UNIT 4:

Drilling machines: Classification, constructional features, drilling & related operations, types of drill & drill bit nomenclature, drill materials.

6 Hrs

Instructional Objectives

At the end of this lesson, the students will be able to:

(i) State the basic purposes of use of drilling machines

(ii) Classify the types of drilling machines

(iii) Illustrate the general kinematic system of drilling machine and explain its working principle

(iv) State and visualise the various common and other possible applications of drilling machines

Basic purposes of use of drilling machines

- Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing (premachined) holes:
    - ✓ of different diameter ranging from about 1 mm 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.

Classification of drilling machines:

1. General purpose drilling machines of common use:

a) Table top small sensitive drilling machine:

These small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (φ≤ 10 mm) drills. Fig. 4.1 typically shows one such machine.

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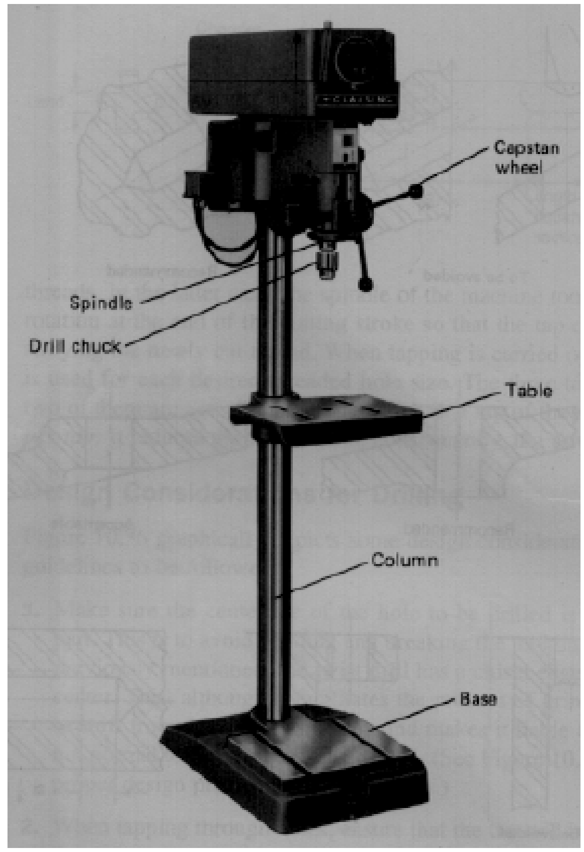

Fig. 4.1 *Table top sensitive drilling machine*

Fig. 4.2 *Pillar Drilling machine*

b) Pillar drilling machine:

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Fig. 4.2 typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.

c) Column drilling machine

These box shaped column type drilling machines as shown in Fig. 4.3 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.

d) Radial drilling machine

This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig. 4.4. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swivelled and / or tilted.

Fig. 4.3 *Column drilling machine*

Fig. 4.4 *Radial drilling machine*

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e) CNC column drilling machine

In these versatile and flexibly automatic drilling machine having box-column type rigid structure the work table movements and spindle rotation are programmed and accomplished by Computer Numerical Control (CNC). These modern sophisticated drilling machines are suitable for piece or batch production of precision jobs.

2. General purpose drilling machines with more specific use.

a) Hand drills:

Unlike the grouted 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 as shown in Fig. 4.5. The small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air.

b) Gang drilling machine

In this almost single purpose and more productive machine a number (2 to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig. 4.6 schematically shows a typical gang drilling machine.

Fig. 4.5 *Hand drill in operation*

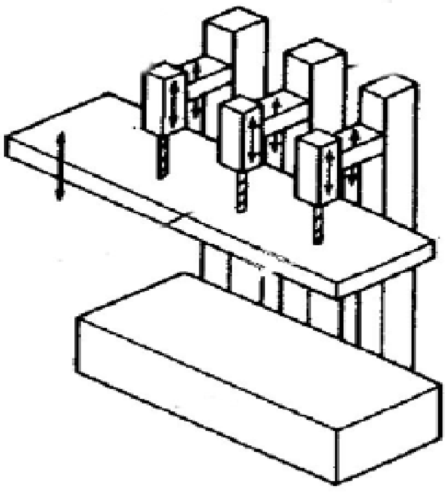

Fig. 4.6 *Schematic view of a gang drilling machine*

c) Turret (type) drilling machine

Turret drilling machines are structurally rigid column type but are more productive like gang drill by having a pentagon or hexagon turret as shown in Fig. 4.7. The turret bearing 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.

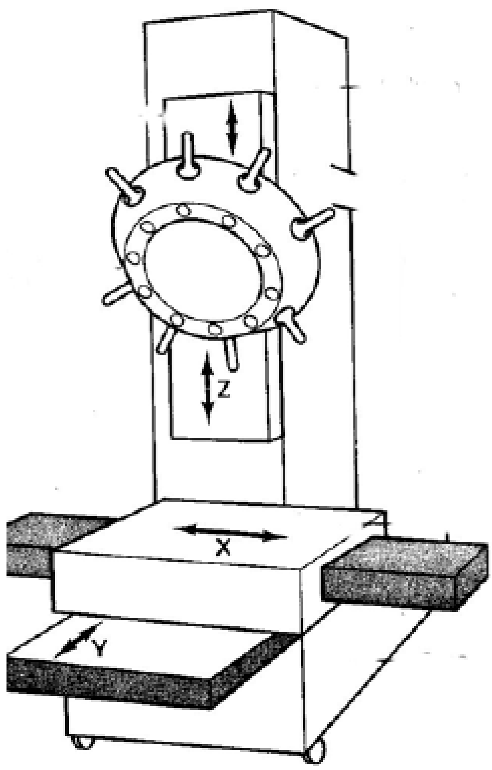

Fig. 4.7 *Schematic view of turret type drilling machine*

d) Multispindle drilling machine

In these high production machine tools a large number of drills work simultaneously on a blank through a jig specially made for the particular job. The entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. Fig. 4.8 shows a typical multispindle drilling machine. The rotation 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 multispindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.

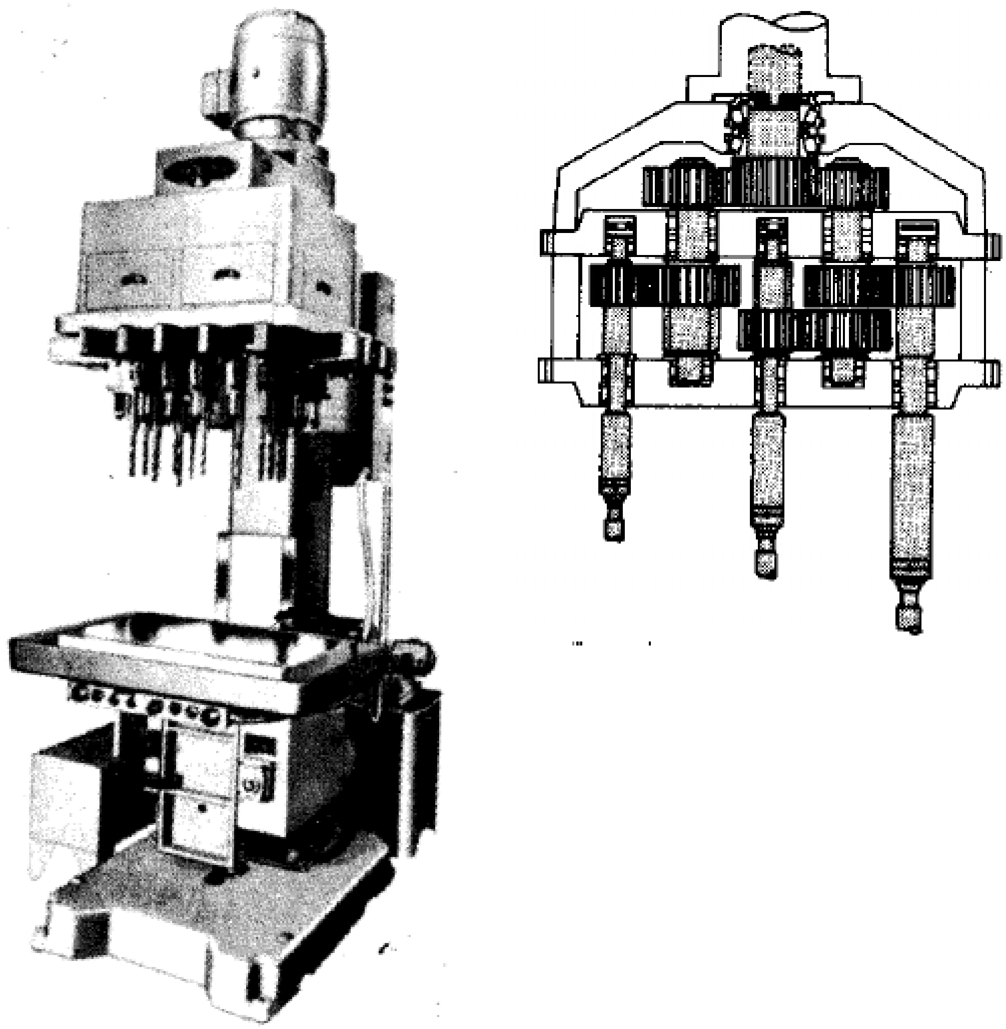

Fig. 4.2.8 *A typical multi spindle drilling machine*

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e) Micro (or mini) drilling machine

This type of tiny drilling machine of height within around 200 mm is placed or clamped on a table, as shown in Fig. 4.9 and operated manually for drilling small holes of around 1 to 3 mm diameter in small workpieces.

Fig. 4.9 *Photographic view of a micro (or mini) drilling machine*

f) 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 ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis which are provided with

- ✓ high spindle speed
- ✓ high rigidity
- ✓ tool guide
- ✓ pressurised cutting oil for effective cooling, chip removal and lubrication at the drill tip.

Deep hole drilling machines are available with both hard automation and CNC system.

Kinematic System of general purpose drilling machine and their principle of working:

Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the workpiece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. Even for the same type of machine tool, say column drilling machine, the designer may take different kinematic structure depending upon productivity, process capability, durability, compactness, overall cost etc targeted. Fig. 4.10 schematically shows a typical kinematic system of a very general purpose drilling machine, i.e., a column drilling machine having 12 spindle speeds and 6 feeds.

The kinematic system enables the drilling machine the following essential works;

Cutting motion:

The cutting motion in drilling machines is attained by rotating the drill at different speeds (r.p.m.). Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. It is shown in Fig. 4.10 that the drill gets its rotary motion from the motor through the speed gear box (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed to any of the 12 speeds by shifting the cluster gears in the SGB. The direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanism, RM-s shown in the figure.

Feed motion

In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (within a range) depending upon the tool-work materials and other conditions and requirements.

Fig. 4.10 visualises that the drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGA), and the clutch. The feed rate can be changed to any of the 6 rates by shifting the gears in the FGB. And the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism, RM-s as shown. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quil.

The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

Tool work mounting

The taper shank drills are fitted into the taper hole of the spindle either directly or through taper socket(s). Small straight shank drills are fitted through a drill chuck having taper shank. The workpiece is kept rigidly fixed on the bed (of the table). Small jobs are generally held in vice and large or odd shaped jobs are directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed as indicated in Fig. 4.10.

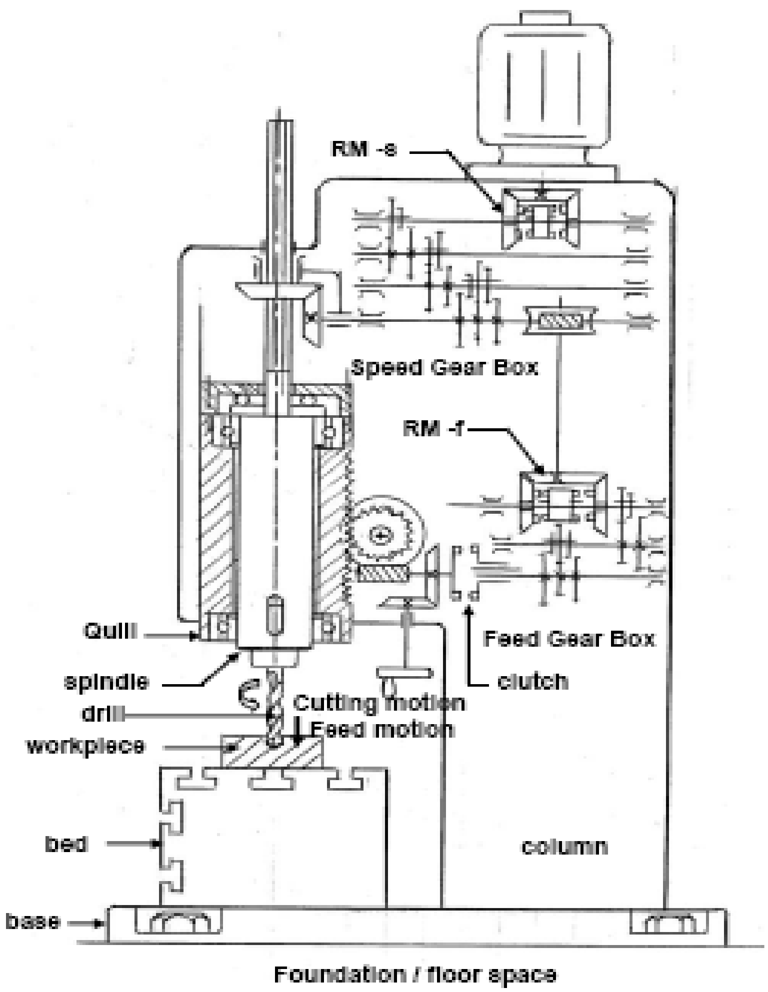

Fig. 4.10 *Schematic view of the drives of a drilling machine*

Application of drilling machines:

Drilling machines of different capacity and configuration are basically used for originating cylindrical holes and occasionally for enlarging the existing holes to full or partial depth. But different types of drills are suitably used for various applications depending upon work material, tool material, depth and diameter of the holes.

General purpose drills may be classified as;

1. **According to material :**
   - High speed steel – most common
   - Cemented carbides
     - ✓ Without or with coating
     - ✓ In the form of brazed, clamped or solid
2. **According to size**
   - Large twist drills of diameter around 40 mm
   - Microdrills of diameter 25 to 500 µm
   - Medium range (most widely used) diameter ranges between 3 mm to 25 mm.
3. **According to number of flutes**
   - Two fluted – most common
   - Single flute – e.g., gun drill (robust)
   - Three or four flutes – called slot drill
4. **According to helix angle of the flutes**
   - Usual – 20^0 to 35^0 – most common

- Large helix : 45° to 60° 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.

5. 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

6. 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

7. According to specific applications

- Centre drills (Fig. 4.11) : for small axial hole with 60° taper end to accommodate lathe centre for support
- Step drill and subland drill (Fig. 4.12) : for small holes with two or three steps
- Half round drill, gun drill and crank shaft drill (for making oil holes) – shown in Fig. 4.13
- Ejector drill for high speed drilling of large diameter holes
- Taper drill for batch production
- Trepanning tool (Fig. 4. 14) : for large holes in soft materials

Besides making holes, drilling machines may be used for various other functions using suitable cutting tools.

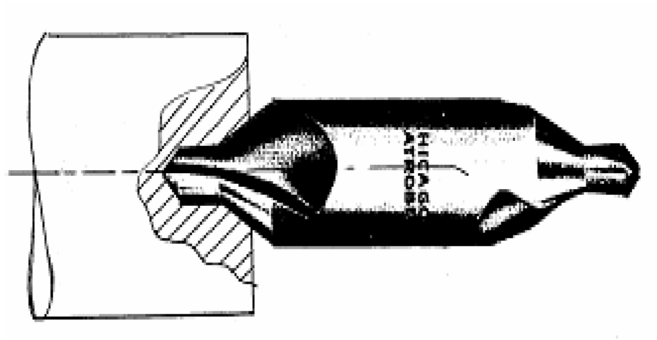

Fig. 4.11 *Centre Drill*

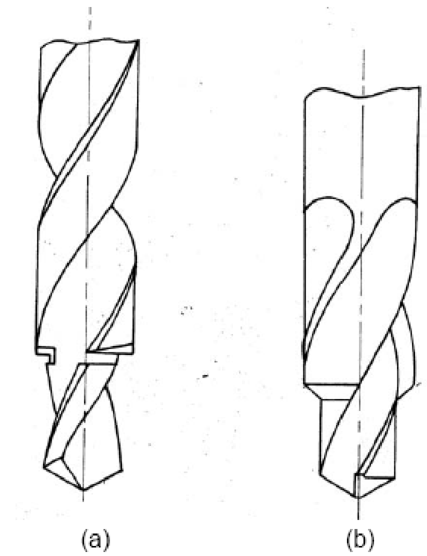

Fig. 4.12 *(a) Stepped drill and (b) subland drill*

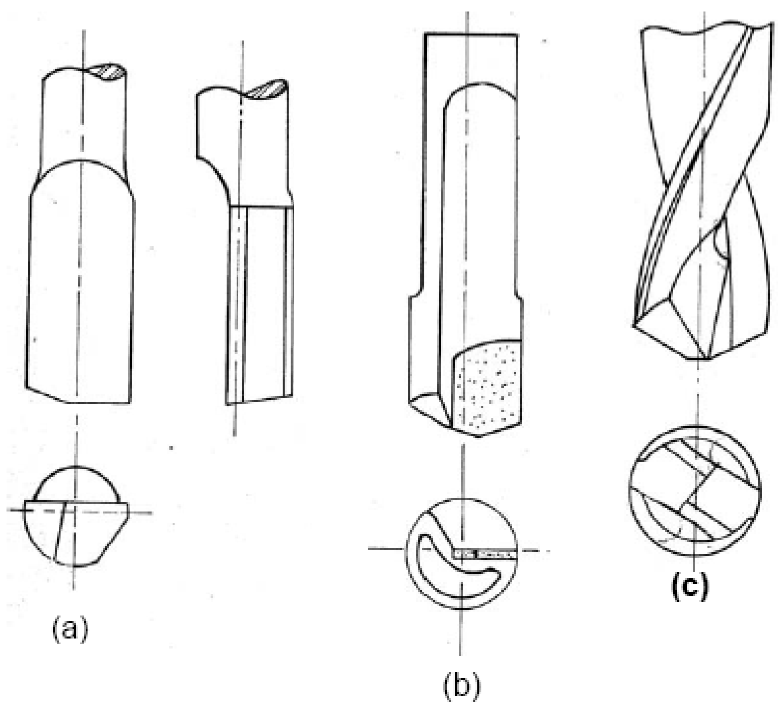

Fig. 4.13 *Schematic views of (a) half round drill, (b) gun drill and (c) crank shaft drill*

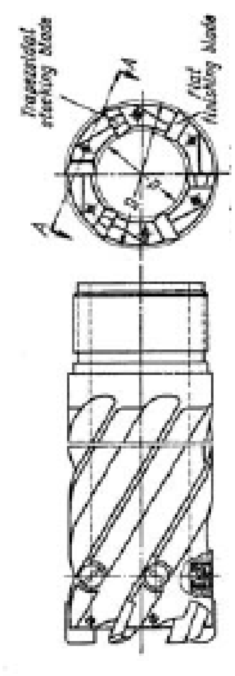

Fig. 4.14 *Schematic view of a trepanning tool.*

The wide range of applications of drilling machines include:

- Origination and / or enlargement of existing straight through or stepped holes of different diameter and depth in wide range of work materials – this is the general or common use of drilling machines
- Making rectangular section slots by using slot drills having 3 or four flutes and 180^0 cone angle
- Boring, after drilling, for accuracy and finish or prior to reaming
- Counterboring, countersinking, chamfering or combination using suitable tools as shown in Fig. 4.15
- Spot facing by flat end tools (Fig. 4.16)
- Trepanning for making large through holes and or getting cylindrical solid core.
- Reaming is done, if necessary, after drilling or drilling and boring holes for accuracy and good surface finish. Different types of reamers of standard sizes are available as shown in Fig. 4.17 for different applications.
- Cutting internal screw threads mounting a tapping attachment in the spindle.

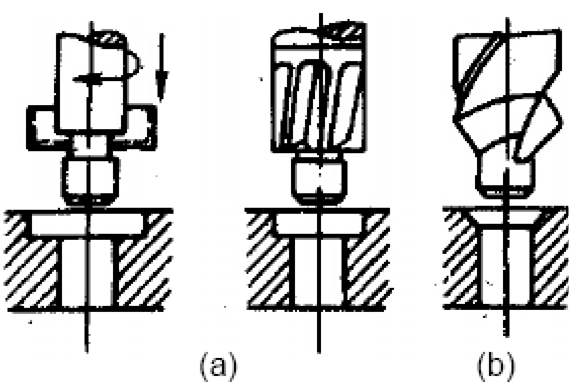

Fig. 4.15 *Schematic view of (a) counter boring and (b) countersinking*

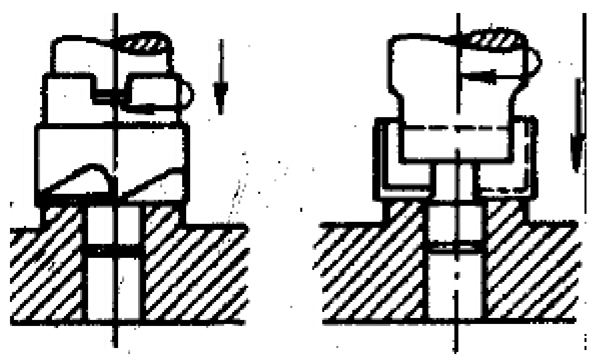

Fig. 4.16 *Schematic view of spot facing*

Standard hole making processes include:

- **Drilling -** Drilling is the process of producing or enlarging a hole. This is accomplished by rotating the tool and/or workpiece.
- **Reaming -** Enlarging an existing hole with a multi-edged tool (reamer) for dimensional accuracy and/or surface finish

Spot facing - Smoothing, squaring, and/or flattening a surface:

- **Counter sinking -** operation or producing a tapered feature at the end of a hole. Most popular application is a feature for a flathead screw (82 degrees) to sit flush with a surface.
- **Counter boring -** Enlarging of an existing hole at one end. This enlarged hole is concentric with the existing hole and is flat at the bottom. One application of this process is a feature to set the head of a bolt below a surface.

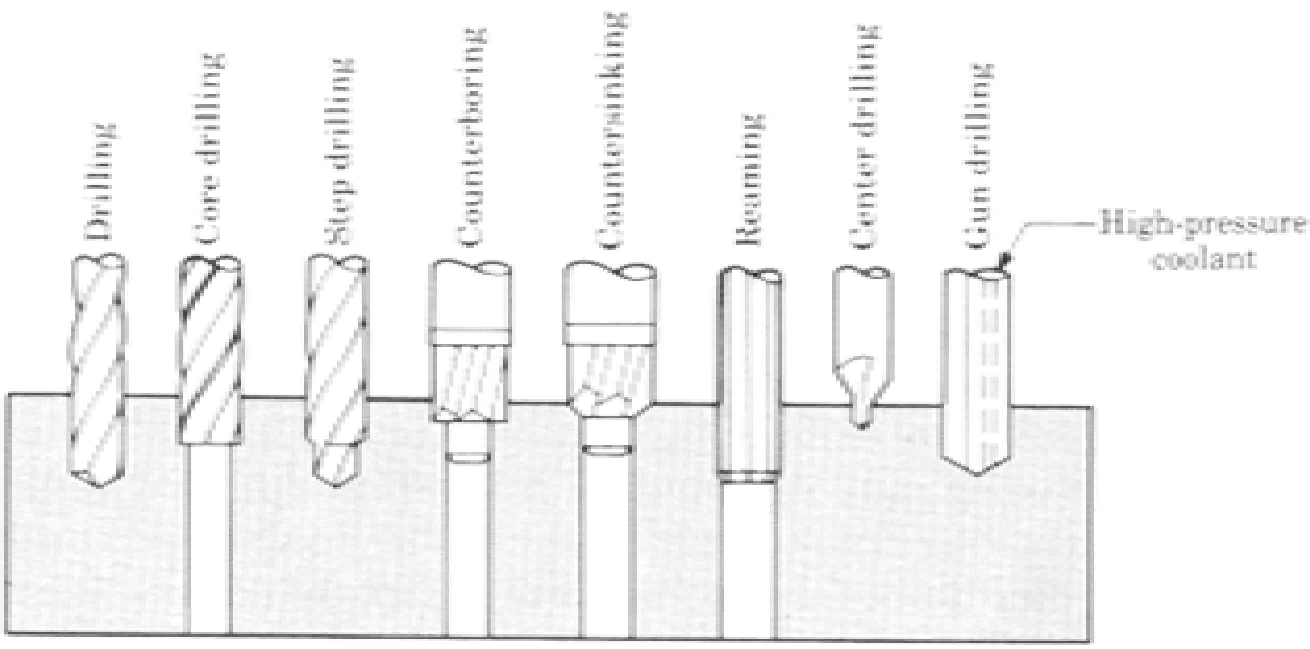

Fig. 4.18 Various operations done on a Drilling machine

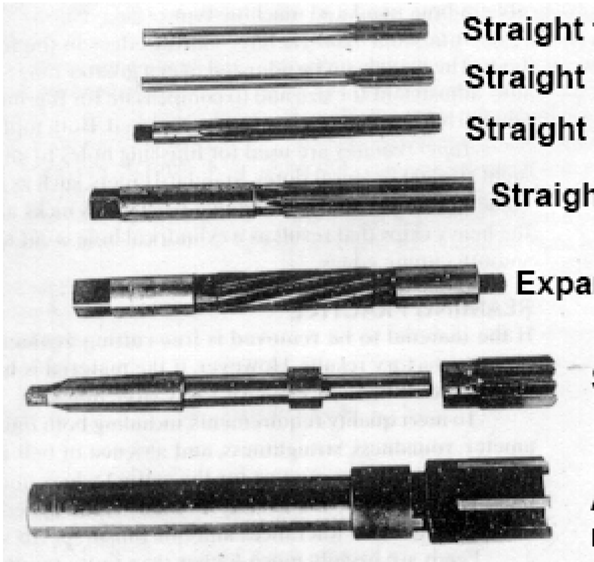

Fig. 4.17 *Different types of reamers.*

Note: Several other operations can also be done, if desired, in drilling machines by using special tools and attachment.