6.3 DRILLING AND REAMING

Introduction

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-tooth cutting tools called *drills* or *drill bits*. Various cutting tools are available for drilling, but the most common is the *twist drill*.

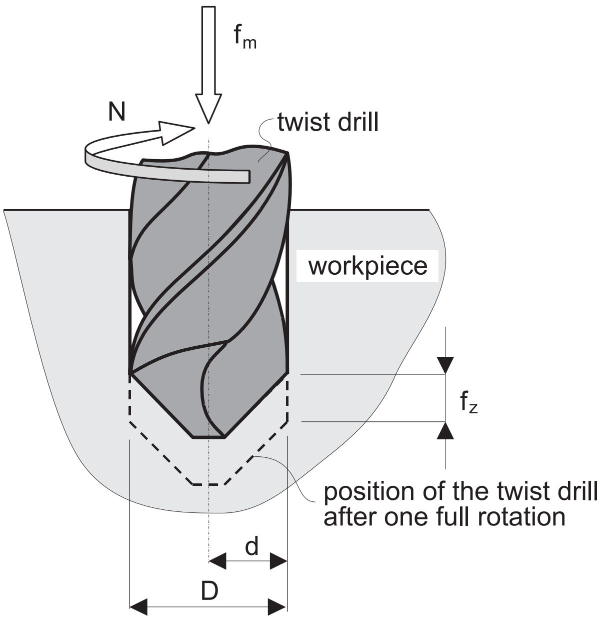
Drilling operation.

Reaming is a process of improving the quality of already drilled holes by means of cutting tools called *reamers*. Drilling and reaming are performed on a *drilling press*, although other machine tools can also perform this operation, for instance lathes, milling machines, machining centers.

In drilling and reaming, the primary motion is the rotation of the cutting tool held in the spindle. Drills and reamers execute also the secondary feed motion. Some finishing reaming operations are manual.

Cutting conditions in drilling

The twist drill is a cutting tool with two symmetrical opposite cutting edges, each removing part of the material in the form of chip.



Basics of a drilling operation.

Cutting velocity V in drilling is not a constant along the major cutting edge as opposed to the other machining operations. It is zero at the center of the twist drill, and has a maximum value at the drill corner. The maximum cutting speed is given by

$$V = \pi DN$$

where D is the drill diameter, and N is the rotational speed of the drill.

As in the case of turning and milling, cutting speed V is first calculated or selected from appropriate reference sources (see *Section 5.10 Selection of Cutting Conditions)*, and then the rotational speed of the drill N, which is used to adjust drill press controls is calculated.

Two types of *feed* in drilling can be identified:

❶ *feed per tooth* f_z: has the same meaning as in the other multi-tooth cutting tools. Feeds per tooth are roughly proportional to drill diameter, higher feeds for larger diameter drills.

❷ *feed per minute* f_m: feed per minute is calculated taking into account the rotational speed N,

$$f_m = 2f_zN$$

Feed per minute is used to adjust the feed change gears.

In drilling, *depth of cut* d is equal to the half of drill diameter,

$$d = ½\ D$$

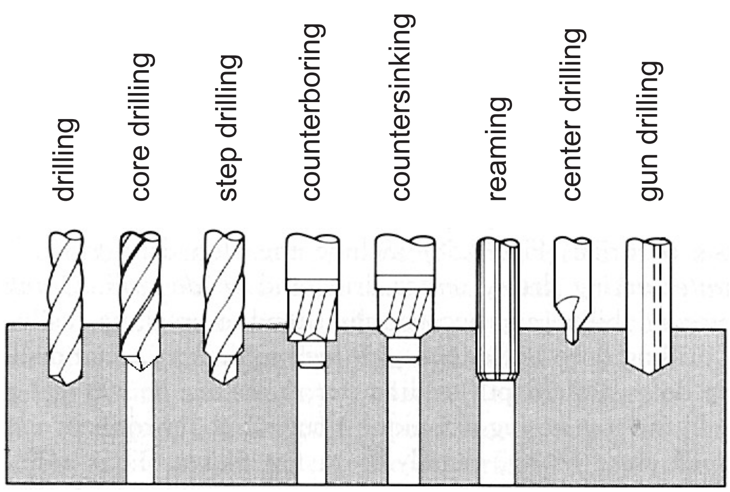
where D is the drill diameter. In core drilling, a drilling operation used to enlarge an existing hole of diameter D_{hole}, depth of cut is given by

$$d = ½\ (D_{drill} - D_{hole})$$

where D_{drill} is the drill diameter, and D_{hole} is the diameter of the hole being enlarged.

Drilling and reaming operations

Several operation are related to drilling, most of them illustrated in the figure:



Drilling and reaming operations.

- *Drilling* is used to drill a round blind or through hole in a solid material. If the hole is larger than ~30 mm, its a good idea to drill a smaller pilot hole before core drilling the final one. For holes larger than ~50 mm, three-step drilling is recomended;
- *Core drilling* is used to increase the diameter of an existing hole;
- *Step drilling* is used to drill a stepped (multi-diameter) hole in a solid material;
- *Counterboring* provides a stepped hole again but with flat and perpendicular relative to hole axis face. The hole is used to seat internal hexagonal bolt heads;
- *Countersinking* is similar to counterboring, except that the step is conical for flat head screws:
- *Reaming* provides a better tolerance and surface finish to an initially drilled hole. Reaming slightly increases the hole diameter. The tool is called *reamer*;
- *Center drilling* is used to drill a starting hole to precisely define the location for subsequent drilling. The tool is called *center drill.* A center drill has a thick shaft and very short flutes. It is therefore very stiff and will not walk as the hole is getting started;
- *Gun drilling* is a specific operation to drill holes with very large *length-to-diameter* ratio up to L/D ~300. There are several modifications of this operation but in all cases cutting fluid is delivered directly to the cutting zone internally through the drill to cool and lubricate the cutting edges, and to remove the chips (see *Section 5.6 Cutting Fluids*);

Drilling machines

Drill press

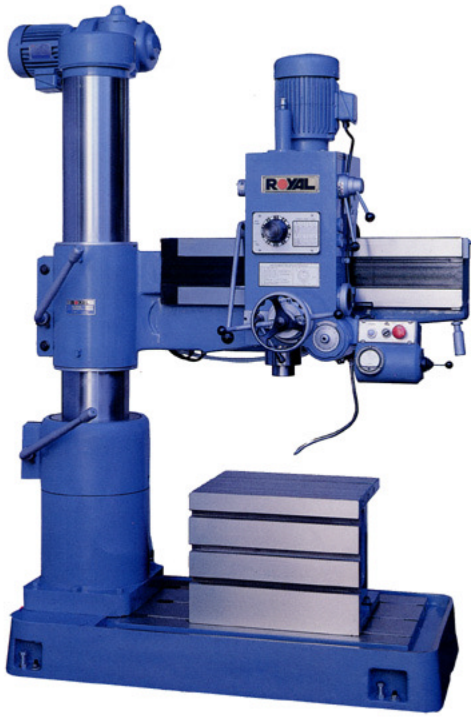
Although a *hand drill* is commonly used for drilling of small holes, a *drill press* is preferable when the location and orientation of the hole must be controlled accurately. A drill press is composed of a base that supports a column, the column in turn supports a table. Work can be supported on the table with a *vise* or hold down *clamps*, or the table can be swivelled out of the way to allow tall work to be supported directly on the base. Height of the table can be adjusted with a table lift crank than locked in place with a table lock. The column also supports a power head containing a motor. The motor turns the spindle at a speed controlled by a variable speed control dial. The spindle holds a drill chuck to hold the cutting tools (drill bits, center drills, reamers, etc.).The machine tool described is a typical *upright drill press*. The smaller modifications, mounted on a table rather than the floor are known as *bench drills*.

Upright drill press.

Bench drill press.

Radial drill

This is the largest drill press designed to drill up to 100-mm diameter holes in large workparts. It has a radial arm along which the drilling head can be moved and clamped.



Radial drill press.

Other drilling machines

The *gang drill* is a drill press consisting of a series of drill presses connected together in an in-line arrangement so that a series of drilling operations can be done in sequence.

In the *multiple-spindle drill*, several drill spindles are connected together to drill multiple holes simultaneously into the workpart.

Numerical control drill presses are available to control the positioning of the holes in the workparts. These drill presses are often equipped with turrets to hold multiple tools that can be indexed under control of the NC program. The term *CNC turret drill* is used for these machine tools.

Workholding equpment

Workholding on a drill press is accomplished by clamping the part in a *vise*, *fixture*, or *jig*.

A *vise* is a general-purpose workholding device possessing two jaws that grasp the work in position.

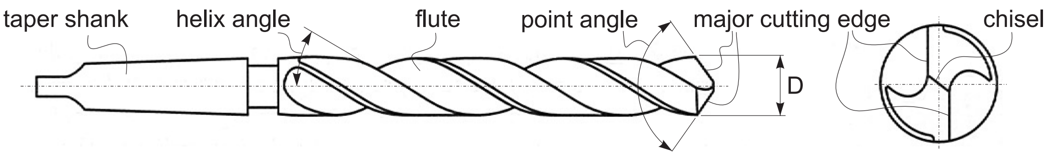
A *fixture* is a workholding device that is usually custom designed for the particular workpart. The fixture can be designed to achieve higher accuracy in positioning the part relative to the machining operation, faster production rates, and greater operator convenience in use.

A *jig* is a workholding device that is also specially designed for the workpart. The distinguishing feature between a jig and a fixture is that the jig provides a means of guiding the tool during the drilling operation. A fixture does not provide this tool guidance feature. A jig used for drilling is called a *drill jig*.

Drills and reamers

Twist drill

The twist drill does most of the cutting with the tip of the bit. It has two flutes to carry the chips up from the cutting edges to the top of the hole where they are cast off. The standard drill geometry is shown in the figure:



Standard geometry of a twist drill.

The typical helix angle of a general purpose twist drill is 18~30º while the point angle (which equals two times the major cutting edge angle, see page 101) for the same drill is 118º.

Some standard drill types are,

- straight shank: this type has a cylindrical shank and is held in a chuck;
- taper shank: his type is held directly in the drilling machine spindle.

Drills are normally made of HSS but carbide-tipped drills, and drills with mechanically attached carbide inserts are commonly used in many operations, especially on CNC drilling machines:

Coated HSS twist drills.

Carbide-tipped twist drills.

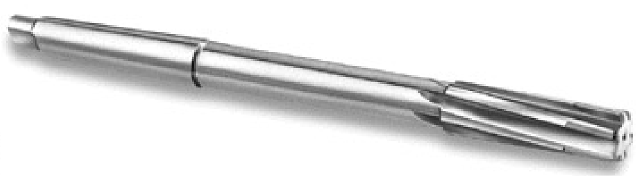
Indexable inserts twist drills.

Reamers

The reamer has similar geometry. The difference in geometry between a reamer and a twist drill are:

- The reamer contains four to eight straight or helical flutes, respectively cutting edges.
- The tip is very short and does not contain any cutting edges.

Straight-flute reamer with taper shank.



Helical-flute reamer with taper shank.