexing, compound indexing and differential indexing with suitable examples. (Anna Univ. Dec 07)

- It is a special work holding device used in a milling machine. Dividing head can also be considered as a milling machine attachment.
- An important function and use of milling machines is for cutting slots, grooves etc. which are to be equally spaced around the circumference of a blank, for example, gear cutting, ratchet wheels, milling cutter blanks, reamers etc.
- This necessitates holding of the blank (work piece) and rotating it the exact amount for each groove or slot to be cut. This process is known as “indexing”. The work piece is rotated by turning the index crank by means of handle.

- Since the gear ratio of worm and worm wheel is 40:1, it takes 40 turns of the crank to rotate the spindle and hence the work piece through one complete revolution. Thus one turn of the crank rotatesthe work



piece through 1/40th of a turn.

Fig. Dividing head

Index plate: It helps to accomplish indexing (dividing) of the work into equal divisions. It is a circular plate approximately 6 mm thick, with holes (equally spaced) arranged in concentric circles. The space between two subsequent holes is same for each circle; however it is different for different circles. A plate can have through holes or blind holes on its faces.

For a plain dividing head, the index plate is fixed to the body of the dividing head while in the case of universal dividing head it is mounted on the sleeve of the worm shaft. Various manufactures in U.S.A. and other countries have produced index plates with different number of hole circles.

For example *The index plates available with the Brown and Sharpe milling machines are:*

Plate No. 1 - 15, 16, 17, 18, 19, 20

Plate No. 2 - 21, 23, 27, 29, 31, 33

Plate No. 3 - 37, 39, 41, 43, 47, 49

The index plate used on the Cincinnati and Parkinson milling machine is:

Obverse (A) - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43

Reverse (B) - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, and 66

Index plates made in Germany are:

Plate No. 1	-	23, 25, 28, 31, 39, 43, 51, 59
Plate No. 2	-	16, 27, 30, 33, 41, 47, 53, 61
Plate No. 3	-	22, 24, 29, 36, 37, 49, 57, 63

The high number index plates are used to increase the indexing capacity. These index plates are similar to those discussed earlier except that these contain very large number of holes. Cincinnati Milling Machine Co. U.S.A. produces a set of three plates with holes on both sides of the plate as given below:

Plate No. 1	Obverse (A) -	30, 48, 69, 91, 99, 117, 129, 147, 171, 177, 189
Reverse (B) -	36, 67, 81, 97, 111, 127, 141, 157, 169, 183, and 194	
Plate No 2	Obverse (A) -	34, 46, 79, 93, 109, 123, 139, 153, 167, 181, 197
Reverse (B) -	32, 44, 77, 89, 107, 121, 137, 151, 163, 179, and 193	
Plate No. 3	Obverse (A) -	26, 42, 73, 87, 103, 119, 133, 149, 161, 175, 191
Reverse (B) -	28, 38, 71, 83, 101, 113, 131, 143, 159, 173, and 187	

It is importance to note that there is no standard followed internationally in this regard. The number of plates supplied varies with different manufacturers. However this does not change the principle of indexing. It should be put up with in mind that larger the number of plates, and more the hole circles and holes wider is the range of indexing and accuracy.

Types of dividing heads: The various dividing heads used with milling machines are:

1. ***Plain indexing head:*** A plain dividing head has a fixed spindle axis and the spindle rotates only about a horizontal axis.
2. ***Universal indexing head:*** In this, the spindle can be rotated at different angles in the vertical plane from horizontal to vertical. This head performs the following functions: indexes the work piece, imparts a continuous rotary motion to the work piece for milling helical grooves (flutes of drills, reamers, milling cutters etc.) and setting the work piece in a given inclined position with reference to the table.
3. ***Optical indexing head:*** These models are used for high precision angular setting of the work piece with respect to the cutter. For reading the angles, an optical system is built into the dividing head.

Methods of indexing: The various methods of indexing are discussed below:

Direct indexing;

- In this, the index plate is directly mounted on the dividing head spindle. The intermediate use of worm and worm wheel is avoided.
- For indexing, the index pin is pulled out on a hole, the work and the index plate are rotated the desired number of holes and the pin is engaged. Both plain and universal heads can be used in this manner.
- Direct indexing is the most rapid method of indexing, but fractions of a complete turn of the spindle are limited to those available with the index plate. With a standard indexing plate having 24 holes, all factors of 24 can be indexed, that is, the work can be divided into 2,3,4,6,8,12 and 24 parts.

Simple or plain indexing:

- In this, the index plate selected for the particular application, is fitted on the worm shaft and locked through a locking pin. To index the work through any required angle, the index crank pin is withdrawn from a hole in the index plate.
- The work piece is indexed through the required angle by turning the index crank through a calculated number of whole revolutions and holes on one of the hole circles, after which the index pin is relocated in the required hole. If the number of divisions on the job circumference (that is number of indexing) needed is z, then the number of turns (n) that the crank must be rotated for each indexing can be found from the formula: **n =** turns.

Example 1: Indexing 28 divisions.

This can be done as follows using any one of the Brown and Sharpe plates. One full rotation + 9 holes in 21 hole circle in plate No. 2.

One full rotation + 21 holes in 49 hole circle in plate No. 3.

Compound indexing

- When the available capacity of the index plates is not sufficient to do a given indexing, the compound indexing method can be used. First, the crank is moved in the usual fashion in the forward direction.
- Then a further motion is added or subtracted by rotating the index plate after locking the plate with the plunger. This is termed as compound indexing. For example, if the indexing is done by moving the crank by 5 holes in the 20 hole circle and then the index plate together with the crank is indexed back by a hole with the locking plunger registering in a 15 hole circle.

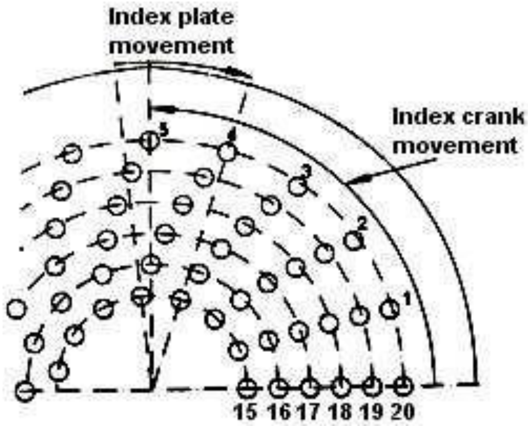


Fig. An example of compound indexing

Differential indexing

This is an automatic way to carry out the compound indexing method. In this the required division is obtained by a combination of two movements:

The movement of the index crank similar to the simple indexing.

The simultaneous movement of the index plate, when the crank is turned.

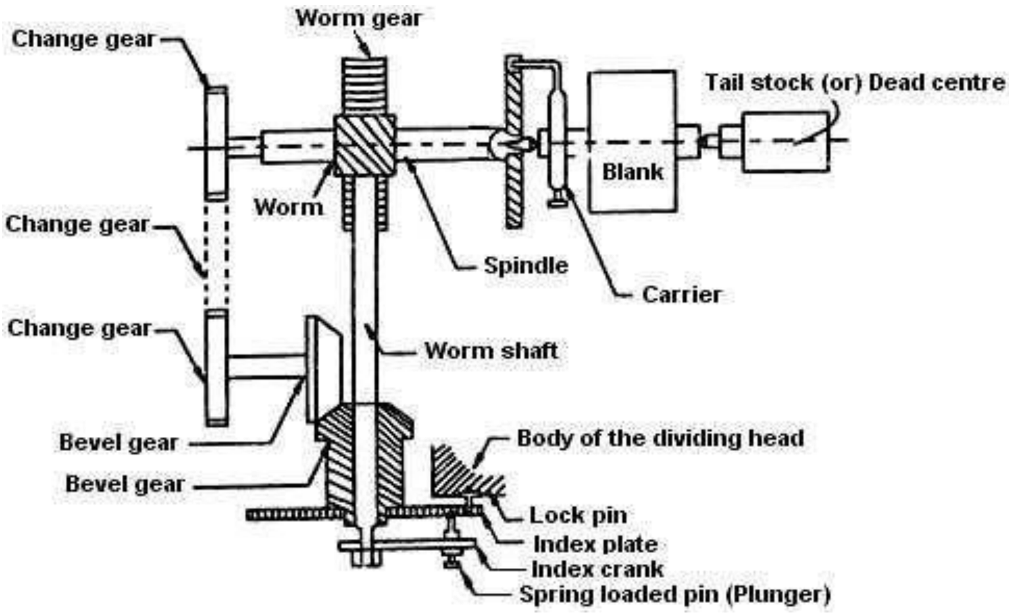


Fig. Arrangement for differential indexing

In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing head spindle while another gear is mounted on a shaft and is connected to the shaft of the index plate through bevel gears. When the index crank is rotated, the motion is communicated to the work piece spindle. Since the work piece spindle is connected to the index plate through the intermediate gearingas explained above, the index plate will also start rotating.

- The procedure of calculation is explained with the following example.
- The change gear set available is 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

Example 3: Obtain the indexing for 209 divisions.

The required indexing is 40/209 which cannot be obtained with any of the index plates available. Choose the nearest possible division. For example, the indexing decided is 40/200= 4/20

The actual indexing decided is 4 holes in a 20 hole circle. This indexing will be more than required. Ideally the workpiece should complete one revolution when the crank is moved through 209 turns at the above identified indexing. The actual motion generated when the crank is moved 209 times

Hence the index plate has to move in the reverse by this amount during the 209 turns to compensate for the larger indexing being done by the index crank.

Angular indexing

Sometimes it is desirable to carry out indexing using the actual angles rather than equal numbers along the periphery. Here, angular indexing would be useful. The procedure remains the same as in the previous cases, except that the angle will have to be first converted to equivalent divisions. Since 40 revolutions of the crank equals to a full rotation of the work piece, which means 360^0, one revolution of the crank is equivalent to 9^0. The formula to find the index crank movement is given below.

Index crank movement	=	Angular displacement of work (in degrees) / 9
	=	Angular displacement of work (in minutes) / 540
	=	Angular displacement of work (in seconds) / 32400

Example 4: Calculate the indexing for 19^0 40'.

19^0 40' = (19 x 60) + 40 = 1140 + 40 = 118

This can be done as follows using the Brown and Sharpe plates. Two full rotations + 5 holes in 27 hole circle in plate No. 2.

CUTTER HOLDING DEVICES USED IN A MILLING MACHINE

There are several methods of holding and rotating milling cutters by the machine spindle depending on the different designs of the cutters. They are

1 Arbors

The cutters have a bore at the centre are mounted and keyed on a short shaft called arbor..

2 Collets

A milling machine collet is a form of sleeve bushing for reducing the size of the taper hole at the nose of the spindle so that an arbor or a milling cutter having a smaller shank than the spindle taper can be fitted into it.

3 Adapter

An adapter is a form of collet used on milling machine having standardized spindle end. Cutters having straight shanks are usually mounted on adapters. An adapter can be connected with the spindle by a draw bolt or it may be directly bolted to it.

4 Spring collets

Straight shank cutters are usually held on a special adapter called “spring collet” or “spring chuck”. The cutter shank is introduced in the cylindrical hole provided at the end of the adapter and then the nut is lightened. This causes the split jaws of the adapter to spring inside, and grip the shank firmly.

5 Bolted cutters

The face milling cutters of larger diameter having no shank are bolted directly on the nose of the spindle. For this purpose four bolt holes are provided on the body of the spindle. This arrangement of holding cutter ensures utmost rigidity.

6 Screwed on cutters

The small cutters having threaded holes at the centre are screwed on the threaded nose of an arbor which is mounted on the spindle in the usual manner.

SPECIAL ATTACHMENTS USED IN MILLING MACHINES

The attachments are intended to be fastened to or joined with one or more components of the milling machine for the purpose of enhancing the range, versatility, productivity and accuracy of operation. Some classes of milling machine attachments are used for positioning and driving the cutter by altering the cutter axis and speed, whereas other classes are used for positioning, holding and feeding the work along a specified geometric path. The following are the different attachments used on standard column and knee type horizontal milling machine.

1. Universal milling attachment

- For milling by solid end mill type and face milling cutters, separate vertical axis type milling machines are available.
- But horizontal arbor type milling machines can also be used for those operations to be done by end milling and smaller size face milling cutters by using the universal milling attachment.
- The rotation of the horizontal spindle is transmitted into rotation about vertical axis and also in any inclined direction by this attachment which thus extends the processing capabilities and application range of the milling machine.

2 Indexing head or dividing head

- This attachment is also considered as an accessory.

3. Rotary table

- This device may also be considered both accessory or attachment and is generally used in milling machines for both offline and online indexing / rotation of the work piece, clamped on it, about vertical axis.

4. Slotting attachment

- ❖ Such simple and low cost attachment is mounted on the horizontal spindle for producing keyways and contoured surface requiring linear travel of single point tool in milling machine where slotting machine and broaching machine are not available.
- ❖ The mechanism inside the attachment converts rotation of the spindle into reciprocation of the single point tool in vertical direction. The direction of the tool path can also be tilted by swiveling the circular base of the attachment body.

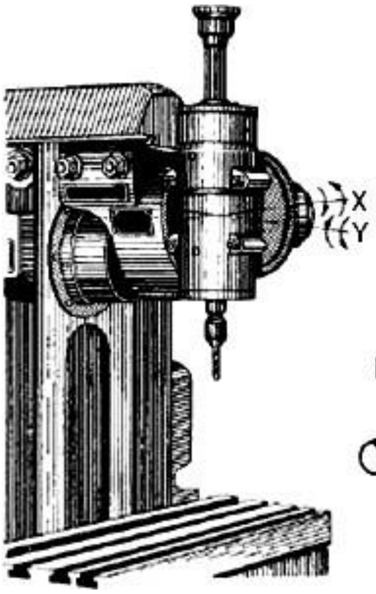


Fig. Universal milling attachment

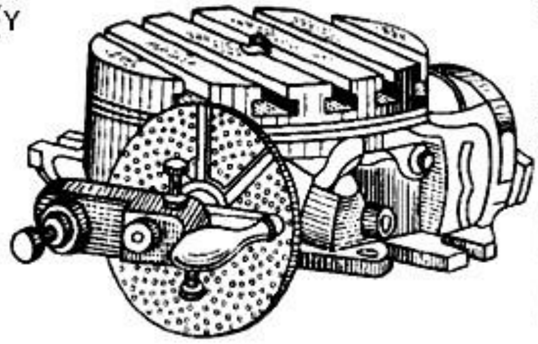


Fig. Rotary table

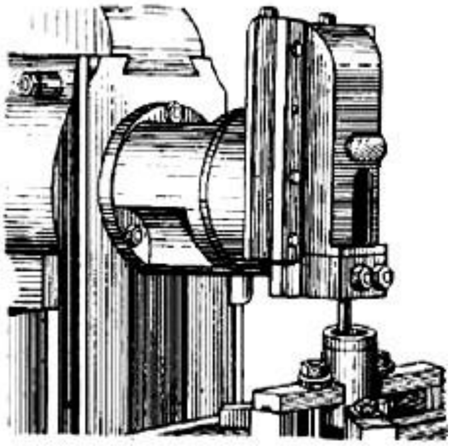


Fig. Slotting attachment

MILLING CUTTERS

Milling machines are mostly general purpose and have wide range various types and sizes of milling cutters.

A milling cutter is a multi-edged rotary cutting tool having the shape of a solid of revolution with cutting teeth arranged either on the periphery or on the end face or on both. Usually, the cutter is held in a fixed (but rotating) position and the work piece moves past the cutter during the machining operation.

1. Cutter materials

Intermittent cutting nature and usually complex geometry necessitate making the milling cutters mostly by HSS which is unique for high tensile and transverse rupture strength, fracture toughness and formability almost in all respects i.e. forging, rolling, powdering, welding, heat treatment, machining (in annealed condition) and grinding. Tougher grade cemented carbides are also used without or with coating, where feasible, for high productivity and product quality. In some cutters tungsten carbide teeth are brazed on the tips of the teeth or individually inserted and held in the body of the cutter by some mechanical means. Carbide tipped cutter is especially adapted to heavy cuts and increased cutting speeds. *The advantages of carbide tipped cutters (either solid or inserted blade type) are:*

- ❖ Their high production capacity.
- ❖ The high quality of the surfaces they produce.

2. Types of milling cutters

Many different kinds of milling cutters are used in milling machines. They are:

1 Slab or plain milling cutters: Straight or helical fluted

Plain milling cutters are hollow straight HSS cylinder of 40 to 80 mm outer diameter having 4 to 16 straight or helical equi-spaced flutes or cutting edges on the circumference. These are used in horizontal arbor to machine flat surfaces parallel to the axis of rotation of the spindle. Very wide plain milling cutters are termed as slab milling cutters.

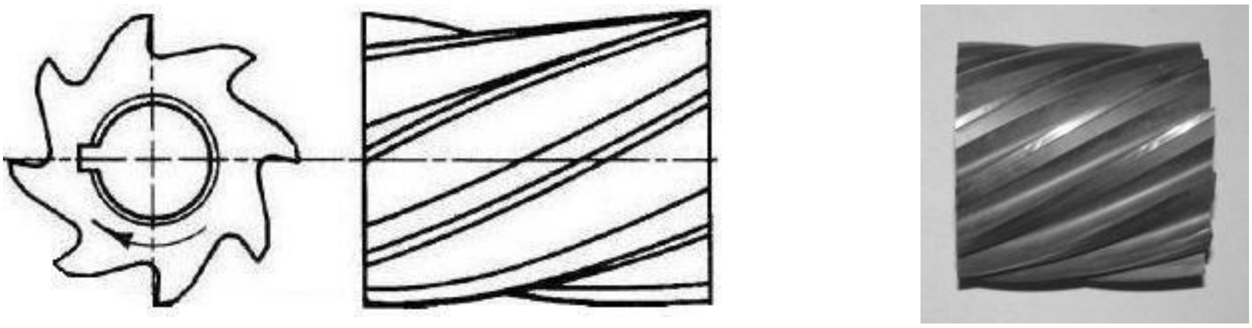


Fig. Slab or plain milling cutter

2. Side milling cutters: Single side or double sided type

These arbor mounted disc type cutters have a large number of cutting teeth at equal spacing on the periphery. Each tooth has a peripheral cutting edge and another cutting edge on one face in case of single side cutter and two more cutting edges on both the faces leading to double sided cutter. One sided cutters are used to produce one flat surface or steps comprising two flat surfaces at right angle. Both sided cutters are used for making rectangular slots bounded by three flat surfaces.

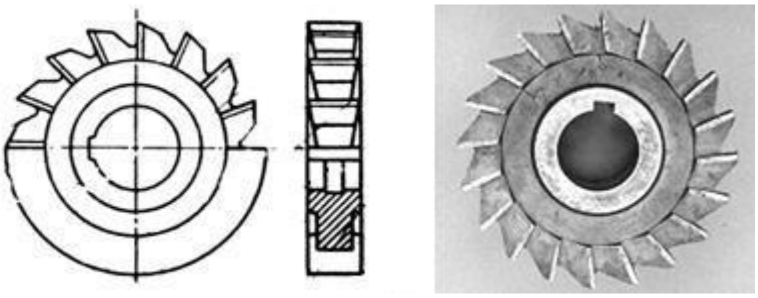
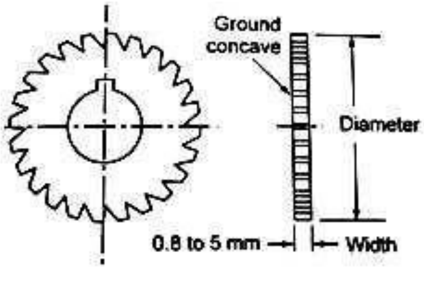


Fig. side milling cutters

3. Slitting saws or parting tools

These milling cutters are very similar to the slotting cutters having only one peripheral cutting edge on each tooth.



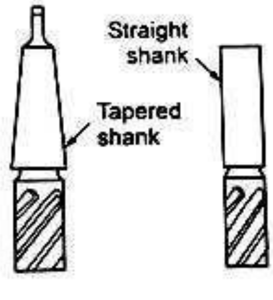


Fig. Slitting saw **Fig. End milling cutters** **Fig. Face milling cutter**

4 End milling cutters: With straight or taper shank

The common characteristics of end milling cutters are:

- Mostly made of High Speed Steel.
- 4 to 12 straight or helical teeth on the periphery and face.
- Diameter ranges from about 1 mm to 40 mm.
- Very versatile and widely used in vertical spindle type milling machines.
- End milling cutters requiring larger diameter are made as a separate cutter body which is fitted in the spindle through a taper shank arbor (Shell end mills)

5 Face milling cutters

The main characteristics of face milling cutters are:

- Usually large in diameter (80 to 800 mm) and heavy.
- Used only for machining flat surfaces in different orientations.
- Mounted directly in the vertical and / or horizontal spindles.
- Coated or uncoated carbide inserts are clamped at the outer edge of the carbon steel body.
- Generally used for high production machining of large jobs.

6 Form cutters

These cutters have irregular profiles on the cutting edges in order to generate an irregular outline of the work. These disc type HSS cutters are generally used for making grooves or slots of various profiles.

Slotting cutters

Slotting cutters are of end mill type like T-slot cutter or dove tail cutter.

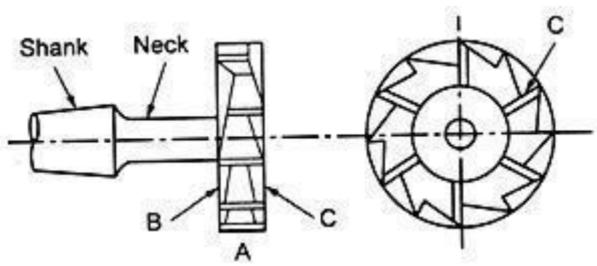


Fig. T-slot milling cutter

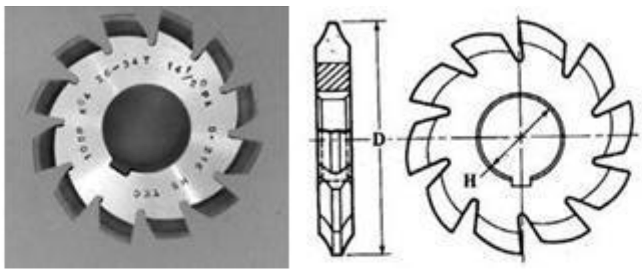


Fig. Involute gear milling cutter

Gear (teeth) milling cutters

Fig. 3.80 illustrates an involute gear milling cutter. Gear milling cutters are made of HSS and available mostly in disc form like slot milling cutters and also in the form of end mill for producing teeth of large module gears. The form of these tools conforms to the shape of the gear tooth-gaps bounded by two involutes. Such form relieved cutters can be used for producing teeth of straight and helical toothed

external spur gears and worm wheels as well as straight toothed bevel gears.

Spline shaft cutters

These disc type HSS form relieved cutters are used for cutting the slots of external spline shafts having 4 to 8 straight axial teeth.

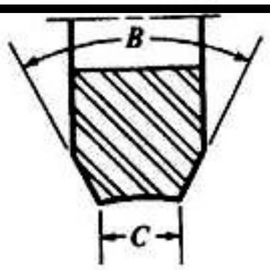


Fig. Tooth section of a spline shaft cutter

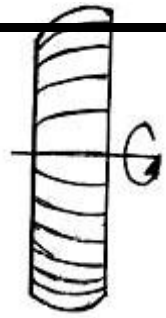


Fig. Tool form cutter

Tool form cutters

Form milling type cutters are also used widely for cutting slots are flutes of different cross section e.g. the flutes of twist drills, milling cutters, reamers etc., and gushing of hobs, taps, short thread milling cutters etc.

Thread milling cutters

These shank type solid HSS or carbide cutters having threaded like annular grooves with equi- spaced gushing are used in automatic single purpose milling machines for cutting the threads in large lot production of screws, bolts etc. Both internal and external threads are cut by the tool. These milling cutters are used for long thread milling also (e.g. lead screws, power screws, worms etc).

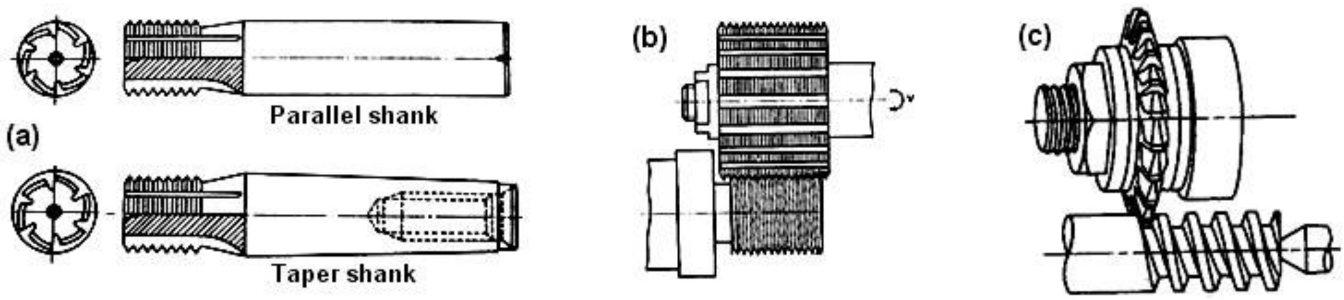


Fig. (a) Internal thread milling cutters (b) Short thread milling cutter (c) Long thread milling cutter

Convex and concave milling cutters

These cutters have teeth curved outwards or inwards on the circumferential surface to form the contour of a semicircle. These cutters produces concave or convex semicircular surface on the work pieces. The diameter of the cutters ranges from 50 mm to 125 mm and the radius of the semicircle varies from 1.5 mm to 20 mm.

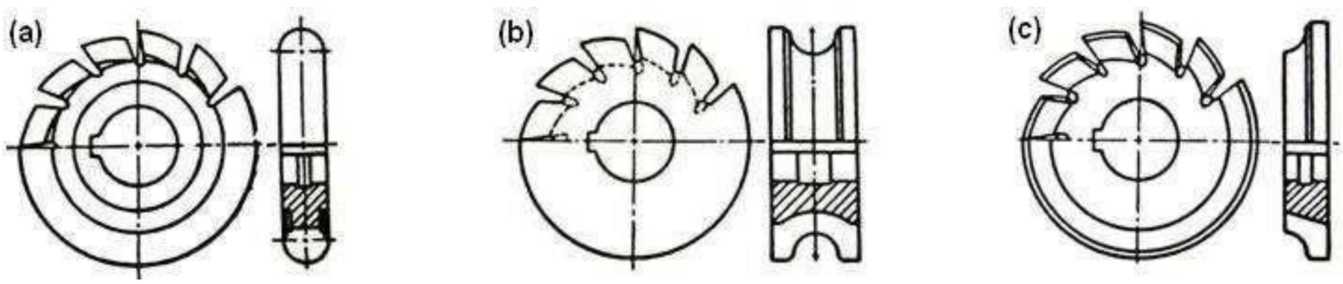


Fig. (a) Convex milling cutter (b) Concave milling cutter and (c) Corner rounding milling cutter

Corner rounding milling cutters

These cutters have teeth curved inwards on the circumferential surface to form the contour of a quarter circle. The cutter produces a convex quarter circular surface on the work piece. These are used for cutting a radius on the corners or edge of the work piece. The diameter of the cutter ranges from 1.5 mm to 20 mm.

Angle milling cutters

These cutters are made as single or double angle cutters and are used to machine angles other than 90^0. The cutting edges are formed at the conical surface around the periphery of the cutter. The double angle milling cutters are mainly used for cutting spiral grooves on a piece of blank.

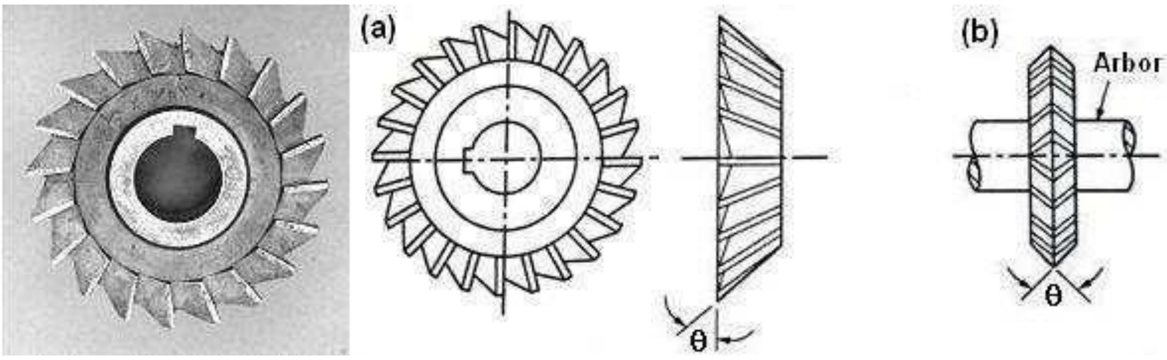


Fig. (a) Single angle milling cutter and (b) Double angle milling cutter

7 Woodruff key slot milling cutters

These cutters are small standard cutters similar in construction to a thin small diameter plain milling cutter, intended for the production of woodruff key slots. The cutter is provided with a shank and may have straight or staggered teeth.

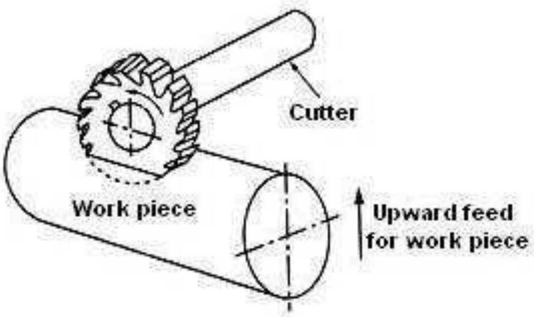


Fig. Woodruff key slot milling cutter

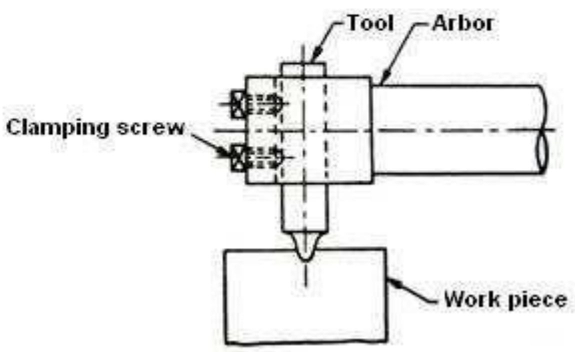


Fig. Schematic view of a fly cutter

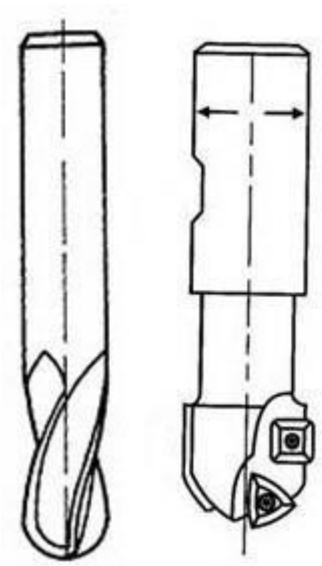
8 Fly cutters

These are simplest form of cutters and are mainly used in experimental shops or in tool room works. The cutter consists of a single point cutting tool attached to the end of an arbor. This cutter may be considered as an emergency tool when the standard cutters are not available. The shape of the tool tip

is the replica of the contour to be machined.

9 Ball nose end mill

Small end mill with ball like hemispherical end is often used in CNC milling machines for machining free form 3-D or 2-D contoured surfaces. These cutters may be made of HSS, solid carbide or steel body with coated or uncoated carbide inserts clamped.



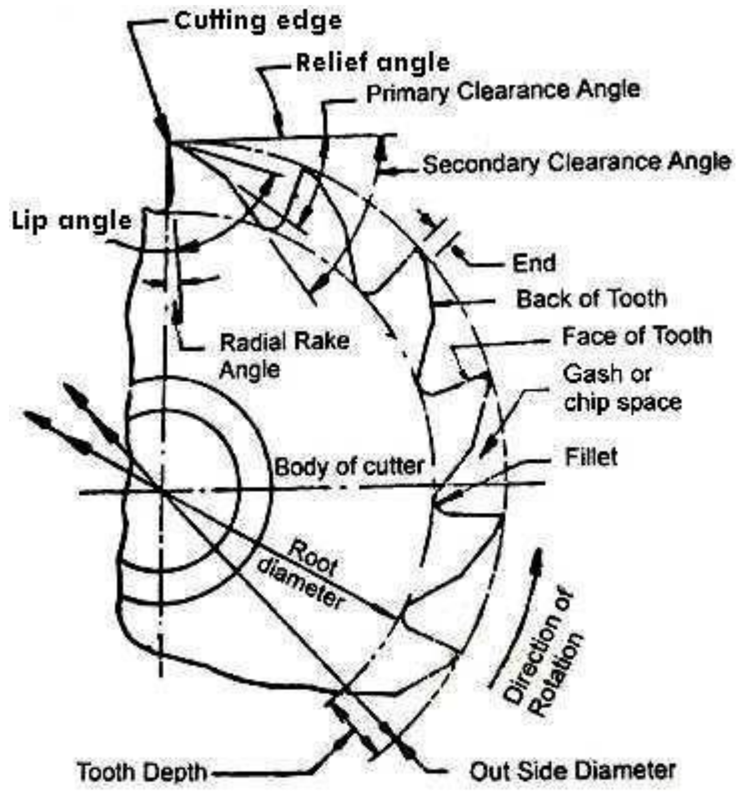


Fig. Ball nose end mills

Fig. Elements of a plain milling cutter

ELEMENTS OF A PLAIN MILLING CUTTER

The major parts and angles of a plain milling cutter are illustrated in Fig. 3.89.

Body of cutter: The part of the cutter left after exclusion of the teeth and the portion to which the teeth are attached.

Cutting edge: The edge formed by the intersection of the face and the circular land or the surface left by the provision of primary clearance.

Face: The portion of the gash adjacent to the cutting edge on which the chip impinges as it is cut from the work

Fillet: The curved surface at the bottom of gash that joins the face of one tooth to the back of the tooth immediately ahead.
Gash: The chip space between the back of one tooth and the face of the next tooth.The part of the back of tooth adjacent to the cutting edge which is relieved to avoid interference between the surface being machined and the cutter.

Outside diameter: The diameter of the circle passing through the peripheral cutting edge.

Root diameter: The diameter of the circle passing through the bottom of the fillet.

Cutter angles: Similar to a single point cutting tool, the milling cutter teeth are also provided with rake, clearance and other cutting angles in order to remove metal efficiently.

Relief angle: The angle in a plane perpendicular to the axis. The angle between land of a tooth and tangent to the outside diameter of cutter at the cutting edge of that tooth.

Lip angle: The included angle between the land and the face of the tooth, or alternatively the angle between the tangent to the back at the cutting edge and the face of the tooth.

Primary clearance angle: The angle formed by the back of the tooth with a line drawn tangent to the periphery of the cutter at the cutting edge.

Secondary clearance angle: The angle formed by the secondary clearance surface of the tooth with a line drawn tangent to the periphery of the cutter at the cutting edge.

***Rake angle (Radial*)**: The angle measured in the diametral plane between the face of the tooth and a radial line passing through the tooth cutting edge. The rake angle which may be positive, negative or zero.**
24. List out various milling operations. (Nov/Dec 2005 & April/May 2013,2015)

Milling machines are mostly general purpose machine tools and used for piece or small lot production. In general, all milling operations can be grouped into two types.

They are: peripheral milling and face milling.

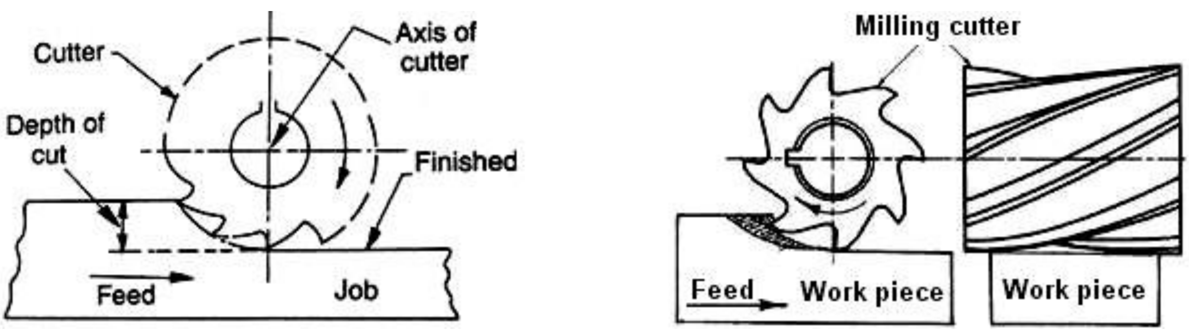


Fig. Schematic view of the peripheral milling operation

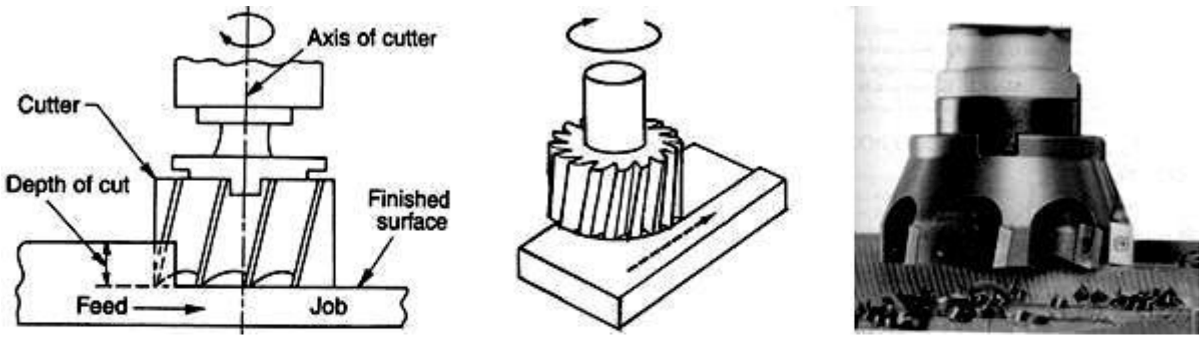


Fig. Schematic view of the face milling operation

Peripheral milling

Here, the finished surface is parallel to the axis of rotation of the cutter and is machined by cutter teeth on the periphery of the cutter..

Special type - End milling

It may be considered as the combination of peripheral and face milling operation. The cutter has teeth both on the end face and on the periphery. The cutting characteristics may be of peripheral or face milling type according to the cutter surface used.

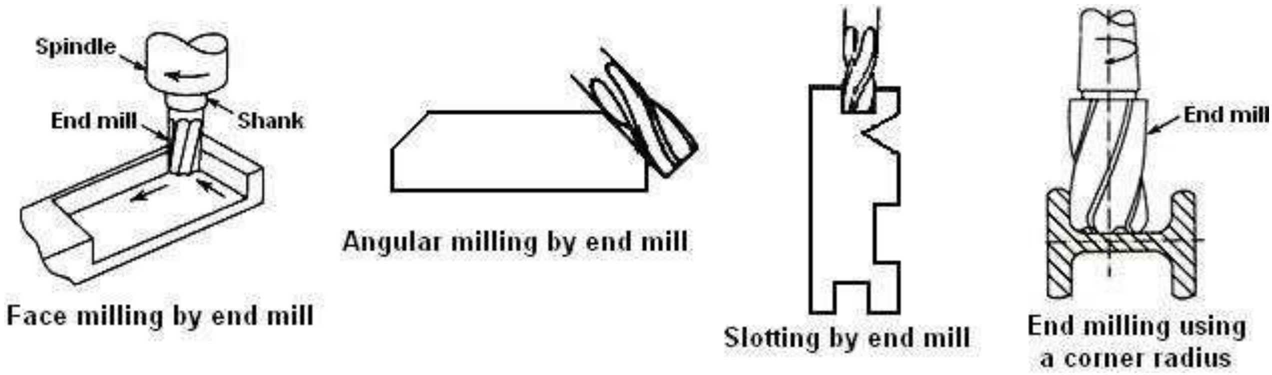


Fig. Schematic views of the different end milling operations

According to the relative movement between the tool and the work, the peripheral milling operation is classified into two types. They are: up milling and down milling.

Up milling or conventional milling Here, the cutter rotates in the opposite direction to the work table movement. In this, the chip starts as zero thickness and gradually increases to the maximum. The cutting force is directed upwards and this tends to lift the work piece from the work holding device. Each tooth slides across a minute distance on the work surface before it begins to cut, producing a wavy surface.

This tends to dull the cutting edge and consequently have a lower tool life.

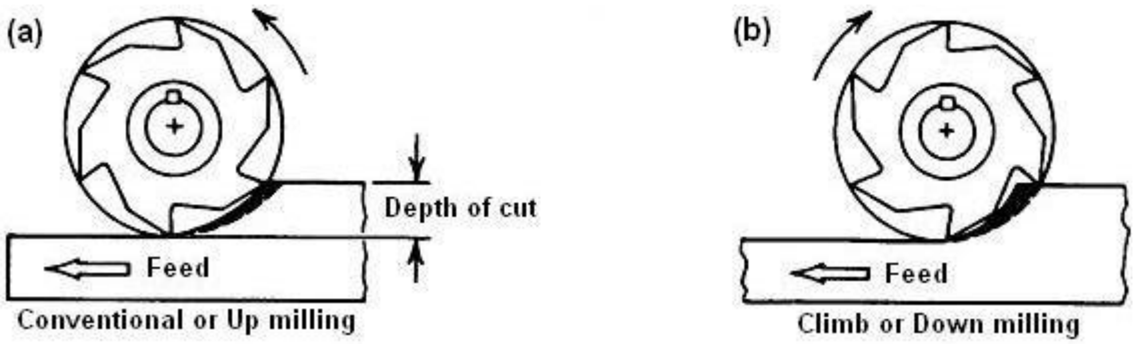


Fig. Schematic views of (a) Up milling process and (b) Down milling process

As the cutter progresses, the chip accumulate at the cutting zone and carried over with the teeth which spoils the work surface.

Down milling or climb milling

Here, the cutter rotates in the same direction as that of the work table movement. In this, the chip starts as maximum thickness and gradually decreases to zero thickness. This is suitable for obtaining fine finish on the work surface. The cutting force acts downwards and this tends to seat the work piece firmly in the work holding device. The chips are deposited behind the cutter and do not interfere with the cutting. Climb milling allows greater feeds per tooth and longer tool life between regrinds than up milling.

1 Basic functions of milling machine

Milling machines of various types are widely used for the following purposes:

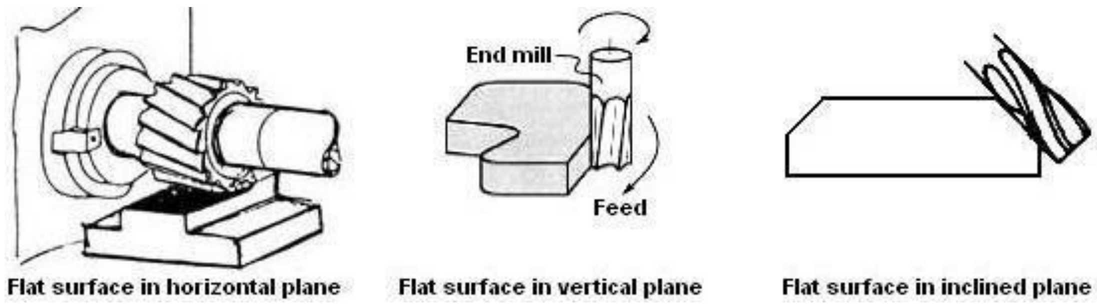


Fig. Producing flat surface in horizontal, vertical and inclined planes

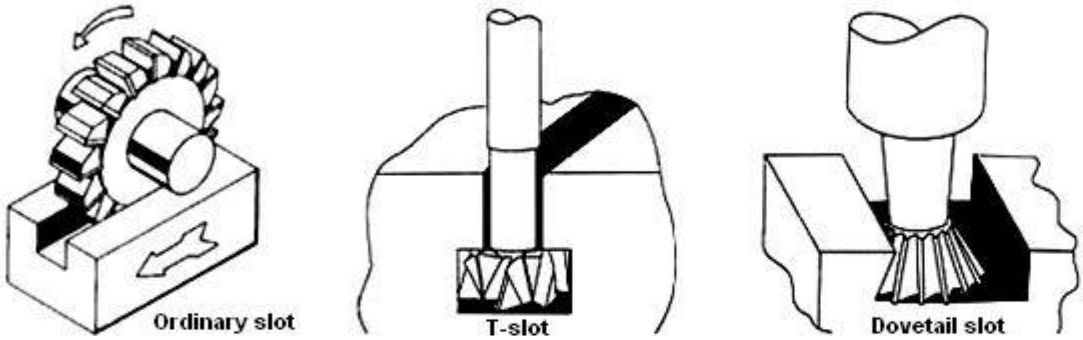
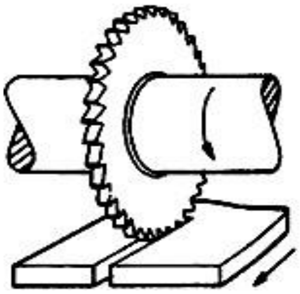


Fig. Machining slots of various cross sections



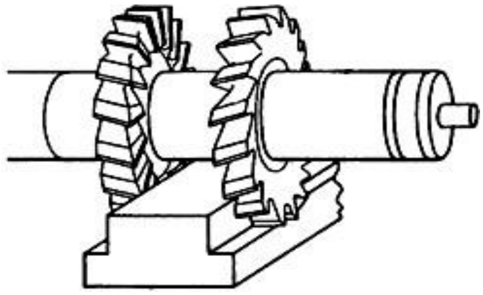


Fig. Parting by slitting saw   Fig. Straddle milling

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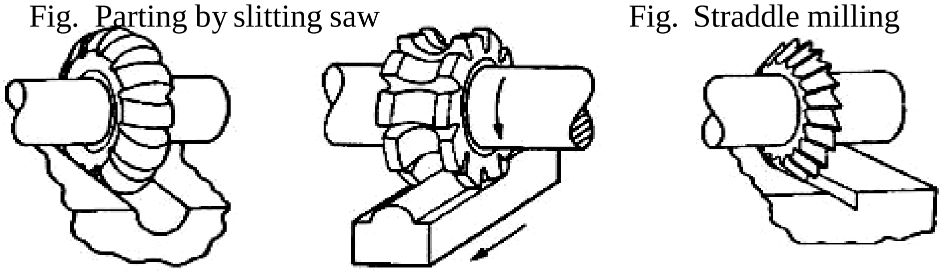
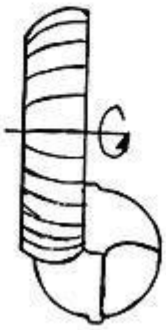


Cutting helical grooves like flutes of the drills.



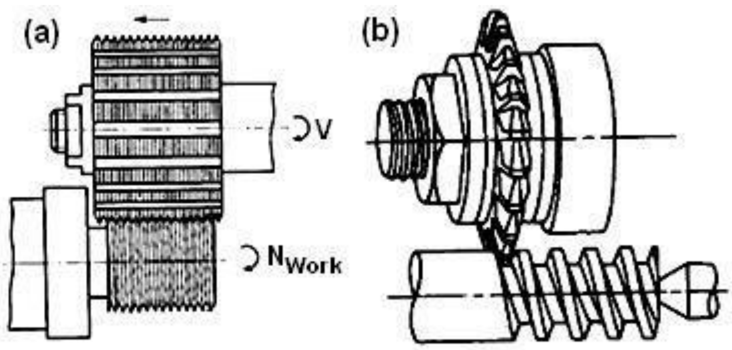


Fig. Cutting of drill flutes   Fig. (a) Short thread milling (b) Long thread milling

Short thread milling for small size fastening screws, bolts etc. and long thread milling on large lead screws, power screws, worms etc.

Cutting teeth of spur gears, straight toothed bevel gears, worm wheels, sprockets in piece or batch production.

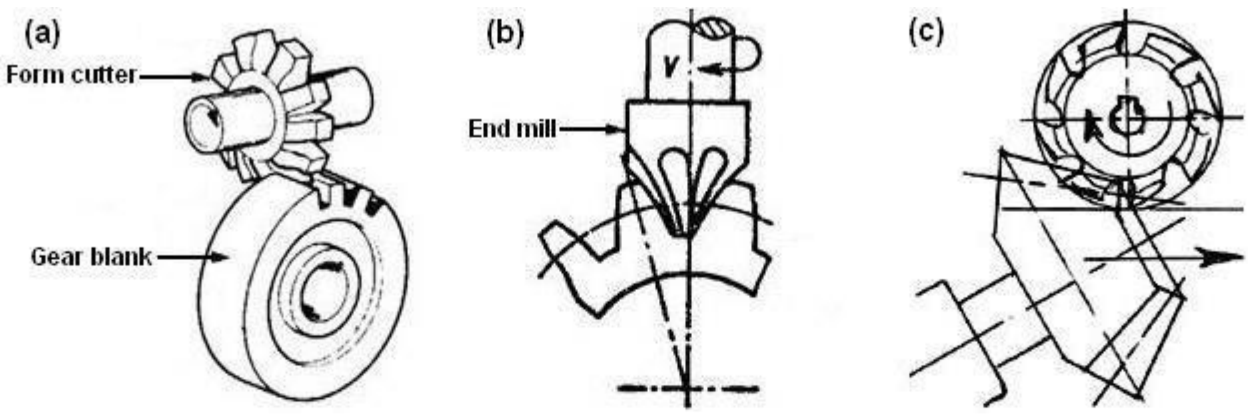
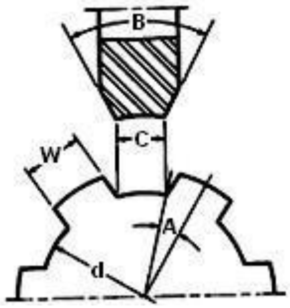


Fig. (a) Cutting teeth of spur gear by disc type cutter (b) Cutting teeth of spur gear by end mill

(c) Cutting teeth of straight toothed bevel gear by disc type cutter



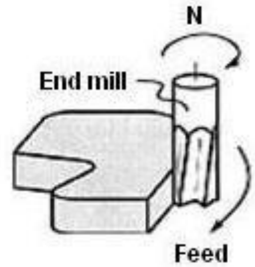


Fig. Cutting slots of external spline shaft **Fig. Profile milling of a cam**

Fig. (a) Surface contouring of 3-D surface (b) Surface contouring of die cavity

Gang milling: Gang milling operation is employed for quick production of complex contours comprising a number of parallel flat or curved surfaces.

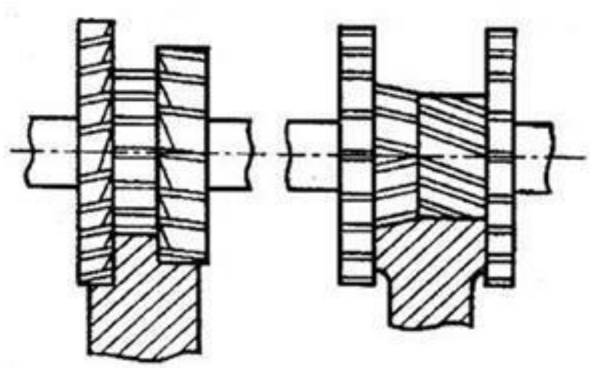


Fig. Gang milling

Turning by rotary tools: During turning like operations in large heavy and odd shaped jobs its speed (rpm) is essentially kept low. For enhancing productivity and better cutting fluid action rotary tools like milling cutters are used.

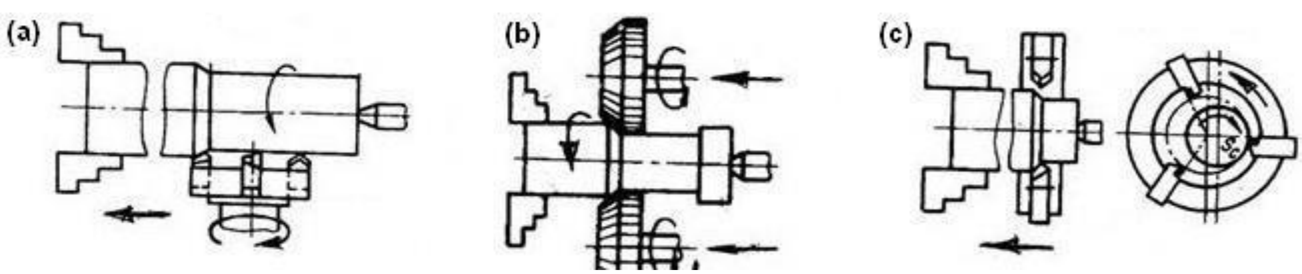


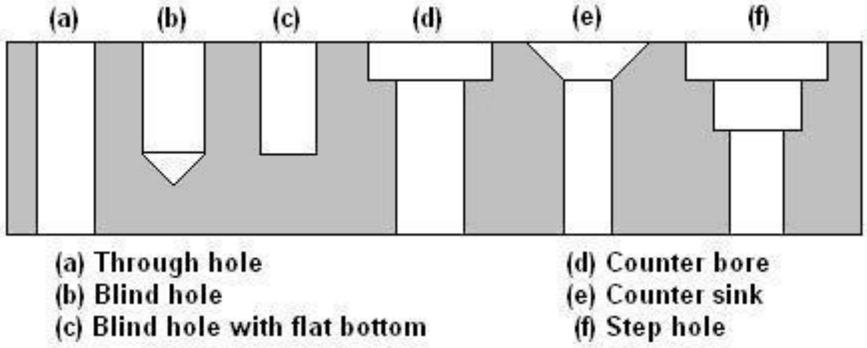
Fig. (a, b and c) Turning by rotary milling cutters

<u>HOLE MAKING</u>

25. Discuss the various hole making processes. (April/May 2011)

Machining round holes in metal stock is one of the most common operations in the manufacturing industry. It is estimated that of all the machining operations carried out, there are about20

% hole making operations. Literally no work piece leaves the machine shop without having a hole made in it.



The various types of holes are shown in Fig.

26. Discuss any three gear manufacturing methods.

(a) Casting

- For casting of gears sand moulds or permanent moulds are prepared and then molten metal is poured into the mold cavity to get the required gear.
- Cast iron gears are made by this method comfortably. These gears (casted gears) cannot be very fine, these are rough, low strength, and with some inaccuracies in operation. There cost of production is very low.
- This method is recommended for manufacturing of large sized gears where cost and power transmission are important than operating accuracy and noise level.

(b) Plastic Moulding.

- Plastic mould is also one of the ways of gear manufacturing. In plastic moulding gears of plastic material can be manufactured by using injection moulding or compression moulding.
- These are the very light duties gears used for transmission of very low amount of power but maintains velocity ratio accurately.
- Plastic moulding is also used for making gears of metal in this process the metallic work piece is heated first to bring it to a plastic state and then it is moulded to the required shape with the help of mechanical tools, die, and application of pressure.
- This process is used to make light duty smaller gears with accuracy. Non-ferrous metals can also be used as raw material for gear making by plastic moulding methods.

(c) Machining

- This is most widely used gear manufacturing method. Gear blank of accurate size and shape is first prepared by cutting it from metal stock.
- The gear blank can also be the metal casting. This method lies under the category of chip forming process.
- Gear is prepared by cutting one by one tooth in the gear blank of desired shape and size along it periphery. Different gear cutting methods are used in this category.

27. List the various Gears Shaping Process, explain any two with neat sketch and mention their advantage and limitations. (Apr/ May 2010)

Gear shaping is one of the gear generating methods. In this process gear tooth are accurately sized and shaped by cutting them by a multipoint cutting tool. Various gear shaping processes are listed and then described below:

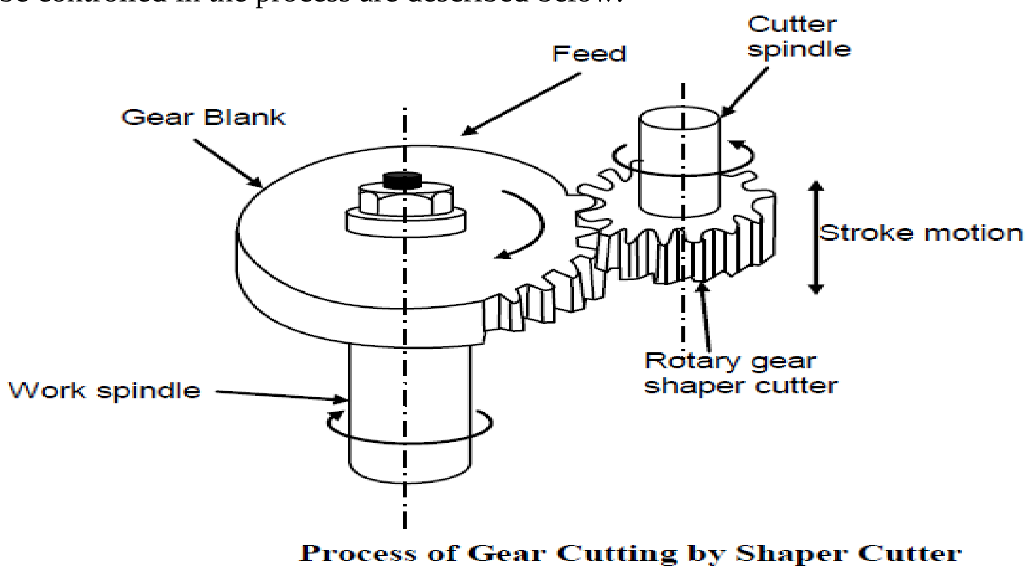
(a) Gear cutting by gear shaper.

(b) Rack planning process.

(c) Hobbing process.

Gear Cutting by Gear Shaper

- This process uses a pinion shaped cutter carrying clearance on the tooth face and sides and a hole at its centre for mounting it on a stub arbor or spindle of the machine. The cutter is mounted by keeping its axis in vertical position.
- It is also made reciprocating along the vertical axis up and down with adjustable and pre-decides amplitude. The cutter and the gear blank both are set to rotate at very low rpm about their respective axis.
- The relative rpm of both (cutter and blank) can be fixed to any of the available value with the help of a gear train. This way all the cutting teeth of cutter come is action one-by-one giving sufficient time for their cooling and incorporating a longer tool life.
- The specific advantages of the process over other processes, its product cycle time is very low and negligible dimensional variability from one unit to other in case of mass production. The main parameters to be controlled in the process are described below.



Process of Gear Cutting by Shaper Cutter

Cutting Speed

- Shaper cutter can move vertically upward and downward during the operation. The downward during the operation.
- The downward movement of the cutter is the cutting stroke and its speed (linear) with which it comes down is the cutting speed.
- After the completion of cutting stroke, cutter comes back to its top position which is called return stroke.

There is no cutting in the return stroke. Length of cutting stroke can be adjusted to any value out of available values on the machine.

Indexing Motion

- Indexing motion is equivalent to feed motion in the gear shaping operation. Slow rotations of the gear cutter and work piece provide the circular feed to the operation.
- These two rpms are adjusted with the help of a change gear mechanism. The rpm are relatively adjusted such that each rotation of the cutter the gear blank revolves through revolution.

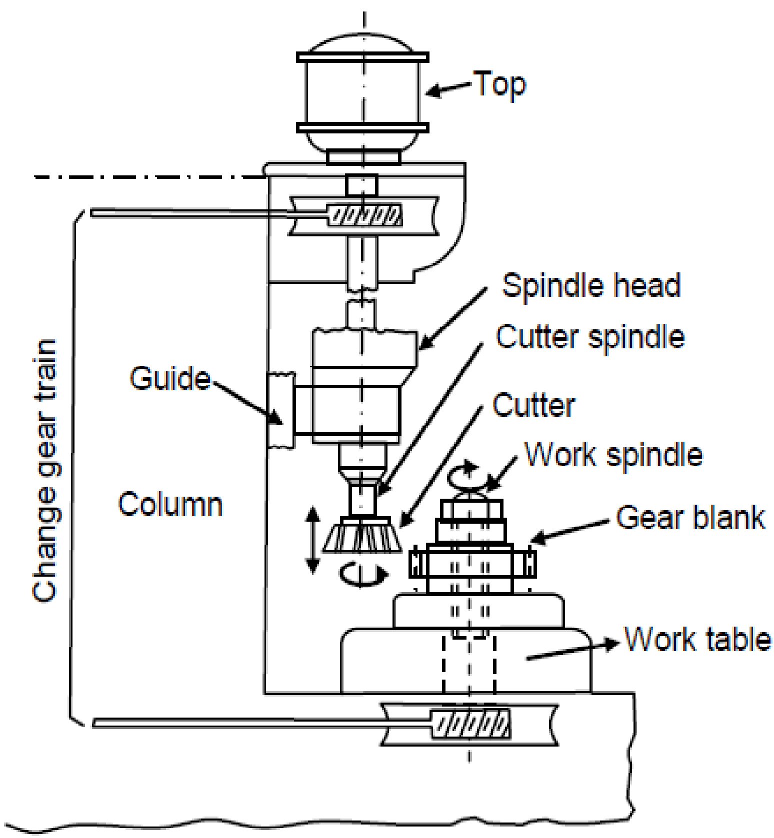
Where

n = Number of teeth of cutter, and

N = Number of teeth to be cut on the blank.

Depth of Cut

- Indexing movement or circular feed and reciprocating motions continue until the required numbers of teeth to the required depth are made all along the periphery of the gear blank.
- The required depth is maintained gradually by cutting the teeth into two or three pass. In each successive pass, the depth of cut is increased as compared to its previous path.
- This gradual increase in depth of cut takes place by increasing the value of linear feed in return stroke.
- The whole of this process is carried out an a gear shaping machine which is of the shape of a column and knee type milling machine. All the motions given to gear blank and gear cutter are set controlled very precisely.



Setup for Gear Shaping Machine

Advantages of Gear Shaping Process

Main advantages of gear shaping process are described below:

(a) Shorter product cycle time and suitable for making medium and large sized gears in mass production.

(b) Different types of gears can be made except worm and worm wheels.

(c) Close tolerance in gear cutting can be maintained.

(d) Accuracy and repeatability of gear tooth profile can be maintained comfortably.

(e) For same value of gear tooth module a single type of cutter can be used irrespective of number of teeth in the gear.

Limitations of gear shaping process:

(a) It cannot be used to make worm and work wheel which is a particular type of gear.

(b) There is no cutting in the return stroke of the gear cutter, so there is a need to make return stroke faster than the cutting stroke.

(c) In case of cutting of helical gears, a specially designed guide containing a particular helix and helix angle, corresponding to the teeth to be made, is always needed on urgent basis.

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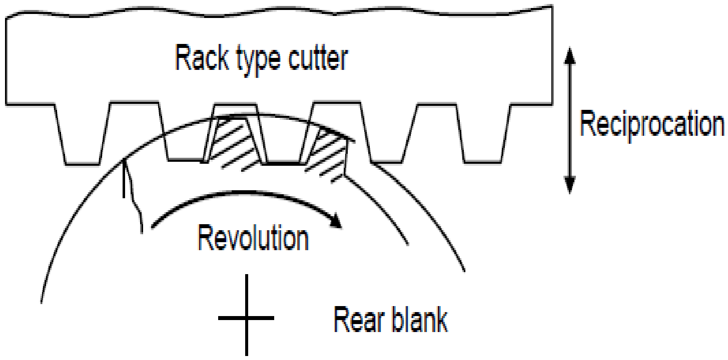


Gear shaping by rack type cutter

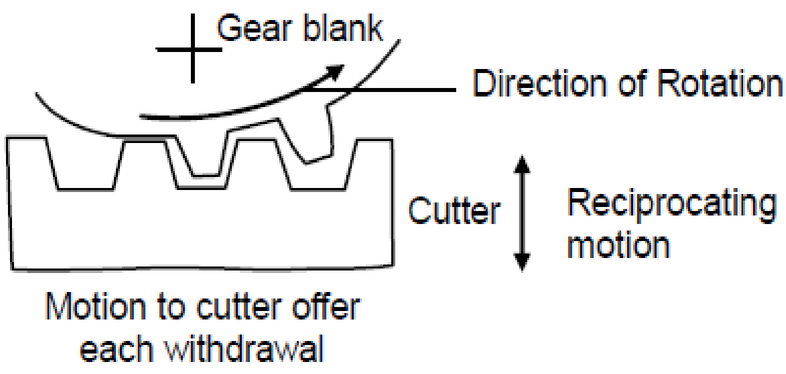
A few of the initial teeth of rack type cutter perform the cutting action and remaining teeth to very small removal of work piece material, these are used to maintain dimensional accuracy of the already cut teeth and to provide them a good finishing.

The basic principle of gear shaping is same but by slight altering the process some more different methods of gear shaping are discussed below.

Sunderland Process

- This process is named after the name of its inventor. In this process the cutter reciprocates in a direction towards and away from the gear blank.
- Cutter is gradually fed into the gear blank to the required depth. As soon as cutting is completed upto the desired depth, the blank rotates through one pitch distance.

- The cutter also moves along with the blank and then suddenly withdraws, stepped back by an amount equal to one pitch distance and again made to reciprocate in the normal way.
- The gear blank does not move till the completion of whole cutting upto the required depth. The whole motion and movement control is basically maintained with the help of synchronous motor and gear train.



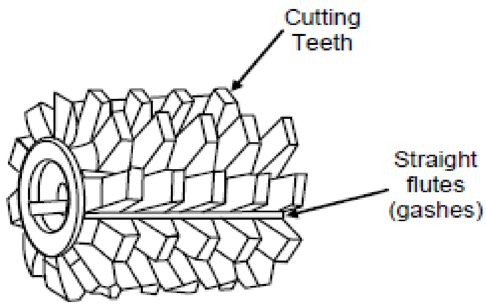
Process of Sunderland Gear Shaping Process

Mang Process

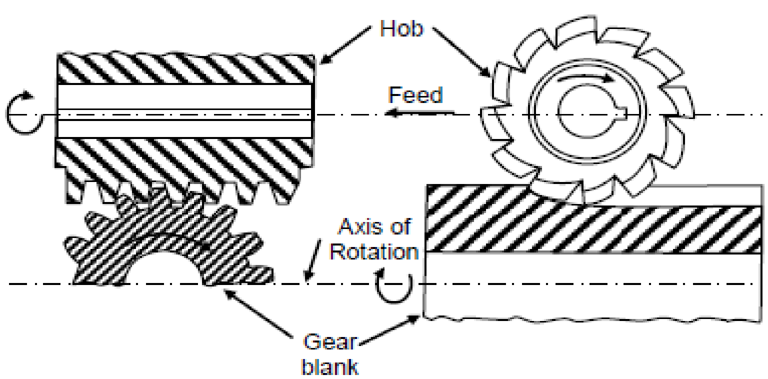
In this process gear blank is mounted on the machine table, keeping its axis in a vertical position. The cutter head, carrying rack type cutter, slides vertically in the sides provided at the front of the machine. The cutter can be set at any angle in a vertical plane. The cutter can also be made reciprocating in any direction. The rest of the process re-samples with other gear shaping processes.

28. Explain Gear Hobbing Process with neat sketch and list the Advantages and Limitations of Gear Hobbing Process. (Apr/ May 2004)

- In addition to the gear shaping process another process used for gear generation is gear hobbing. In this process, the gear blank is rolled with a rotating cutter called hob.
- Gear hobbing is done by using a multipoint cutting tool called gear hob. It looks like a worm gear having a number of straight flutes all around its periphery parallel to its axis. These flutes are so shaped by giving proper angles to them so that these work as cutting edges.
- In gear hobbing operation, the hob is rotated at a suitable rpm and simultaneously fed to the gear blank. The gear blank is also kept as revolving.
- Rpm of both, gear blank and gear hob are so synchronized that for each revolution of gear bob the gear blank rotates by a distance equal to one pitch distance of the gear to be cut.
- Motion of both gear blank and hob are maintained continuously and steady. The hob teeth behave like screw threads, having a definite helix angle.
- During operation the hob is tilted to helix angle so that its cutting edges remain square with the gear blank. Gear hobbing is used for making a wide variety of gears like spur gear, helical, hearing-bone, splines and gear sprockets, etc.



Gear Hob



Process of Gear Hobbing

❖ Three important parameters are to be controlled in the process of gear hobbing indexing movement, feedrate and angle between the axis of gear blank and gear hobbing tool (gear hob).

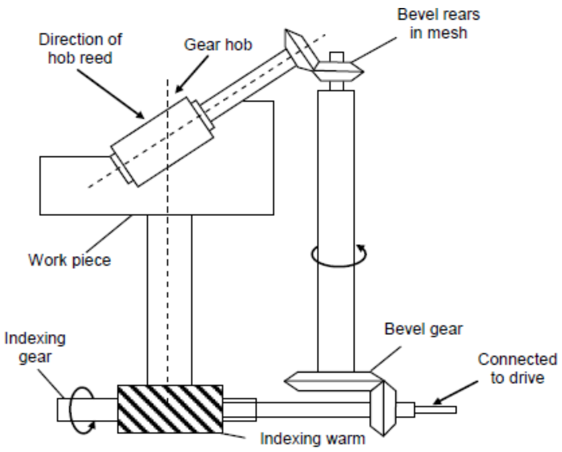
❖ The aims of hob are set at an inclination equal to the helix angle of the hob with the vertical axis of the blank. If a helical gear is to be cut, the hob axis is set at an inclination equal to the sum of the helix angleof the hob and the helix angle of the helical gear. Proper gear arrangement is used to maintain rpm ratio of gear blank and hob.

❖ The operation of gear hobbing involves feeding the revolving hob till it reaches to the required depth of the gear tooth. Simultaneously it is fed in a direction parallel to the axis of rotation.

❖ The process of gear hobbing is classified into different types according to the directions of feeding the hob for gear cutting.

The classification is described as given

below.Hobbing with Axial Feed



Setup for Gear Hobbing Machine

In this process the gear hob is fed against the gear blank along the face of the blank and parallel to its axis. This is used to make spur and helical gears.

Hobbing with Radial Feed

In this method the hob and gear blanks are set with their axis normal to each other. The rotating hob is fed against the gear blank in radial direction or perpendicular to the axis of gear blank. This method is used to make the worm wheels.

Hobbing with Tangential Feed

This is also used for cutting teeth on worm wheel. In this case, the hob is held with its axis horizontal butat right angle to the axis of the blank. The hob is set at full depth of the tooth and then fed forward axially. The hob is fed tangential to the face of gear blank.

Advantages and Limitations of Gear Hobbing Process

(a) Gear hobbing is a fast and continuous process so it is realized as economical process as compared to othergear generation processes.
(b) Lower production cycle time, i.e. faster production rate.
(c) The process has a larger variability's in the following of sense as compared to other gear machining processes.
(d) Capable to make wide variety of gears like spur gear, helical gears, worms, splines, sprockets, etc.
(e) Process of required indexing (named so) is quite simplified and capable to make any number of teeth withconsistent accuracy of module.

(f) A special type of gear named herringbone gear cam be generated by gear hobbing exclusively.
(g) Wide variety of batch size (small to large volume) can be accommodated by this process.
(h) Several gear blanks, mounted on the same arbor, can be processed simultaneously.
(i) Hob is multipoint cutting tool having multi cutting teeth or edges at a time few number of cutting edgeswork so lots of time is available to dissipate the generated heat. There is no overheating and cutting tool.

29. Explain Finishing of Gear Teeth operations. (Apr/ May 2006)

- For smooth running, good performance and long service life, the gears need to be accurate in dimensionsand forms to have high surface finish and to be hard and wear resistive at their tooth flanks which are achieved by some gear teeth finishing work after near accurate preforming and machining.
- Small gears made by cold rolling generally do not require further finishing. If a rolled gear needs further surface hardening only then little finishing by grinding or lapping is done after hardening.
- Gears produced to near-net-shape by die casting, powder metallurgy, extrusion, blanking etc. need little finishing. But machined and hardened gear teeth are essentially finished for accuracy and surface finish.
- Common methods of gear teeth finishing Gear teeth, after performing and machining, are finished generally by;

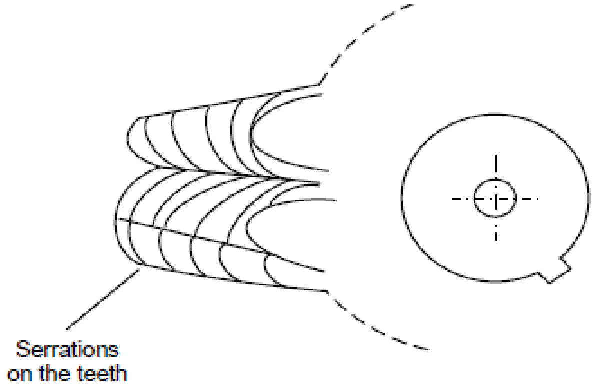
  - For soft and unhardened gears
    - ✓ Gear shaving
    - ✓ Gear rolling or burnishing
  - For hard and hardened gears
    - ✓ Grinding
    - ✓ Lapping
  - For soft but precision gears
    - ✓ Shaving followed by surface hardening and then lapping

Gear finishing operation

- Surface of gear teeth produced by any of the generating process is not accurate and of good quality (smooth).
- Dimensional inaccuracies and rough surface generated so become the source of lot of noise, excessive wear,play and backlash between the pair of gears in mesh. These all result in loss of power to be transmitted and incorrect velocity ratios.
- This can be summarized as inefficient power transmission. In order to overcome these problems some finishing operations are recommended for the produced gears. Sometimes poor quality of finish and dimensional inaccuracies occur due to hardening of a produced gear.
- The prepared (generated) gear is subjected to various hardening processes leading to various problems creating inaccuracies. So finishing operations are to be done at last.

Gear shaving

- Gear shaving is a process of finishing of gear tooth by running it at very high rpm in mesh with a gear shaving tool.
- A gear shaving tool is of a type of rack or pinion having hardened teeth provided with serrations. These serrations serve as cutting edges which do a scrapping operation on the mating faces of gear to be finished.

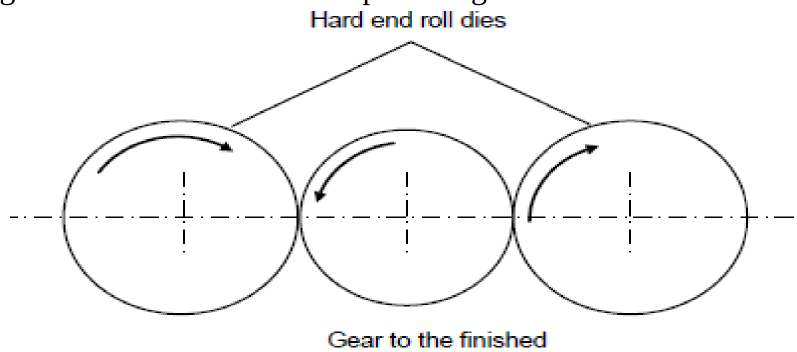


Gear Shaving Tool

Roll Finishing Of Gear Tooth

- This process involves use of two hardened rolling dies containing very accurate tooth profile of the gear to be finished. The gear to be finished is in between the two dies and all three are revalued about their axis.

- Pressure is exerted by both the rolling dies over the gear to be finished. The material of the die is very hard as compare to the material of gear so there is a plastic deformation of high points and burrs on the profile ofgear tooth resulting to smooth surface.
- The gear to be finished is mounted on a vertical reciprocating shaft and it is kept in mesh with three hardened burnishing compatible gears.
- The burnishing gears are fed into the cut gear and revalued few revaluations in both the directions. Plastic deformation of irregularities in cold state takes place to give smooth surface of the gear.



Roll Finishing

Gear Grinding

In this operation abrasive grinding wheel of a particular shape and geometry are used for finishing of gear teeth. Gear to be finished is mounted and reciprocated under the grinding wheel. Each of the gear teeth is subjected to grinding operations this way.

Gear teeth grinding

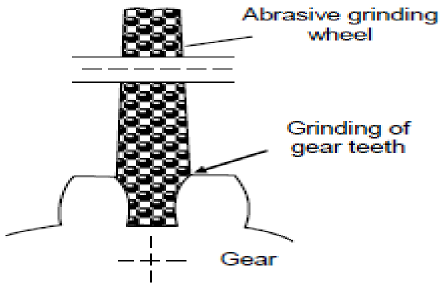
Grinding is a very accurate method and is, though relatively expensive, more widely used for finishing teeth of different type and size of gears of hard material or hardened surfaces. The properly formed and dressed wheel finishes the gear teeth flanks by fine machining or abrading action of the fine abrasives. Like gear milling, gear grinding is also done on two principles

- Forming
- Generation, which is more productive and accurate.

Gear teeth grinding on forming principle

- This is very similar to machining gear teeth by a single disc type form milling cutter. Where the grinding wheel is dressed to the form that is exactly required on the gear. Need of indexing makes the process slow and less accurate.

- The wheel or dressing has to be changed with change in module, pressure angle and even number of teeth. Form grinding may be used for finishing straight or single helical spur gears, straight toothed bevel gears aswell as worm and worm wheels.



Gear Grinding

Gear teeth grinding on generation principle

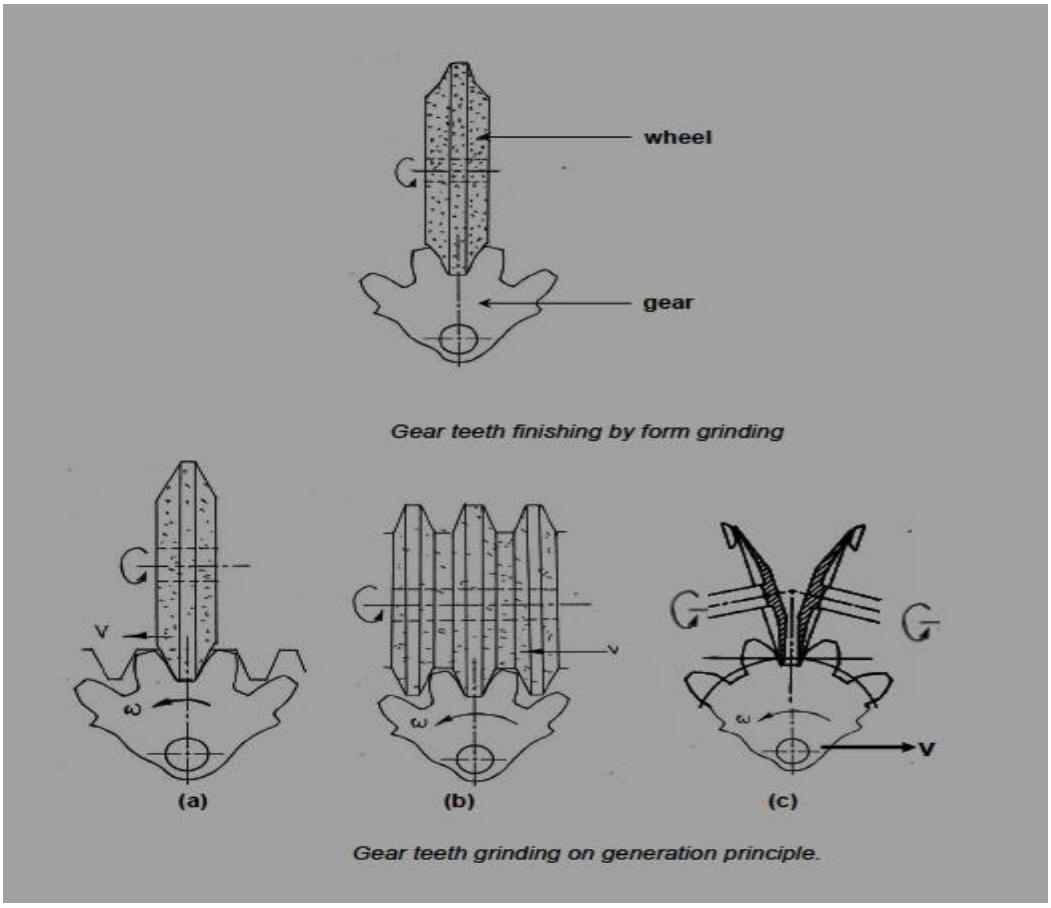
The simplest and most widely used method is very similar to spur gear teeth generation by one or multi- toothed rack cutter. The single or multi-ribbed rotating grinding wheel is reciprocated along the gear teeth as shown. Other tool – work motions remain same as in gear teeth generation by rack type cutter.

Lapping of a Gear

The process of lapping is used to improve surface finish of already made teeth. In this process the gear tobe lapped is run under load in mesh with cast iron toothed laps.

Abrasive paste is introduced between the teeth. It is mixed with oil and made to flow through the teeth.

One of the mating members (either gear or lapping tool) is reciprocated axially along with the revaluations.



Gear teeth grinding on generation principle.

Gear Honing

- It is used for super finishing of the generated gear teeth. Honing machines are generally used for this operation. The hones are rubbed against the profile generated on the gear tooth. Gear lapping and gear honing are the lost finishing operations of a gear generation process.
- In the above gear finishing operations some operations are based on metal cutting by removing very small size of chips like gear shaving, gear grinding, lapping and honing and some other operations like gear burnishing, roll finishing and based on finishing by plastic deformation of metal.

30. Write down the General Applications of Gears.

Gears of various type, size and material are widely used in several machines and systems requiring positive and stepped drive. The major applications are:

- Speed gear box, feed gear box and some other kinematic units of machine tools.
- Speed drives in textile, jute and similar machineries
- Gear boxes of automobiles
- Speed and / or feed drives of several metal forming machines
- Machineries for mining, tea processing etc.
- Large and heavy duty gear boxes used in cement industries, sugar industries, cranes, conveyors etc.
- Precision equipment clocks and watches.
- Industrial robots and toys.