UNIT - II

LATHE AND DRILLING MACHINES

CENTRE LATHE

Lathe is the oldest machine tool invented, starting with the Egyptian tree lathes. It is the father of all machine tools. Its main function is to remove material from a work piece to produce the required shape and size. This is accomplished by holding the work piece securely and rigidly on the machine and then turning it against the cutting tool which will remove material from the work piece in the form of chips. It is used to machine cylindrical parts. Generally single point cutting tool is used. In the year 1797 Henry Maudslay, an Englishman, designed the first screw cutting lathe which is the forerunner of the present day high speed, heavy duty production lathe.

Classification of lathes

Lathes are very versatile of wide use and are classified according to several aspects:

According to configuration:

- Horizontal - Most common for ergonomic conveniences.
- Vertical - Occupies less floor space, only some large lathes are of this type.

According to purpose of use:

- General purpose - Very versatile where almost all possible types of operations are carried out on wide ranges of size, shape and materials of jobs; e.g.: centre lathes.
- Single purpose - Only one (occasionally two) type of operation is done on limited ranges of size and material of jobs; e.g.: facing lathe, roll turning lathe etc.
- Special purpose - Where a definite number and type of operations are done repeatedly over long time on a specific type of blank; e.g.: capstan lathe, turret lathe, gear blanking lathe etc.

According to size or capacity:

- Small (low duty) - In such light duty lathes (up to 1.1 kW), only small and medium size jobs of generally soft and easily machinable materials are machined.
- Medium (medium duty) - These lathes of power nearly up to 11 kW are most versatile and commonly used.
- Large (heavy duty)
- Mini or micro lathe - These are tiny table-top lathes used for extremely small size jobs and precision work; e.g.: Swiss type automatic lathe.

According to configuration of the jobs being handled:

- Bar type - Slender rod like jobs being held in collets.
- Chucking type - Disc type jobs being held in chucks.
- Housing type - Odd shape jobs, being held in face plate.

According to precision:

- Ordinary
- Precision (lathes) - These sophisticated lathes meant for high accuracy and finish and are relatively more expensive.

According to number of spindles:

- Single spindle - Common.
- Multi-spindle (2, 4, 6 or 8 spindles) - Such uncommon lathes are suitably used for fast and mass production of small size and simple shaped jobs.

According to type of automation:

- Fixed automation - Conventional; e.g.: single spindle automat & Swiss type automatic lathe
- Flexible automation - Modern; e.g.: CNC lathe, turning centre etc.

According to degree of automation:

- Non-automatic - Almost all the handling operations are done manually; e.g.: centre lathes.
- Semi-automatic - Nearly half of the handling operations, irrespective of the processing operations, are done automatically and rest manually; e.g.: copying lathe, relieving lathe etc.
- Automatic - Almost all the handling operations (and obviously all the processing operations) are done automatically; e.g.: single spindle automat, Swiss type automatic lathe, etc.

CONSTRUCTIONAL FEATURES

Major parts of a centre lathe

Amongst the various types of lathes, centre lathes are the most versatile and commonly used. *Fig. 2.1 shows the basic configuration of a center lathe.* The major parts are:

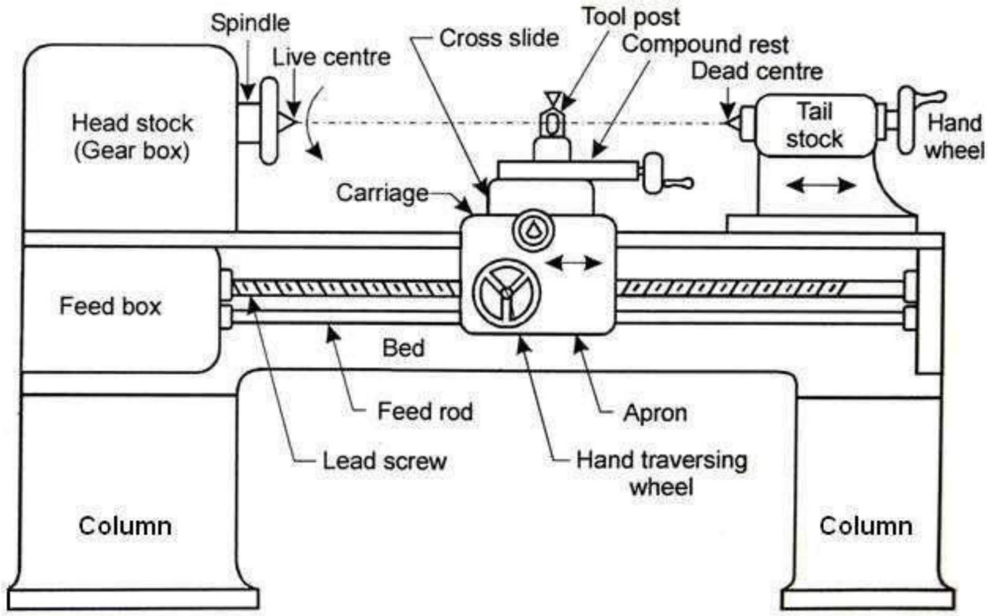


Fig. 2.1 Schematic view of a center lathe

Headstock It holds the spindle and through that power and rotation are transmitted to the job at different speeds. Various work holding attachments such as three jaw chucks, collets, and centres can be held in the spindle. The spindle is driven by an electric motor through a system of belt drives and gear trains. Spindle rotational speed is controlled by varying the geometry of the drive train.

Tailstock The tailstock can be used to support the end of the work piece with a center, to support longer blanks or to hold tools for drilling, reaming, threading, or cutting tapers. It can be adjusted in position along the ways to accommodate different length work pieces. The tailstock barrel can be fed along the axis of rotation with the tailstock hand wheel.

Bed Headstock is fixed and tailstock is clamped on it. Tailstock has a provision to slide and facilitate operations at different locations. The bed is fixed on columns and the carriage travels on it.

Carriage It is supported on the lathe bed-ways and can move in a direction parallel to the lathe axis. The carriage is used for giving various movements to the tool by hand and by power. It carries saddle, cross-slide, compound rest, tool post and apron.

Saddle It carries the cross slide, compound rest and tool post. It is an H-shaped casting fitted over the bed. It moves alone to guide ways.

Cross-slide It carries the compound rest and tool post. It is mounted on the top of the saddle. It can be moved by hand or may be given power feed through apron mechanism.

Compound rest It is mounted on the cross slide. It carries a circular base called swivel plate which is graduated in degrees. It is used during taper turning to set the tool for angular cuts. The upper part known as compound slide can be moved by means of a hand wheel.

Tool post It is fitted over the compound rest. The tool is clamped in it.

Apron Lower part of the carriage is termed as the apron. It is attached to the saddle and hangs in front of the bed. It contains gears, clutches and levers for moving the carriage by a hand wheel or power feed.

Feed mechanism The movement of the tool relative to the work piece is termed as "feed". The lathe tool can be given three types of feed, namely, longitudinal, cross and angular.

When the tool moves parallel to the axis of the lathe, the movement is called longitudinal feed. This is achieved by moving the carriage.

When the tool moves perpendicular to the axis of the lathe, the movement is called cross feed. This is achieved by moving the cross slide.

When the tool moves at an angle to the axis of the lathe, the movement is called angular feed. This is achieved by moving the compound slide, after swiveling it at an angle to the lathe axis.

Feed rod The feed rod is a long shaft, used to move the carriage or cross-slide for turning, facing, boring and all other operations except thread cutting. Power is transmitted from the lathe spindle to the apron gears through the feed rod via a large number of gears.

Lead screw The lead screw is long threaded shaft used as a master screw and brought into operation only when threads have to cut. In all other times the lead screw is disengaged from the gear box and remains stationary. The rotation of the lead screw is used to traverse the tool along the work to produce screw. The half nut makes the carriage to engage or disengage the lead screw.

Kinematic system and working principle of a centre lathe

Fig. 2.2 schematically shows the kinematic system of a 12 speed centre lathe.

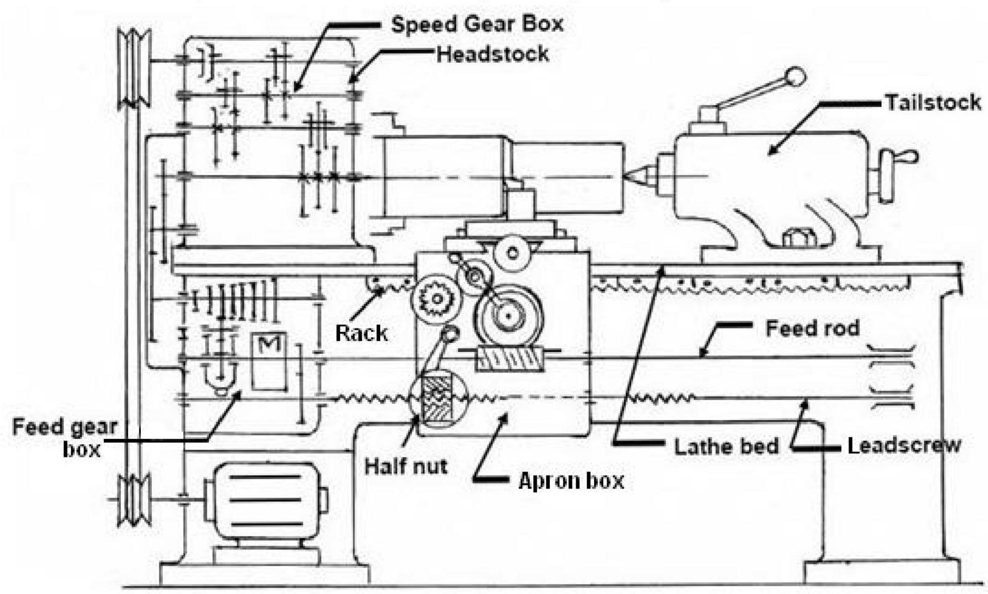


Fig. 2.2 Kinematic system of a 12 speed centre lathe

For machining in machine tools the job and the cutting tool need to be moved relative to each other. ***The tool-work motions are:***

- Formative motions: - cutting motion, feed motion.
- Auxiliary motions: - indexing motion, relieving motion.

In lathes: Cutting motion is attained by rotating the job and feed motion is attained by linear travel of the tool either axially for longitudinal feed or radially for cross feed.

It is noted, in general, from Fig. 2.2. The job gets rotation (and power) from the motor through the belt-pulley, clutch and then the speed gear box which splits the input speed into a number (here 12) of speeds by operating the cluster gears.

The cutting tool derives its automatic feed motion(s) from the rotation of the spindle via the gear quadrant, feed gear box and then the apron mechanism where the rotation of the feed rod is transmitted:

- Either to the pinion which being rolled along the rack provides the longitudinal feed.
- Or to the screw of the cross slide for cross or transverse feed.

While cutting screw threads the half nuts are engaged with the rotating lead screw to positively cause travel of the carriage and hence the tool parallel to the lathe bed i.e., job axis.

The feed-rate for both turning and threading is varied as needed by operating the Norton gear and the Meander drive systems existing in the feed gear box (FGB). The range of feeds can be augmented by changing the gear ratio in the gear quadrant connecting the FGB with the spindle.

As and when required, the tailstock is shifted along the lathe bed by operating the clamping bolt and the tailstock quill is moved forward or backward or is kept locked in the desired location. *The versatility or working range of the centre lathes is augmented by using several special attachments.*

Headstock driving mechanisms

There are two types of headstock driving mechanisms as follows:

1. Back geared headstock.
2. All geared headstock.

Back geared headstock

Back gear arrangement is used for reducing the spindle speed, which is necessary for thread cutting and knurling. *The back gear arrangement is shown in Fig.2.3.*

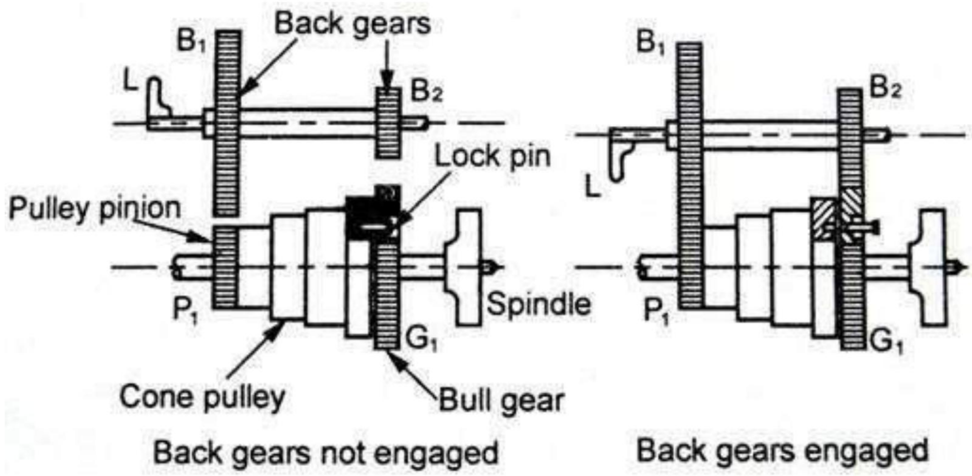


Fig. 2.3 Back gear arrangement

There is one stepped cone pulley in the lathe spindle. This pulley can freely rotate on the spindle. A pinion gear P_1 is connected to small end of the cone pulley. P_1 will rotate when cone pulley rotates. Bull gear G_1 is keyed to lathe spindle such that the spindle will rotate when Gear G_1 rotates. Speed changes can be obtained by changing the flat belt on the steps. A bull gear G_1 may be locked or unlocked with this cone pulley by a lock pin.

There are two back gears B_1 and B_2 on a back shaft. It is operated by means of hand lever L; back gears B_1 and B_2 can be engaged or disengaged with G_1 and P_1. For getting direct speed, back gear is not engaged. The step cone pulley is locked with the main spindle by using the lock pin. The flat belt is changed for different steps. Thus three or four ranges of speed can be obtained directly.

For getting slow or indirect speeds, back gear is engaged by lever L and lock pin is disengaged. Now, power will flow from P_1 to B_1. B_1 to B_2 (same shaft), B_2 to G_1 to spindle. As gear B_1 is larger than P_1, the speed will further be reduced at B_1. B_1 and B_2 will have the same speeds. The speed will further be reduced at G_1 because gear G_1 is larger than B_2. So, the speed of spindle is reduced by engaging the back gear.

All geared headstock

All geared headstock is commonly used in modern lathes because of the following advantages:

- It gives wider range of spindle speeds.
- It is more efficient and compact than cone pulley mechanism.
- Power available at the tool is almost constant for all spindle speeds.
- Belt shifting is eliminated.
- The vibration of the spindle is reduced.
- More power can be transmitted.

The all geared headstock is shown in Fig 2.4.

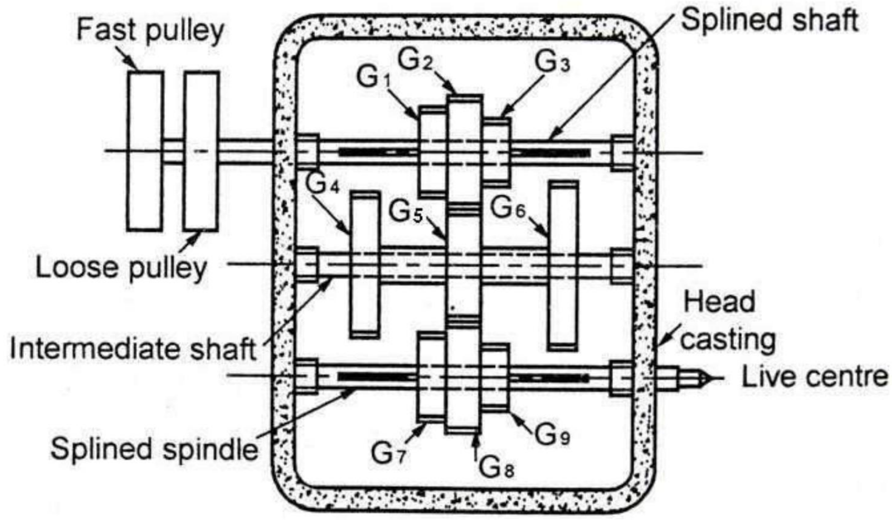


Fig. 2.4 All geared headstock

The power from the constant speed motor is delivered to the spindle through a belt drive. Speed changing is made by levers. The different spindle speeds are obtained by shifting the levers into different positions to obtain different gear combinations. This mechanism has a splined spindle, intermediate shaft and a splined shaft. The splined shaft receives power from motor through a belt drive.

This shaft has 3 gears namely G_1, G_2 and G_3. These gears can be shifted with the help of lever along the shaft. Gears G_4, G_5 and G_6 are mounted on intermediate shaft and cannot be moved axially. Gears G_7, G_8 and G_9 are mounted on splined headstock spindle and can be moved axially be levers. Gears G_1, G_2 and G_3 can be meshed with the gears G_4, G_5 and G_6 individually. Similarly, gears G_7, G_8, G_9 can be meshed with gear G_4, G_5 and G_6 individually. Thus, it provides nine different speeds.

Feed mechanisms

The feed mechanism is used to transmit power from the spindle to the carriage. Therefore, it converts rotary motion of the spindle into linear motion of the carriage. The feed can be given either by hand or automatically. For automatic feeding, the following feed mechanisms are used:

- Tumbler gear reversing mechanism.
- Quick-change gearbox.
- Tumbler gear quick-change gearbox.
- Apron mechanism.
- Bevel gear feed reversing mechanism.

Tumbler gear reversing mechanism

Tumbler gear mechanism is used to change the direction of lead screw and feed rod. By engaging tumbler gear, the carriage can be moved along the lathe axis in either direction during thread cutting or automatic machining. *Fig. 2.5 shows the schematic arrangement of tumbler gear reversing mechanism.*

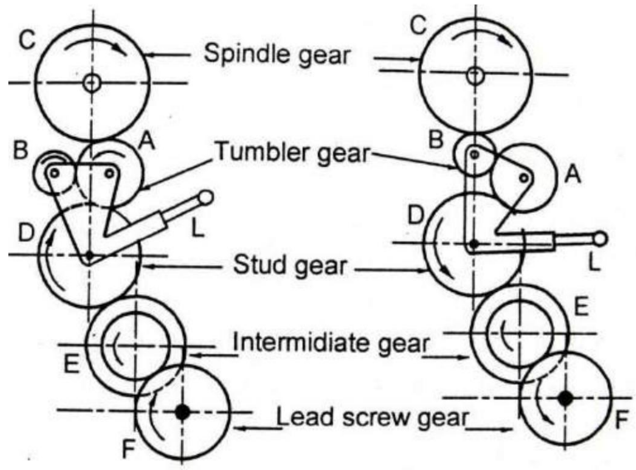


Fig. 2.5 Tumbler gear reversing mechanism

The tumbler gear unit has two pinions (A and B) of same size and is mounted on a bracket. The bracket is pivoted at a point and can be moved up and down by a lever L. The bracket may be placed in three positions i.e., upward, downward and neutral. Gear 'C' is a spindle gear attached to the lathe spindle. Gear 'D' is the stud gear. The stud gear is connected to the lead screw gear through a set of intermediate gears.

When the lever is shifted upward position, the gear 'A' is engaged with spindle gear 'C' and the power is transmitted through C-A-D-E-F. During this position, lead screw will rotate in the same direction as spindle rotates (i.e. both anticlockwise). Now, the carriage moves towards the headstock. When the lever is shifted downward, the gear 'B' is engaged with spindle gear 'C' and the power is transmitted through C-B-A-D-E-F. Hence, the lead screw will rotate in the opposite direction of the spindle. Now, the carriage moves towards tailstock.

When the bracket is in neutral position, the engagement of tumbler gears is disconnected with the spindle gear. Hence, there is no power transmission to lead screw.

Quick-change gear box

Quick-change gearbox is used to get various power feeds in the lathe. *Fig. 2.6 shows the schematic arrangement of quick-change gear box.*

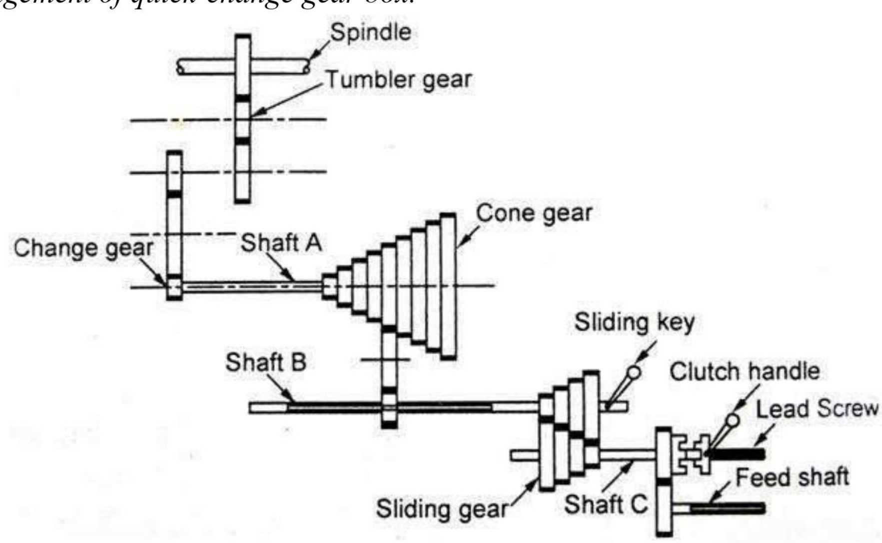


Fig. 2.6 quick-change gear box

Power from the lathe spindle is transmitted to feed shaft through tumbler gear, change gear train and quick-change gearbox. Shaft A (Cone gear shaft) contains 9 different sizes of gears keyed with it. Shaft B (Sliding gear shaft) has a gear and it receives 9 different speeds from shaft A by the use of sliding gear. Shaft B is connected to shaft C (Driven shaft) through 4 cone years. Therefore, Shaft C can get 9 X 4 = 36 different speeds. The shaft C is connected to lead screw by a clutch and feed rod by a gear train. Lead screw is used for thread cutting and feed rod is used for automatic feeds.

Tumbler gear quick-change gear box

The different speed of the driving shaft is obtained by a tumbler gear and cone gear arrangement. *Fig. 2.7 shows the schematic arrangement of tumbler gear quick-change gear box.*

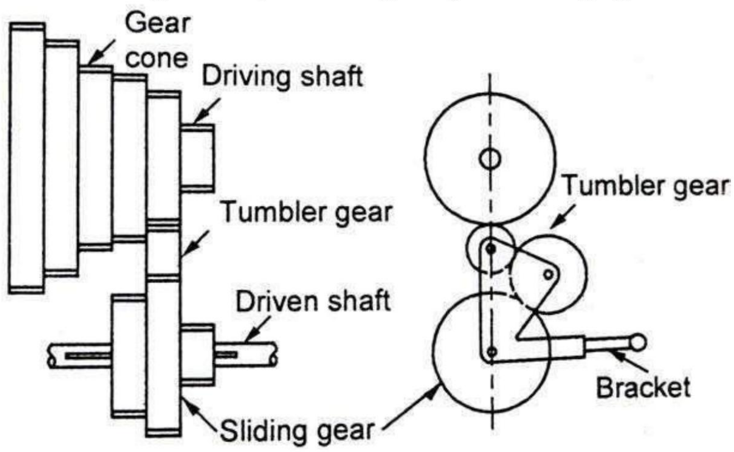


Fig. 2.7 Tumbler gear quick-change gearbox

It is simpler than quick-change gearbox. A tumbler gear and a sliding gear are attached to the bracket as shown in Fig. 2.7. Driving shaft has a cone gear made up of different sizes of gears. The sliding gear is keyed to the driven shaft which is connected by the lead screw or feed rod. The sliding gear can be made to slide and engaged at any desired position. By sliding the sliding gear to various positions and engaging the tumbler gear, various speeds can be obtained.

Apron mechanism

Fig. 2.8 shows the schematic arrangement of apron mechanism.

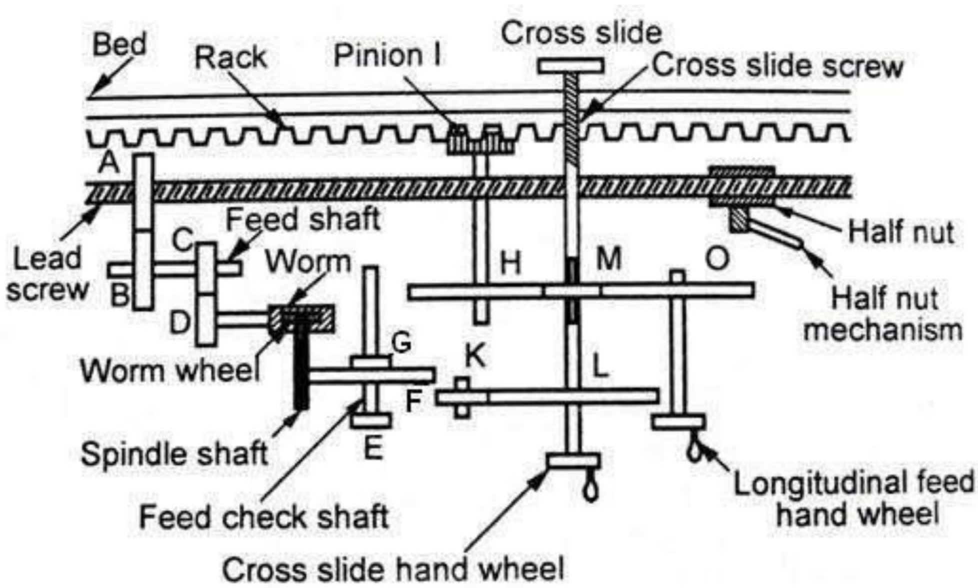


Fig. 2.8 Apron mechanism

Lead screw and feed rod is getting power from spindle gear through tumbler gears. Power is transmitted from feed rod to the worm wheel through gears A, B, C, D and worm.

A splined shaft is attached with worm wheel. The splined shaft is always engaged with the gears F and G which are keyed to the feed check shaft. A knob ‘E’ is fitted with feed check shaft. Feed check knob ‘E’ can be placed in three positions such as neutral, push-in and pull-out.

When the feed check knob ‘E’ is in neutral position, power is not transmitted either to cross feed screw or to the carriage since gears F and G have no connection with H and K. Therefore, hand feed is given as follows. When the longitudinal feed hand wheel rotates, pinion I will also be rotated through I and H. pinion I will move on rack for taking longitudinal feed. For getting cross feed, cross slide screw will be rotated by using cross slide hand wheel.

When the feed check knob ‘E’ is push-in, rotating gear G will be engaged to H. then the power will be transmitted to pinion I. pinion I will rotate on rack. So, automatic longitudinal feed takes place. When the feed check knob ‘E’ is pulled-out, the rotating gear F will be engaged to K. Hence, the power will be transmitted to cross feed screws through L. This leads to automatic cross feed.

For thread cutting, half nut is engaged by half nut lever after putting knob ‘E’ neutral position. Half nut is firmly attached with the carriage. As the lead screw rotates, the carriage will automatically move along the axis of the lathe. Both longitudinal and cross feed can be reversed by operating the tumbler gear mechanism.

Bevel gear feed reversing mechanism

The tumbler gear mechanism being a non-rigid construction cannot be used in a modern heavy duty lathe. The clutch operated bevel gear feed reversing mechanism incorporated below the head stock or in apron provides sufficient rigidity in construction. *Fig. 2.9 shows the schematic arrangement of bevel gear feed reversing mechanism.*

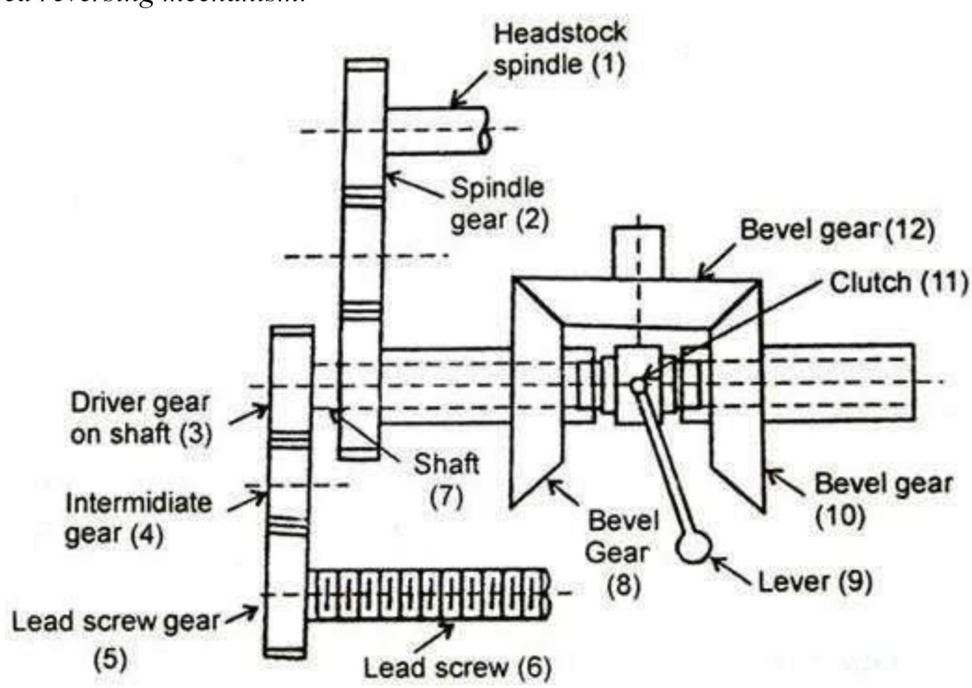


Fig. 2.9 Bevel gear feed reversing mechanism

The motion is communicated from the spindle gear 2 to the gear on the stud shaft through the intermediate gear. The bevel gear 8 is attached to the gear on the stud shaft and both of them can freely rotate on shaft 7. The bevel gear 8 meshes with bevel gear 12 and 12 mesh with 10. 12, 10 and 8 are having equal number of teeth. The bevel gear 10 can also rotate freely on shaft 7.

A clutch 11 is keyed to the shaft 7 by a feather key and may be shifted to left or right, by the lever 9 to be engaged with the gear 8 or 10 or it remains in the neutral position. When the clutch engages with bevel gear 8, gear 3 which is keyed to the shaft 7 and the lead screw, rotates in the same direction as the gear 2. The direction of rotation is reversed when the clutch 11 engages with gear 10.

Mounting of jobs in centre lathe

Without additional support from the tailstock

Chucks - 3 jaw self centering chuck or universal chuck and 4 jaw independent chuck

Fig. 2.10 (a and b) visualizes 3-jaw and 4-jaw chucks which are mounted at the spindle nose and firmly hold the job in centre lathes. Premachined round bars are quickly and coaxially mounted by simultaneously moving the three jaws radially by rotating the scroll (disc with radial threads) by a key *as can be seen in the diagram 2.10 (a)*

The four jaw chucks, available in varying sizes, are generally used for essentially more strongly holding non-circular bars like square, rectangular, hexagonal and even odder sectional jobs in addition to cylindrical bars, both with and without premachining at the gripping portion. The jaws are moved radially independently by rotating the corresponding screws which push the rack provided on the back side of each jaw *as can be seen in the diagram 2.10 (b).*

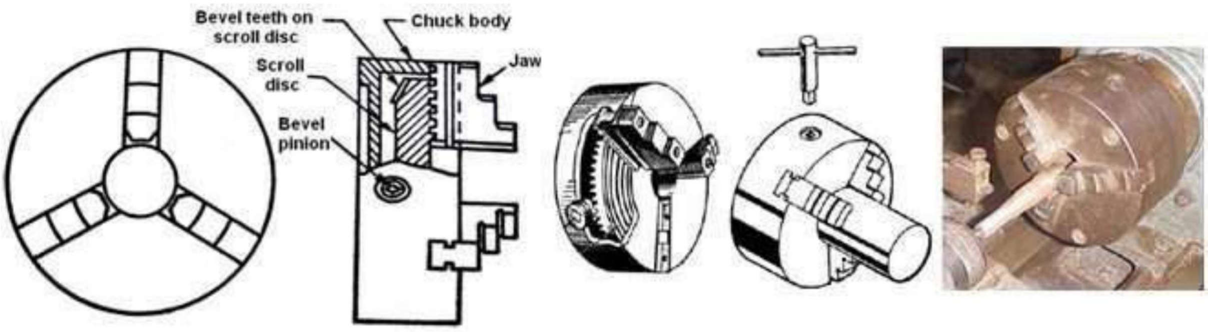


Fig. 2.10 (a) 3-jaw self centering chuck or universal chuck

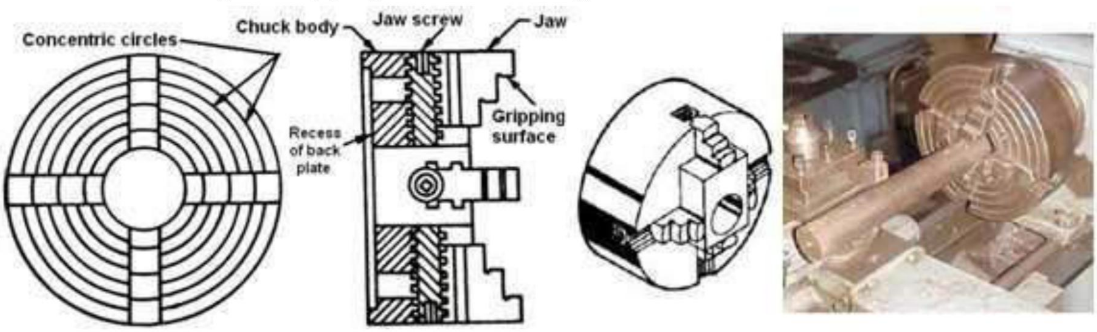
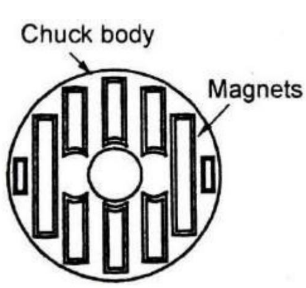


Fig. 2.10 (b) 4-jaw independent chuck

Magnetic chuck

This is used for holding thin jobs. When the pressure of jaws is to be prevented, this chuck is used. The chuck gets magnetic power from an electro-magnet. Only magnetic materials can be held on this chuck. *Fig. 2.11 shows the magnetic chuck.*



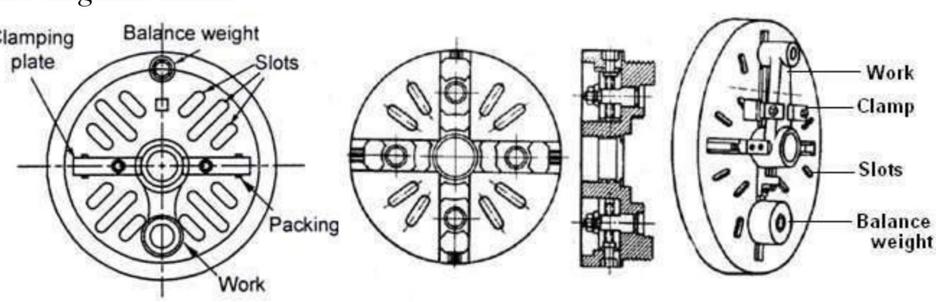


Fig. 2.11 Magnetic chuck Fig. 2.12 Face plate

Face plate

A face plate *as shown in Fig. 2.12* consists of a circular disc bored out and threaded to fit the nose of lathe spindle. This has radial, plain and T slots for holding work by bolts and clamps. Face plates are used for holding work pieces which cannot be conveniently held between centres or by chucks.

Angle plate

Angle plate is a cast iron plate that has two faces at right angles to each other. Holes and slots are provided on both faces *as shown in Fig. 2.13 (a).* An angle plate is used along with the face plate when holding eccentric or unsymmetrical jobs that are difficult to grip directly on the face plate *as shown in Fig. 2.13 (b).*

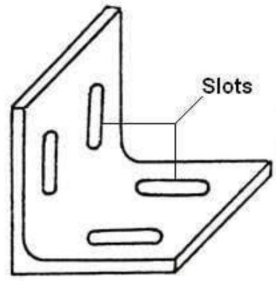


Fig. 2.13 (a) Angle plate

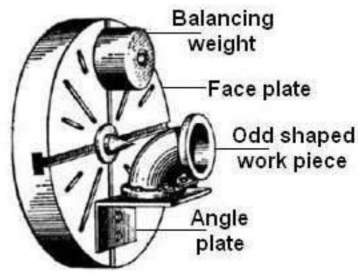


Fig. 2.13 (b) Angle plate used along with face plate

With additional support from the tailstock

Catch plate or driving plate

It is circular plate of steel or cast iron having a projected boss at its rear. The boss has a threaded hole and it can be screwed to the nose of the headstock spindle. The driving is fitted to the plate. It is used to drive the work piece through a carrier or dog when the work piece is held between the centres. *Fig. 2.14 shows the catch plate.*

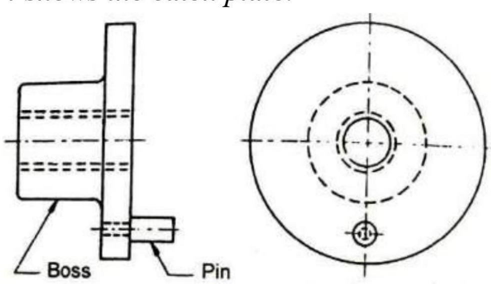
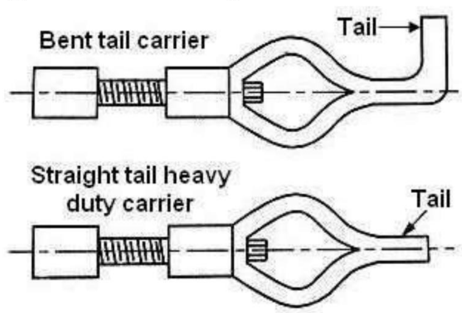


Fig. 2.14 Catch plate



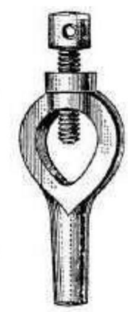


Fig. 2.15 Types of carriers

Carriers or Dogs

It is used to transfer motion from the driving plate to the work piece held between centres. The work piece is inserted into the hole of the dog and firmly secured in position by means of set screw. *The different types of carriers are shown in Fig 2. 15.*

Mandrels

A mandrel is a device used for holding and rotating a hollow work piece that has been previously drilled or bored. The work revolves with the mandrel which is mounted between two centres. The mandrel should be true with accurate centre holes for machining outer surface of the work piece concentric with its bore. To avoid distortion and wear it is made of high carbon steel.

The ends of a mandrel are slightly smaller in diameter and flattened to provide effective gripping surface of the lathe dog set screw. The mandrel is rotated by the lathe dog and the catch plate and it drives the work by friction. Different types of mandrels are employed according to specific requirements. *Fig. 2.16 shows the different types of mandrels in common use.*

In-between centres (by catch plate and carriers)

Fig. 2.17 schematically shows how long slender rods are held in between the live centre fitted into the headstock spindle and the dead centre fitted in the quill of the tailstock. The torque and rotation are transmitted from the spindle to the job with the help of a lathe dog or catcher which is again driven by a driving plate fitted at the spindle nose.

Depending upon the situation or requirement, different types of centres are used at the tailstock end *as indicated in Fig. 2.18.* A revolving centre is preferably used when desired to avoid sliding friction between the job and the centre which also rotates along with the job.

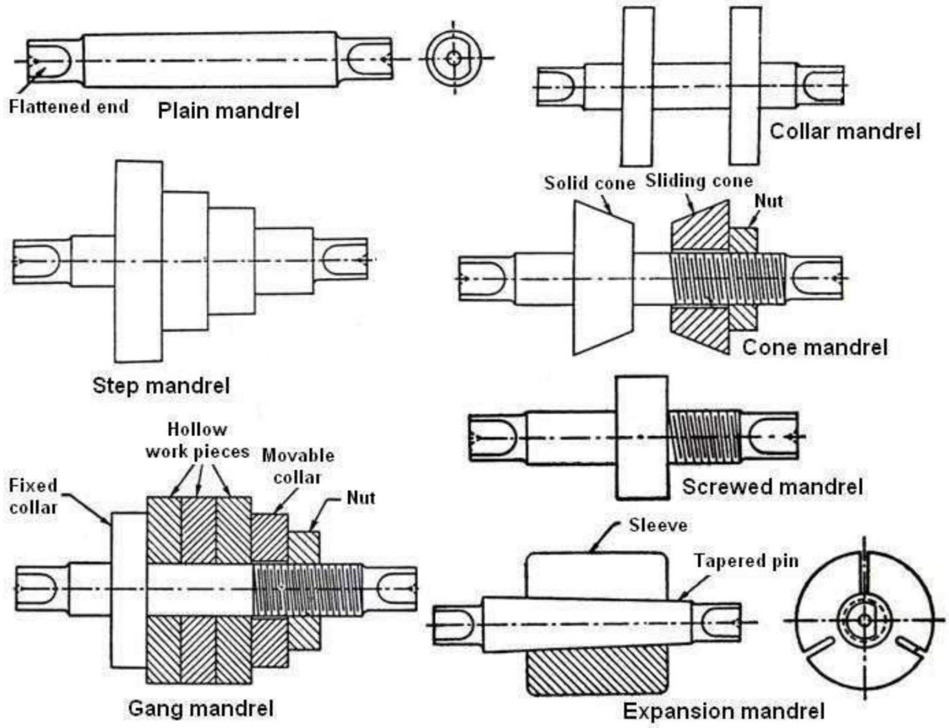


Fig. 2.16 Types of mandrels

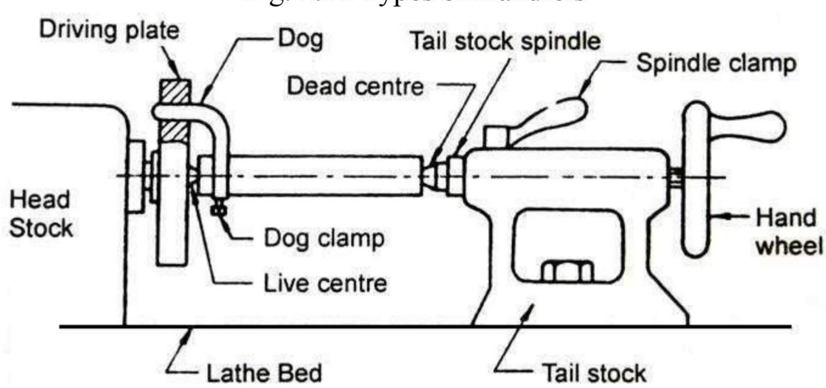


Fig. 2.17 Work held between centres

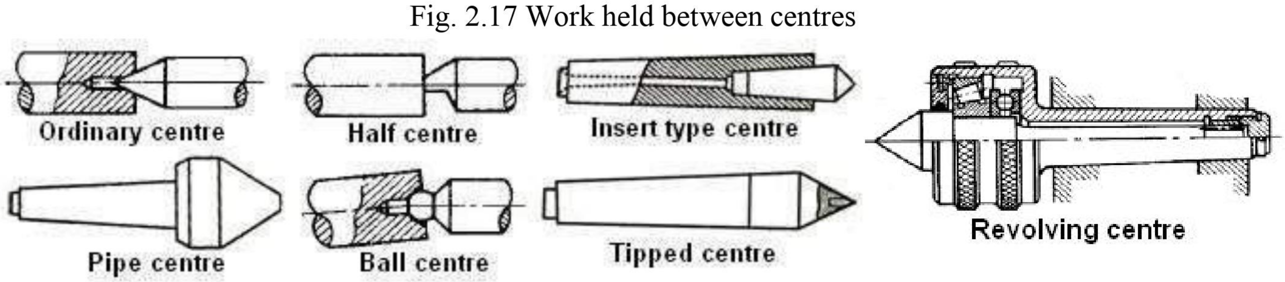


Fig. 2.18 Types of centres

Ordinary centre: It is used for general works.

Insert type centre: In this the steel "insert" can be replaced instead of replacing the whole centre.

Half centre: It is similar to ordinary centre and used for facing bar ends without removal of the centre.

Pipe centre: It is used for supporting pipes and hollow end jobs.

Ball centre: It has ball shaped end to minimize the wear and strain. It is suitable for taper turning.

Tipped centre: Hard alloy tip is brazed into steel shank. The hard tip has high wear resistant.

Revolving centre: The ball and roller bearings are fitted into the housing to reduce friction and to take up end thrust. This is used in tail stock for supporting heavy work revolving at a high speed.

In-between chuck and centre

Heavy and reasonably long jobs of large diameter and requiring heavy cuts (cutting forces) are essentially held strongly and rigidly in the chuck at headstock with support from the tailstock through a revolving centre *as can be seen in Fig. 2.19.*

Fig. 2.19 Work held between chuck and revolving centre

In-between headstock and tailstock with additional support of rest

To prevent deflection of the long slender jobs like feed rod, lead screw etc. due to sagging and cutting forces during machining, some additional supports are provided *as shown in Fig. 2.20.* Such additional support may be a steady rest which remains fixed at a suitable location or a follower rest which moves along with the cutting tool during long straight turning without any steps in the job's diameter. *Fig. 2.21 (a and b) shows the steady rest and follower rest.*

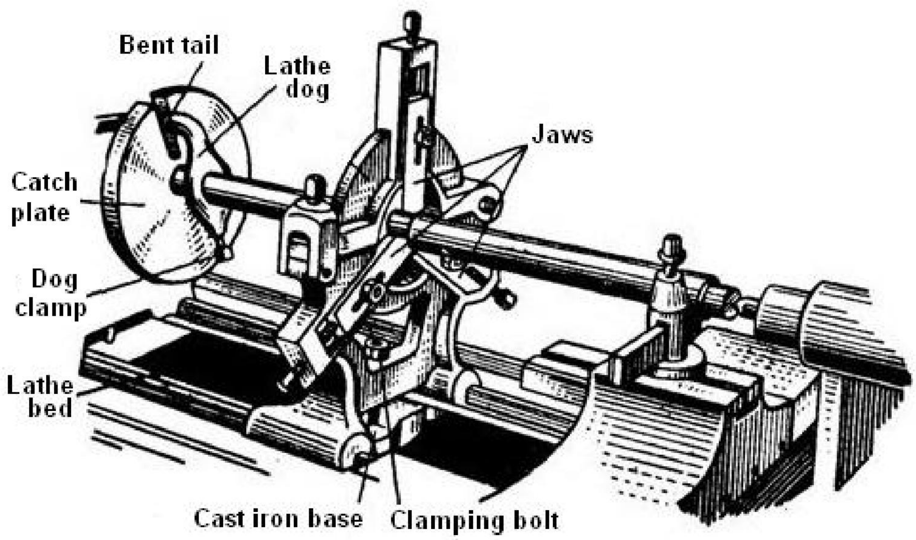


Fig. 2.20 Slender job held with extra support by steady rest

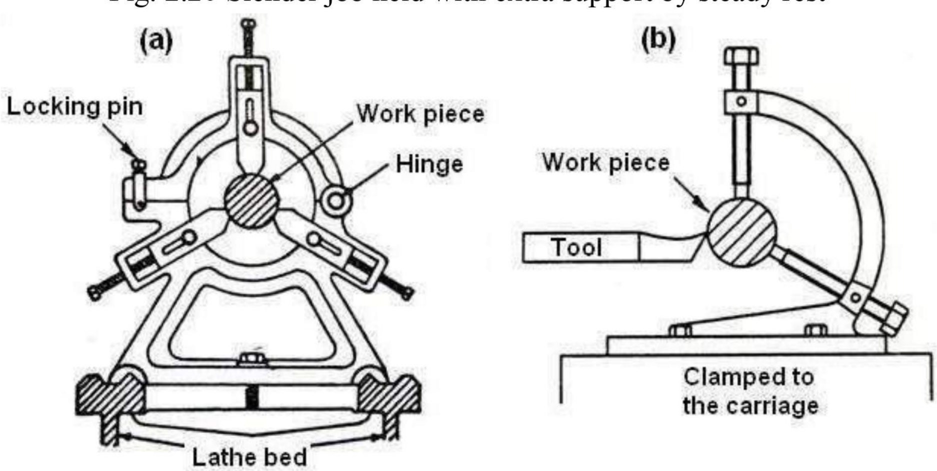


Fig. 2.21 (a) Steady rest and (b) Follower rest

Mounting of tools in centre lathe

Different types of tools, used in centre lathes, are usually mounted in the following ways:

- HSS tools (shank type) in tool post.
- HSS form tools and threading tools in tool post.
- Carbide and ceramic inserts in tool holders.
- Drills and reamers, if required, in tailstock.
- Boring tools in tool post.

Fig. 2.22 (a and b) is typically showing mounting of shank type HSS single point tools in rotatable (only one tool) and indexable (up to four tools) tool posts. *Fig. 2.22 (c) typically shows* how a circular form or thread chasing HSS tool is fitted in the tool holder which is mounted in the tool post.

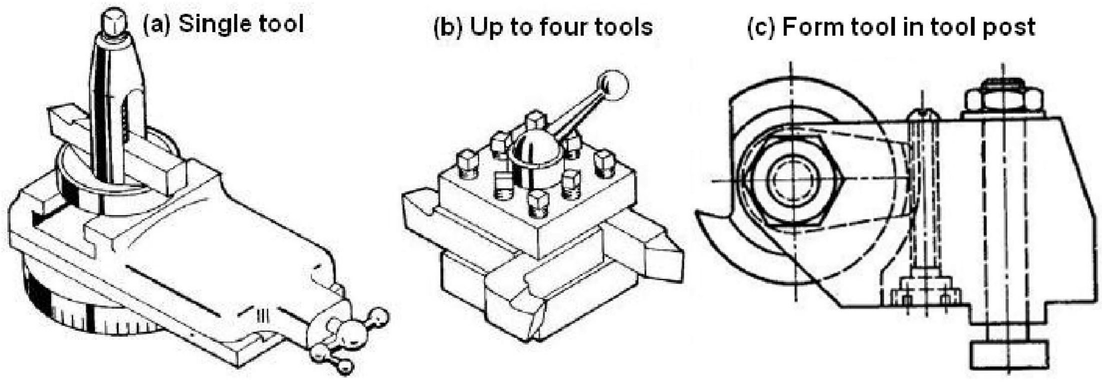


Fig. 2.22 Mounting of (a and b) shank type tools in tool post and (c) form tool in tool post

Carbide, ceramic and cermet inserts of various size and shape are mechanically clamped in the seat of rectangular sectioned steel bars which are mounted in the tool post. *Fig. 2.23 (a, b, c and d) shows the common methods of clamping such inserts.* After wearing out of the cutting point, the insert is indexed and after using all the corner tips the insert is thrown away.

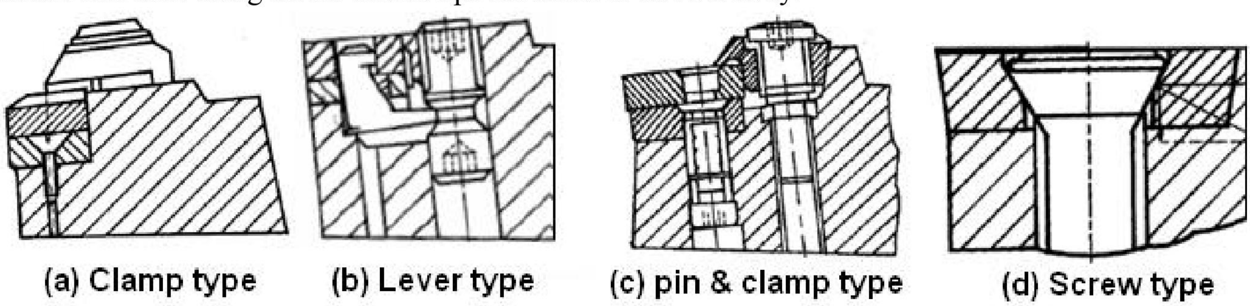


Fig. 2.23 Mounting of tool inserts in tool holders by mechanical clamping

For originating axial hole in centre lathe, the drill bit is fitted into the tailstock which is slowly moved forward against the rotating job *as indicated in Fig. 2.24.* Small straight shank drills are fitted in a drill chuck whereas taper shank drill is fitted directly into the tailstock quill without or with a socket.

Fig. 2.24 Holding drill chuck and drill in tailstock

Often boring operation is done in centre lathe for enlarging and finishing holes by simple shank type HSS boring tool. The tool is mounted on the tool post and moved axially forward, along with the saddle, through the hole in the rotating job *as shown in Fig. 2.25 (a)*. For precision boring in centre lathe, the tool may be fitted in the tailstock quill supported by bush in the spindle *as shown in Fig. 2.25 (b)*.

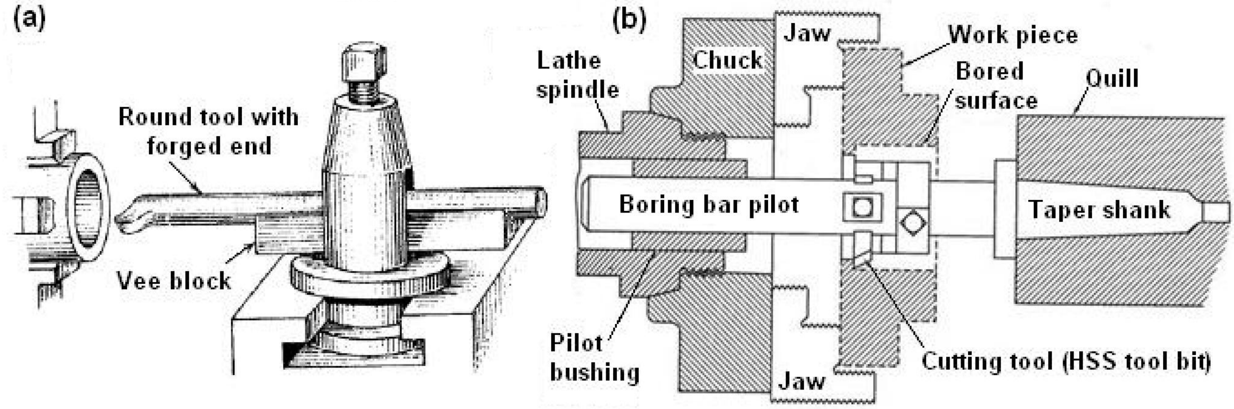


Fig. 2.25 (a) Boring tool mounted in the tool post Fig. 2.25 (b) Precision boring in centre lathe

CUTTING TOOLS

For general purpose work, a single point cutting tool is used in centre lathes. But for special operations multi point tools may be used. *Single point lathe tools are classified as follows:*

According to the method of manufacturing the tool

- Forged tool.
- Tipped tool brazed to the carbon steel shank.
- Tipped tool fastened mechanically to the carbon steel shank.

According to the method of holding the tool

- Solid tool.
- Tool bit inserted in the tool holder.

According to the method of using the tool

- Turning tool, facing tool, forming tool, chamfering tool, finishing turning tool, round nose tool, external threading tool, internal threading tool, boring tool, parting tool, knurling tool, etc.

According to the method of applying feed

- Right hand tool.
- Left hand tool.
- Round nose tool.

According to the method of manufacturing the tool

Forged tool

These tools are manufactured from high carbon steel or high speed steel. The required shape of the tool is given by forging the end of a solid tool steel shank. The cutting edges are then ground to the shape to provide necessary tool angles. *Fig. 2.26 (a) shows a forged tool.*

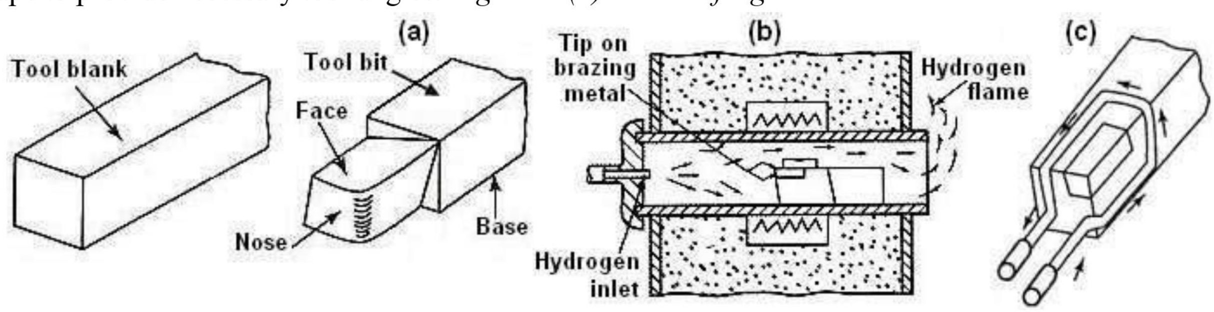


Fig. 2.26 (a) Forged tool (b) Furnace bracing of a tool tip (c) Induction brazing of a tool tip

Tipped tool brazed to the carbon steel shank

Stellite and cemented carbide tool materials, in view of the very high cost, brittleness, and low tensile strength, are used in the form of small tips. They are made to the various shapes to form different types of tools and are attached permanently to the end of a carbon steel shank by a brazing operation. High speed steel due to its high cost is also sometimes used in the form of tips brazed on carbon steel shank. *Fig. 2.26 (b and c) shows the furnace and induction brazing of a tool tip on carbon steel shank.*

Tipped tool fastened mechanically to the carbon steel shank

To ensure rigidity that a brazed tool does not offer, tips are sometimes clamped at the end of a tool shank by means of a clamp and bolt. Ceramic tips which are difficult to braze are clamped at the end of a shank. *Fig. 2.27 shows a mechanically fastened tipped tool.*

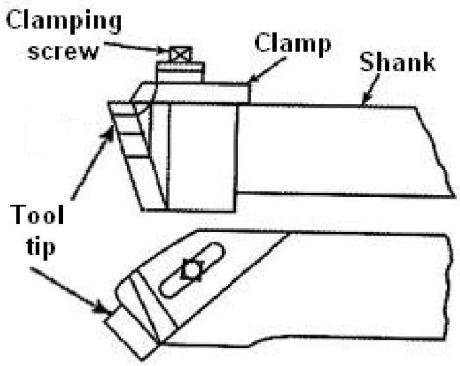


Fig. 2.27 Mechanically fastened tool tip

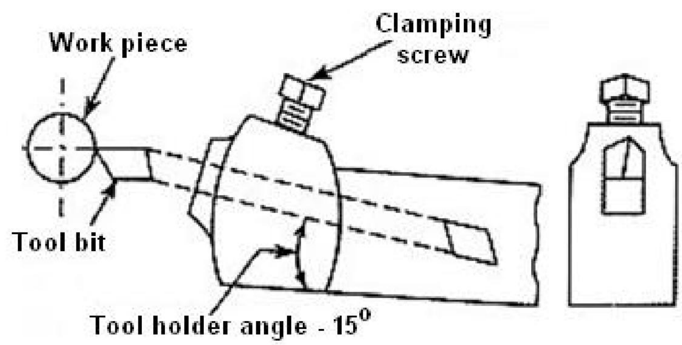


Fig. 2.28 Tool holder and tool bit

According to the method of holding the tool

Solid tool

Solid tools are made of high carbon steel forged and ground to the required shape. They are mounted directly on the tool post of a lathe. *Fig. 2.26 (a) shows a solid tool.*

Tool bit inserted in the tool holder

A tool bit is a small piece of cutting material having a very short shank which is inserted in a forged carbon steel tool holder and clamped in position by bolt or screw. A tool bit may be of solid type or tipped one according to the type of the cutting tool material. Tool holders are made of different designs according to the shape and purpose of the cutting tool. *Fig. 2.28 illustrates a common type of tool holder using high speed steel tool bit.*

According to the method of using the tool

Fig. 2.29 shows the various tools used in centre lathe according to the method of using the tool.

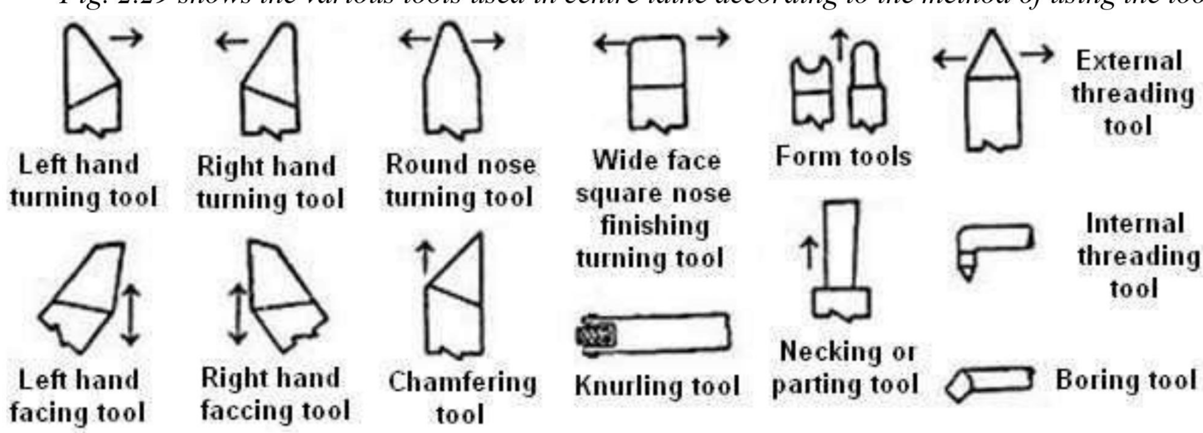


Fig. 2.29 Various tools used in centre lathe according to the method of using the tool

VARIOUS OPERATIONS

The machining operations generally carried out in centre lathe are:

- Rough and finish turning - The operation of producing cylindrical surface.
- Facing - Machining the end of the work piece to produce flat surface.
- Centering - The operation of producing conical holes on both ends of the work piece.
- Chamfering - The operation of beveling or turning a slope at the end of the work piece.
- Shouldering - The operation of turning the shoulders of the stepped diameter work piece.
- Grooving - The operation of reducing the diameter of the work piece over a narrow surface. It is also called as recessing, undercutting or necking.
- Axial drilling and reaming by holding the cutting tool in the tailstock barrel.
- Taper turning by
  - Offsetting the tailstock.
  - Swiveling the compound slide.
  - Using form tool with taper over short length.
  - Using taper turning attachment if available.
  - Combining longitudinal feed and cross feed, if feasible.
- Boring (internal turning); straight and taper – The operation of enlarging the diameter of a hole.
- Forming; external and internal.
- Cutting helical threads; external and internal.
- Parting off - The operation of cutting the work piece into two halves.
- Knurling - The operation of producing a diamond shaped pattern or impression on the surface.

In addition to the aforesaid regular machining operations, some more operations are also occasionally done, if desired, in centre lathes by mounting suitable attachments available in the market. *Some of those common operations carried out in centre lathe are shown in Fig. 2.30.*

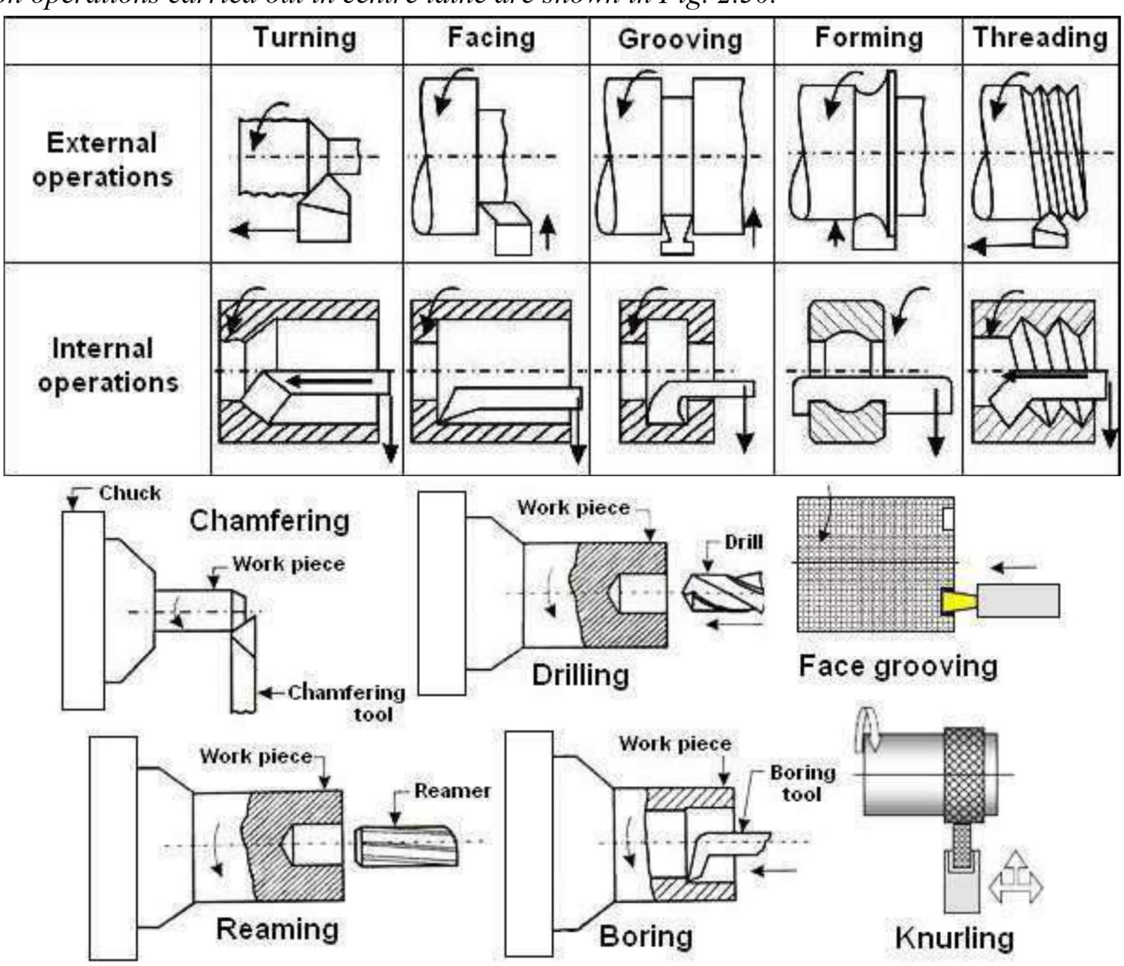


Fig. 2.30 Some common machining operations carried out in a centre lathe

TAPER TURING METHODS

A taper may be defined as a uniform change in the diameter of a work piece measured along its length. *Taper may be expressed in two ways:*

- Ratio of difference in diameter to the length.
- In degrees of half the included angle.

Fig. 2.31 shows the details of a taper.

D - Large diameter of the taper.
d - Small diameter of the taper.
l - Length of tapered part.
α - Half angle of taper.

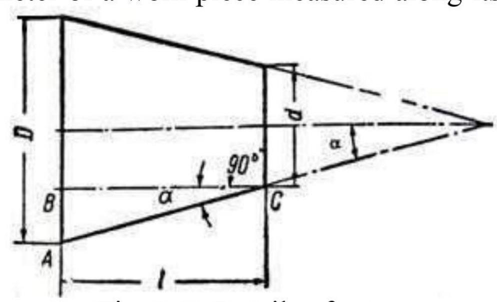


Fig. 2.31 Details of a taper

Generally, taper is specified by the term conicity. *Conicity is defined as the ratio of the difference in diameters of the taper to its length.* Conicity, $\mathbf{K} = \frac{D - d}{l}$ 2.1

Taper turning is the operation of producing conical surface on the cylindrical work piece on lathe.

Taper turning by a form tool

Fig. 2.32 illustrates the method of turning taper by a form tool. A broad nose tool having straight cutting edge is set on to the work at half taper angle, and is fed straight into the work to generate a tapered surface. In this method the tool angle should be properly checked before use. This method is limited to turn short length of taper only. This is due to the reason that the metal is removed by the entire cutting edge will require excessive cutting pressure, which may distort the work due to vibration and spoil the work surface.

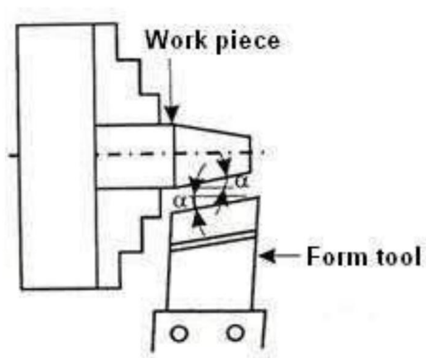


Fig. 2.32 Taper turning by a form tool

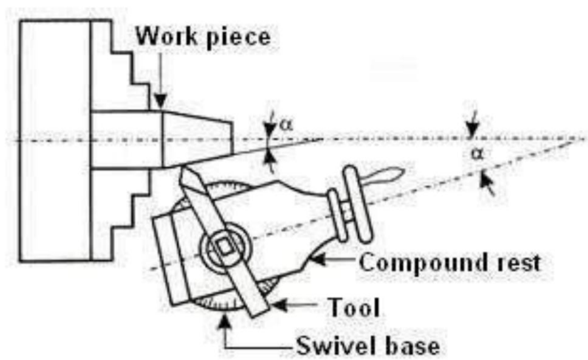


Fig. 2.33 Taper turning by swiveling the compound rest

Taper turning by swiveling the compound rest

Fig. 2.33 illustrates the method of turning taper by swiveling the compound rest. This method is used to produce short and steep taper. In this method, work is held in a chuck and is rotated about the lathe axis. The compound rest is swiveled to the required angle and clamped in position.

The angle is determined by using the formula, $\mathbf{tan\alpha} = \frac{D - d}{2l}$ 2.2

Then the tool is fed by the compound rest hand wheel. This method is used for producing both internal and external taper. This method is limited to turn a short taper owing to the limited movement of the compound rest. The compound rest may be swiveled at 45^0 on either side of the lathe axis enabling it to turn a steep taper. The movement of the tool in this method being purely controlled by hand, this gives a low production capacity and poorer surface finish.

Taper turning by offsetting the tailstock

Fig. 2.34 illustrates the method of turning taper by offsetting the tailstock. The principle of turning taper by this method is to shift the axis of rotation of the work piece, at an angle to the lathe axis, which is equal to half angle of the taper, and feeding the tool parallel to the lathe axis.

This is done when the body of the tailstock is made to slide on its base towards or away from the operator by a set over screw. The amount of set over being limited, this method is suitable for turning small taper on long jobs. The main disadvantage of this method is that live and dead centres are not equally stressed and the wear is not uniform. Moreover, the lathe carrier being set at an angle, the angular velocity of the work is not constant.

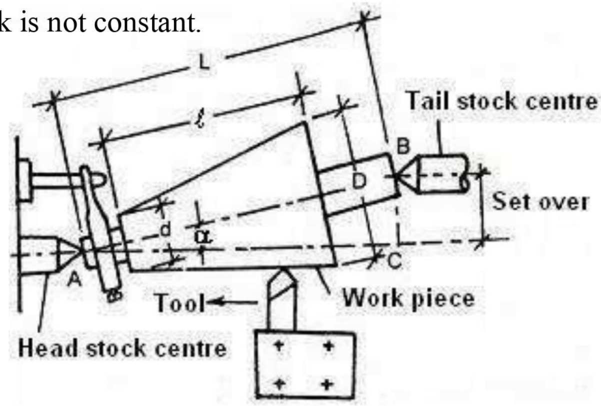


Fig. 2.34 Taper turning by offsetting the tailstock

The amount of set over required to machine a particular taper may be calculated as:

From the right angle triangle ABC in Fig.2.34; BC =AB sinα, where BC = set over

Set over = L sinα 2.3

If the half angle of taper (α), is very small, for all practical purposes, sinα = tanα

Set over = L tanα = L x $\frac{D-d}{2l}$ in mm. 2.4

If the taper is turned on the entire length of the work piece, then l= L, and the equation (2.4) becomes:

Set over = L x $\frac{D-d}{2L} = \frac{D-d}{2}$ 2.5

$\frac{D-d}{l}$ being termed as the conicity or amount of taper, the formula (2.4) may be written in the following form: **Set over =** $\frac{\text{entire length of the work x conicity}}{2}$

Taper turning by using taper turning attachment

Fig. 2.35 schematically shows a taper turning attachment. It consists of a bracket or frame which is attached to the rear end of the lathe bed and supports a guide bar pivoted at the centre. The guide bar having graduations in degrees may be swiveled on either side of the zero graduation and is set at the desired angle with the lathe axis. When this attachment is used the cross slide is delinked from the saddle by removing the binder screw. The rear end of the cross slide is then tightened with the guide block by means of a bolt. When the longitudinal feed is engaged, the tool mounted on the cross slide will follow the angular path, as the guide block will slide on the guide bar set at an angle to the lathe axis.

The required depth of cut is given by the compound slide which is placed at right angles to the lathe axis. The guide bar must be set at half taper angle and the taper on the work must be converted in degrees. The maximum angle through which the guide bar may be swiveled is 10^0 to 12^0 on either side of the centre line. *The angle of swiveling the guide bar can be determined from the equation 2.2.*

The advantages of using a taper turning attachment are:

- The alignment of live and dead centres being not disturbed; both straight and taper turning may be performed on a work piece in one setting without much loss of time.
- Once the taper is set, any length of work piece may be turned taper within its limit.
- Very steep taper on a long work piece may be turned, which cannot be done by any other method.
- Accurate taper on a large number of work pieces may be turned.
- Internal tapers can be turned with ease.

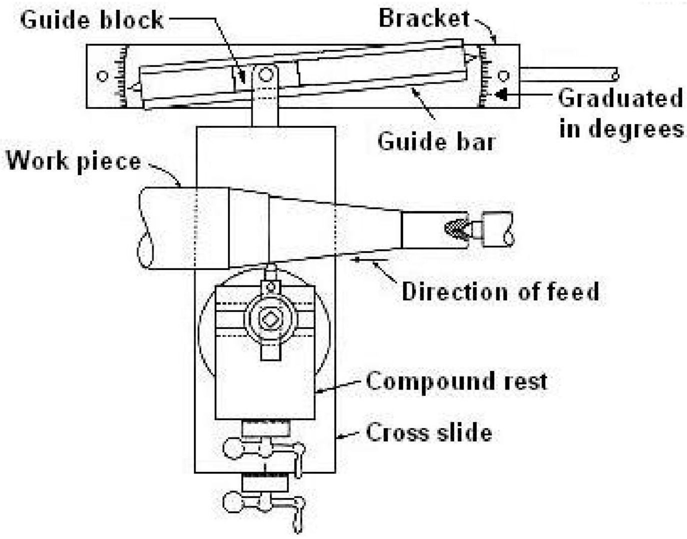


Fig. 2.35 Taper turning attachment

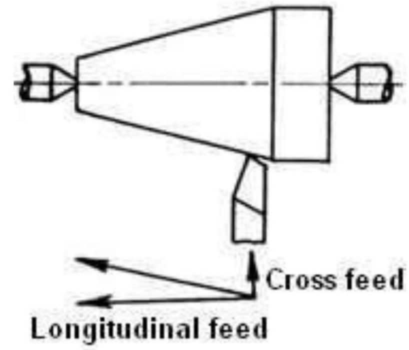


Fig. 2.36 Taper turning by combining feed

Taper turning by combining longitudinal feed and cross feed

Fig. 2.36 illustrates the method of turning taper by combining longitudinal feed and cross feed. This is a more specialized method of turning taper. In certain lathes both longitudinal and cross feeds may be engaged simultaneously causing the tool to follow a diagonal path which is the resultant of the magnitude of the two feeds. The direction of the resultant may be changed by varying the rate of feeds by changing gears provided inside the apron.

THREAD CUTTING METHODS

Thread cutting is one of the most important operations performed in a centre lathe. It is possible to cut both external and internal threads with the help of threading tools. There are a large number of thread forms that can be machined in a centre lathe such as Whitworth, ACME, ISO metric, etc. The principle of thread cutting is to produce a helical groove on a cylindrical or conical surface by feeding the tool longitudinally when the job is revolved between centres or by a chuck (for external threads) and by a chuck (for internal threads). The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the workpiece.

The lead screw of the lathe has a definite pitch. The saddle receives its traversing motion through the lead screw. Therefore a definite ratio between the longitudinal feed and rotation of the headstock spindle should be found out so that the relative speeds of rotation of the work and the lead screw will result in the cutting of a thread of the desired pitch. This is effect by change gears arranged between the spindle and the lead screw or by the change gear mechanism or feed gear box used in a modern lathe. Thread cutting on a centre lathe is a slow process, but it is the only process of producing square threads, as other methods develop interference on the helix. *Fig.2.37 illustrates the principle of thread cutting.*

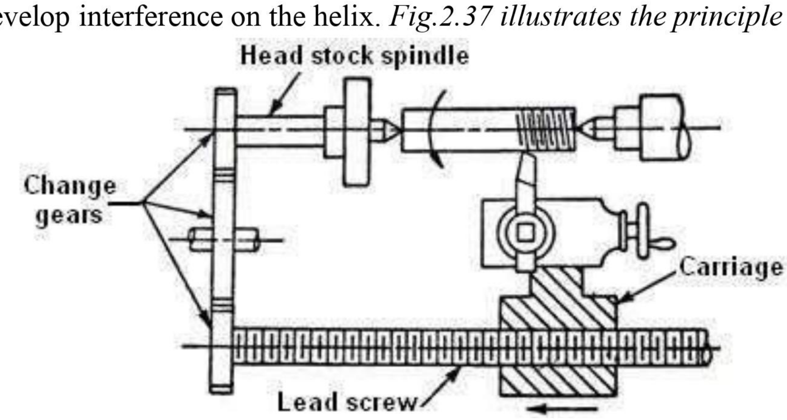


Fig. 2.37 Principles of thread cutting

Change gear ratio

Centre lathes are equipped with a set of change gears. A typical set contains the following change gears with number of teeth: 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 125 and 127. The change gear ratio (i_{cg}) must be transformed by multiplying numerator and denominator by a suitable number, to obtain gears available in the change gear set.

The change gear ratio may result either in a 'Simple gear train' or 'Compound gear train'. In modern lathes using quick change gears, the correct gear ratio for cutting a particular thread is quickly obtained by simply shifting the levers in different positions which are given in the charts or instruction plates supplied with the machine.

Calculation for change gear ratio

Metric thread on Metric lead screw

Calculation for change gear ratio for cutting metric thread on a centre lathe with a metric lead screw is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Lead screw turn}}{\text{Spindle turn}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}}$$

Example 2.1: The pitch of the lead screw is 12 mm, and the pitch of the thread to be cut is 3 mm. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} = \frac{3}{12} = \frac{1}{4} = \frac{1 \times 20}{4 \times 20} = \frac{20}{80}$$

Therefore the driver gear will have 20 teeth and the driven gear will have 80 teeth. This is effect by simple gear train.

Example 2.2: The pitch of the lead screw is 6 mm, and the pitch of the thread to be cut is 1.25 mm. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} = \frac{1.25}{6} = \frac{1.25 \times 4}{6 \times 4} = \frac{5}{4} \times \frac{1}{6} = \frac{5 \times 10}{4 \times 10} \times \frac{1 \times 20}{6 \times 20} = \frac{50 \times 20}{40 \times 120}$$

Therefore the driver gears will have 50 teeth & 20 teeth and the driven gears will have 40 teeth & 120 teeth. This is effect by compound gear train.

Metric thread on British or English standard lead screw

Calculation for change gear ratio for cutting metric thread on a centre lathe with a British or English standard lead screw may be carried out by introducing a translating gear of 127 teeth. If the lead screw has *n* threads per inch and the thread to be cut has *p* mm pitch then;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} = \frac{p}{1/n} = \frac{p\,n}{25.4} = \frac{p\,n}{25.4 \times 5/5} = \frac{5\,p\,n}{127}$$

Since pitch = $\frac{1}{\text{number of threads per inch}}$ and 1 inch = 25.4 mm

Example 2.3: The lead screw has 4 threads per inch, and the pitch of the thread to be cut is 7 mm. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{5\,p\,n}{127} = \frac{5 \times 7 \times 4}{127} = \frac{140}{127} = \frac{70 \times 2}{127} = \frac{70 \times 2 \times 20}{127 \times 20} = \frac{70 \times 40}{127 \times 20}$$

Therefore the driver gears will have 70 teeth & 40 teeth and the driven gears will have 127 teeth & 20 teeth. This is effect by compound gear train.

British or English standard thread on English lead screw

Calculation for change gear ratio for cutting British or English standard thread on a centre lathe with an English lead screw is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{1/\text{number of threads per inch to be cut}}{1/\text{number of threads per inch on the lead screw}} = \frac{\text{Pitch of the thread to be cut}}{\text{Pitch of the lead screw}} \qquad 2.9$$

Example 2.4: The lead screw has 4 threads per inch, and the screw thread to be cut has 26 threads per inch. For this condition the change gear ratio is as follows;

$$\frac{\text{Driver teeth}}{\text{Driven teeth}} = \frac{1/\text{number of threads per inch to be cut}}{1/\text{number of threads per inch on the lead screw}} = \frac{1/26}{1/4} = \frac{4}{26} = \frac{4 \times 5}{26 \times 5} = \frac{4 \times 5}{13 \times 10}$$

$$= \frac{4 \times 5}{13 \times 5} \times \frac{5 \times 10}{10 \times 10} = \frac{20 \times 50}{65 \times 100}$$

Therefore the driver gears will have 20 teeth & 50 teeth and the driven gears will have 65 teeth & 100 teeth. This is effect by compound gear train.

Thread cutting procedure

1. The work piece should be rotated in anticlockwise direction when viewed from the tail stock end.
2. The excess material is removed from the workpiece to make its diameter equal to the major diameter of the screw thread to be generated.
3. Change gears of correct size are fitted to the end of the bed between the spindle and the lead screw.
4. The thread cutting tool is selected such that the shape or form of the cutting edge is of the same form as the thread to be generated. In a metric thread, the included angle of the cutting edge should be ground exactly 60^0.
5. A thread tool gauge or a centre gauge is used against the turned surface of the workpiece to check the form of the cutting edge so that each face may be equally inclined to the centre line of the workpiece. *This is illustrated in Fig. 2.38.*

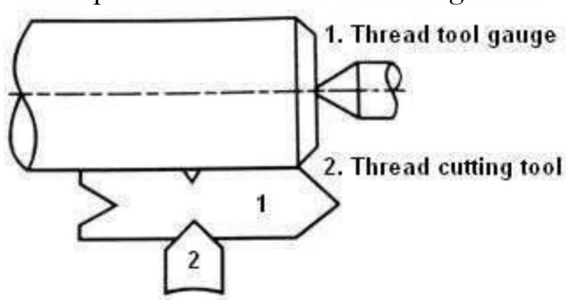


Fig. 2.38 Checking of the cutting edge

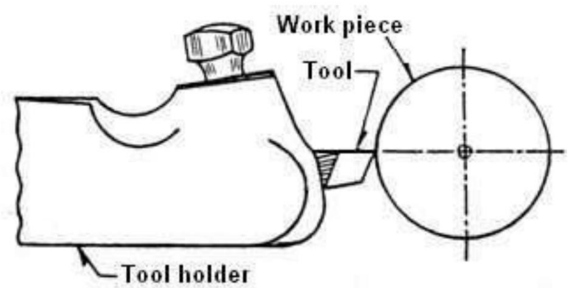


Fig. 2.39 Mounting of the cutting tool

6. Then the tool is mounted in the tool post such that the top of the tool nose is horizontal and is in line with the axis of rotation of the workpiece. *This is illustrated in Fig. 2.39.*
7. The speed of the spindle is reduced by ½ to ¼ of the speed required for turning according to the type of material being machined.
8. The tool is fed inward until it first scratches the surface of the workpiece. The graduated dial on the cross slide is noted or set to zero. Then the split nut or half nut is engaged and the tool moves along helical path over the desired length.
9. At the end of tool travel, it is quickly withdrawn by means of cross slide. The split nut is disengaged and the carriage is returned to the starting position, for the next cut. These successive cuts are continued until the thread reaches its desired depth (checked on the dial of cross slide).
10. For cutting left hand threads the carriage is moved from left to right (i.e. towards tail stock) and for cutting right hand threads it is moved from right to left (i.e. towards headstock).

Depth of cut in thread cutting

The depth of first cut is usually 0.2 to 0.4 mm. This is gradually decreased for the successive cuts until for the final finishing cut; it is usually 0.025 to 0.075 mm. The depth of cut is applied by advancing the tool either radially (called as plunge cutting) or at an angle equal to half angle of the thread (called as compound cutting) (30^0 incase of metric threads) by swiveling the compound rest. *Fig. 2.40 schematically shows the method of applying plunge cut and compound cut.*

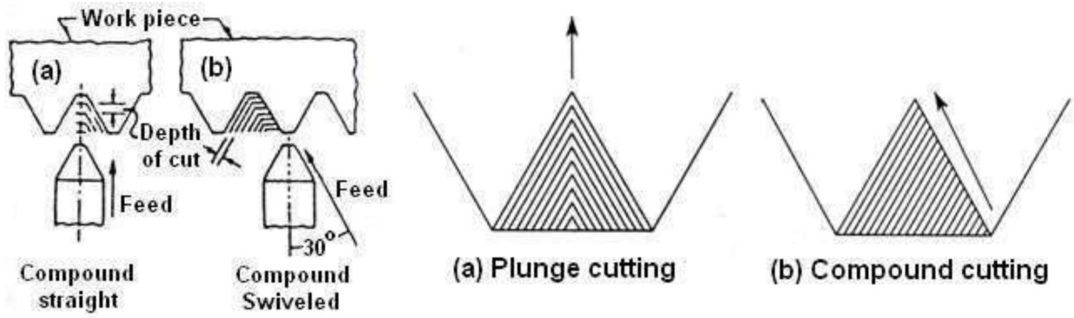


Fig. 2.40 *schematic view of the method of applying plunge cut and compound cut*

Plunge cutting In this the absence of side and back rake will not produce proper cutting except on brass and cast iron. Cutting takes place along a longer length of the tool. This gives rise to difficulties in machining in terms of higher cutting forces and consequently chattering. This result in poor surface finish and lower tool life, thus this method is not generally preferred. This method is used for taking very light finishing cuts and for cutting square, acme and worm threads.

Compound cutting *Compound cutting is superior to the plunge cutting as it:*

- Permits the tool to have a top rake.
- Permits cutting to take place on one edge of the tool only.
- Allows the chips to slide easily across the face of the tool without crowding.
- Reduces cutting strain that acts on the tool.
- Reduces the tendency to cause the tool to 'dig-in'.

So compound cutting is more preferred compared with plunge cutting.

Picking up the thread

Several cuts are necessary before the full depth of thread is reached. It is essential that the tool tip should always follow the same thread profile generated in the first cut; otherwise the workpiece will be spoiled. This is termed as picking up the thread. The different methods of picking up the thread are:

Reversing the machine After the end of one cut the machine is reversed while keeping the half nut permanently engaged and retaining the engagement between the tool and the workpiece. The spindle reversal would bring the cutting tool to the starting point of the thread following the same path in reverse. After giving a further depth of cut the spindle is again reversed and the thread cutting is continued in the normal way. This is easy to work and is some what more time consuming due to the idle time involved in stopping and reversing of the spindle at the end of each stroke.

Marking the lathe parts The procedure is to mark the lead screw and its bracket, the large gear and the head stock casting, and the starting position of the carriage on the lathe bed. The aim is to bring each of the markings on the lead screw and gear opposite the markings on the stationary portions of the lathe, and have the carriage at the starting position before attempting to engage the split nut.

Using a chasing dial *Fig. 2.41 shows the basic configuration of a chasing dial.* This is also called as thread indicator. This is a special attachment used in modern lathes for accurate "picking up" of the thread. This dial indicates when to close the split or half nuts. This is mounted on the right end of the apron. It consists of a vertical shaft with a worm gear engaged with the lead screw. The top of the vertical shaft has a revolving dial marked with lines and numbers to indicate equal divisions of the circumference. The dial turns with the lead screw so long the half nut is not engaged. If the half nut is closed and the carriage moves along, the dial stands still.

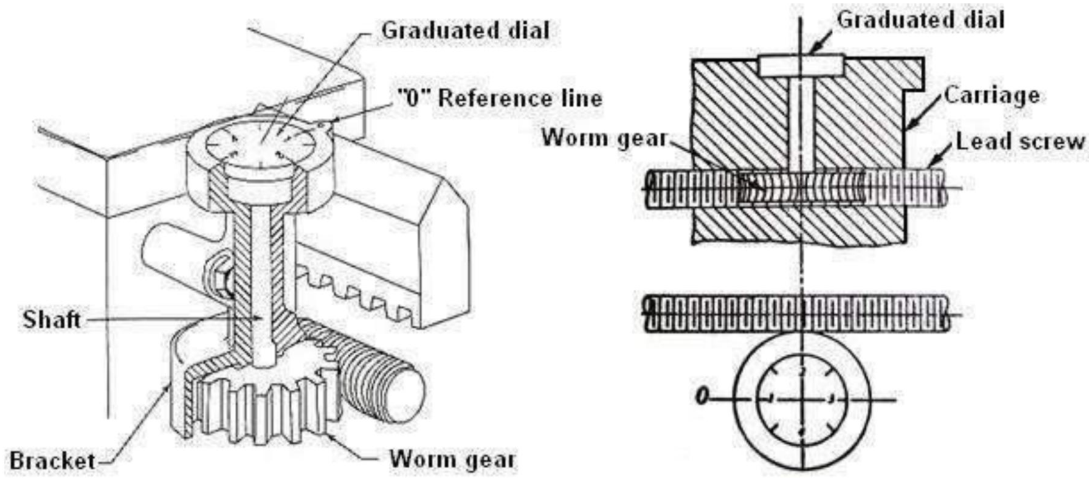


Fig. 2.41 Thread chasing dial

As the dial turns, the graduations pass a fixed reference line. The half-nut is closed for all even threads when any line on the dial coincides with the reference line. For all odd threads, the half-nut is closed at any numbered line on the dial coincides with the reference line. The corresponding number is determined from the charts. If the pitch of the thread to be cut is an exact multiple of the pitch of the lead screw, the thread is called even thread; otherwise the thread is called odd thread.

Thread chaser A chaser is a multipoint threading tool having the same form and pitch of the thread to be chased. *An external thread chaser is shown in Fig. 2.42 (a).* A chaser is used to finish a partly cut thread to the size and shape required. *Fig. 2.42 (b) shows finishing of a partly cut thread by a thread chaser.* Thread chasing is done at about ½ of the speed of turning.

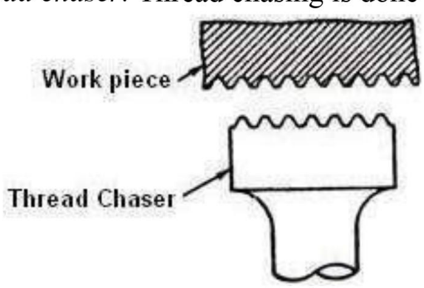


Fig. 2.42 (a) External thread chaser

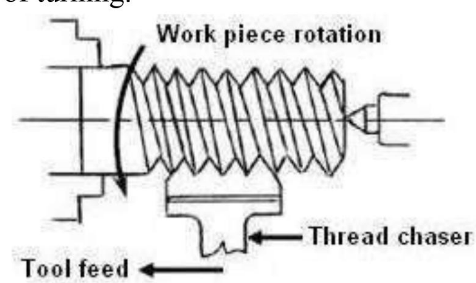


Fig. 2.42 (b) Finishing of a partly cut thread

Other methods for cutting external threads

External thread cutting by dies

Machine screws, bolts or studs are quickly made by different types of dies which look and apparently behave like nuts but made of hardened tool steel or HSS and having sharp internal cutting edges. The dies are coaxially rotated around the premachined rod like blank with the help of handle, die stock or die holder. First the proper die is selected according to the thread to be cut. A die holder is selected and the die is inserted in the holder. Then the die holder with die is placed in the tail stock spindle. The work piece is held in a chuck or a collet and rotated at a very slow speed. The tail stock is turned in to cut the threads. The machine is stopped as soon as the correct length of the thread is machined. The threads can also be cut by screwing the die (held in a die holder) on the work piece held and rotated between centres.

Different types of dies used for cutting external threads are:

- ***(a) Solid die:*** It is used for making threads of usually small pitch and diameter in one pass.
- ***(b) Spring die:*** The die ring is provided with a slit, the width of the slit is adjustable by a screw to enable elastically slight reduction in the bore and thus cut the thread in number of passes with lesser force on hands.

- ***(c) Split die:*** The die is made in two pieces, one fixed and one movable (adjustable) within the cavity of the handle or wrench to enable cut relatively larger threads or fine threads on harder blanks easily in number of passes, the die pieces can be replaced by another pair for cutting different threads within small range of variation in size and pitch.
- ***(d) Pipe die:*** Pipe threads of large diameter but smaller pitch are cut by manually rotating the large wrench (stock) in which the die is fitted through a guide bush.

However the quality of the threads will depend upon the perfection of the dies and skill of the operator. *Fig. 2.43 shows the hand operated dies of common use.*

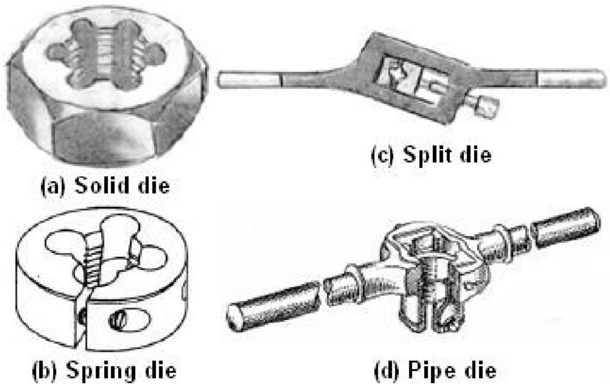


Fig. 2.43 Hand operated dies

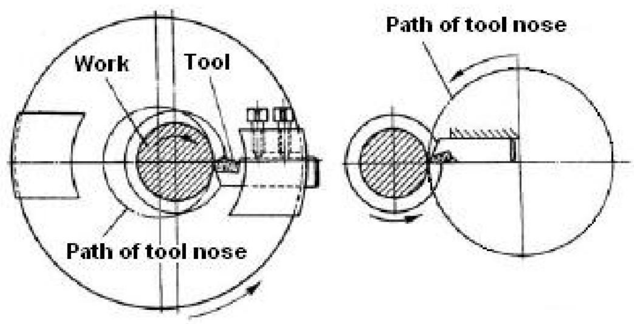


Fig. 2.44 Thread cutting by rotating tool

External thread cutting by rotating tools

Often it becomes necessary to machine large threads on one or very few pieces of heavy blanks of irregular size and shape like heavy castings or forgings. In such cases, the blank is mounted on face plate in a centre lathe with proper alignment. The deep and wide threads are produced by intermittent cutting action by a rotating tool. A separate attachment carrying the rotating tool is mounted on the saddle and fed as usual by the lead screw of the centre lathe. *Fig. 2.44 schematically shows the principles of thread cutting by rotating tool*. The tool is rotated fast but the blank much slowly. This intermittent cut enables more effective lubrication and cooling of the tool.

External thread cutting by milling cutters

This process gives quite fast production by using suitable thread milling cutters in centre lathes. The milling attachment is mounted on the saddle of the lathe. *Thread milling is of two types:*

Long thread milling Long and large diameter screws like machine lead screws are reasonably accurately made by using a large disc type form milling cutter *as illustrated in Fig. 2.45 (a).*

Short thread milling Threads of shorter length and fine pitch are machined at high production rate by using a HSS milling cutter having a number of annular threads with axial grooves cut on it for generating cutting edges. Each job requires only around 1.25 revolution of the blank and very short axial (1.25 pitch) and radial (1.5 pitch) travel of the rotating tool. *This is illustrated in Fig. 2.45 (b).*

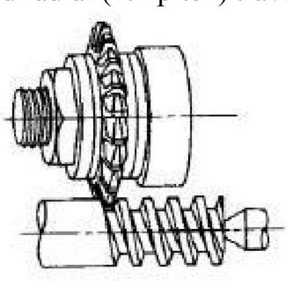


Fig. 2.45 (a) Long thread milling

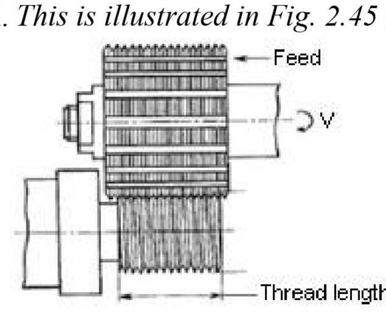


Fig. 2.45 (b) Short thread milling

External thread cutting on tapered surface

First the surface is turned taper to the required angle by any one of the taper turning methods. The thread cutting tool is then set perpendicular to the lathe axis and not to the tapered surface. To produce an accurate thread a taper turning attachment is used. This is swiveled to be the half taper angle. The thread is finished in the usual manner. *Fig. 2.46 shows the setup for thread cutting on a taper.*

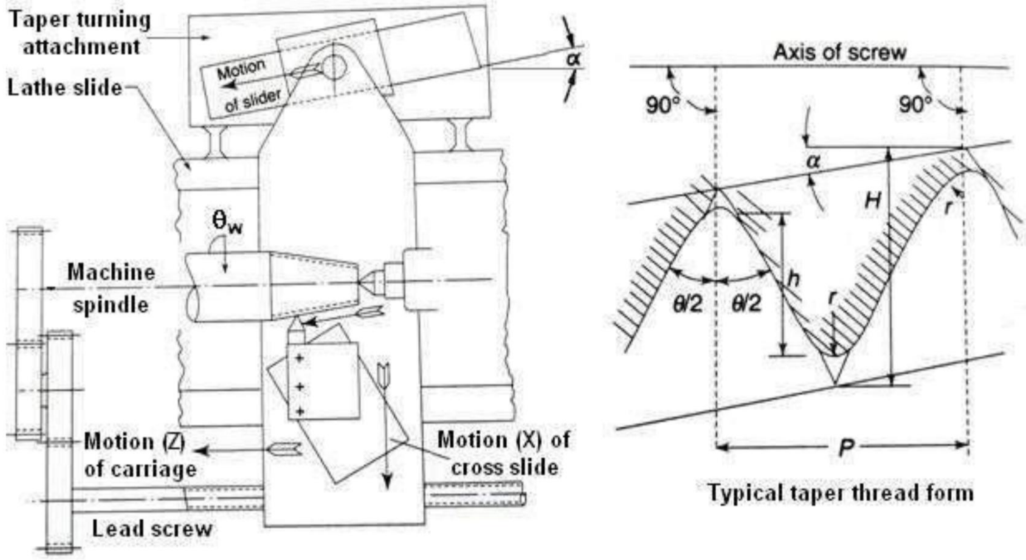


Fig. 2.46 Setup for thread cutting on a taper

Internal thread cutting

The principle of cutting internal threads is shown in Fig. 2.47 (a). It is similar to that of an external thread, the only difference being in the tool used. The tool is similar to a boring tool with cutting edges ground to the shape conforming to the type of the thread to be cut. The hole is first bored to the root diameter of the thread. For cutting metric thread, the compound slide is swiveled 30^0 towards the headstock. The tool is fixed on the tool post or on the boring bar after setting it at right angles to the lathe axis, using a thread gauge. *The use of thread gauge is illustrated in Fig. 2.47 (b).* The depth of cut is given by the compound slide and the thread is finished in the usual manner.

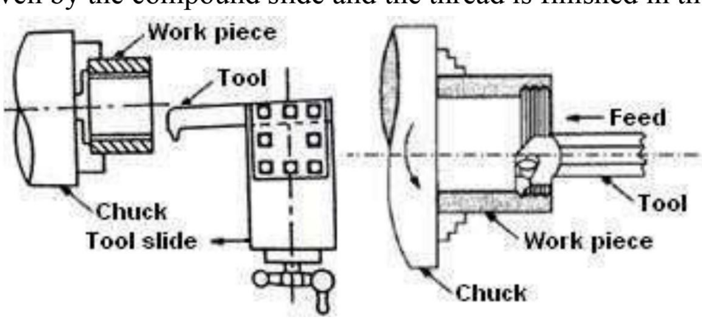


Fig. 2.47 (a) Internal thread cutting operation

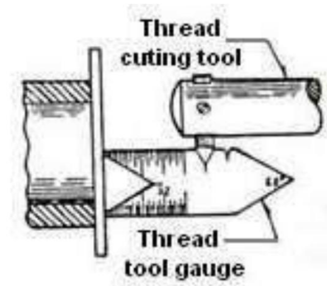


Fig. 2.47 (b) Setting of cutting edge

Other methods for cutting internal threads

Internal thread cutting by taps

Internal screw threads of usually small size are cut manually, if needed, in plates, blocks, machine parts etc. by using taps which look and behave like a screw but made of tool steel or HSS and have sharp cutting edges produced by axial grooving over the threads *as shown in Fig. 2.48 (a).* Three taps namely, taper tap, second tap and bottoming tap are used consecutively after drilling a tap size hole through which the taps are axially pushed helically with the help of a handle or wrench. Threads are often tapped by manually rotating and feeding the taps through the drilled hole in the blank held in centre lathe spindle *as shown in Fig. 2.48 (b).*

Different types of taps used for cutting internal threads are:

- ***Straight solid taps:*** Used for small jobs.
- ***Taps with adjustable blades:*** Usually for large diameter jobs.
- ***Taper or nut taps*:** Used for cutting threads in nuts.

However the quality of the threads will depend upon the perfection of the taps and skill of the operator.

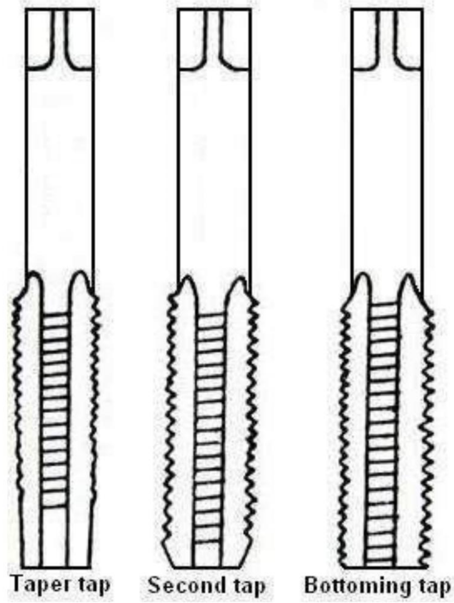


Fig. 2.48 (a) Hand operated taps

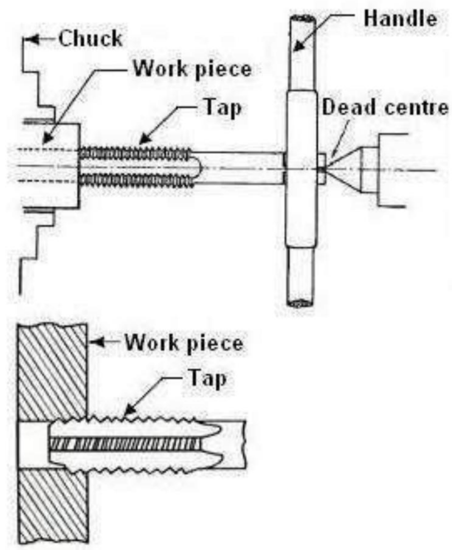


Fig. 2.48 (b) Hand operated tapping in centre lathe

Internal thread cutting by milling cutters

The typical internal thread milling cutters are shown in Fig. 2.49. This cutter produces internal threads very rapidly. The principle of operation is similar to that of an external short thread milling.

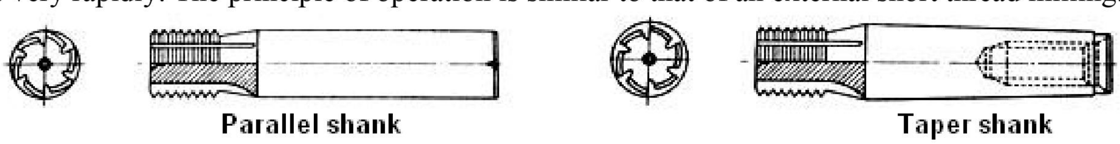


Fig. 2.49 Internal thread milling cutters

SPECIAL ATTACHMENTS

Each general purpose conventional machine tool is designed and used for a set of specific machining work on jobs of limited range of shape and size. But often some unusual work also need to be done in a specific machine tools, e.g. milling in a lathe, tapping in a drilling machine, gear teeth cutting in shaping machine and so on. Under such conditions, some special devices or systems are additionally used being mounted in the ordinary machine tools. Such additional special devices, which augment the processing capability of any ordinary machine tool, are known as attachments. Unlike accessories, attachments are not that inevitable and procured separately as and when required and obviously on extra payment.

Conditions and places suitable for application of attachments in machine tools

With the rapid and vast advancement of science and technology, the manufacturing systems including machine tools are becoming more and more versatile and productive on one hand for large lot or mass production and also having flexible automation and high precision on the other hand required for production of more critical components in pieces or small batches. With the increase of versatility and precision (e.g., CNC machines) and the advent of dedicated high productive special purpose machines, the need of use of special attachments is gradually decreasing rapidly.

However, some attachments are occasionally still being used on non automatic general purpose machine tools in some small and medium scale machining industries:

- When and where machining facilities are very limited.
- When production requirement is very small, may be few pieces.
- Product changes frequently as per job order.
- Repair work under maintenance, especially when spare parts are not available.
- When CNC machine tools and even reasonable number of conventional machine tools cannot be afforded.

Therefore, use of aforesaid attachments is restricted to manufacture of unusual jobs in small quantities under limited facilities and at low cost.

Taper turning attachment

The construction and working principle of the taper turning attachment has been described in Article 2.5.4, Page 66 and illustrated in Fig. 2.35.

Copy turning attachments

The two common types of copy turning attachments are:

Mechanical copy turning attachment

A simple mechanical type copy turning attachment is schematically shown in Fig. 2.50. The entire attachment is mounted on the saddle after removing the cross slide from that. The template replicating the job-profile desired is clamped at a suitable position on the bed. The stylus is fitted in the spring loaded tool slide and while travelling longitudinally along with saddle moves in transverse direction according to the template profile enabling the cutting tool produce the same profile on the job as indicated in the Fig. 2.50.

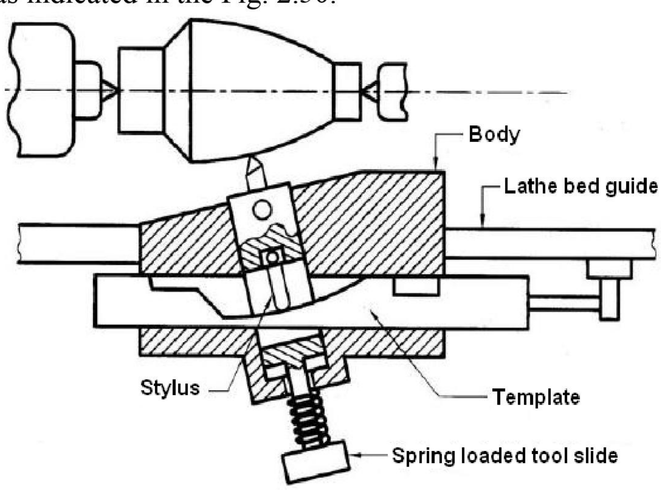


Fig. 2.50 Mechanical type copying attachment

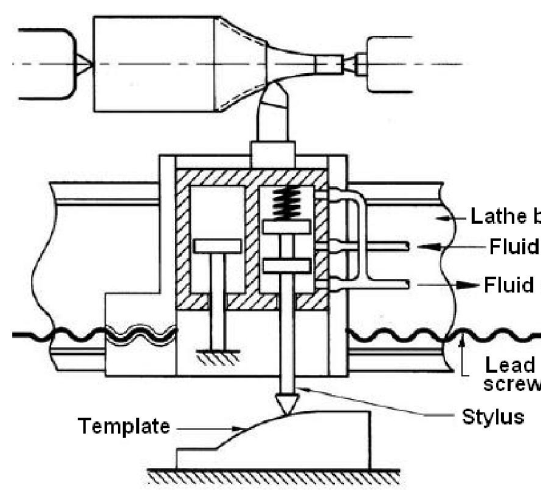


Fig. 2.51 Hydraulic copying attachment

Hydraulic copy turning attachment

The mounting and working principle of hydraulic copying attachment for profile turning in centre lathe are schematically shown in Fig. 2.51. Here also, the stylus moves along the template profile to replicate it on the job. In mechanical system *(Fig. 2.50)* the heavy cutting force is transmitted at the tip of the stylus, which causes vibration, large friction and faster wear and tear. Such problems are almost absent in hydraulic copying, where the stylus works simply as a valve spool against a light spring and is not affected by the cutting force. Hydraulic copying attachment is costlier than the mechanical type but works much smoothly and accurately. The cutting tool is rigidly fixed on the cross slide which also acts as a valve cum cylinder *as shown in Fig 2.51.*

So long the stylus remains on a straight edge parallel to the lathe bed, the cylinder does not move transversely and the tool causes straight turning. As soon as the stylus starts moving along a slope or profile, i.e., in cross feed direction the ports open and the cylinder starts moving accordingly against the piston fixed on the saddle. Again the movement of the cylinder i.e., the slide holding the tool, by same amount travelled by the stylus, and closes the ports. Repeating of such quick incremental movements of the tool, Δx and Δy result in the profile with little surface roughness.

Radius turning attachment

In this attachment, the cross slide is attached to the bed by means of a radius arm whose length is equal to the radius of the spherical component to be produced. The radius arm couples any movement of the cross slide or the carriage and hence the tool tip traces the radius R. *This is illustrated in Fig. 2.52.*

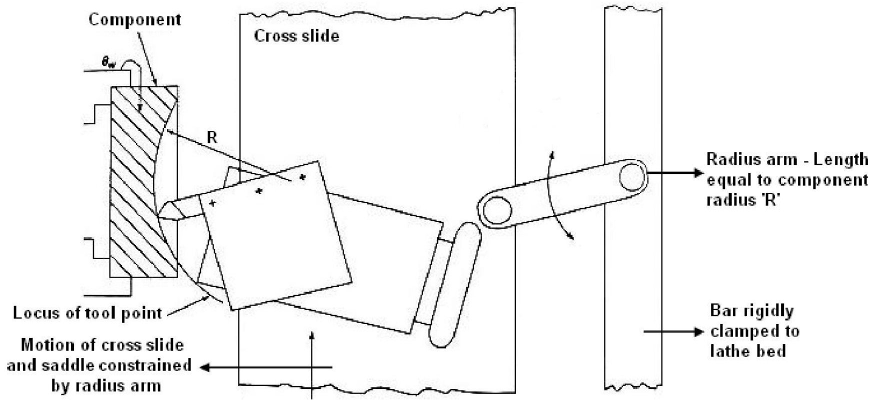


Fig. 2.52 Radius turning attachment

Spherical turning attachment

These simple attachments are used in centre lathes for machining spherical; both convex and concave surfaces and similar surfaces. *Fig. 2.53 schematically visualizes the usual setting and working principle of such attachments. In Fig. 2.53 (a),* the distance R_i can be set according to the radius of curvature desired. *In the type shown in Fig. 2.53 (b),* the desired path of the tool tip is controlled by the profile of the template which is pre-made as per the radius of curvature required. The saddle is disconnected from the feed rod and the lead-screw. So when the cross slide is moved manually in transverse direction, the tool moves axially freely being guided by the template only.

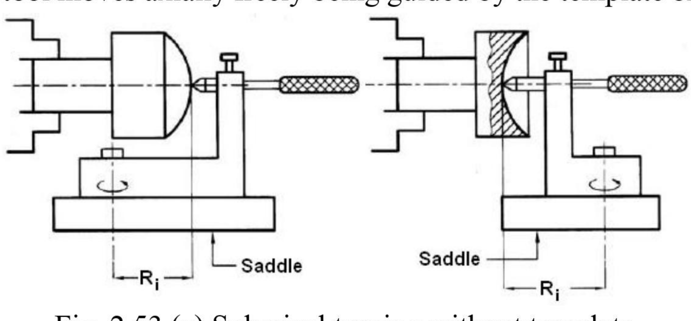


Fig. 2.53 (a) Spherical turning without template

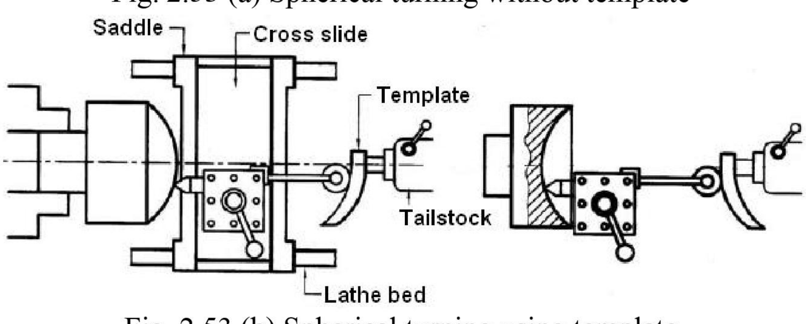


Fig. 2.53 (b) Spherical turning using template

Milling attachment

For cutting grooves or keyways Here, the work piece is held on the cross slide by using a special attachment and the end milling cutter is held in the chuck. Then the feed is given by a vertical slide provided on the special attachment. *Fig. 2.54 (a) shows a typical end milling attachment.*

For cutting multiple grooves and gear The attachment has a milling head, comprising a motor, a small gear box and a spindle to hold the milling cutter, mounted on the saddle after removing the cross slide etc., *as shown in Fig. 2.54 (b).* The work piece is held stationary between centres. The feeding is given by the carriage and vertical movement is given by the provision made on the attachment. Grooves are made on the periphery of the work piece by rotating the work piece. For cutting gears, a universal dividing head is fitted on the rear end of the headstock spindle to divide the work equally.

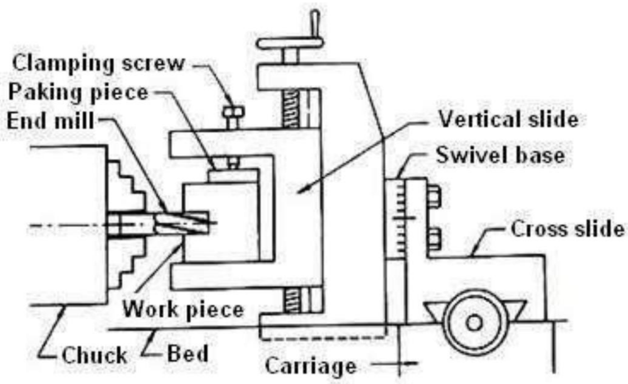


Fig. 2.54 (a) End milling attachment

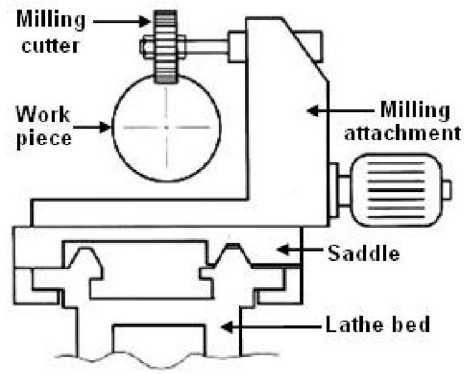


Fig. 2.54 (b) Milling attachment

Cylindrical grinding attachment

Grinding attachment is very similar to milling attachment. It has a bracket. It is mounted on the cross slide. A grinding wheel attached to the bracket is driven by a separate motor. The work piece may be held between centres or in a chuck. The grinding wheel is fed against the work piece. In this operation both work piece and grinding wheel rotate. By using this attachment both the external and internal grinding operation can be done. *Fig. 2.55 Shows a typical grinding attachment used in centre lathe.*

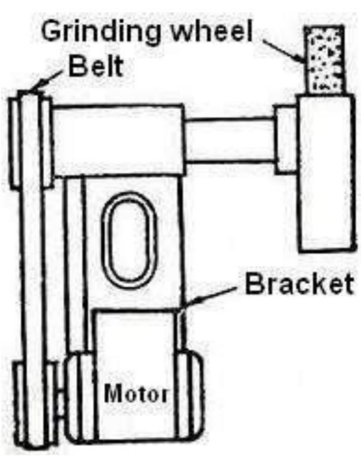


Fig. 2.55 Cylindrical grinding attachment

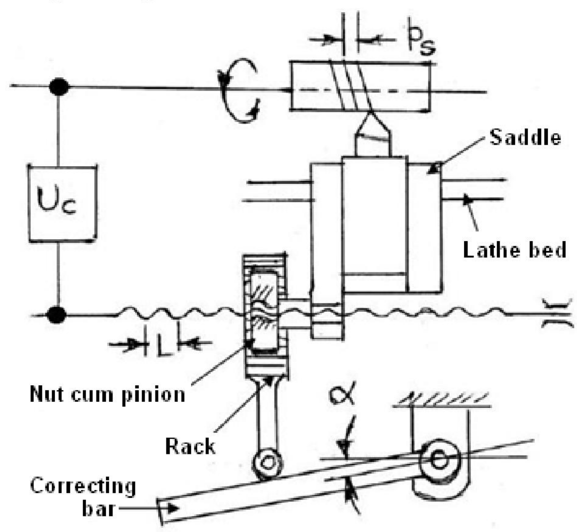


Fig. 2.56 Thread pitch correcting attachment

Thread pitch correcting attachment

While cutting screw thread in centre lathes by single point chasing tool, often the actual pitch, p_a deviates from the desired (or stipulated) pitch, p_s by an error (say $\pm \Delta p$) due to some kinematic error in the lathe. *Mathematically:* $\mathbf{p_s - p_a = \pm \Delta p}$ 2.10

Therefore for correct pitch, the error $\pm \Delta p$ need to be compensated and this may be done by a simple differential mechanism, namely correcting bar attachment *as schematically indicated in Fig. 2.56. In equation 4.6.1:*

$$\mathbf{p_a = U_C.L} \qquad 2.11$$

$$\mathbf{\pm \Delta p = p_s.L \tan(\pm\alpha) / (\pi m Z)} \qquad 2.12$$

where, UC - Transmission ratio.

L - Lead of the lead screw.

M - Module of teeth.

Z - No. of teeth of the gear fixed with the nut and is additionally rotated slightly by the movement of the rack along the bar.

Such differential mechanism of this attachment can also be used for intentionally cutting thread whose pitch will be essentially slightly more or less than the standard pitch, as it may be required for making differential screws having threads of slightly different pitch at two different locations of the screw.

Relieving attachment

The teeth of form relieved milling cutters like gear milling cutters, taps, hobs etc. are provided with flank having Archimedean spiral curvature. Machining and grinding of such curved flanks of the teeth need relieving motion to the tool (or wheel) *as indicated in Fig. 2.57 (a). The attachment schematically shown in Fig. 2.57 (b)* is comprised of a spring loaded bracket which holds the cutting tool and is radially reciprocated on the saddle by a plate cam driven by the feed rod as indicated.

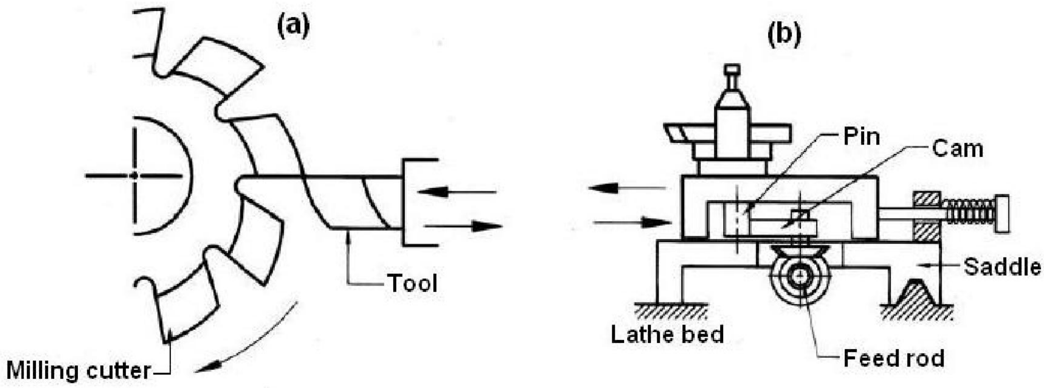


Fig. 2.57 Relieving attachment used in lathe

Super finishing attachment

Super finishing attachment used on a centre lathe is shown in Fig. 2.58 (a and b). Major parts and operating elements of super finishing attachment are discussed below:

Support bar: It is clamped into the tool holder of the lathe, and the super finishing attachment is fastened to the round shaft. It can be turned into right position to the work piece and then fixed.

Stone guide: The stone guide consists of an air cylinder with piston, to which the stone holder is fastened. It is operated by the control valve. By actuating this valve, the stone moves against the work piece. The stone guide is connected with the attachment by means of a dovetail guide, allowing longitudinal adjustment and fastening in every position desired. The attachment can be provided with a second stone guide to attain a double efficiency when machining larger work piece, or for finishing two bearing sections at the same time.

Stone holder: The stone holders are fastened in the position rod of the stone guide by means of their spherical head part. The universal movability allows the stone to be set precisely in the work piece.

Stroke regulation valve: This Valve is used for regulating the oscillation stroke. The stroke is lengthened by turning the valve to the left and reduced by turning to the right up to its complete stop.

Stroke value indicator: The stone guide is provided with a scale showing two crossing straight lines. The stroke value can be read off from the apparent intersection of this straight line.

Pressure gauge: The gauge indicates the pressure applied to the piston of the stone guide. Stone pressure = Gauge indication x Piston surface of stone guide.

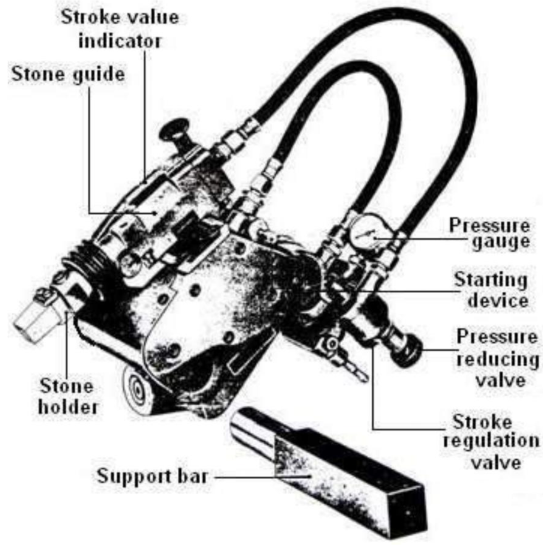


Fig. 2.58 (a) Super finishing attachment

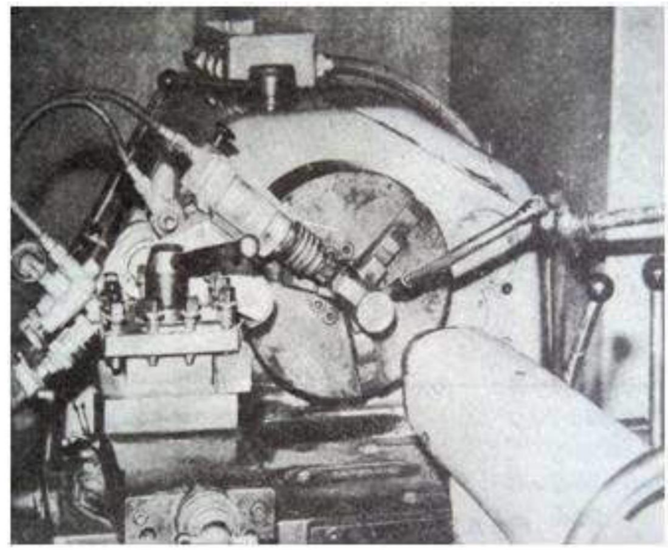


Fig. 2.58 (b) Super finishing attachment on a centre lathe

MACHINING TIME AND POWER ESTIMATION

Machining time

Cutting speed **(V)** = $\frac{+DN}{1000}$ m / min 2.13

where, D – Mean diameter of the work piece (mm).

N – Rotational speed of the work piece (rpm).

The time (t) for a single pass is given by

$$\mathbf{t} = \frac{L + L_o}{fN} \text{ min} \qquad 2.14$$

where, L – Length of the work piece (mm).

L_o – Over travel of the tool (mm).

f – Feed rate (mm / rev).

The number of roughing passes (P_r) is given by

$$\mathbf{P_r} = \frac{A - A_f}{d_r} \qquad 2.15$$

where, A – Total machining allowance (mm).

A_f – Finish machining allowance (mm).

D_r – Depth of cut in roughing (mm).

The number of finishing passes (P_f) is given by

$$\mathbf{P_f} = \frac{Af}{d_f} \qquad 2.16$$

where, d_f – depth of cut in finishing (mm).

Power estimation

Power is the product of cutting force and velocity. In machining process, force component is nothing but the force in the direction of cutting speed. This only considered. Forces in the direction of feed and depth are too small when compared to the force in the direction of cutting speed. So, these two are insignificant. Force involved in orthogonal cutting is the force component in the direction of cutting speed. E.g. turning, facing, parting-off operations, etc. so;

Power required **(W_C) = F_C x V** 2.17

where, V – Cutting speed (m/min) and F_C – Force in the direction of cutting speed (N).

Due to shear and friction, the total power is divided into two components. They are;

1. Power due to shear.
2. Power due to friction.

So, Total power = Power due to shear + Power due to friction

$$\mathbf{W_C = W_s + W_f = [F_s \times V_s] + [F_f \times V_f]} \qquad 2.18$$

where, F_s – Force due to shear.
V_s – Velocity of shear.
F_f – Force due to friction.
V_f – Velocity of friction.

Tool force dynamometers

To estimate power required for machining operations, the force has to be measured by a suitable measuring instruments. Generally, cutting forces in cutting tool are measured in different ways such as: *Dynamometer, Ammeter, Wattmeter, Calorimeter, Thermocouple, etc.* Among these, dynamometers are generally used for measuring cutting forces. Especially, strain gauge dynamometers are used. In this case, spring deflection is measured which is proportional to the cutting forces.

Design requirements for Tool force Dynamometers

For consistently accurate and reliable measurement, the following requirements are considered during design and construction of any tool force dynamometers:

- *Sensitivity:* The dynamometer should be reasonably sensitive for precision measurement.
- *Rigidity:* The dynamometer need to be quite rigid to withstand the forces without causing much deflection which may affect the machining condition.
- *Cross Sensitivity:* The dynamometer should be free from cross sensitivity such that one force (say P_Z) does not affect measurement of the other forces (say P_X and P_Y).
- Stability against humidity and temperature.
- Quick time response.
- High frequency response such that the readings are not affected by vibration within a reasonably high range of frequency.
- *Consistency:* The dynamometer should work desirably over a long period.

Construction and working principle of turning dynamometers

The dynamometers being commonly used nowadays for measuring machining forces accurately and precisely (both static and dynamic characteristics) are either strain gauge type or piezoelectric type. Strain gauge type dynamometers are inexpensive but less accurate and consistent, whereas, the piezoelectric type are highly accurate, reliable and consistent but very expensive for high material cost and rigid construction.

Turning dynamometers may be strain gauge or piezoelectric type and may be of one, two or three dimensions capable to monitor all of P_X, P_Y and P_Z. For ease of manufacture and low cost, strain gauge type turning dynamometers are widely used and preferably of 2D for simpler construction, lower cost and ability to provide almost all the desired force values.

Design and construction of a strain gauge type 2D turning dynamometer is shown schematically in Fig. 2.59 (a and b) and Fig. 2.59 (c) shows the photographic view. Two full bridges comprising four live strain gauges are provided for P_Z and P_X channels which are connected with the strain measuring bridge for detection and measurement of strain in terms of voltage which provides the magnitude of the cutting forces through calibration. *Fig. 2.59 (d) shows the photographic view of a piezoelectric type 3D turning dynamometer.*

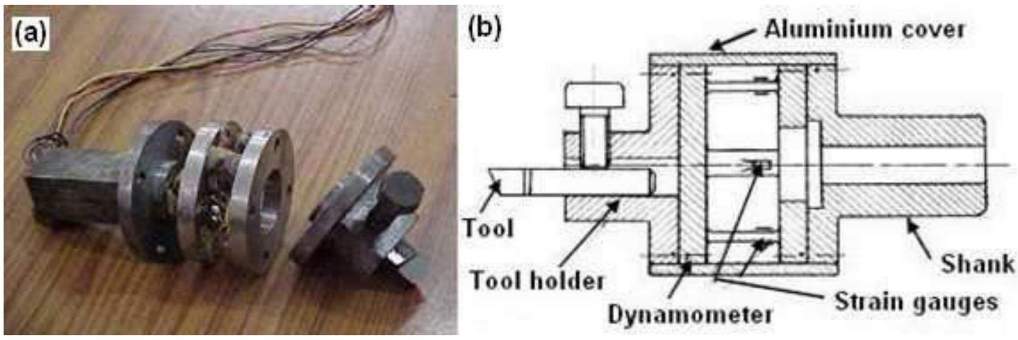


Fig. 2.59 (a and b) Construction of a strain gauge type 2D turning dynamometer

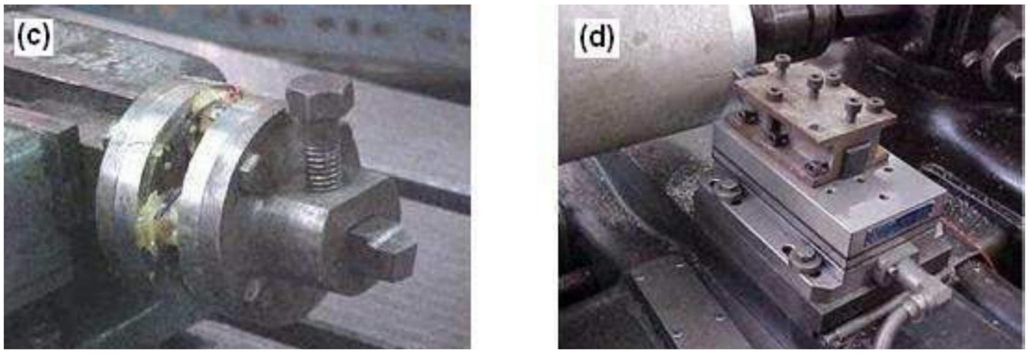


Fig. 2.59 (c) Photographic view of a strain gauge type 2D turning dynamometer
Fig. 2.59 (d) Photographic view of a piezoelectric type 3D turning dynamometer

SPECIAL PURPOSE LATHES

The centre lathe is a general purpose machine tool; it has a number of limitations that preclude it to become a production machine tool. The main limitations of centre lathes are:

- The setting time for the job in terms of holding the job is large.
- Only one tool can be used in the normal course. Sometimes the conventional tool post can be replaced by a square tool post with four tools.
- The idle times involved in the setting and movement of tools between the cuts is large.
- Precise movement of the tools to destined places is difficult to achieve if proper care is not taken by the operator.

All these difficulties mean that the centre lathe cannot be used for production work in view of the low production rate. The centre lathe is thus modified to improve the production rate. The various modified lathes are capstan and turret lathes, semi automatics and automatics. Improvements are achieved basically in the following areas:

- Work holding methods.
- Multiple tool availability.
- Automatic feeding of the tools.
- Automatic stopping of tools at precise locations.
- Automatic control of the proper sequence of operations.

CAPSTAN AND TURRET LATHES

Capstan and turret lathes are production lathes used to manufacture any number of identical pieces in the minimum time. These lathes are development of centre lathes. The capstan lathe was first developed in the year 1860 by Pratt and Whitney of USA.

In contrast to centre lathes, capstan and turret lathes:

- Are relatively costlier.
- Are requires less skilled operator.
- Possess an axially movable indexable turret (mostly hexagonal) in place of tailstock.

- Holds large number of cutting tools; up to four in indexable tool post on the front slide, one in the rear slide and up to six in the turret (if hexagonal) as indicated in the schematic diagrams.
- Are more productive for quick engagement and overlapped functioning of the tools in addition to faster mounting and feeding of the job and rapid speed change.
- Enable repetitive production of same job requiring less involvement, effort and attention of the operator for pre-setting of work-speed and feed rate and length of travel of the cutting tools.
- Are suitable and economically viable for batch production or small lot production.
- Capable of taking multiple cuts and combined cuts at the same time.

Major parts of capstan and turret lathes

Capstan and turret lathes are very similar in construction, working, application and specification. *Fig. 2.60 schematically shows the basic configuration of a capstan lathe and Fig. 2.61 shows that of a turret lathe.* The major parts are:

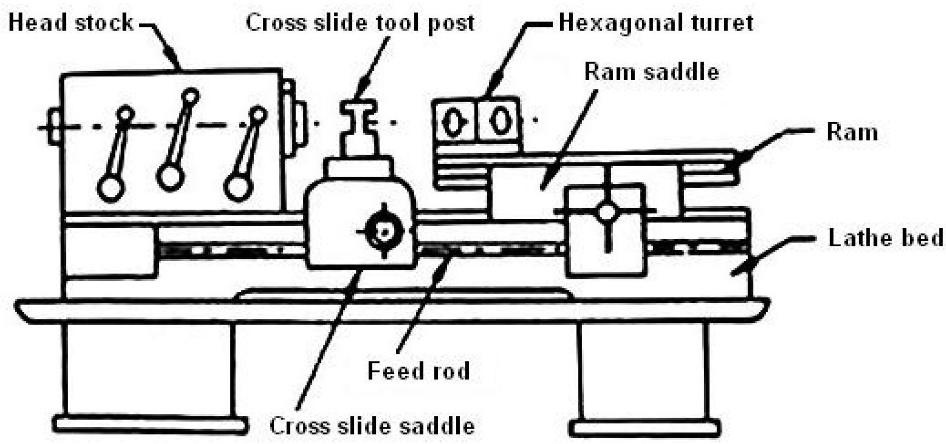


Fig. 2.60 Basic configuration of a Capstan lathe

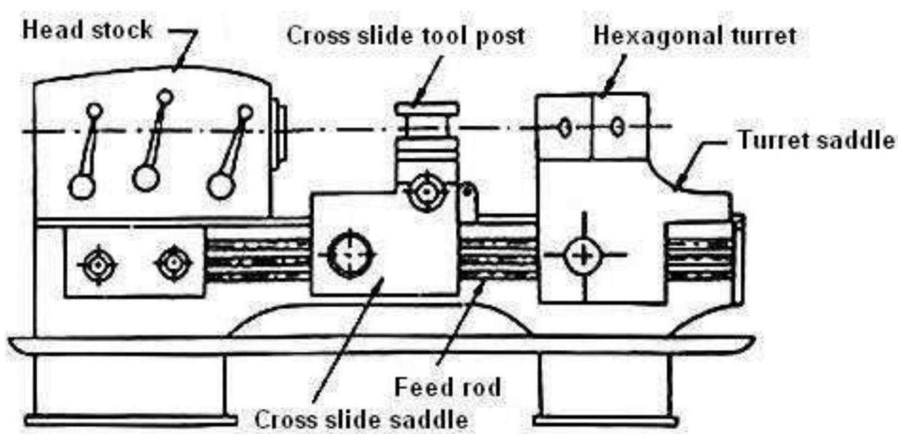


Fig. 2.61 Basic configuration of a Turret lathe

Bed The bed is a long box like casting provided with accurate guide ways upon which the carriage and turret saddle are mounted. The bed is designed to ensure strength, rigidity and permanency of alignment under heavy duty services.

Headstock The head stock is a large casting located at the left hand end of the bed. *The headstock of capstan and turret lathes may be of the following types:*

- Step cone pulley driven headstock.
- Direct electric motor driven headstock.
- All geared headstock.
- Pre-optive or pre-selective headstock.

Step cone pulley driven headstock: This is the simplest type of headstock and is fitted with small capstan lathes where the lathe is engaged in machining small and almost constant diameter of workpieces. Only three or four steps of pulley can cater to the needs of the machine. The machine requires special countershaft unlike that of an engine lathe, where starting, stopping and reversing of the machine spindle can be effected by simply pressing a foot pedal.

Electric motor driven headstock: In this type of headstock the spindle of the machine and the armature shaft of the motor are one and the same. Any speed variation or reversal is effected by simply controlling the motor. Three of four speeds are available and the machine is suitable for smaller diameter of workpieces rotated at high speeds.

All geared headstock: On the larger lathes, the headstocks are geared and different mechanisms are employed for speed changing by actuating levers. The speed changing may be performed without stopping the machine.

Pre-optive or pre-selective headstock: It is an all geared headstock with provisions for rapid stopping, starting and speed changing for different operations by simply pushing a button or pulling a lever. The required speed for next operation is selected beforehand and the speed changing lever is placed at the selected position. After the first operation is complete, a button or a lever is simply actuated and the spindle starts rotating at the selected speed required for the second operation without stopping the machine. This novel mechanism is effect by the friction clutches.

Cross slide and saddle In small capstan lathes, hand operated cross slide and saddle are used. They are clamped on the lathe bed at the required position. The larger capstan lathes and heavy duty turret lathes are equipped with usually two designs of carriage.

- Conventional type carriage.
- Side hung type carriage.

Conventional type carriage This type of carriage bridges the gap between the front and rear bed ways and is equipped with four station type tool post at the front, and one rear tool post at the back of the cross slide. This is simple in construction.

Side hung type carriage The side-hung type carriage is generally fitted with heavy duty turret lathes where the saddle rides on the top and bottom guide ways on the front of the lathe bed. The design facilitates swinging of larger diameter of workpieces without being interfered by the cross-slide. The saddle and the cross-slide may be fed longitudinally or crosswise by hand or power. The longitudinal movement of each tool may be regulated by using stop bars or shafts set against the stop fitted on the bed and carriage. The tools are mounted on the tool post and correct heights are adjusted by using rocking or packing pieces.

Ram saddle In a capstan lathe, the ram saddle bridges the gap between two bed ways, and the top face is accurately machined to provide bearing surface for the ram or auxiliary slide. The saddle may be adjusted on lathe bed ways and clamped at the desired position. The hexagonal turret is mounted on the ram or auxiliary slide.

Turret saddle In a turret lathe, the hexagonal turret is directly mounted on the top of the turret saddle and any movement of the turret is effected by the movement of the saddle. The movement of the turret may be effected by hand or power.

Turret The turret is a hexagonal-shaped tool holder intended for holding six or more tools. Each face of the turret is accurately machined. Through the centre of each face accurately bored holes are provided for accommodating shanks of different tool holders. The centre line of each hole coincides with the axis of the lathe when aligned with the headstock spindle. In addition to these holes, there are four tapped holes on each face of the turret for securing different tool holding attachments. *The photographic view of a hexagonal turret is shown in Fig. 2.62.*

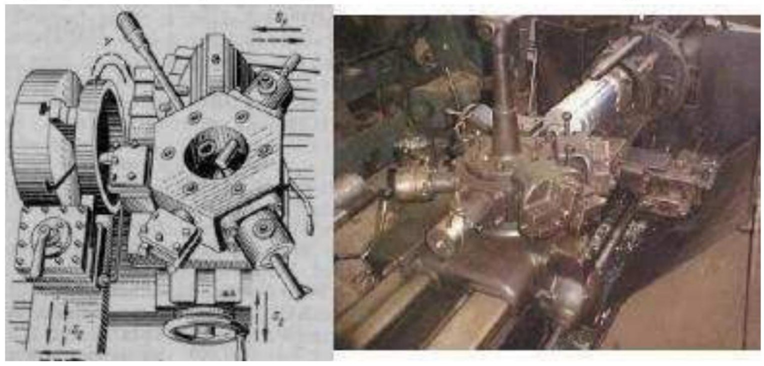


Fig. 2.62 Photographic view of a hexagonal turret

Working principle of capstan and turret lathes

The work pieces are held in collets or chucks. In turret lathes, large work pieces are held by means of jaw chucks. These chucks may be hydraulically or pneumatically operated. In a capstan lathe, bar stock is held in collet chucks. A bar feeding mechanism is used for automatic feeding of bar stock. At least eleven tools can be set at a time in turret and capstan lathes. Six tools are held on the turret faces, four tools in front square tool post and one parting off tool at the rear tool post. While machining, the turret head moves forward towards the job. After each operation, the turret head goes back. The turret head is indexed automatically and the next tool comes into machining position. The indexing is done by an indexing mechanism. The longitudinal movement of the turret corresponding to each of the turret position can be controlled independently.

By holding different tools in the turret faces, the operations like drilling, boring, reaming, counter boring, turning and threading can be done on the component. Four tools held on the front tool post are used for different operations like necking, chamfering, form turning and knurling. The parting off tool in the rear tool post is used for cutting off the workpiece. The cross wise movements of the rear and front tool posts are controlled by pre-stops.

Bar feeding mechanisms

The capstan and turret lathes while working on bar work require some mechanism for bar feeding. The long bars which protrude out of the headstock spindle require to be fed through the spindle up to the bar stop after the first piece is completed and the collet chuck is opened. In simple cases, the bar may be pushed by hand. But this process unnecessarily increases the total production time by stopping, setting, and starting the machine. Therefore, various types of bar feeding mechanisms have been designed which push the bar forward immediately after the collet releases the work without stopping the machine, enabling the setting time to be reduced to the minimum.

Type 1: *This mechanism is shown in Fig. 2.63.* After the work piece is complete and part off, the collet is opened by moving the lever manually in the rightward direction. Further movement of the lever in the same direction causes forward push of the bar with the help of ratchet - pawl system. After the projection of the bar from the collet face to the desired length controlled by a preset bar stop generally held in one face of the turret, the lever is moved in the leftward direction to close the collet. Just before closing the collet, the leftward movement of the lever pushes the ratchet bar to its initial position.

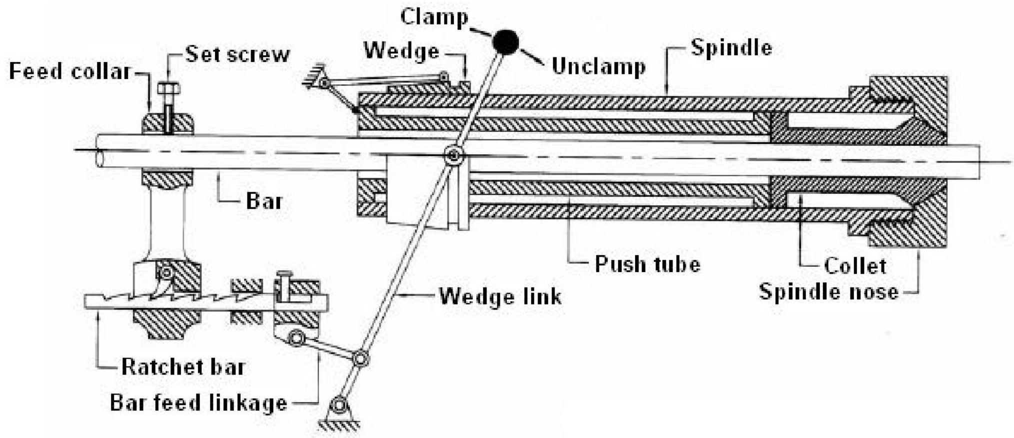


Fig. 2.63 Bar feeding mechanism

Type 2: *This mechanism is shown in Fig. 2.64.* The bar is passed through the bar chuck, spindle of the machine and then through the collet chuck. The bar chuck rotates in the sliding bracket body which is mounted on a long sliding bar. The bar chuck grips the bar centrally by two set screws and rotates with the bar in the sliding bracket body. One end of the chain is connected to the pin fitted on the sliding bracket and the other end supports a weight. The chain running over two fixed pulleys mounted on the sliding bar. The weight constantly exerts end thrust on the bar chuck while it revolves on the sliding bracket and forces the bar through the spindle at the moment the collet chuck is released. Thus bar feeding may be accomplished without stopping the machine.

In this way the bar is fed without stopping the machine. After a number of such feedings, the bar chuck will approach the rear end of the head stock. Now the bar chuck is released from the bar and brought to the left extreme position. Then it is screwed on to the bar.

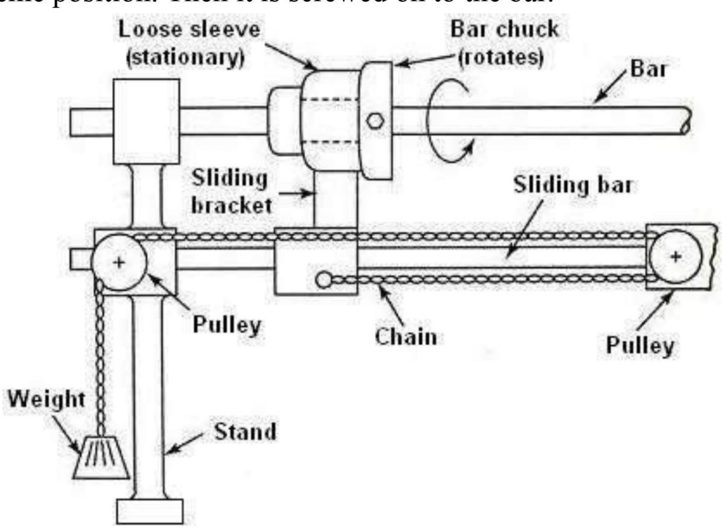


Fig. 2.64 Bar feeding mechanism

Turret indexing mechanism

Construction: *Fig. 2.65 shows the schematic view of the turret indexing mechanism.* It illustrates an inverted plan of the turret assembly. This mechanism is also called as Geneva mechanism. There is a small vertical spindle fixed on the turret saddle. At the top of the spindle, the turret head is mounted. Just below the turret head on the same spindle, a circular index plate having six slots, a bevel gear and a ratchet are mounted. There is a spring actuated plunger mounted on the saddle which locks the index plate this prevents the rotation of turret during the machining operation. A pin fitted on the plunger projects out of the housing. An actuating cam and an indexing pawl are fitted to the lathe bed at the required position. Both cam and pawl are spring loaded.

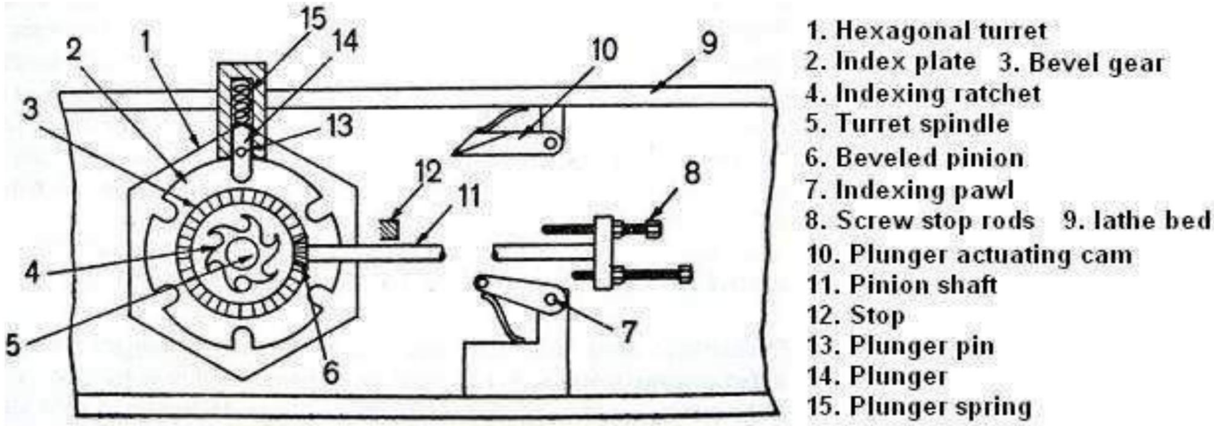


Fig. 2.65 Turret indexing mechanism

Working principle: When the turret reaches the backward position (after machining) the projecting pin of the plunger rides over the sloping surface of the cam. So the plunger is released from the groove of the index plate. Now the spring loaded pawl engages the ratchet groove and rotates it. The index plate and the turret spindle rotate through 1/6 of a revolution. The pin and the plunger drop out of the cam and hence the plunger locks the index plate at the next groove. The turret is thus indexed and again locked into the new position automatically. The turret holding the next tool is now fed forward and the pawl is released from the ratchet plate by the spring pressure.

The corresponding movement of the stop rods with the indexing of the turret can also be understood from the Fig. 2.65. The pinion shaft has a bevel pinion at one end. The bevel pinion meshes with the bevel gear mounted on the turret spindle. At its other end, a circular plate is connected. Six adjustable stop rods are fitted to this circular plate. When the turret rotates, the bevel pinion will also rotate. And hence the circular stop plate is also indexed by 1/6 of a revolution. The ratio of the teeth between the pinion and the gear is chosen according to this rotation.

Work holding devices used in capstan and turret lathes

The standard practice of holding the work piece between two centres in a centre lathe finds no place in a capstan lathe or turret lathe as there is no dead centre to support the work piece at the other end. Therefore, the work piece is held at the spindle end by the help of chucks and fixtures. The usual methods of holding the work piece in a capstan and turret lathes are:

1. Jaw chucks

The jaw chucks are used in capstan lathes having two, three or four jaws depending upon the shape of the work piece. The jaw chucks are used to support odd sized jobs or jobs having larger diameter which cannot be introduced through the headstock spindle and gripped by collet chucks.

2-jaw chuck self centering chuck

It is used for bar work. The two jaws hold the irregular work more readily since the clamping is at two points which are diametrically opposite. It is available in size from about 125 mm to 250 mm outside diameter to hold bar stock of diameter from about 20 mm to 45 mm.

3-jaw chuck self centering chuck

It is used for holding round or hexagonal bar stock or other symmetrical work. It is suitable for gripping larger diameter bars, circular castings, forgings etc. It is available in size from about 100 mm to 750 mm outside diameter and they can hold work up to about 650 mm diameter. The 3-jaw chuck has been described in Article 2.2.5.1, Page 57 and illustrated in Fig. 2.10 (a).

4-jaw independent chuck

It is used occasionally for gripping irregular shaped workpieces, where the number of articles required does not justify the manufacture of special fixtures. It is used for holding rough castings and square or octagonal work. Each jaw can be operated independently and is reversible. It is available in sizes up to about 1000 mm diameter. The 4-jaw chuck has been described in Article 2.2.5.1, Page 57 and illustrated in Fig. 2.10 (b).

Combination chuck

The combination chuck is shown in Fig. 2.66. As the name implies, a combination chuck may be used both as a self centering and an independent chuck to take advantage of both the types. The jaws may be operated individually by separate screws or simultaneously by the scroll disc. The screws mounted on the frame have teeth cut on its underside which meshes with the scroll and all the jaws together with the screws move radially when the scroll is made to rotate by a pinion.

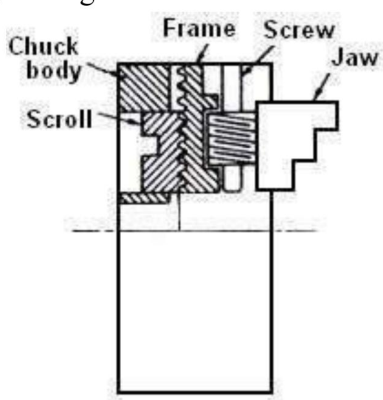


Fig. 2.66 Combination chuck

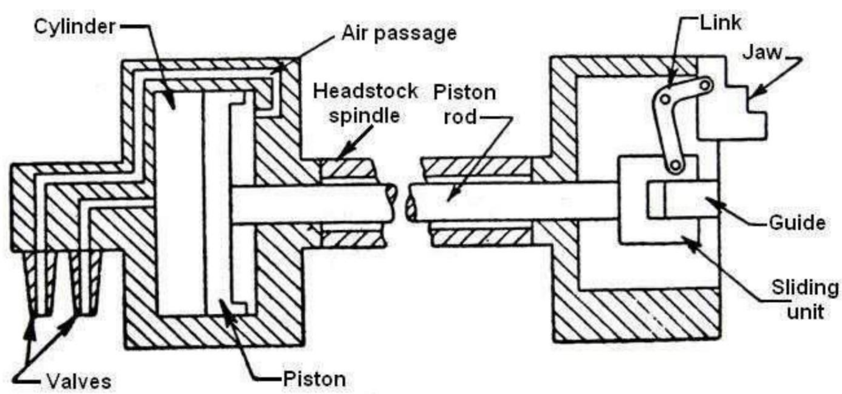


Fig. 2.67 Air operated chuck

Air operated chuck

The air operated chuck is shown in Fig. 2.67. Heavy duty turret lathes and capstan lathes engaged in mass production work are equipped with air operated chucks for certain distinct advantages. The chuck grips the work piece quickly and is capable of taking powerful grip with least manual exertion. The chucks are operated by air at a pressure of 5.5 kg/cm^2 to 7 kg/cm^2.

The mechanism incorporates an air cylinder mounted at the back end of the headstock spindle and rotates with it. Fluid pressure may be communicated to the cylinder by operating a valve with a lever and the piston will slide within the cylinder. The movement of the piston is transmitted to the jaws by means of connecting rod and links. A guide is provided for the movement of the connecting rod.

To clamp the work piece, compressed air is admitted to the cylinder at the right side of the piston. The piston slides to the left side and the jaws grip the work piece securely. To release the work piece, the air is admitted to the left side of the piston. Then the piston slides to the right side and the jaws unclamp the work piece.

2. Collet chucks

Collet chucks or collets are used mainly to hold bar stock, especially in the smaller sizes. A collet is a circular steel shell having three or four equally spaced slits extending the greater part of its length. These slits impart springing action to the collet. That is why, collets are also known as “spring collets”. The collet nose is made thicker to form the jaws. The outside surface of the nose fits in the taper hole of the hood. The inside of the collet is made according to the shape of the work to be held.

Collets are much more suitable than a self centering chuck in mass production work due to its quickness in action and accurate setting. The collets may be operated by hand or by power. The collets are classified by the methods used to close the jaws on the work.

Push out type Collet chuck

The push out type collet chuck is shown in Fig. 2.68 (a). In this type the taper of the collet nose and hood converge towards the right. To grip the work, the tapered portion of the spring collet is pushed into the mating taper of the hood. There is a tendency of the bar to be pushed slightly outward when the collet is pushed for gripping. If the bar is fed against a stop bar fitted on the turret head, this slight outward movement of the bar ensures accurate setting of the length for machining.

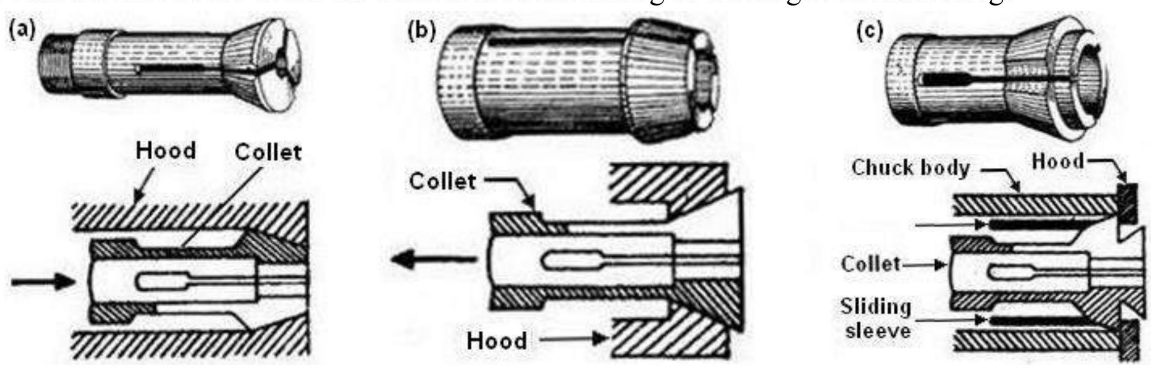


Fig. 2.68 Collet chucks (a) Push out type (b) draw back type (c) Dead length type

Draw back or Draw in type Collet chuck

The draw back type collet chuck is shown in Fig. 2.68 (b). In this type the taper of the collet nose and hood converge towards the left. To grip the work, the tapered portion of the spring collet is pulled back into the mating taper of the hood which causes the split end of the collet to close in and grip the bar. The machining length of the bar in this type of chuck cannot be accurately set as the collet while closing will draw the bar slightly inward towards the spindle.

Dead length type Collet chuck

The dead length type collet chuck is shown in Fig. 2.68 (c). For accurate positioning of the bar, both the push out and draw in type collet present some error due to the movement of the bar along with the collet while gripping. This difficulty is removed by using a stationary collet on the bar. In this type the taper of the collet nose converge towards the left. A sliding sleeve is placed between the collet and the hood. This sliding sleeve has a tapered edge which fits on the taper of the collet nose. To grip the work, the sliding sleeve is pushed towards the right. This makes the collet to close in and grip the bar. The end movement of the collet is prevented by the shoulder stop.

3. Fixtures

A fixture may be described as a special chuck built for the purpose of holding, locating and machining a large number of identical pieces which cannot be easily held by conventional gripping devices. Fixtures also serve the purpose of accurately locating the machining surface.

The main functions of a fixture are as follows:

- It accurately locates the work.
- It grips the work properly, preventing it from bending or slipping during machining operations.
- It permits rapid loading and unloading of workpieces.

Tool holding devices used in capstan and turret lathes

The wide variety of work performed in a capstan or turret lathe in mass production necessitated designing of many different types of tool holders for holding tools for typical operations. The tool holders may be mounted on turret faces or on cross-slide tool post and may be used for holding tools for bar and chuck work. Certain tool holders are used for holding tools for both bar and chuck work while box tools are particularly adapted in bar work.

Straight cutter holder

This is a simple tool holder constructed to take standard section tool bits. The shank of the holder can be mounted directly into the hole of the turret face or into a hole of a multiple turning head. In this type of holder, the tool is held perpendicular to the shank axis. The tool is gripped in the holder by three set screws. Different operations like turning, facing, boring, counter boring, chamfering, etc. can be performed by holding suitable tools in the holder. *Fig.2.69 illustrates a straight cutter holder.*

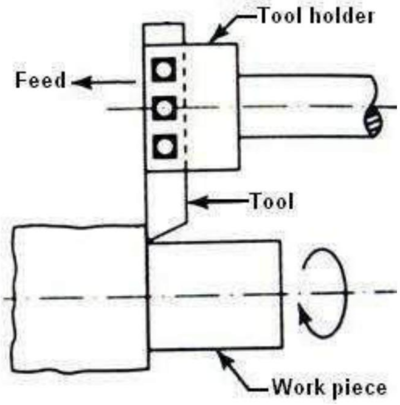


Fig. 2.69 straight cutter holder

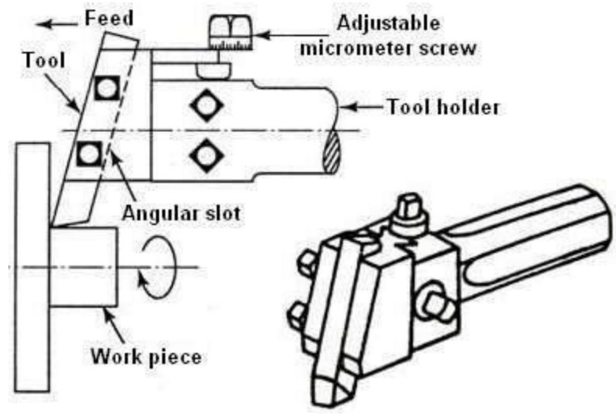


Fig. 2.70 Adjustable angle cutter holder

Plain or adjustable angle cutter holder

It is similar as that of a straight cutter holder but having an angular slot. The tool is fitted in this slot by means of setscrews. The inclination of the tool helps in turning or boring operations close to the chuck jaws or up to the shoulder of the work piece without any interference. In plain type of holder, the setting of the cutting edge relative to the work is effect by opening the set screws and then adjusting the tool by hand. In adjustable type of holder, the accurate setting of the tool can be effect by rotating a micrometer screw. *Fig.2.70 illustrates an adjustable angle cutter holder.*

Multiple cutter holder

This holder can accommodate two or more tools in its body. This feature enables turning of two different diameters simultaneously. This will reduce the time of machining. Turning and boring tools can also be set in the holder to perform two operations at a time. *Fig.2.71 illustrates a multiple cutter holder.*

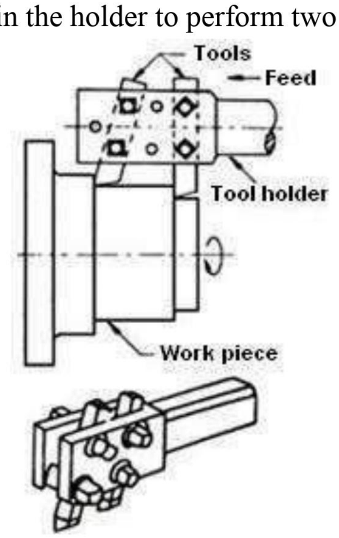


Fig. 2.71 Multiple cutter holder

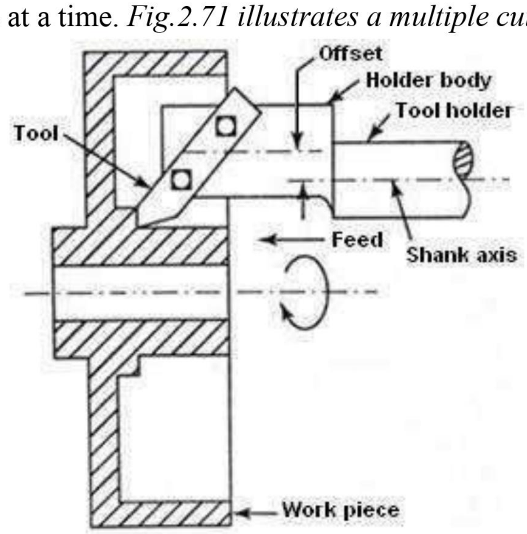


Fig. 2.72 Offset cutter holder

Offset cutter holder

In this type, the holder body is made offset with the shank axis. Larger diameter work can be turned or bored by this type of holder. *Fig.2.72 illustrates an offset cutter holder.*

Combination tool holder or multiple turning head

It is used for holding straight, angular, multiple or offset cutter holders, boring bars, etc. for various turning and boring operations, so that it may be possible to undertake a number of operations simultaneously. The tools are set at different positions on the work surface by inserting the shank of tool holders in different holes of the multiple head body, and they are secured to it by tightening separate set screws. A boring bar is held at the central hole of the head which is aligned with the axis of the supporting flange. The head is supported on the turret face by tightening four bolts passing through the holes of the flange. The tool holder has a guide bush. The pilot bar projecting from the head stock of the machine; slides inside the guide bush. This gives additional support to the tool while cutting and prevents any vibration or deflection. *Fig.2.73 illustrates a combination tool holder.*

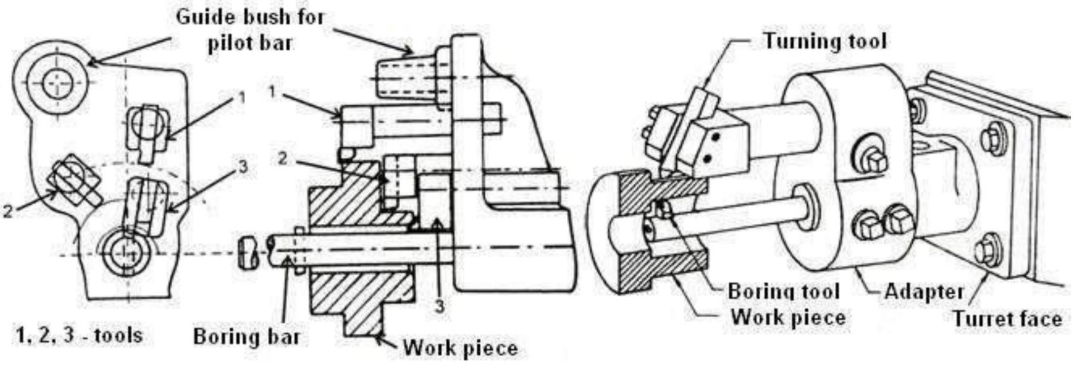


Fig. 2.73 Combination tool holder

Sliding tool holder

It is useful for rough and finish boring, recessing, grooving, facing, etc. The holder consists of a vertical base on which a slide is fitted. The slide may be adjusted up or down accurately by rotating a hand wheel provided with a micrometer dial. Two holes are provided on the sliding unit for holding tools. The lower hole which is aligned with the lathe axis is used for holding boring bars, drills, reamers, etc. The upper hole accommodates a turning tool holder. After necessary adjustments the slide is clamped to the base by a clamping lever for turning or boring operations. For facing or recessing operations, the crosswise movement of the tool is obtained in the vertical plane. The slide is equipped with two adjustable stops for facing or similar operations in order to be able to duplicate the workpiece. The holder base is clamped directly on the turret face by studs. *Fig.2.74 illustrates a sliding tool holder.*

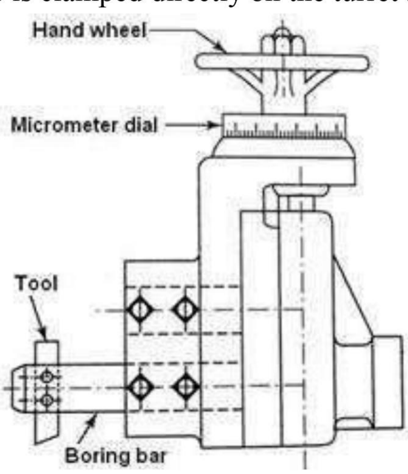


Fig. 2.74 Sliding tool holder

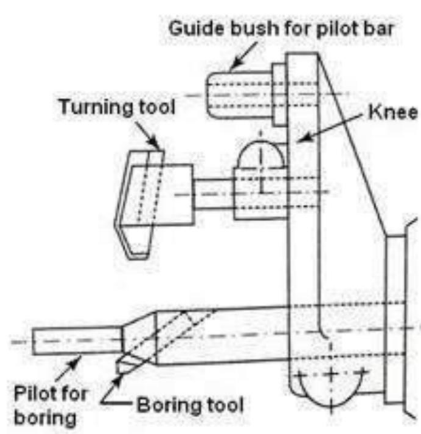


Fig. 2.75 Knee tool holder

Knee tool holder

It is useful for simultaneous turning and boring or turning and drilling operations. The knee holder is bolted directly on the turret face. The axis of the lower hole coincides with the lathe axis and is used for holding boring bars, drills, etc. The turning tool holder is fitted in to the centre hole. A guide bush is provided at the top of the holder for running of pilot bar. *Fig.2.75 illustrates a knee tool holder.*

Flange tool holder

This holder is also called as extension holder, drill holder or boring bar holder. These holders are intended for holding drills, reamers, boring bars, etc. The twist drills having Morse taper shanks are usually held in a socket which is parallel outside and tapered inside. The socket is introduced in the hole of the flange tool holder and clamped to it by set screws. The flanged end of the holder is bolted directly to the face of the turret and is accurately centered. *Fig.2.76 illustrates a flange tool holder.*

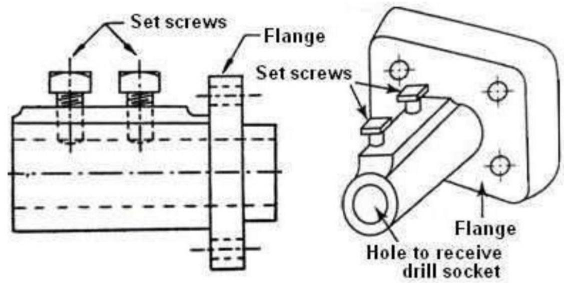


Fig. 2.76 Flange tool holder

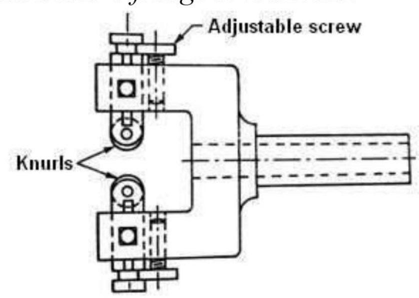


Fig. 2.77 Knurling tool holder

Knurling tool holder

It may be mounted on the turret face or on the tool posts of the cross-slide. The holders with knurls mounted on the cross-slide can perform knurling operation on any diameter work. *Fig 2.77 illustrates a knurling tool holder which is fitted on the turret face.* The position of knurls can be adjusted in a vertical plane to accommodate different diameters of work, while the relative angle between them can also be varied to produce different patterns of knurled surface.

Form tool holder

Two sets of form tool holders have been designed for holding straight and circular form cutters. The usual procedure of holding a form tool holder is on the cross-slide. In the straight form tool holder, the tool is mounted on a dovetail slide and the height of the cutting edge may be adjusted by moving the tool within the slide. The height of the circular form tool may be adjusted by rotating the circular cutter. *Fig.2.78 illustrates a form tool holder.*

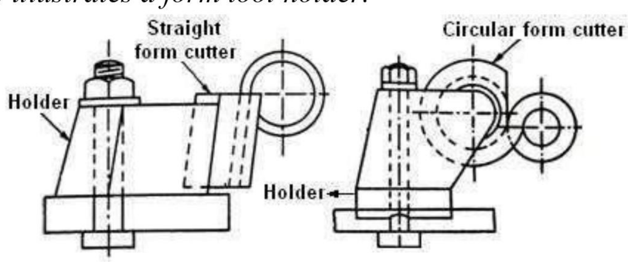


Fig. 2.78 Form tool holder

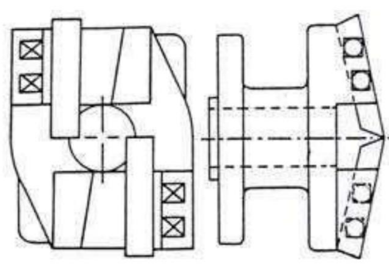


Fig. 2.79 Balanced tool holder

Balanced tool holder

Its name is derived from the fact that the tools mounted on the holder are so arranged that the cutting thrust exerted by one of the tools on the work is balanced by the cutting thrust developed by the other tool fitted on the holder. This prevents any bending of the work and obviates the use of any other work support. *Fig.2.79 illustrates a balanced tool holder.*

V-Steady tool holder

The V-steady box tool holders are used for lending support to the workpiece while cutting action progresses from the end of a bar stock. Both the tool and V-steady are mounted on the adjustable slide in order to set the required diameter of the machined part and to position the tool relative to the V-steady. The V-steady tool holder is mainly used in brass work. *Fig.2.80 illustrates a V-Steady tool holder.*

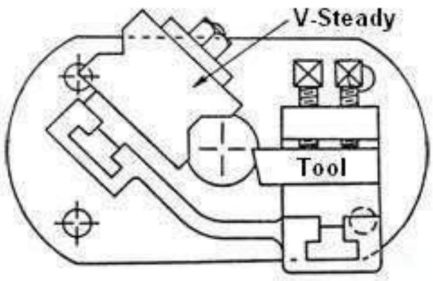


Fig. 2.80 V-Steady tool holder

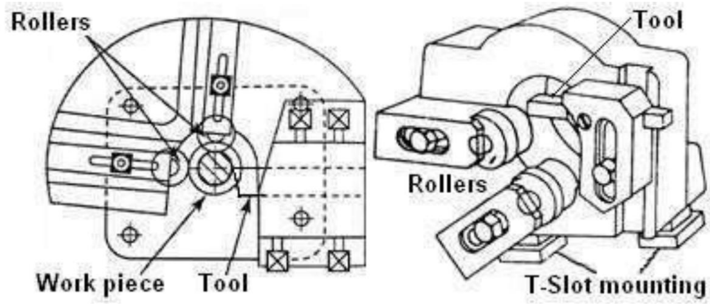


Fig. 2.81 Roller steady box tool holder

Roller steady box tool holder

It is commonly used in bar work for turning steel rods. In construction, it replaces V-steady and in its place two rollers are used to provide support to the work. The tool and the rollers can be adjusted in the holder for proper setting. A high class finish is obtained on the work surface due to burnishing action of the rollers on the work. The rollers acting against the cutting pressure remove the feed marks on the workpiece. *Fig.2.81 illustrates a roller steady box tool holder.*

Comparison of capstan and turret lathes

Sl . No.	Capstan lathe	Turret lathe
1	Turret head is mounted on a ram which slides over the saddle.	Turret head is directly mounted on saddle. But it slides on the bed.
2	The turret movement is limited.	The turret moves on the entire length of the bed without any restriction.
3	Hence shorter work piece can be machined.	Longer work piece can be machined.
4	Its construction does not provide rigidity due to overhanging of ram beyond the bed.	It provides rigidity and strong.
5	It is suitable for light duty applications.	It is suitable for heavy duty applications.
6	Turret head can be moved manually.	Turret head cannot be moved manually.
7	The maximum size of 60 mm diameter work can be accommodated.	It can accommodate only from 125 to 200mm.
8	No cross-wise movement to turret.	Facing and turning are usually done by cross-wise movement of turret.
9	Overhung type of cross-slide is not used.	Overhung type of cross-slide is provided for some specific operations.

Specifications of capstan and turret lathes

The main sizes to be specified in any capstan and turret lathes are:

- Maximum diameter of the workpiece that can be machined.
- Swing over cross slide.
- Swing over bed.

E.g. 100-200-250 refers to the maximum diameter that can be machined by using this size of lathe is 100 mm, the size of swing over cross slide is 200 mm and the size of swing over bed is 250 mm.

In addition to the above sizes, the following details are also needed to specify the full description about the machine:

- Power of the main drive motor.
- Range of spindle speeds.
- Range of feeds for the carriage.
- Range of feeds for the turret or saddle.
- Total weight of the machine.
- Floor space required.

AUTOMATIC LATHES

Highly automated machine tools especially of the lathe family are ordinarily classified as semi automatics and automatics. Automatics as their name implies are machine tools with a fully automatic work cycle. Semi automatics are machine tools in which the actual machining operations are performed automatically in the same manner as on automatics. In this case however, the operator loads the blank into the machine, starts the machine, checks the work size and removes the completed piece by hand.

2.11.1 Work holding devices used in automatic lathes

Automation is incorporated in machine tool systems to enable faster and consistently accurate processing operations for increasing productivity and reducing manufacturing cost in batch and mass production. Therefore, in semiautomatic and automatic machine tools mounting and feeding of the work piece or blank is done much faster but properly.

Mostly collet chucks are used for holding the work pieces. Collet chucks inherently work at high speed with accurate location and strong grip. The chucks are actuated manually or semi automatically in semi automatic lathes and automatically in automatic lathes. The collet chucks has been described in Article 2.10.5, Page 87 and illustrated in Fig. 2.68 (a, b and c).

SEMI AUTOMATICS

Semi automatics are employed for machining work from separate blanks. The operator loads and clamps the blanks, starts the machine and unloads the finished work. *The characteristic features of semi automatic lathes are:*

- Some major auxiliary motions and handling operations like bar feeding, speed change, tool change etc. are done quickly and consistently with lesser human involvement.
- The operators need lesser skill and putting lesser effort and attention.
- Suitable for batch or small lot production.
- Costlier than centre lathes of same capacity.

2.12.1 Classification of semi automatics

Depending upon the number of work spindle, these machines are classified as:

Single spindle semi automatics

- ***Centre type:*** In this type, the workpiece is held between centres, for which a head stock and a tail stock are mounted on the bed of the machine. Usually, external stepped or formed surfaces are machined on this machine. The work is machined by two groups of cutting tools. The front tool slide holds the cutting tools which require a longitudinal feed motion to turn the steps of a shaft, while the rear tool slide carries the tools that require a transverse feed motion to perform operations such as facing, shouldering, necking, chamfering etc.
- ***Chucking type:*** In this type, the workpiece is held in a chuck. Such a machine may be equipped with various tool slide arrangements. In addition to longitudinal and transverse feed tool slides, these machines may also be equipped with a central end working tool slide or a turret if internal surfaces are also to be machined in addition to the external surfaces.

Multi spindle semi automatics

The machine may also be built in two designs:

- Centre type.
- Chucking type.

These multi spindle semi automatics are classified as:

- Parallel action or single station type.
- Progressive action or multi station type.

AUTOMATS

These are machine tools in which the components are machined automatically. The working cycle is fully automatic that is repeated to produce identical parts without participation of the operator. All the working and idle operations are performed in a definite sequence by the control system adopted in the automats which is set up to suit a given work.

Classification of Automats

The automats can be classified as follows:

According to the type of work materials used:

- Bar stock machine.
- Chucking machine.

According to the number of spindles:

- Single spindle machine.
- Multi spindle machine.

According to the position of spindles:

- Horizontal spindle type.
- Vertical spindle type.

According to the use:

- General purpose machine.
- Single purpose machine.

According to the feed control:

- Single cam shaft rotating at constant speed.
- Single cam shaft with two speeds.
- Two cam shafts.

Advantages of automats over conventional lathes

- Mass production of identical parts.
- High accuracy is maintained.
- Time of production is minimized.
- Less floor space is required.
- Unskilled labor is enough. It minimizes the labor cost.
- Constant flow of production.
- One operator can be utilized to operate more than one machine.
- The bar stock is fed automatically.
- Scrap loss is reduced by eliminating operator error.

Comparison of automats and semiautomatics

Sl . No.	Automats	Semi automatics
1	Loading and unloading of work piece are done automatically by the machine.	Loading and unloading are done manually.
2	Feeding of bar stock and bringing the tools to correct machining positions are done automatically.	These are done manually.
3	A single operator can attend a number of machines when they are arranged together as a group.	An operator can attend to only one or two machines at a line.
4	Production time and cost less.	Not so less.
5	Best suitable for production of small size components.	Suitable for large size components.
6	Initial cost of machine is high.	Initial cost is lower than that of automatic lathe.

SINGLE SPINDLE AUTOMATS

These machines have only one spindle. So, one component can be machined at a time. These are modified form of turret lathe. These machines have maximum of 4 cross slides in addition to a 6 station or 8 station turret. These cross slides are operated by disc cams which draws the power from the main spindle through cycle time change gears. The single spindle automats are of the following types:

SINGLE SPINDLE AUTOMATIC CUTTING OFF MACHINE

This machine produces large quantities of workpieces of smaller diameter and shorter lengths. Components with simple form are produced in this machine by means of cross sliding tools.

Construction This machine is simple in design. The head stock with the spindle is mounted on the bed. Two cross slides are located on the bed at the front end of the spindle. The front cross slides are used for turning and forming operations. The rear tool slide is used for facing, chamfering, recessing, under cutting and cutting off operations. Cams on a camshaft actuate the movements of the cross slides through a system of levers.

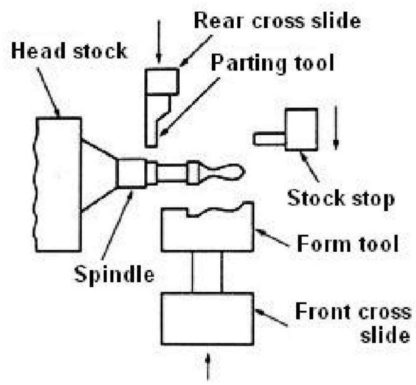


Fig. 2.82 Arrangement of tool slide

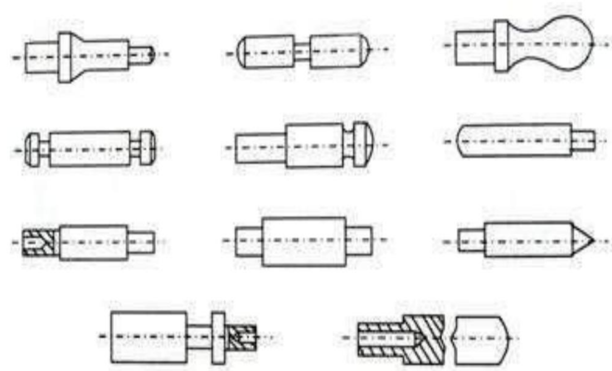


Fig. 2.83 Simple parts produced on cutting off machine

Working principle *Typical arrangement of tool slide in an automatic cutting off machine is illustrated in Fig. 2.82.* The required length of work piece (stock) is fed out with a cam mechanism, up to the stock stop which is automatically advanced in line with the spindle axis, at the end of each cycle. The stock is held in the collect chuck of the rotating spindle. The machining is done by tools held in cross slides operating only in the crosswise direction. The form tool held in the front tool slide produces the required shape of the component. The parting off tool in the rear tool slide is used to cut off the component after machining. Special attachments can be employed if holes or threads are required on the simple parts.

This machine has a single cam shaft which controls the working and idle motions of the tools. The cam shaft runs at constant speed. Therefore working motions and idle motions takes place at the same speed. Hence the cycle time is more. *Typical simple parts (from 3 mm to 20 mm in diameter) produced on this machine are shown in Fig. 2.83.*

SWISS TYPE AUTOMATIC SCREW MACHINE

This machine was designed and developed in Switzerland. So it is often called as Swiss auto lathe. This machine is also known as 'Sliding head screw machine', or 'Movable headstock machine', because the head stock is movable and the tools are fixed. This machine is used for machining long accurate parts of small diameter (2 mm to 25 mm).

Construction *Fig. 2.84 schematically shows the basic configuration of a Swiss type automatic screw machine.* This machine has the following parts:

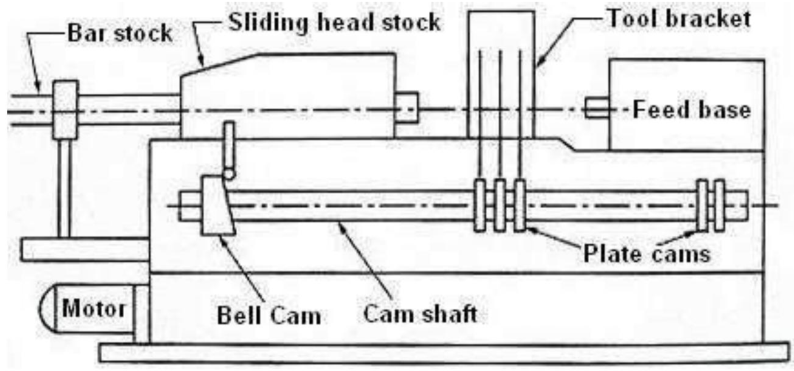


Fig. 2.84 Swiss type automatic screw machine

Sliding Head Stock: This head stock has a collet. The bar stock is held in this collet. The headstock slides along the guide ways of the bed. A bell cam connected to the cam shaft controls this sliding motion.

Tool Bracket: The tool bracket is mounted on the bed way near the head stock. The tool bracket supports 4 or 5 toll slides. It also has a bush for supporting and guiding the bar stock. Two slides are positioned horizontally (front and rear) on which the turning tools are normally clamped. The other slides are arranged above these slides. These slides can move radially. All the slides can move back and forth. These slides are actuated independently by sets or rocker arms and plate cams. Plate cams are fitted to the cam shaft. *The tool bracket is shown schematically in Fig. 2.85 (a) and photographically in Fig. 2.85 (b).*

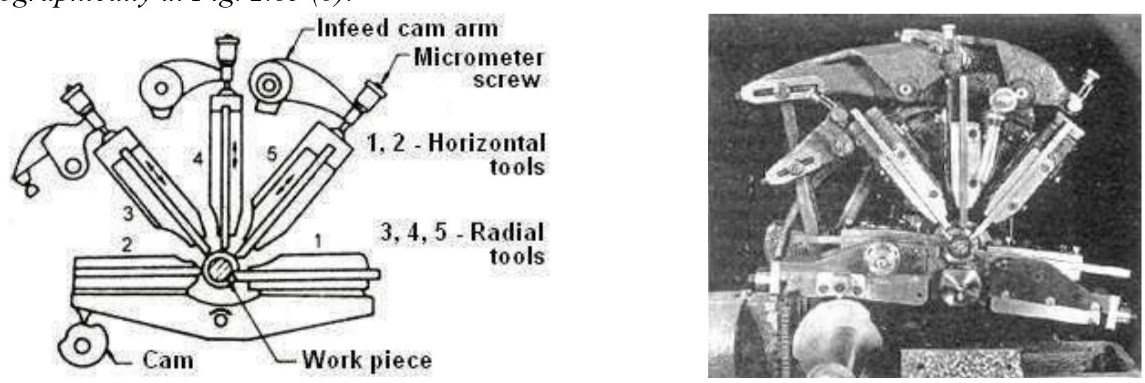


Fig. 2.85 (a) Schematic view of a tool bracket Fig. 2.85 (a) Photographic view of a tool bracket

Feed Base: The feed base is a special attachment mounted at the right hand side of the bed. This can move along the bed. Using this attachment, operations like drilling, boring, thread cutting with taps or dies etc., are done. The movement of the feed base is controlled by the plate cam fitted to the cam shaft.

Cam Shaft: The cam shaft is mounted at the front of the machine. It has a bell cam at the left end. This controls the sliding movement of the head stock. Plate cams fitted at the centre of the shaft controls the movement of the tool slides. Plate cam at the right end of the cam shaft controls the movement of the feed base.

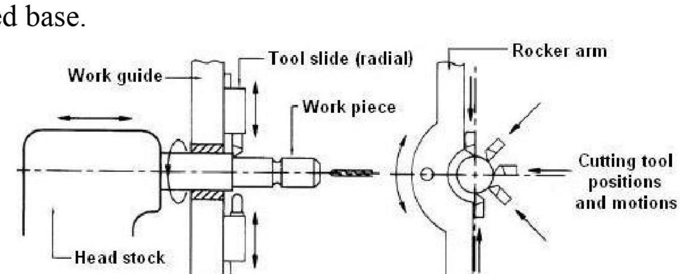


Fig. 2.86 Working principle of the Swiss type automatic screw machine

Working principle *Fig. 2.86 shows the working principle of the Swiss type automatic screw machine.* The stock is held by a rotating collet in the head stock and all longitudinal feeds are obtained by a cam which moves the head stock as a unit. Most diameters turning are done by two horizontal tool slides while the other three slides are used principally for such operations as knurling, chamfering, recessing and cutting off. The tools are controlled and positioned by cams that bring the tools in as needed to turn, face, form, and cut off the workpiece from the bar as it emerges from the bushing.

The cutting action is confined close to the support bushing reducing the overhang to a minimum. As a result, the work can be machined to very close limits. All tools can work at a time. After the work piece is machined, the head stock slides back to the original position. One revolution of the cam shaft produces one component.

A wide variety of formed surfaces may be obtained on the workpiece by synchronized alternating or simultaneous travel of the headstock (longitudinal feed) and the cross slide (approach to the depth of cut). The bar stock used in these machines has to be highly accurate and is first ground on centreless grinding machines to ensure high accuracy. *Parts produced on this machine are shown in Fig. 2.87.*

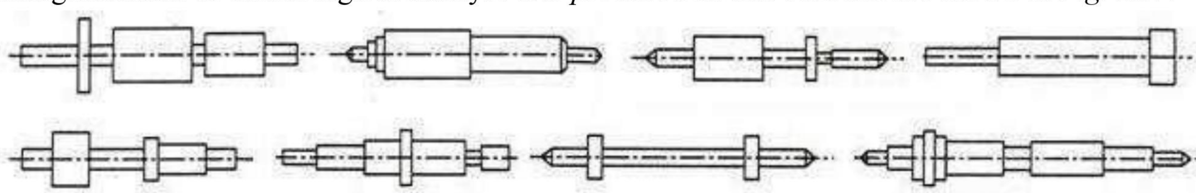


Fig. 2.87 Simple parts produced on Swiss auto lathe

Advantages

- It is used to precision turning of small parts.
- Wide range of speeds is available.
- It is rigid in construction.
- Micrometer tool setting is possible.
- Interchangeability of cams is possible.
- Tolerance of 0.005 mm to 0.0125 mm is obtained.

SINGLE SPINDLE AUTOMATIC SCREW TYPE MACHINE

This is essentially wholly automatic bar type turret lathe. This is very similar to capstan and turret lathes with reference to tool layout, but all the tool movements are cam controlled, such that full automation in manufacturing is achieved. This is designed for machining complex external and internal surfaces on parts made of bar stock or of separate blanks. These machines are made in several sizes for bar work from 12.7 mm to 60 mm diameter.

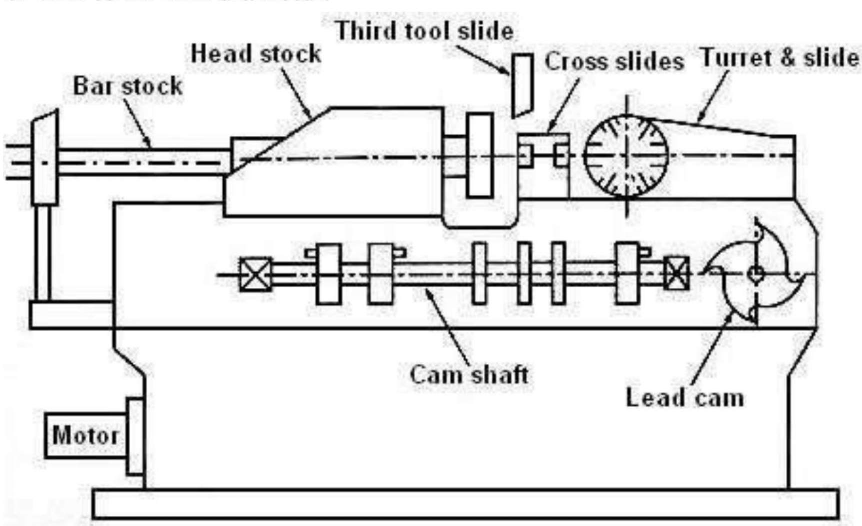


Fig. 2.88 Single spindle automatic screw cutting machine

Construction *Fig. 2.88 schematically shows the basic configuration of a single spindle automatic screw cutting machine.* Up to ten different cutting tools may be employed at a time in this machine. The tools are fixed in indexing turret and in cross-slides. The turret carries six tools. Two cross-slides (front and rear) are employed for cross-feeding tools. A vertical slide for parting off operation may also be provided. It is installed above the work spindle. The stationary headstock, mounted on the left end of the bed, houses the spindle which rotates in either direction.

Working principle The bar stock is held in a collet chuck and advanced by a feed finger after each piece is finished and cut off. All movements of the machine units are actuated by cams mounted on the camshaft. The bar stock is pushed through stock tube in a bracket and its leading end is clamped in rotating spindle by means of a collet chuck. The bar is then fed out for the next part by stock feeding mechanism. Longitudinal turning and machining of the central hole are performed by tools mounted on turret slide. The cut off and form tools are mounted on the cross-slides. At the end of each cut, turret slide is withdrawn automatically and indexed to bring the next tool into position. One revolution of camshaft produces one component. It is used for producing small jobs, screws, stepped pins, taper pins, bolts, etc. *Typical parts produced on this machine are shown in Fig. 2.89.*

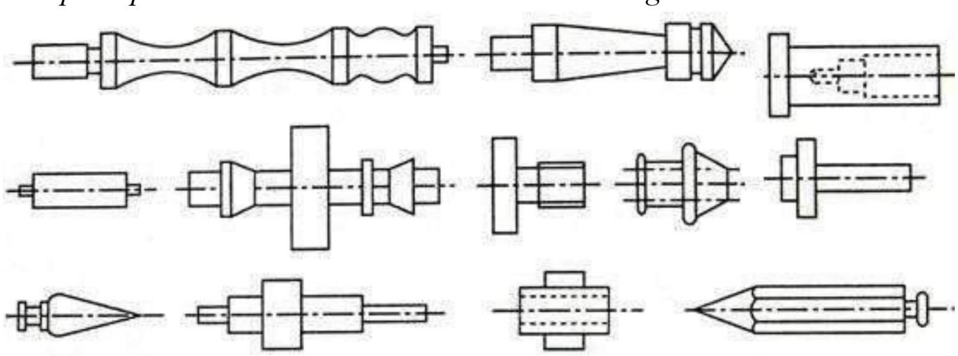


Fig. 2.89 Parts produced on single spindle automatic screw cutting machine

MULTI SPINDLE AUTOMATS

The multi spindle automats are the fastest type of production machines and are made in a variety of models with 2, 4, 5, 6 or 8 spindles. Each of the spindles is provided with its own set of tools for operation. As a result, more than one work piece can be machined simultaneously in these machines. In contrast to the single spindle automat, where one turret face at a time is working on one spindle, the multi spindle automat has all turret faces working on all spindles at the same time. The production rate of a multi spindle automat, however, is less than that of the corresponding number of single spindle automats. E.g. the production rate of a 4 spindle automat is not four times but only 2½ to 3 times more than that of a single spindle automat.

Classification of multi spindle automats

The multi spindle automats can be classified as follows:

According to the type of stock used:

- Bar stock machine.
- Chucking type machine.

According to the position of spindles:

- Horizontal spindle type.
- Vertical spindle type.

According to the principle of operation:

- Parallel action type.
- Progressive action type.

Comparison of single spindle automat and multi spindle automat

Sl . No.	Single spindle automat	Multi spindle automat
1	There is only one spindle.	There are 2,4,5,6 or 8 spindles.
2	Only one work piece can be machined at a time.	More number of work pieces can be machined at a time.
3	The rate of production is low.	The rate of production is high.
4	Machining accuracy is higher.	Machining accuracy is lower.
5	Tool setting time is less.	Tool setting time is more.
6	Tooling cost is less.	Tooling cost is more.
7	Economical for shorter as well as longer runs.	Economical for longer runs only.
8	The time required to produce one job is the sum of all turret operation times.	The time required to produce one job is the time of the longest cut in any one spindle.
9	Tools in turret are indexed.	Work pieces held in spindles are indexed (Progressive action machine)

PARALLEL ACTION MULTI SPINDLE AUTOMAT

These machines are usually automatic cutting off bar type machines. This is also called as 'multiple-flow' machine. In this machine, the same operation is performed on each spindle and a workpiece is finished in each spindle in one working cycle. The rate of production is very high, but the machine can be employed to machine simple parts only since all the machining processes are done at one position. *Fig. 2.90 shows the basic configuration of a parallel action multi spindle automat.*

They are used to perform the same work as single spindle automatic cutting off machines. Centering or a single drilling operation can also be performed on certain models. The machine consists of a frame with a head stock. The horizontal work spindles which are arranged in a line, one above the other, are housed in this headstock. Cross slides are located at the right and left hand sides of the spindles and carry the cross feeding tools. All the working and the auxiliary motions of the machine units are obtained from the cam mounted on the cam shaft.

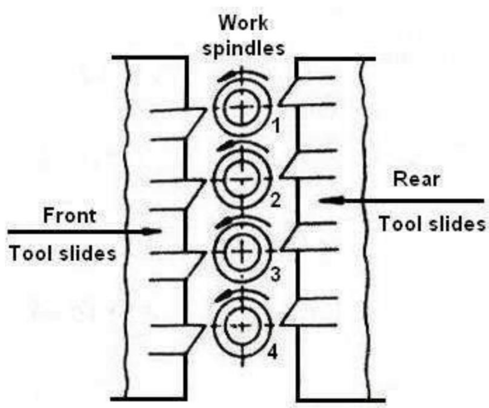


Fig. 2.90 Parallel action multi spindle automat

PROGRESSIVE ACTION MULTI SPINDLE AUTOMAT

In this machine the blanks clamped in each spindle are machined progressively in station after station.

Construction *Fig. 2.91 shows the basic configuration of a six-spindle progressive action automat.* The headstock is mounted at the left end of the base of the machine. It contains a spindle carrier which periodically indexes through a definite angle (360^0 divided by the number of spindles) about a horizontal axis through the centre of the machine at each tool retraction. The main tool slide (end tool slide), which accommodates tooling for all of the spindles, travels on the spindle carrier stem. The number of tool slides or faces is equal to the number of spindles.

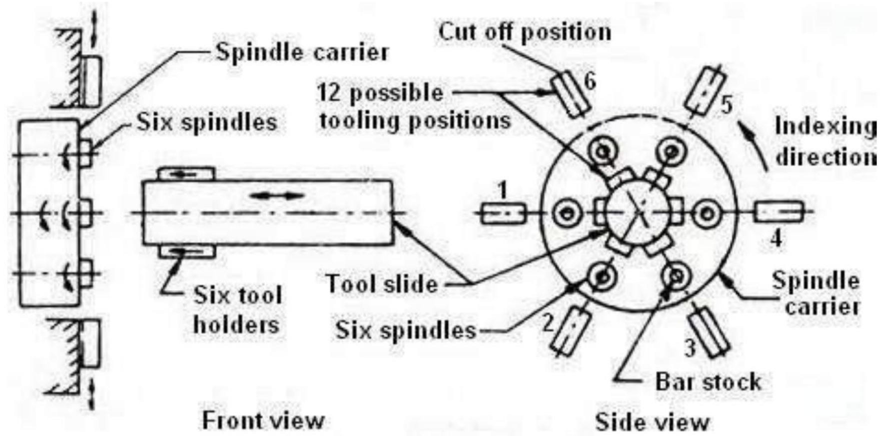


Fig. 2.91 Six-spindle progressive action automat

The working spindles are mounted in this spindle carrier. The working spindles carry the collets on which the workpieces are held. The bar stock is fed to the working spindle from the rear.

Cross slides which carry tools for operations such as cut off, turning, facing, forming, chamfering etc. are mounted in a frame above the face of the spindle carrier. These cross slides travel radially inward for cutting operation. The number of cross slides is equal to the number of spindles. The feed of each tool, both cross slide tools and end slide tools, is controlled by its own individual cam.

Working principle The spindle carrier indexes on its own axis by 60^0 ($360^0/6$) at each tool retraction. As the spindle carrier indexes, it carries the work from station to station, where various tools operate on it. The stock moves around the circle in counter clockwise direction and comes to the station number 6 for cutting off. A finished component is obtained for one full revolution of the spindle carrier. *Typical parts produced on this machine are shown in Fig. 2.92.*

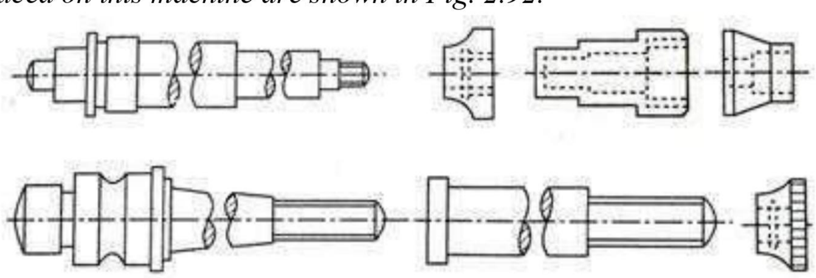


Fig. 2.92 Parts produced on multi spindle automatic lathe

2.20.1 Comparison of parallel action and progressive action multi spindle automat

Sl . No.	Parallel action multi spindle automat	Progressive action multi spindle automat
1	Same operation is done on all jobs in all the spindles.	Different operations are done on jobs at each station one after another.
2	In one cycle the number of components produced simultaneously is equal to the number of spindles.	It is not so. (i.e.) The number of components produced in one cycle is not equal to the number of spindles. For every indexing of component (spindle) one component is produced.
3	Rate of production is very high.	Rate of production is moderate.
4	If anything goes wrong in one station, the production in that particular station only is affected.	If anything goes wrong in one station, the production is completely affected in all the stations.
5	Small parts of simple shapes are produced.	Parts of complicate shapes can be produced.

HOLE MAKING

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 about 20 % 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. 2.93.*

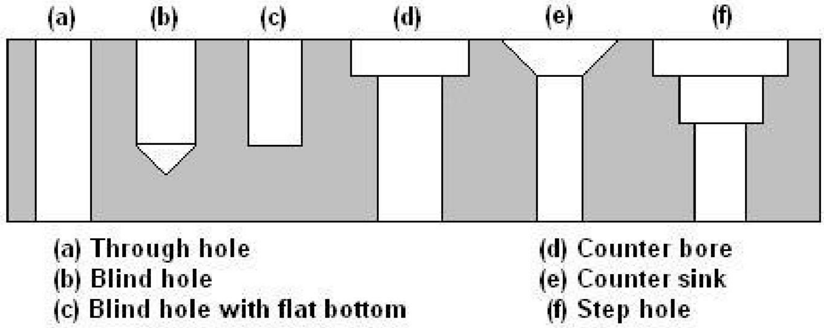


Fig. 2.93 various types of holes

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

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. *Fig. 2.94 illustrates a hand drilling machine.*

Fig. 2.94 Hand drilling machine

Fig. 2.95 Table top sensitive drilling machine

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 ($\varphi \leq 10$ mm) drills. *Fig.2.95 illustrates a table top sensitive drilling machine.*

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. 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. 2.96 illustrates a floor mounting sensitive drilling machine.*

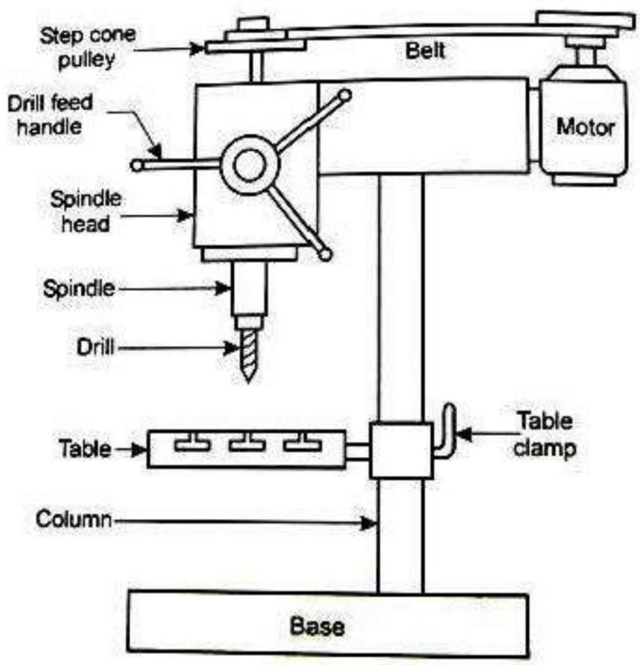


Fig. 2.96 Floor mounting sensitive drilling machine

Fig. 2.97 Pillar drilling machine

Pillar or Round column section upright drilling machine

Fig. 2.97 illustrates a pillar or round column section upright drilling machine. 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.

Box column section upright drilling machine

Fig. 2.98 illustrates a box column section upright drilling machine. The major parts are:

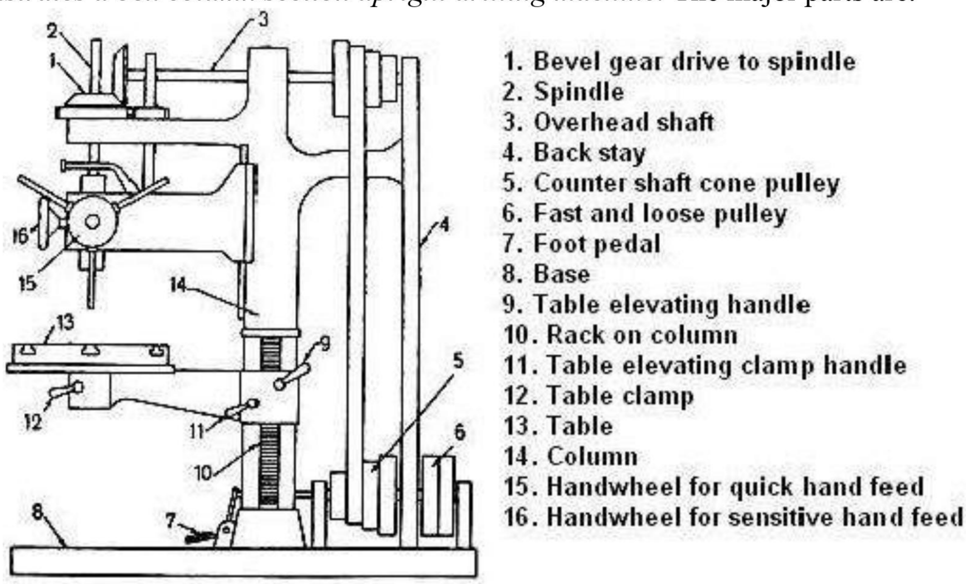


Fig. 2.98 Box column section upright drilling machine

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.

Column It is the vertical member of the machine which supports the table and the head containing all the driving mechanism. The column should be sufficiently rigid so that it can take up the entire cutting pressure of the drill. The column may be made of box section or of round section. Box column is a more rigid unit. In box column type, the front face of the column is accurately machined to form guide ways on which the table can slide up and down for vertical adjustment.

Table It is mounted on the column and is provided with T-slots for clamping the work directly on its face. The table may be round or rectangular in shape. The table may have three types of adjustments: vertical adjustment, radial adjustment about the column, and circular adjustment about its own axis. After the required adjustments have been made the table and the arm are clamped in position.

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.

Radial drilling machine

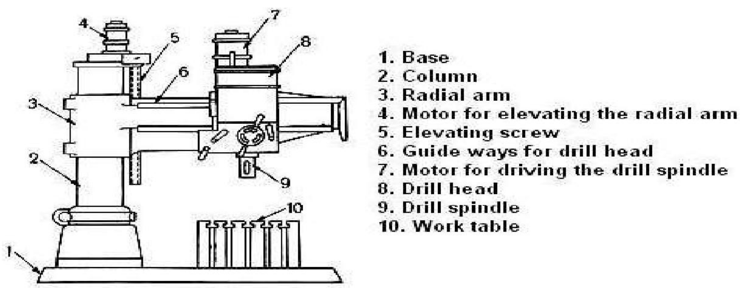


Fig.2.99 illustrates a radial drilling machine. The major parts are: Fig. 2.100 Radial drilling machine

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.

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.

Gang drilling machine

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. *Fig. 2.101 illustrates a typical gang drilling machine.*

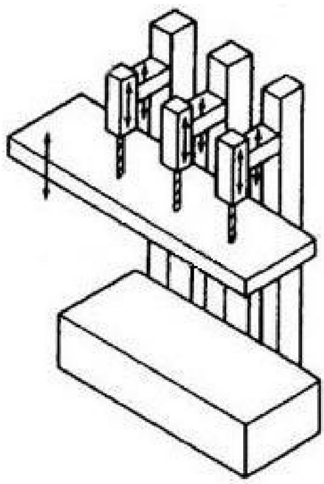


Fig. 2.101 Gang drilling machine

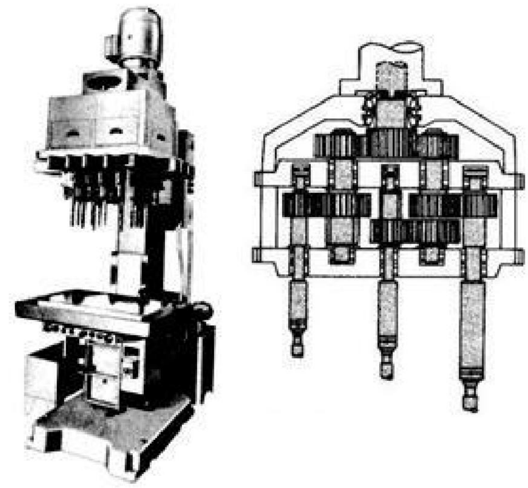


Fig. 2.102 Multiple spindle drilling machine

Multiple spindle drilling machine

Fig. 3.102 schematically shows a typical multiple spindle drilling machine. In this high production machine a large number of drills work concurrently on a blank through a jig 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.

Deep hole drilling machine

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:

- High spindle speed.
- High rigidity.
- Tool guide.
- Pressurized cutting oil for effective cooling, chip removal and lubrication at the drill tip.

Fig. 2.103 schematically shows a deep hole drill tool used in the deep hole drilling operation.

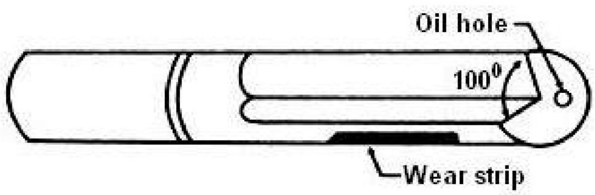


Fig. 2.103 Deep hole drill

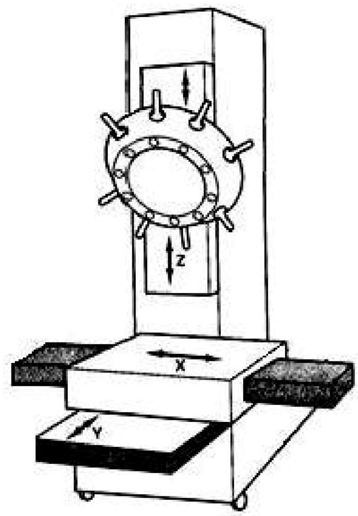


Fig. 2.104 Turret type drilling machine

Turret type drilling machine

Fig. 3.104 schematically shows a typical 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.

Spindle and drill head assembly

The spindle is a vertical shaft which holds the drill. It receives its motion from the top shaft though bevel gears. A long key-way is cut on the spindle and the bevel gear is connected to it by a sliding key. This construction is made to allow the spindle to be connected with the top shaft irrespective of its position when the spindle is raised or lowered for feeding the drill into the work piece. The spindle rotates within a non-rotating sleeve which is known as the quill. Rack teeth are cut on the outer surface of the sleeve. The sleeve may be moved up or down by rotating a pinion which meshes with the rack and this movement is imparted to the spindle to give the required feed.

The downward movement of the spindle is effected by rotating the pinion which causes the quill to move downward exerting pressure on the spindle through a thrust bearing and washer. The spindle is moved upward by the upward pressure exerted by the quill acting against a nut attached to the spindle through the thrust bearing. The lower end of the spindle is provided with Morse taper hole for accommodating taper shank drill. A slot is provided at the end of the taper hole for holding the tang of the drill to impart it a positive drive. *The drill spindle assembly is illustrated in Fig. 2.105.*

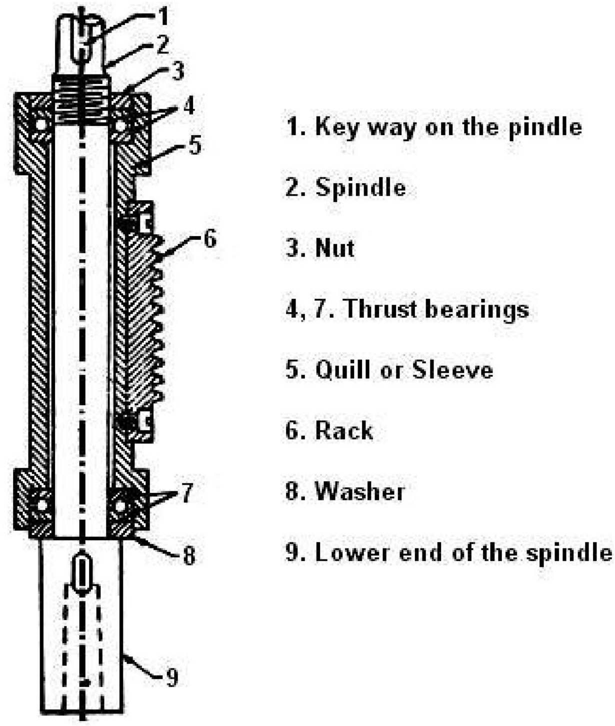


Fig. 2.105 Drill spindle assembly

Spindle drive mechanism

The spindle drive mechanism of a drilling machine incorporates an arrangement for obtaining multiple speed of the spindle similar to a lathe to suit to various machining conditions.

Multiple speed of the spindle may be obtained as follows:

- By step cone pulley drive.
- By step cone pulley drive with one or more back gears.
- By gearing.

Step cone pulley drive *Fig. 2.105 shows the schematic view of a spindle driving mechanism incorporating a step cone pulley.* The motion is transmitted from an overhead line shaft to the countershaft mounted on the base of the machine. The countershaft may be started or stopped by shifting the belt from loose pulley to fast pulley or vice versa by operating the foot-pedal 7. The step cone pulley mounted on the head of the machine receives power from the countershaft step cone pulley 5 through the belt. The drill spindle 2 receives power from the overhead shaft 3 through bevel gears 1 and the speed of the spindle may be varied by shifting the belt on different steps of the cone pulley 5. The number of spindle speeds available is dependent upon the number of steps on the cone pulley.

Step cone pulley drive with back gear In order to obtain larger number of spindle speeds back gears are incorporated in the machine in addition to the step cone pulley.

Spindle drive by gearing Modern heavy duty drilling machines are driven by individual motor mounted on the frame of the machine. The multiple speeds may be obtained by sliding gear or sliding clutch mechanism or by the combination of the above two methods.

Feed mechanism

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.

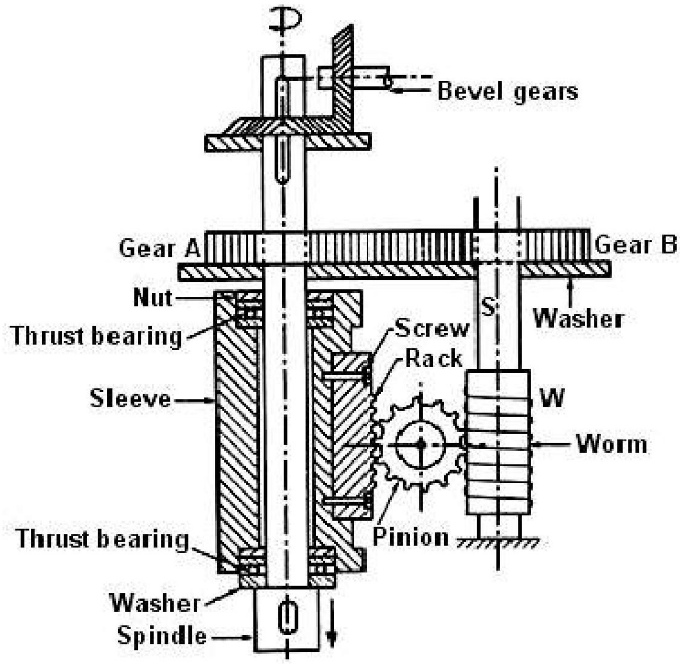


Fig. 2.106 Automatic feed mechanism

The automatic feed is applied while drilling larger diameter holes as the cutting pressure required is sufficiently great. *Fig. 2.106 illustrates the automatic feed mechanism.* 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.

Work holding devices used in drilling machines

Before performing any operation in a drilling machine it is absolutely necessary to secure the work firmly on the drilling machine table. The work should never be held by hand, because the drill while revolving exerts so much of torque on the work piece that it starts revolving along with the tool and may cause injuries to the operator. The work holding devices commonly used for holding the work piece in a drilling machine table are: T-bolts and clamps, machine vises, step blocks, V-blocks, angle plate and drill jigs. *All of them except drill jig have been described in Article 3.2.6 and Page 110.* When the work is heavy and / or of odd shape and size, it is directly clamped on the drilling machine table.

Drill jigs

These are used for holding the work in a mass production process. A drill jig can hold the work securely, locate the work and guide the tool at any desired position. The work may be clamped and unclamped quickly. Jigs are specially designed for each type of work where quantity production is desired. The work is clamped below the jig and the holes are located. The drill is guided by the drill bush. *Fig. 2.107 schematically shows some types of drill jigs used in mass production.*

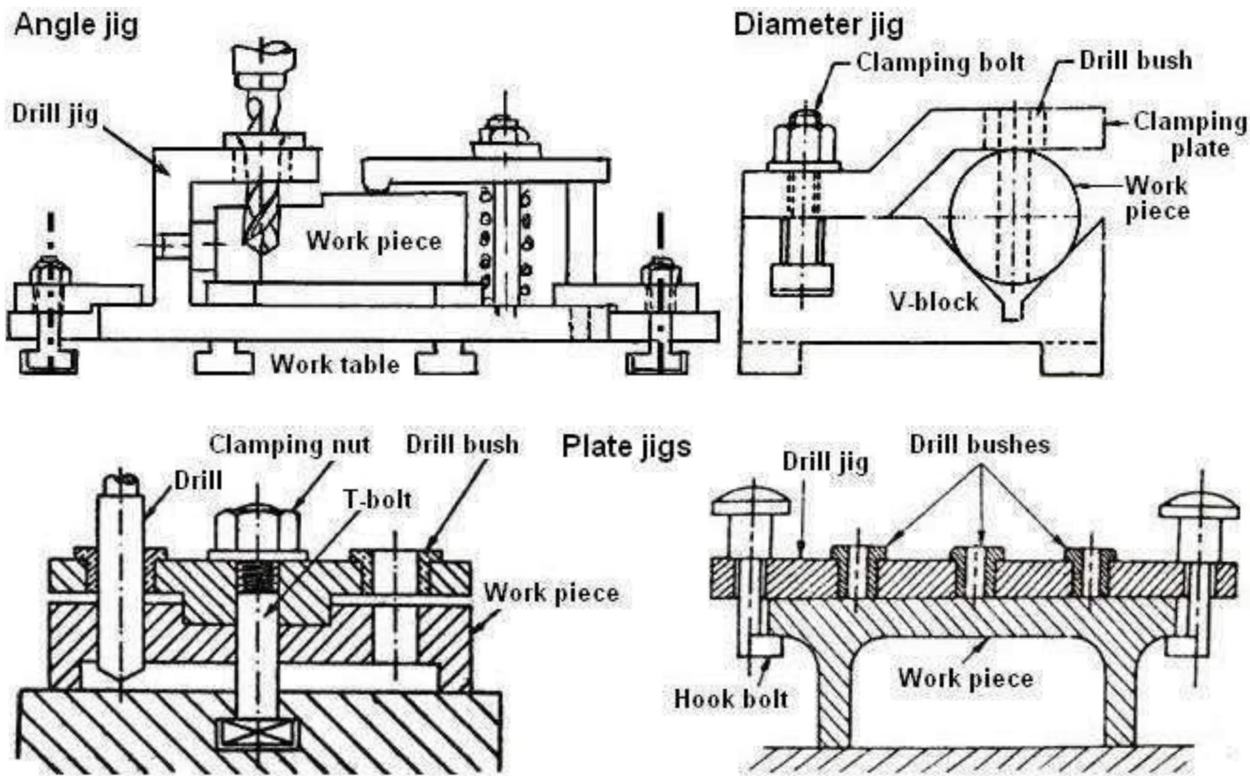


Fig. 2.107 Some types of drill jigs

Tool holding devices used in drilling machines

In drilling machines mostly drills of various type and size are used for drilling holes. Often some other tools are also used for enlarging and finishing drilled holes, counter boring, countersinking, tapping etc. The different methods used for holding tools in a drill spindle are:

- By directly fitting in the spindle.
- By a sleeve.
- By a socket.
- By chucks.

Drill directly fitted in the spindle

All drilling machines have the spindle bored out to a standard Morse taper (1:20) to receive the taper shank of the tool. While fitting the tool the shank is forced in the tapered hole and the tool is gripped by friction. The tool may be rotated with the spindle by friction between the tapered surface and the spindle; but to ensure a positive drive the tang or tongue of the tool fits into a slot at the end of the taper hole. The tool is removed by pressing a tapered wedge known as the drift or key into the slotted hole of the spindle. *Fig. 2.108 (a) shows a drill directly fitted in the spindle. Fig. 2.108 (b) shows a drift.*

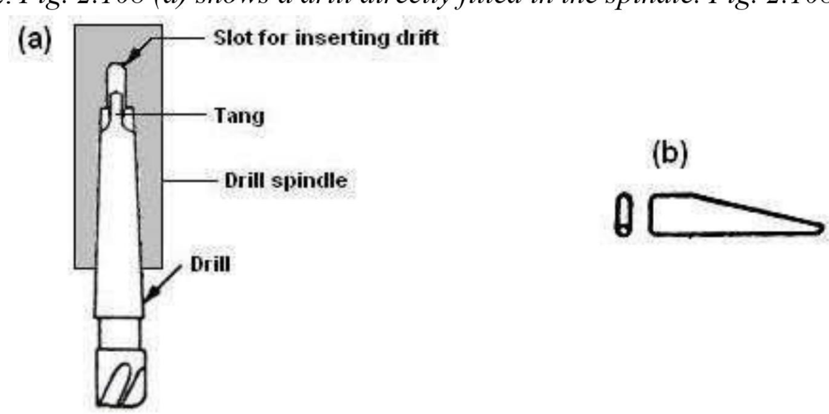


Fig. 2.108 (a) Drill directly fitted in the spindle and (b) Drift or key

Drill sleeve

The drill spindle is suitable for holding only one size of shank. If the taper shank of the tool is smaller than the taper in the spindle hole, a taper sleeve is used. The outside taper of the sleeve conforms to the drill spindle taper and the inside the taper holds the shanks of smaller size tools or smaller sleeves. The sleeve fits into the taper hole of the spindle. The sleeve has a tang which fits into the slot of the spindle. The tang of the tool fits into a slot provided at the end of the taper hole of the sleeve. The sleeve with the tool may be removed by forcing a drift within the slot of the spindle and the tool may be separated from the sleeve by the similar process. Different size of the tool shanks may be held in the spindle by using different sizes of sleeves. *Fig. 2.109 (a) shows a drill sleeve. Fig. 2.109 (b) shows a drill sleeve holding a drill fitted in the drill spindle. Fig. 2.109 (c) shows different sizes of drill sleeves.*

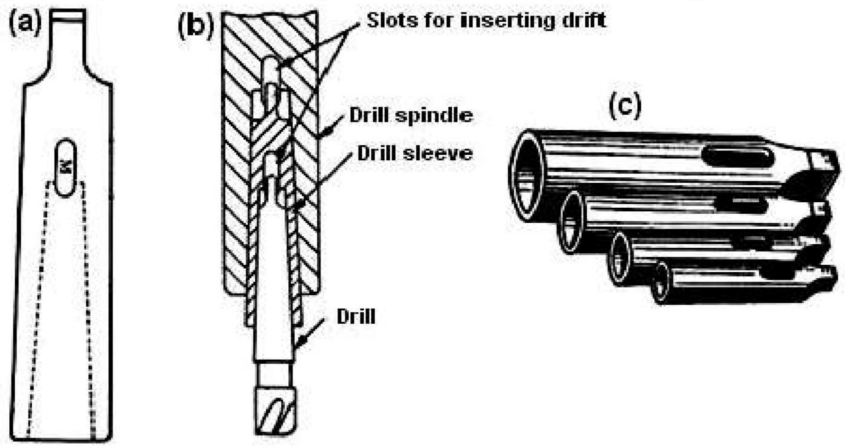


Fig. 2.109 (a) Drill sleeve (b) Drill sleeve holding a drill fitted in the drill spindle and (c) Different sizes of drill sleeves.

Drill socket

When the tapered tool shank is larger than the spindle taper, drill sockets are used to hold the tool. Drill sockets are much longer in size than the drill sleeves. A socket consists of a solid shank attached to the end of a cylindrical body. The taper shank of the socket conforms to the taper of the drill spindle and fits into it. The body of the socket has a tapered hole larger than the drill spindle taper into which the taper shank of any tool may be fitted. The tang of the socket fits into the slot of the spindle and the tang of the tool fits into the slot of the socket. *Fig. 3.124 shows a drill socket.*

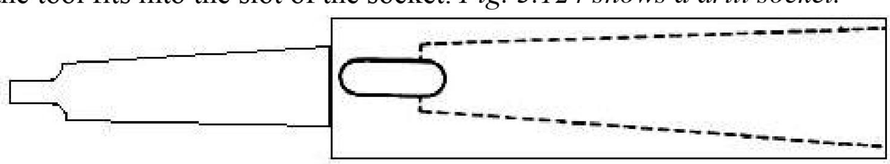


Fig. 2.109 Drill socket

Drill chucks

The chucks are especially intended for holding smaller size drills are any other tools. A sleeve or socket can hold one size of tool shank only; but a drill chuck may be used to hold different sizes of tool shanks within a certain limit. Drill chucks have tapered shanks which are fitted into the drilling machine spindle. Different types of drill chucks are manufactured for different purposes. The most common type of drill chuck used is three jaw self centering drill chuck.

This type of chuck is particularly adapted for holding tools having straight shanks. Three slots are cut 120^0 apart in the chuck body which houses three jaws having threads cut at the back that meshes with a ring nut. The ring nut is attached to the sleeve. Bevel teeth are cut all round the sleeve body. The sleeve may be rotated by rotating a key having bevel teeth cut on its face which meshes with the bevel teeth on the sleeve. The rotation of the sleeve causes the ring nut to rotate in a fixed position and all the three jaws close or open by the same amount from the centre holding or releasing the shank of a tool. *Fig. 2.110 shows a three jaw self centering drill chuck.*

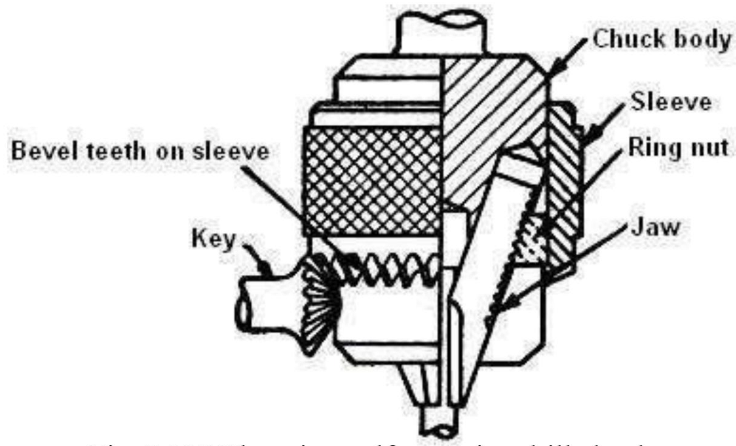


Fig. 2.110 Three jaw self centering drill chuck

Drilling tools

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: $L/\varphi \cong 6$ 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.

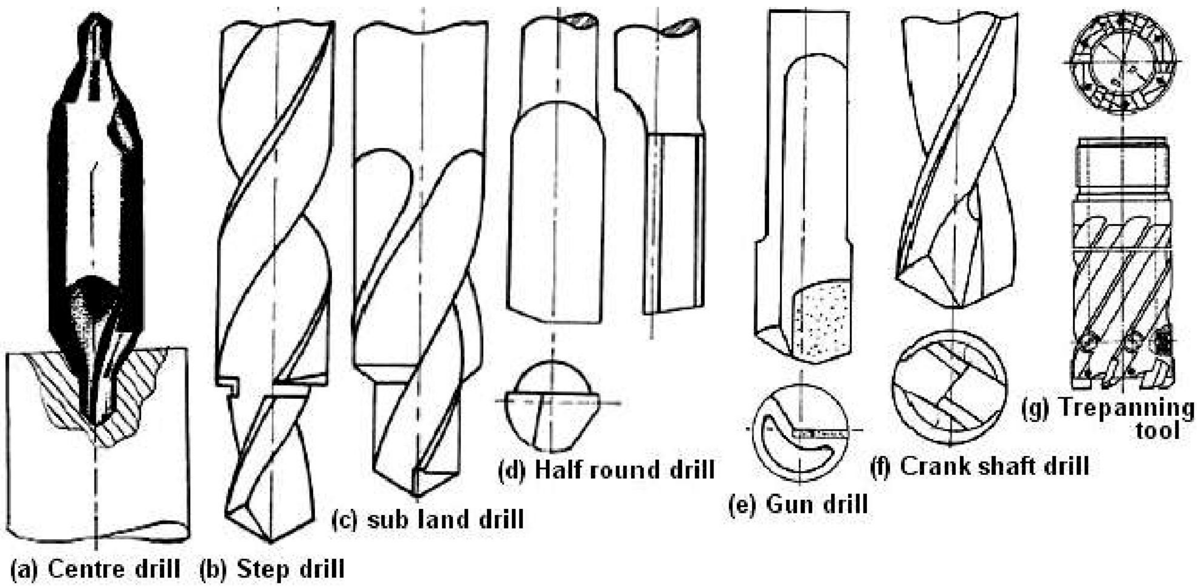


Fig. 2.111 Different types of drills used in various applications

Twist drill nomenclature

The following are the nomenclature, definitions and functions of the different parts of a drill illustrated in Fig. 2.112.

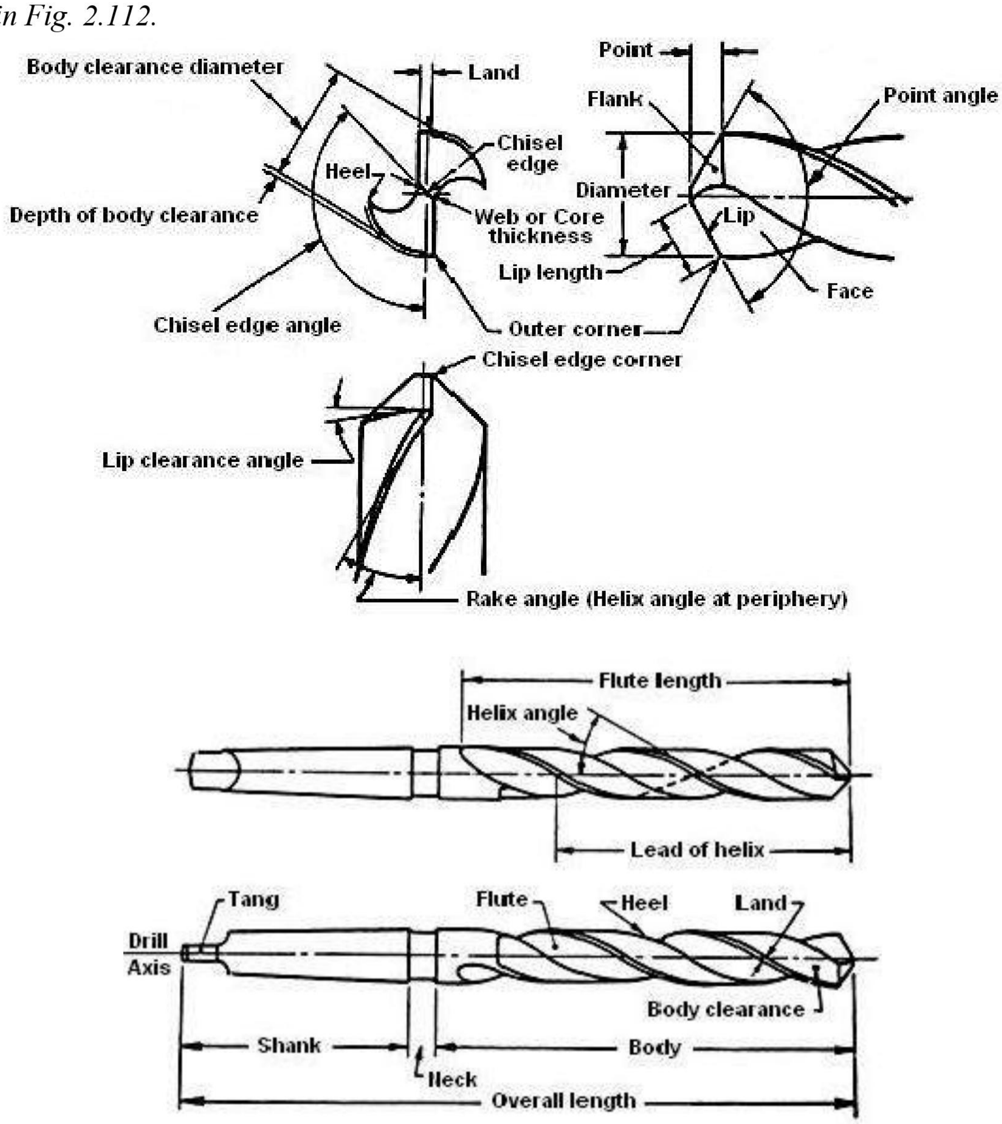


Fig. 2.112 Twist drill nomenclature

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.
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

Chisel edge angle 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.

Drilling operations

The wide range of applications of drilling machines includes:

- 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.

- If necessary Reaming is done on drilled or bored holes for accuracy and good surface finish. Different types of reamers of standard sizes are available for different applications.
- Also used for cutting internal threads in parts like nuts using suitable attachment.

The different operations that can be performed in a drilling machine are shown in Fig. 3.128.

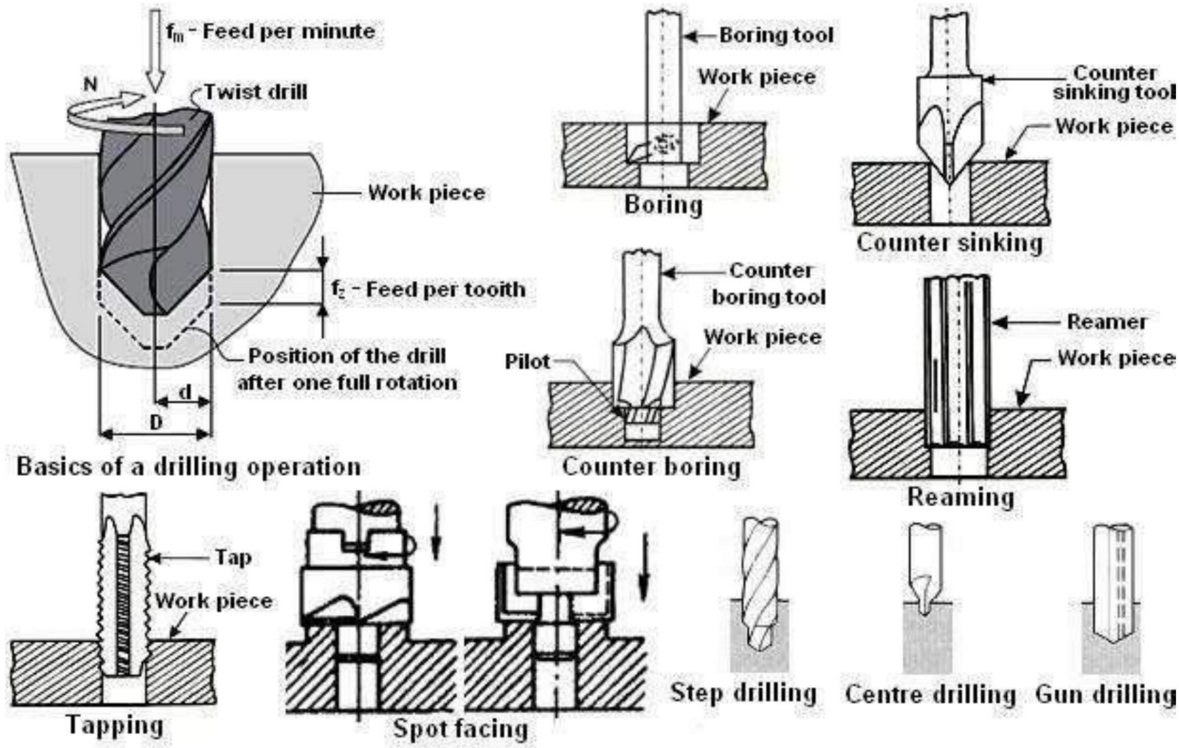


Fig. 2.113 Different operations performed in a drilling machine