LANDMARK UNIVERSITY, OMU-ARAN

LECTURE NOTE: DRILLING.
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DRILLING MACHINE

1 INTRODUCTION

Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill. A drill is a rotary end-cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluid. A drilling machine is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter- boring, countersinking, honing, reaming, lapping, sanding etc.

2 CONSTRUCTION OF DRILLING MACHINE

In drilling machine the drill is rotated and fed along its axis of rotation in the stationary Work-piece. Different parts of a drilling machine are shown in Fig. 1 and are discussed below: (*i*) The head containing electric motor, V-pulleys and V-belt which transmit rotary motion to the drill spindle at a number of speeds. (*ii*) Spindle is made up of alloy steel. It rotates as well as moves up and down in a sleeve. A pinion engages a rack fixed onto the sleeve to provide vertical up and down motion of the spindle and hence the drill so that the same can be fed into the work-piece or withdrawn from it while drilling. Spindle speed or the drill speed is changed with the help of V-belt and V-step-pulleys. Larger drilling machines are having gear boxes for the said purpose. (*iii*) Drill chuck is held at the end of the drill spindle and in turn it holds the drill bit. (*iv*) Adjustable work piece table is supported on the column of the drilling machine. It can be moved both vertically and horizontally. Tables are generally having slots so that the vise or the work-piece can be securely held on it. (*v*) Base table is a heavy casting and it supports the drill press structure. The base supports the column, which in turn, supports the table, head etc. (*vi*) Column is a vertical round or box section which rests on the base and supports the head and the table. The round column may have rack teeth cut on it so that the table can be raised or lowered depending upon the work-piece requirements. This machine consists of following parts

1. Base
2. Pillar
3. Main drive
4. Drill spindle
5. Feed handle
6. Work table

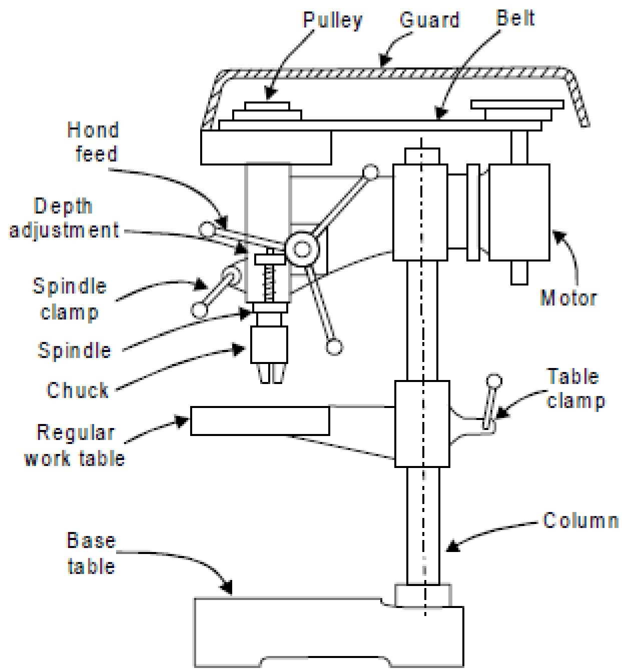

Fig. 1 Construction of drilling machine

22.3 TYPES OF DRILLING MACHINE

Drilling machines are classified on the basis of their constructional features, or the type of work they can handle. The various types of drilling machines are:

(1) Portable drilling machine
(2) Sensitive drilling machine
(*a*) Bench mounting
(*b*) Floor mounting
(3) Upright drilling machine
(*a*) Round column section
(*b*) Box column section machine
(4) Radial drilling machine
(*a*) Plain
(*b*) Semi-universal
(*c*) Universal
(5) Gang drilling machine
(6) Multiple spindle drilling machine
(7) Automatic drilling machine
(8) Deep hole drilling machine
(*a*) Vertical
(*b*) Horizontal

Few commonly used drilling machines are described as under.

- **Portable Drilling Machine**

A portable drilling machine is a small compact unit and used for drilling holes in work-pieces in any position, which cannot be drilled in a standard drilling machine. It may be used for drilling small diameter holes in large castings or weldments at that place itself where they are lying. Portable drilling machines are fitted with small electric motors, which may be driven by both A.C. and D.C. power supply. These drilling machines operate at fairly high speeds and accommodate drills up to 12 mm in diameter.

- **Sensitive Drilling Machine**

It is a small machine used for drilling small holes in light jobs. In this drilling machine, the work-piece is mounted on the table and drill is fed into the work by purely hand control. High rotating speed of the drill and hand feed are the major features of sensitive drilling machine. As the operator senses the drilling action in the work-piece, at any instant, it is called sensitive drilling machine. A sensitive drilling machine consists of a horizontal table, a vertical column, a head supporting the motor and driving mechanism, and a vertical spindle. Drills of diameter from 1.5 to 15.5 mm can be rotated in the spindle of sensitive drilling machine. Depending on the mounting of base of the machine, it may be classified into following types:

1. Bench mounted drilling machine, and
2. Floor mounted drilling machine

- **Upright Drilling Machine**

The upright drilling machine is larger and heavier than a sensitive drilling machine. It is designed for handling medium sized work-pieces and is supplied with power feed arrangement. In this machine a large number of spindle speeds and feeds may be available for drilling different types of work. Upright drilling machines are available in various sizes and with various drilling capacities (ranging up to 75 mm diameter drills). The table of the machine also has different types of adjustments. Based on the construction, there are two general types of upright drilling machine:

(1) Round column section or pillar drilling machine.
(2) Box column section.

The round column section upright drilling machine consists of a round column whereas the upright drilling machine has box column section. The other constructional features of both are same. Box column machines possess more machine strength and rigidity as compared to those having round section column.

- **Radial Drilling Machine**

Fig. 2 illustrates a radial drilling machine. The radial drilling machine consists of a heavy, round vertical column supporting a horizontal arm that carries the drill head. Arm can be raised or lowered on the column and can also be swung around to any position over the work and can be locked in any position. The drill head containing mechanism for rotating and feeding the drill is mounted on a radial arm and can be moved horizontally on the guide-ways and clamped at any desired position. These adjustments of arm and drilling head permit the operator to locate the drill quickly over any point on the work. The table of radial drilling machine may also be rotated through 360 deg. The maximum size of hole that the machine can drill is not more than 50 mm. Powerful drive motors are geared directly into the head of the machine and a wide range of power feeds are available as well as sensitive and geared manual feeds. The radial drilling machine is used primarily for drilling medium to large and heavy work-pieces. Depending on the different movements of horizontal arm, table and drill head, the upright drilling machine may be classified into following types-

1. Plain radial drilling machine
2. Semi universal drilling machine, and
3. Universal drilling machine.

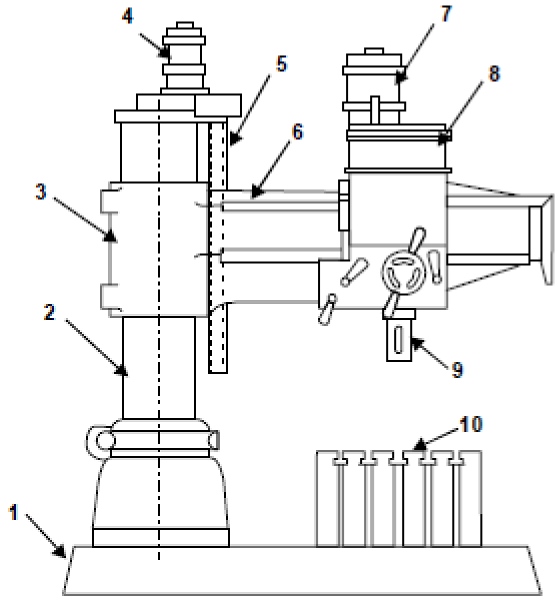

Fig. 2 Radial drilling machine

Parts name

1. Base
2. Column
3. Radial arm
4. Motor for elevating arm
5. Elevating screw
6. Guide ways
7. Motor for driving d rill spindle
8. D rill head
9. D rill spindle
10. Table

In a plain radial drilling machine, provisions are made for following three movements -

1. Vertical movement of the arm on the column,
2. Horizontal movement of the drill head along the arm, and
3. Circular movement of the arm in horizontal plane about the vertical column.

In a semi universal drilling machine, in addition to the above three movements, the drill head can be swung about a horizontal axis perpendicular to the arm. In universal machine, an additional rotatory movement of the arm holding the drill head on a horizontal axis is also provided for enabling it to drill on a job at any angle.

- **Gang Drilling Machine**

In gang drilling machine, a number of single spindle drilling machine columns are placed side by side on a common base and have a common worktable. A series of operation may be performed on the job by shifting the work from one position to the other on the worktable. This type of machine is mainly used for production work.

- **Multiple-Spindle Drilling Machine**

The multiple-spindle drilling machine is used to drill a number of holes in a job simultaneously and to reproduce the same pattern of holes in a number of identical pieces in a mass production work. This machine has several spindles and all the spindles holding drills are fed into the work simultaneously. Feeding motion is usually obtained by raising the worktable.

- ❖ **TYPES OF DRILLS**

A drill is a multi point cutting tool used to produce or enlarge a hole in the work-piece. It usually consists of two cutting edges set an angle with the axis. Broadly there are three types of drills:

1. Flat drill,
2. Straight-fluted drill, and
3. Twist drill

Flat drill is usually made from a piece of round steel which is forged to shape and ground to size, then hardened and tempered. The cutting angle is usually 90 deg. and the relief or clearance at the cutting edge is 3 to 8 deg. The disadvantage of this type of drill is that each time the drill is ground the diameter is reduced. Twist drill is the most common type of drill in use today. The various types of twist drills (parallel shank type and Morse taper shank type) are shown in Fig. 3

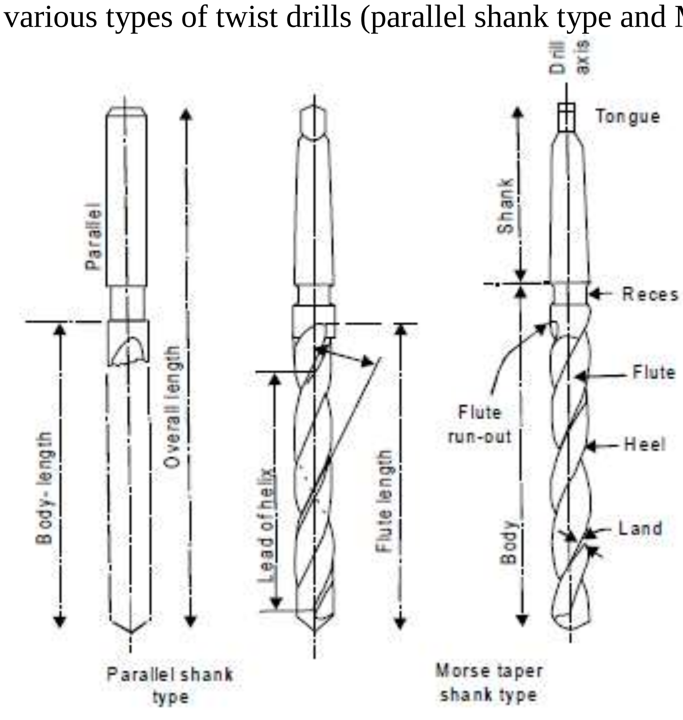

Fig. 3 Types of twist drill

Number sizes

In metric system, the drill is generally manufactured from 0.2 to 100 mm. In British system the drills sizes range from No. 1 to No. 80. Number 80 is the smallest having diameter equal to 0.0135 inch and the number 1 is the largest having diameter equal to 0.228 inch. Number 1 to number 60 is the standard sets of drills. The numbers 61 to 80 sizes drills are not so commonly used. The diameter of drills increases in steps of approximately by 0.002 inch.

Letter sizes

The drill sizes range from A to Z, A being the smallest having diameter equal to 0.234 inch and Z being the largest having diameter equal to 0.413 inch, increasing in steps of approximately O.010 inch fractional sizes: The drill sizes range from 1/64″ inch to 5 inch in steps of 1/64 inches up to 1.75 inches, then the steps gradually increase. The drill sizes range from A to Z, A being the smallest having diameter equal to 0.234 inch and Z being the largest having diameter equal to 0.413 inch, increasing in steps of approximately O.010 inch fractional sizes: The drill sizes range from 1/64″ inch to 5 inch in steps of 1/64 inches up to 1.75 inches, then the steps gradually increase. The drill is generally removed by tapping a wedge shaped drift into the slot in the drilling machine spindle as shown in Fig. 22.4.

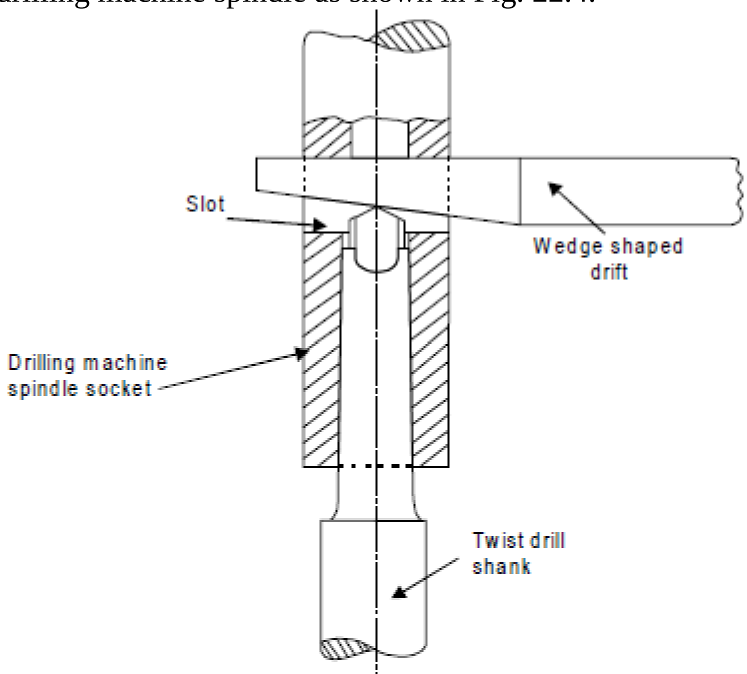

Fig. 4 Removing a drill from drill machine

22.4.1 Twist Drill Geometry

Twist drill geometry and its nomenclature are shown in Fig. 5. A twist drill has three principal parts:

(*i*) Drill point or dead center

(*ii*) Body

(*iii*) Shank.

Drill axis is the longitudinal centre line.

Drill point is the sharpened end of the drill body consisting of all that part which is shaped to produce lips, faces and chisel edge.

Lip or cutting edge is the edge formed by the intersection of the flank and face

Lip length is the minimum distance between the outer corner and the chisel-edge corner of the lip.

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

Chisel edge is the edge formed by the intersection of the flanks.

Flank is that surface on a drill point which extends behind the lip to the following flute.

Flutes are the grooves in the body of the drill, which provide lips, allow the removal of chips, and permit cutting fluid to reach the lips.

Flute length is the axial length from the extreme end of the point to the termination of the flutes at the shank end of the body.
Body is that portion of the drill nomenclature, which extends from the extreme cutting end to the beginning of the shank.
Shank is that portion of the drill by which it is held and driven,
Heel is the edge formed by the intersection of the flute surface and the body clearance.
Body clearance is that portion of the body surface reduced in diameter to provide diametric clearance.
Core or web is the central portion of the drill situated between the roots of the flutes and extending from the point end towards the shank; the point end of the core forms the chisel edge.
Lands are the cylindrically ground surfaces on the leading edges of the drill flutes. The width of the land is measured at right angles to the flute.
Recess is the portion of the drill body between the flutes and the shank provided so as to facilitate the grinding of the body. Parallel shank drills of small diameter are not usually provided with a recess.
Outer corner is the corner formed by the intersection of the lip and the leading edge of the land.
Chisel edge comer is the corner formed by the intersection of a lip and the chisel edge.
Drill diameter is the measurement across the cylindrical lands at the outer corners of the drill. .
Lead of helix is the distance measured parallel to the drill axis between corresponding points on the leading edge of a flute in one complete turn of the flute.
Helix angle is the angle between the leading edge of the land and the drill axis.
Rake angle is the angle between the face and a line parallel to the drill axis. It is bigger at the face edges and decreases towards the center of the drill to nearly 0°. The result is that the formation of chips grows more un-favorable towards the centre.
Lip clearance angle is the angle formed by the flank and a plane at right angles to the drill axis; the angle is normally measured at the periphery of the drill. To make sure that the main cutting edges can enter into the material, the clearance faces slope backwards in a curve. The clearance angle is measured at the face edge, must amount to 5° up to 8°.
Point angle is the included angle of the cone formed by the lips.

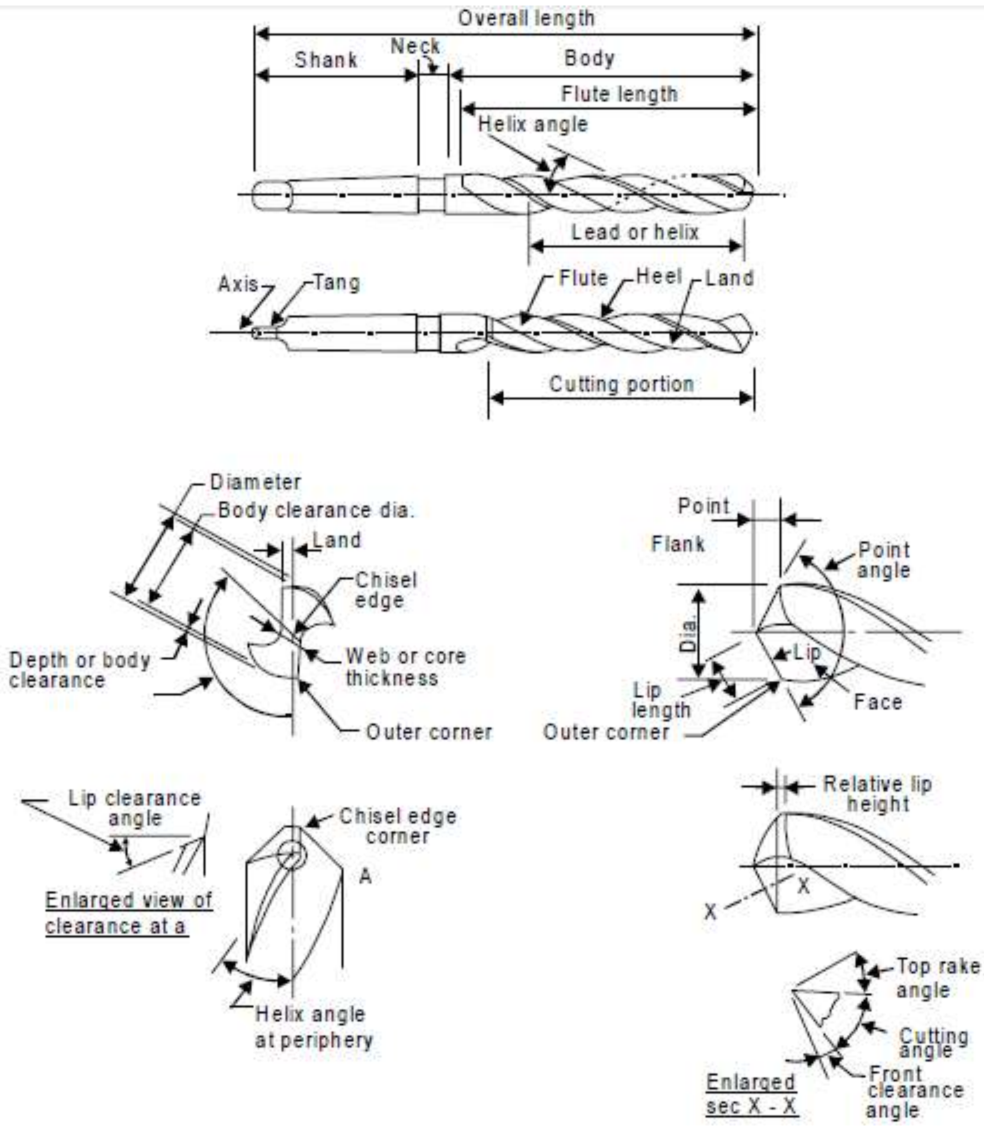

Fig. 5 Geometry and nomenclature of twist drill

- **Drill Material**

Drills are made are made up of high speed steel. High speed steel is used for about 90 per cent of all twist drills. For metals more difficult to cut, HSS alloys of high cobalt series are used.

❖ OPERATIONS PERFORMED ON DRILLING MACHINE

A drill machine is versatile machine tool. A number of operations can be performed on it. Some of the operations that can be performed on drilling machines are:

1. Drilling 2. Reaming
3. Boring 4. Counter boring
5. Countersinking 6. Spot facing
7. Tapping 8. Lapping
9. Grinding 10. Trepanning.

The operations that are commonly performed on drilling machines are drilling, reaming, lapping, boring, counter-boring, counter-sinking, spot facing, and tapping. These operations are discussed as under.

- **Drilling**

This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called drill as shown in Fig. 6. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. The drill machine is started and the drill starts rotating. Cutting fluid is made to flow liberally and the cut is started. The rotating drill is made to feed into the job. The hole, depending upon its length, may be drilled in one or more steps. After the drilling operation is complete, the drill is removed from the hole and the power is turned off.

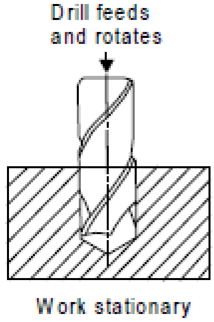

Fig. 6 Drilling operation

- **Reaming**

This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer as shown in Fig. 7. Reaming operation serves to make the hole smooth, straight and accurate in diameter. Reaming operation is performed by means of a multitooth tool called reamer. Reamer possesses several cutting edges on outer periphery and may be classified as solid reamer and adjustable reamer.

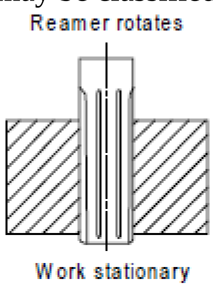

Fig. 7 Reaming operation

- **Boring**

Fig. 8 shows the boring operation where enlarging a hole by means of adjustable cutting tools with only one cutting edge is accomplished. A boring tool is employed for this purpose.

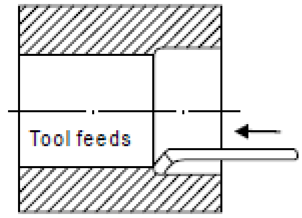

Fig. 8 Boring operation

- **Counter-Boring**

Counter boring operation is shown in Fig. 22.9. It is the operation of enlarging the end of a hole cylindrically, as for the recess for a counter-sunk rivet. The tool used is known as counter-bore.

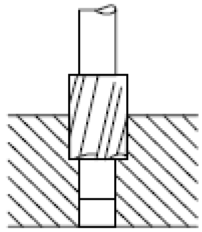

Fig. 9 Counter boring operation

- **Counter-Sinking**

Counter-sinking operation is shown in Fig. 10. This is the operation of making a cone shaped enlargement of the end of a hole, as for the recess for a flat head screw. This is done for providing a seat for counter sunk heads of the screws so that the latter may flush with the main surface of the work.

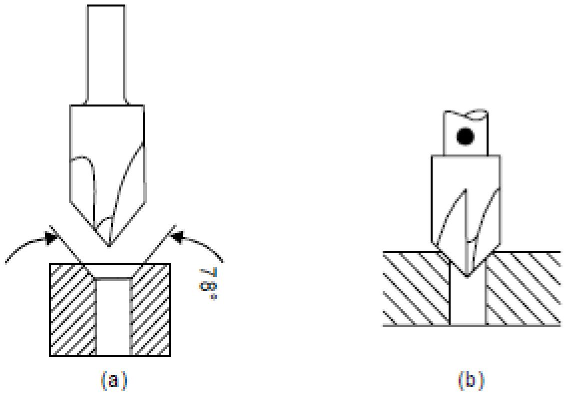

Fig. 10 Counter sinking operation

- **Lapping**

This is the operation of sizing and finishing a hole by removing very small amounts of material by means of an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, by the use of a lapping tool.

- **Spot-Facing**

This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very nearly similar to the counter-bore

- **Tapping**

It is the operation of cutting internal threads by using a tool called a tap. A tap is similar to a bolt with accurate threads cut on it. To perform the tapping operation, a tap is screwed into the hole by hand or by machine. The tap removes metal and cuts internal threads, which will fit into external threads of the same size. For all materials except cast iron, a little lubricate oil is applied to improve the action. The tap is not turned continuously, but after every half turn, it should be reversed slightly to clear the threads. Tapping operation is shown in Fig.11. The geometry and nomenclature of a tap is given in Fig. 12.

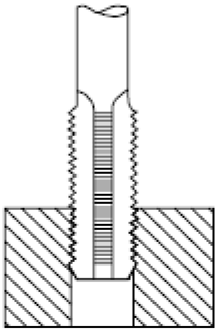

Fig. 11 Tapping operation

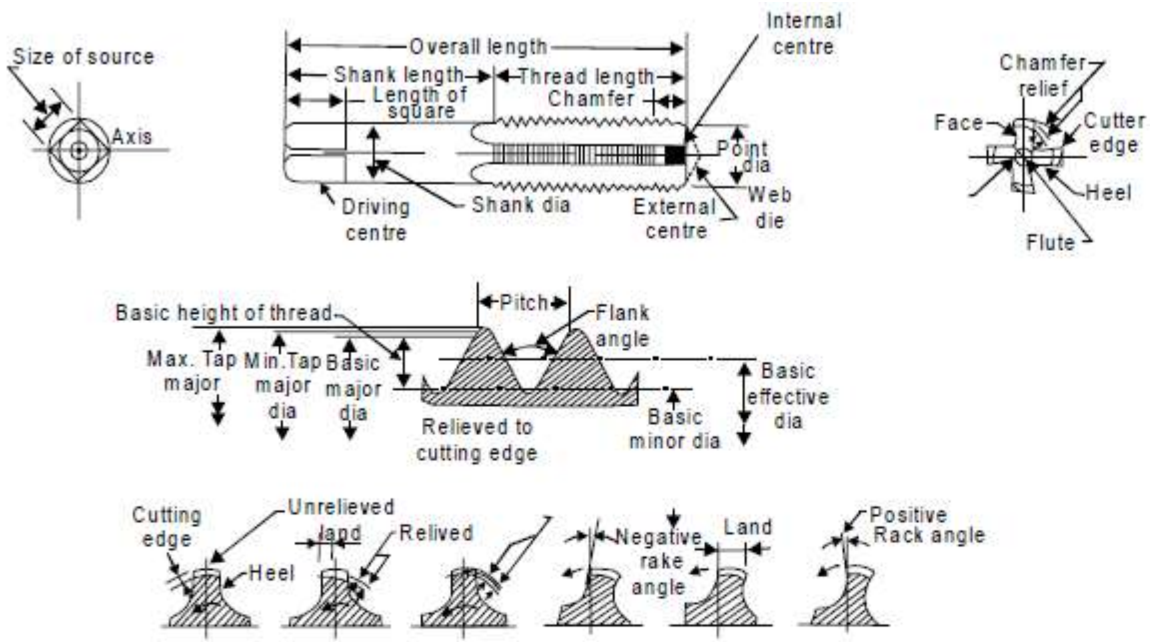

Fig 12

- **Core drilling**

Core drilling operation is shown in Fig. 13. It is a main operation, which is performed on radial drilling machine for producing a circular hole, which is deep in the solid metal by means of revolving tool called drill.

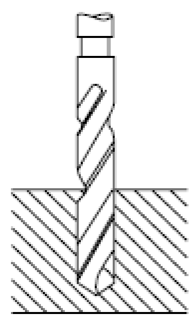

Fig. 13 Core drilling operation

- **SIZE OF A DRILLING MACHINE**

Different parameters are being considered for different types of drilling machines to determine their size. The size of a portable drilling machine is decided by the maximum diameter of the drill that it can hold. The sensitive and upright drilling machines are specified by the diameter of the largest work-piece which can be centered under the drill machine spindle. A radial drilling machine is specified by the length of the arm and the diameter of the column. To specify a drilling machine completely, following other parameters may also be needed:

1. Table diameter
2. Number of spindle speeds and feeds available
3. Maximum spindle travel
4. Morse taper number of the drill spindle
5. Power input
6. Net weight of the machine
7. Floor space required, etc.

- **CUTTING SPEED**

The cutting speed in a drilling operation refers to the peripheral speed of a point on the surface of the drill in contact with the work. It is usually expressed in meters/min. The cutting speed (Cs) may be calculated as:

$Cs = ((22/7) \times D \times N)/1000$

Where, D is the diameter of the drill in mm and

N is the rpm of the drill spindle.

- **FEED**

The feed of a drill is the distance the drill moves into the job at each revolution of the spindle. It is expressed in millimeter. The feed may also be expressed as feed per minute. The feed per minute may be defined as the axial distance moved by the drill into the work per minute. The feed per minute may be calculated as:

$F = Fr \times N$

Where, F = Feed per minute in mm.

Fr = Feed per revolution in mm.

N = R.P.M. of the drill.