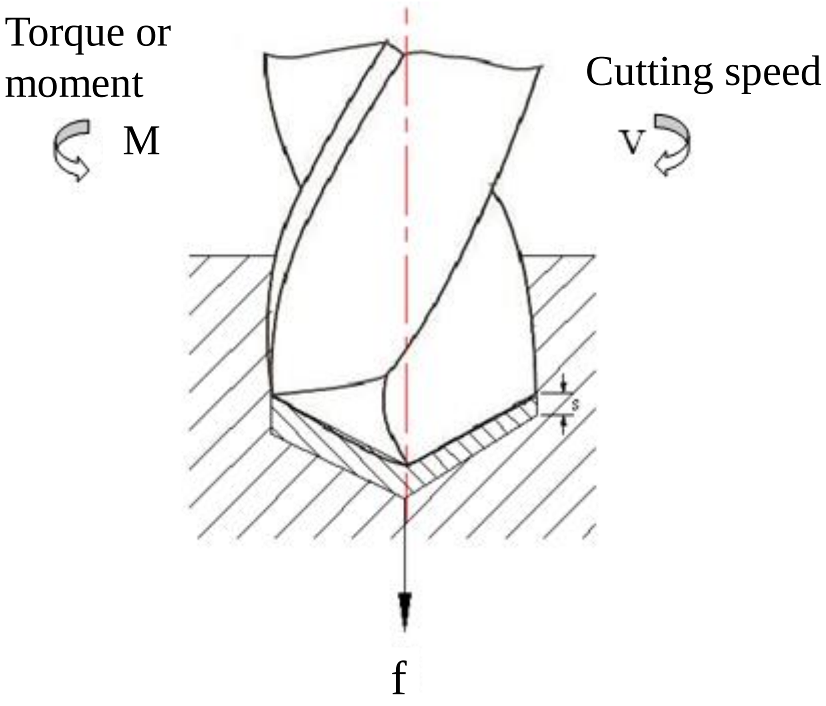
DRILLING OPERATION

Lecture-05

Drilling operation (Sec 23.5)

The process involves feeding a rotating cutting tool into a stationery workpiece.



Drill operation

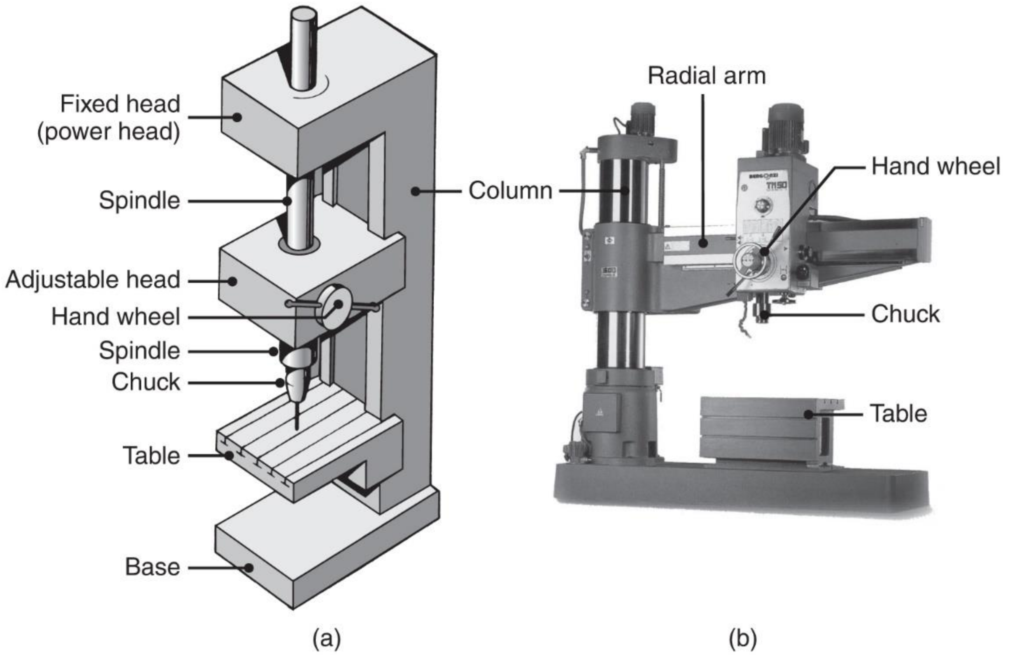


Figure 23.25: (a) Schematic illustration of the components of a vertical drill press.
(b) A radial drilling machine.

https://www.youtube.com/watch?v=tF9-lqBKBOQ

Source: Figure 23.25, Ch23, Textbook

Drilling operation

- Holes are used for assembly with fasteners, for design purposes or for appearance
- **Hole making** is the most important operations in manufacturing
- **Drilling** is a major and common hole-making process

Drilling operation

[Trepanning](#)

[Boring](#)

- *Drills* have high length-to-diameter ratios, capable of producing deep holes
- *Drills* are flexible and should be used with care in order to drill holes accurately and to prevent breakage
- Drills leave a *burr* on the bottom surface upon breakthrough, necessitating deburring operations

		Hole depth/diameter	
Cutting tool	Diameter range (mm)	Typical	Maximum
Twist drill	0.5–150	8	50
Spade drill	25–150	30	100
Gun drill	2–50	100	300
Trepanning tool	40–250	10	100
Boring tool	3–1200	5	8

Table 23.11: General Capabilities of Drilling and Boring Operations.

Source: Table 23.11, Ch23, Textbook

Drilling operation

If high accuracy and high quality finish are required, drilling must be followed by some other operations such as reaming, boring or internal grinding.

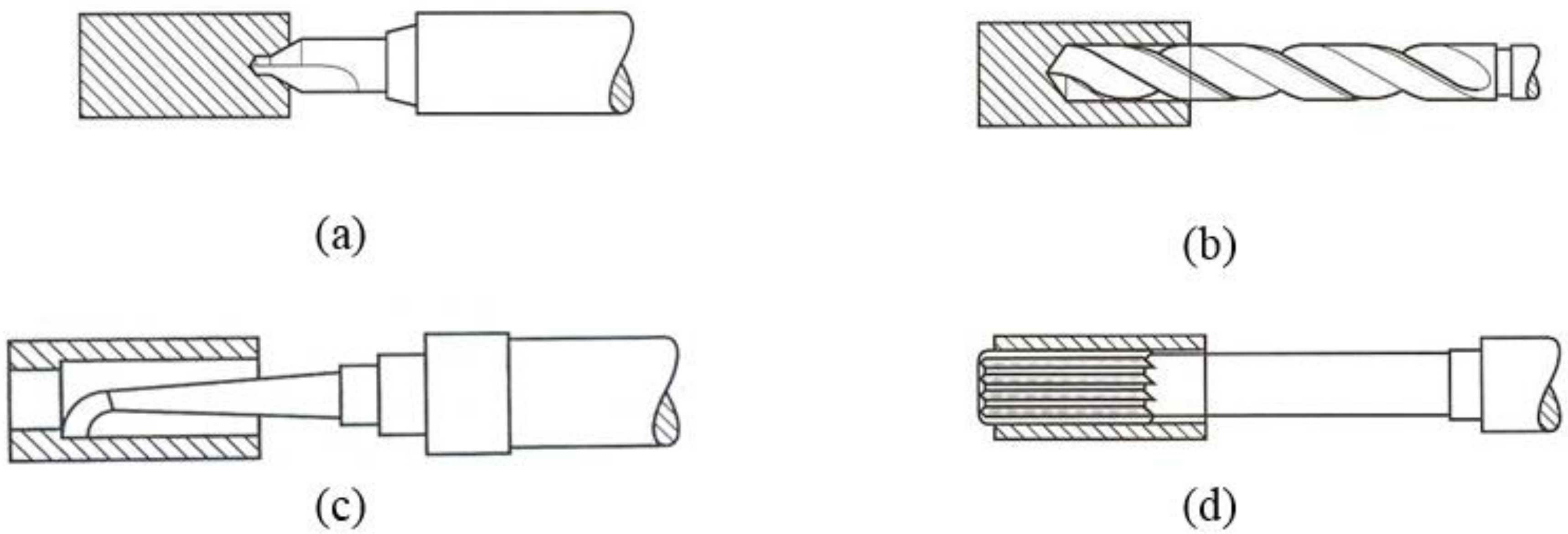


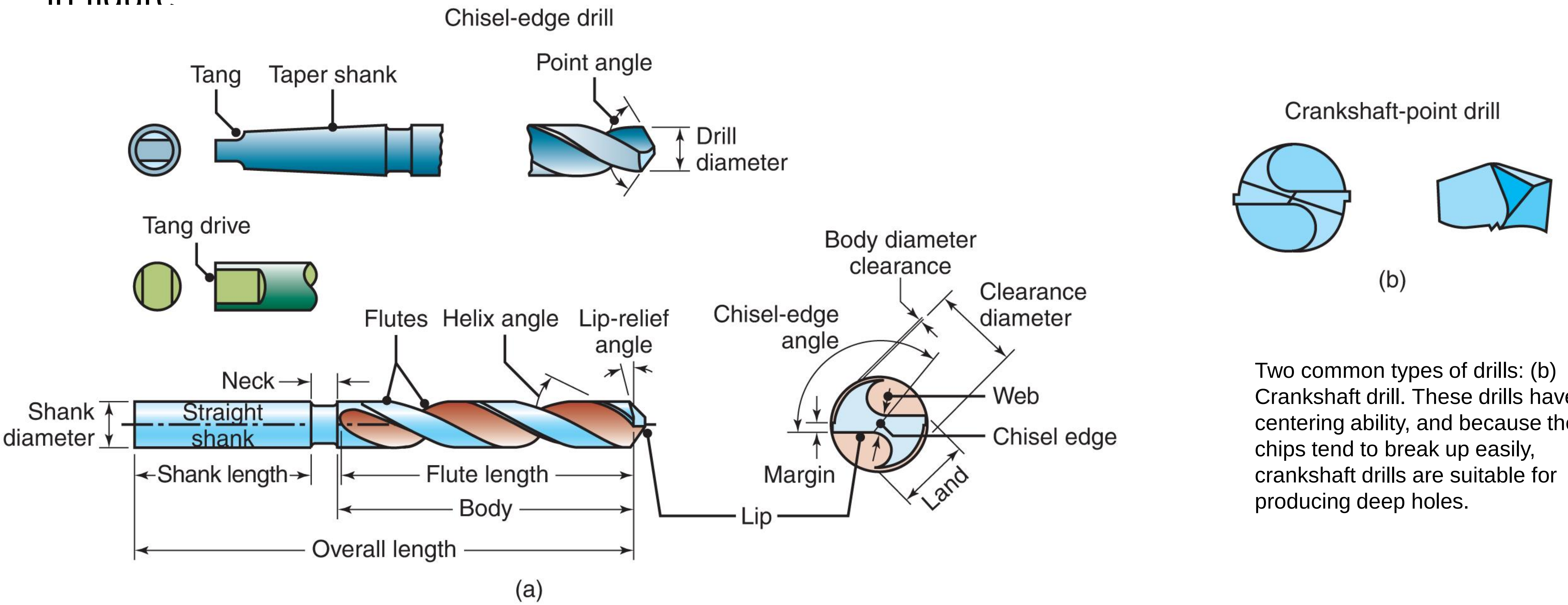
Figure 5.2: Sequence of operations required to obtained an accurate size hole: (a) centering and countersinking, (b) drilling, (c) boring, and (d) reaming

https://www.youtube.com/watch?v=yzncgqcIWaM

* *Source: The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

Twist drill nomenclature

The most widely employed drilling tool is the twist drill which is available in diameters ranging 0.25 to 80 mm. The twist drill consists of a shank, neck, body and point as shown in figure

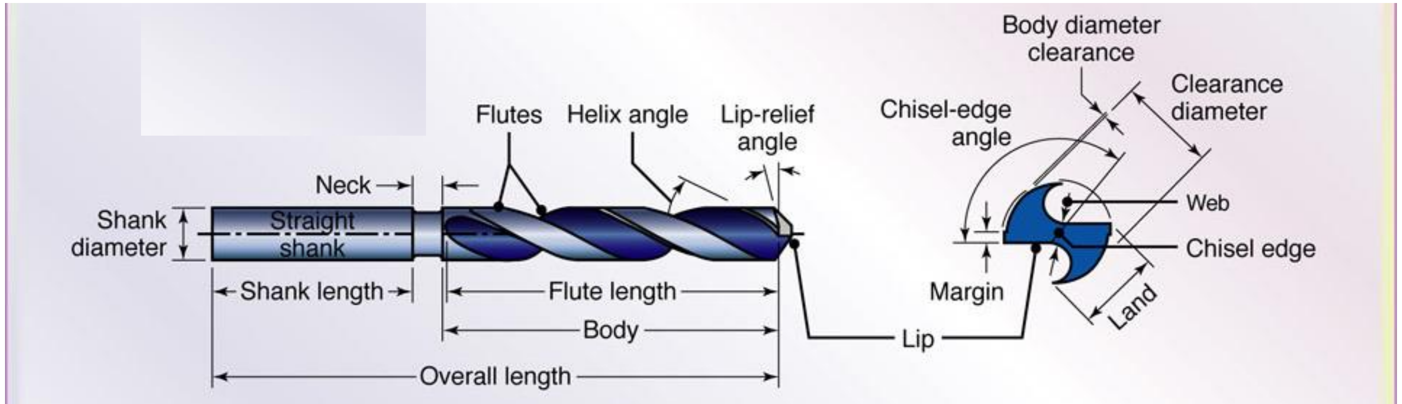


Two common types of drills: (b) Crankshaft drill. These drills have good centering ability, and because the chips tend to break up easily, crankshaft drills are suitable for producing deep holes.

Two common types of drills: (a) Chisel-edge drill. The function of the pair of margins is to provide a bearing surface for the drill against walls of the hole as it penetrates the workpiece. Drills with four margins (*double-margin*) are available for improved guidance and accuracy. Drills can have chip-breaker features.

Source: Figure 23.20, Ch23, Textbook

Twist drill



(a) Chisel-point drill

[Drilling operation: https://www.youtube.com/watch?v=JsxW1AhQqBA](https://www.youtube.com/watch?v=JsxW1AhQqBA)

Twist drill

Twist Drill

- Drills are available with a **chip-breaker** feature ground along the cutting edges
- Other drill-point geometries have been developed to improve drill performance and increase the penetration rate

Other Types of Drills

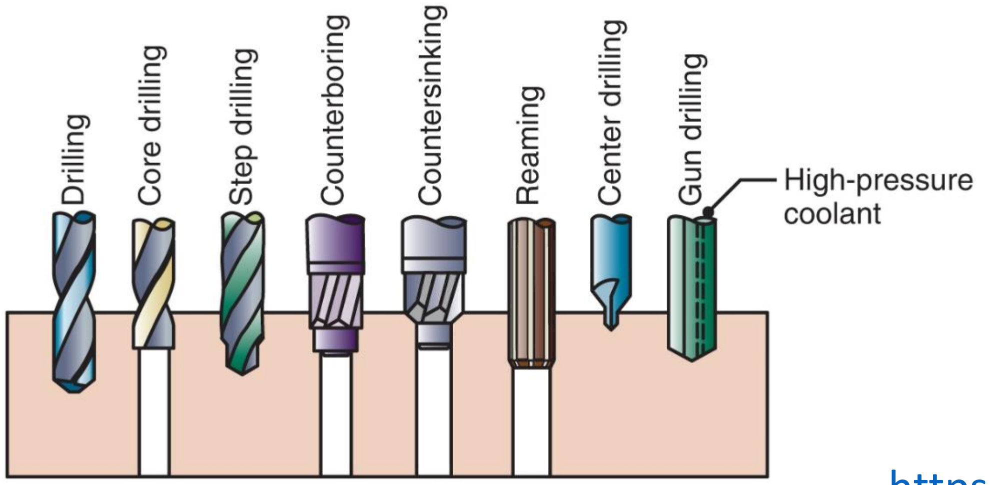


Figure 23.21: Various types of drills and drilling and reaming operations.

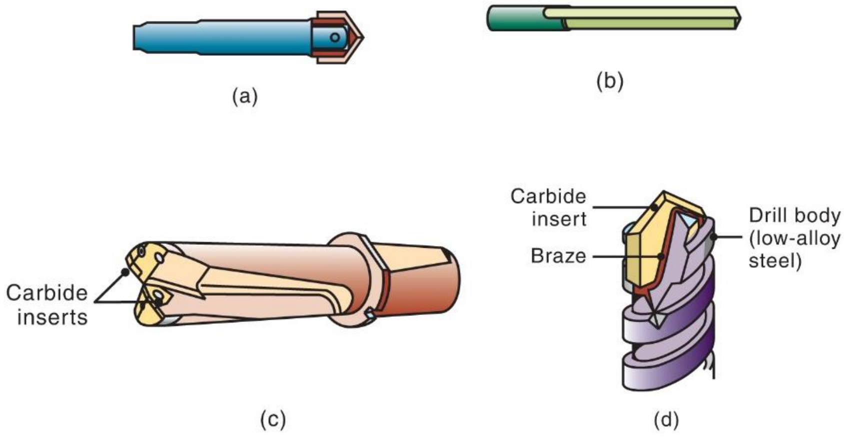


Figure 23.22:

Various types of drills.

(a) Spade drill;

(b) straight-flute drill.

(c) drill with indexable carbide inserts.

(d) drill with brazed-carbide tip.

https://www.youtube.com/watch?v=F66eqzHtdsM

Source: Figure 23.21&22, Ch23, Textbook

Twist drill

Twist Drill

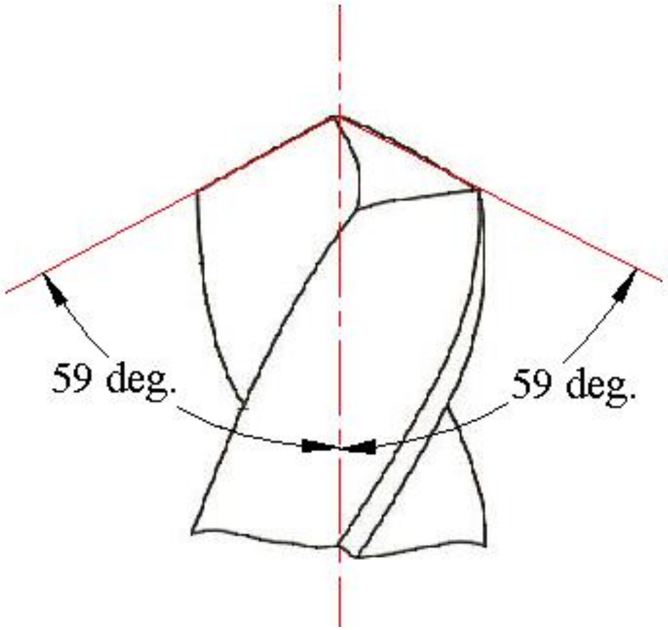
- The most common drill is the conventional *standard-point twist drill*
- The geometry of the drill point is such that *the normal rake angle and velocity of the cutting edge vary with the distance from the center of the drill*
- Main features of this drill are:

1. *Point angle*
2. *Lip-relief angle*
3. *Chiseledge angle*
4. *Helix angle*

Drilling angles

Point angle:

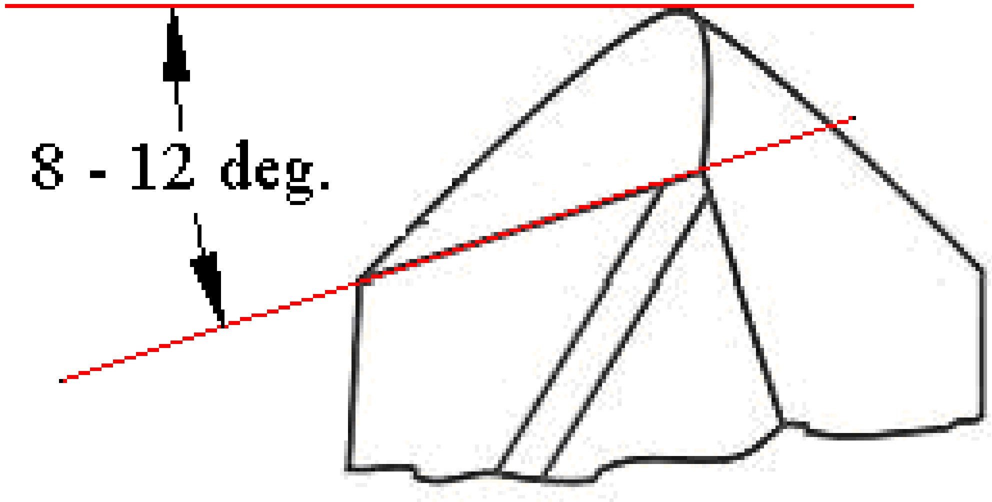
The point angle on a conventional drill is 118^{o} for drilling medium carbon steel.



* *Source: The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

The lip clearance angle

The lip clearance angle vary according to the drilled material, for hard material the range is $6 – 9^o$ and for soft materials up to 15^o.



* ***Source: The selection of Manufacturing Engineering Processes***. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

Drilling Practice

Drilling Recommendations

- The speed is the *surface speed* of the drill at its periphery

Table 23.12: General Recommendations for Speeds and Feeds in Drilling.

			Drill diameter			
			Feed, mm/rev (in./rev)		Speed, rpm	
	Surface speed		1.5 mm	12.5 mm	1.5 mm	12.5 mm
Workpiece material	m/min	ft/min	(0.060 in.)	(0.5 in.)	(0.060 in.)	(0.5 in.)
Aluminum alloys	30–120	100–400	0.025 (0.001)	0.30 (0.012)	6400–25,000	800–3000
Magnesium alloys	45–120	150–400	0.025 (0.001)	0.30 (0.012)	9600–25,000	1100–3000
Copper alloys	15–60	50–200	0.025 (0.001)	0.25 (0.010)	3200–12,000	400–1500
Steels	20–30	60–100	0.025 (0.001)	0.30 (0.012)	4300–6400	500–800
Stainless steels	10–20	40–60	0.025 (0.001)	0.18 (0.007)	2100–4300	250–500
Titanium alloys	6–20	20–60	0.010 (0.0004)	0.15 (0.006)	1300–4300	150–500
Cast irons	20–60	60–200	0.025 (0.001)	0.30 (0.012)	4300–12,000	500–1500
Thermoplastics	30–60	100–200	0.025 (0.001)	0.13 (0.005)	6400–12,000	800–1500
Thermosets	20–60	60–200	0.025 (0.001)	0.10 (0.004)	4300–12,000	500–1500

Note: As hole depth increases, speeds and feeds should be reduced. The selection of speeds and feeds also depends on the specific surface finish required.

Source: Table 23.12, Ch23, Textbook

Drilling Practice

Drilling Recommendations

- The *feed* in drilling is the distance the drill travels into the workpiece per revolution
- *Chip removal* during drilling can be difficult for deep holes in soft and ductile workpiece materials

Table 23.13: General Troubleshooting Guide for Drilling Operations.

Problem	Probable causes
Drill breakage	Dull drill, drill seizing in hole because of chips clogging flutes, feed too high, lip relief angle too small
Excessive drill wear	Cutting speed too high, ineffective cutting fluid, rake angle too high, drill burned and strength lost when drill was sharpened
Tapered hole	Drill misaligned or bent, lips not equal, web not central
Oversize hole	Same as previous entry, machine spindle loose, chisel edge not central, side force on workpiece
Poor hole surface finish	Dull drill, ineffective cutting fluid, welding of workpiece material on drill margin, improperly ground drill, improper alignment

Source: Table 23.13, Ch23, Textbook

Drilling Practice

Drill Reconditioning

- Drills are reconditioned by grinding them either manually or with special fixtures
- Hand grinding is difficult and requires considerable skill in order to produce symmetric cutting edges
- Grinding on fixtures is accurate and is done on special computer controlled grinders

Drilling Practice

Measuring Drill Life

- Drill life is measured by the number of holes drilled before they become dull and need to be re-worked or replaced
- *Drill life* is defined as the number of holes drilled until this transition begins

Drilling Machines

- Drilling machines are used for drilling holes, tapping, reaming and small-diameter boring operations
- The most common machine is the **drill press**

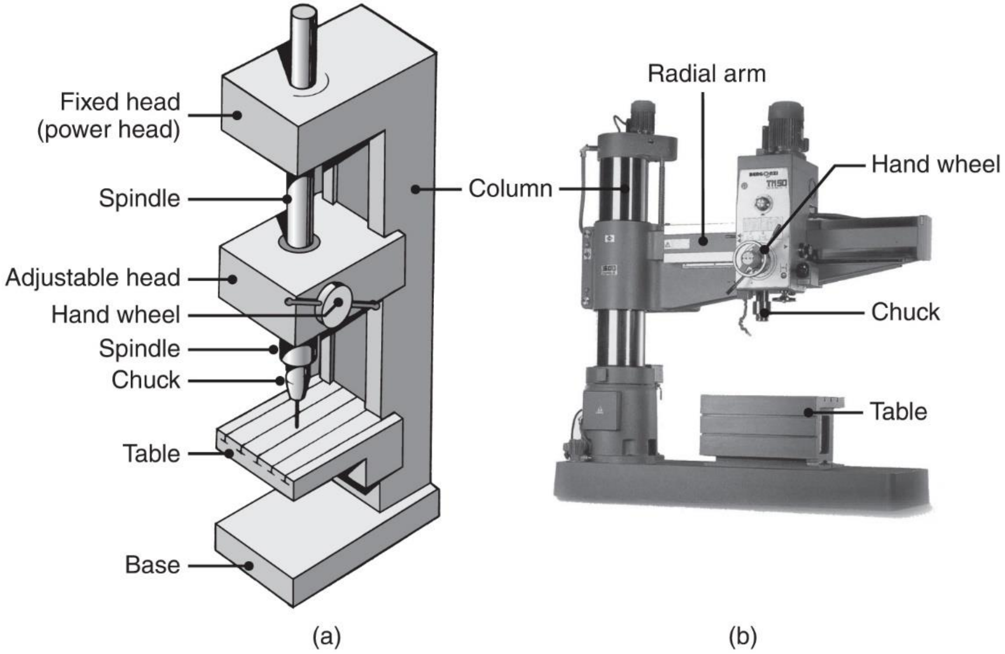


Figure 23.25: (a) Schematic illustration of the components of a vertical drill press.

(b) A radial drilling machine.

Source: Figure 23.25, Ch23, Textbook

Drilling Machines

- The types of drilling machines range from simple *bench type drills* to large *radial drills*
- The drill head of *universal drilling machines* can be swiveled to drill holes at an angle
- Numerically controlled three-axis drilling machines are automate in the desired sequence using turret
- Drilling machines with multiple spindles (**gang drilling**) are used for high-production-rate operations

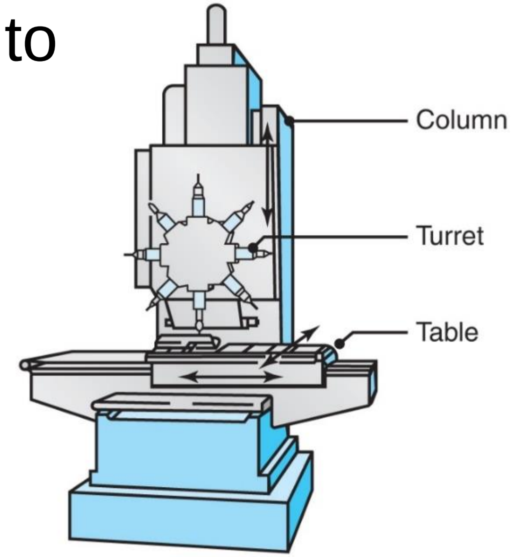


Figure 23.26: A three-axis computer-numerical-control drilling machine. The turret holds as many as eight different tools, such as drills, taps, and reamers.

Gang drilling: https://www.youtube.com/watch?v=a8xT9yROP6E

Source: Figure 23.26, Ch23, Textbook

Design Considerations for Drilling

- Basic design guidelines:

1. Designs should allow holes to be drilled on flat surfaces and perpendicular to the drill motion
2. Interrupted hole surfaces should be avoided
3. Hole bottoms should match standard drill-point angles
4. Through holes are preferred over blind holes
5. Dimples should be provided
6. Parts should be designed with a minimum of fixturing
7. Blind holes must be drilled deeper

Drill materials

Twist drills are manufactured by High speed steel, and also carbide tipped design both coated and uncoated.

Torque, power and cutting force components in drilling

The cutting force component in drilling operation is shown in figure. These components are assumed to be acting at the mid point of both main cutting edges (lips, at a distance of D/4).

Drilling, Drills, and Drilling Machines: Forces and Torque

- *Thrust force (feed force, (P_t))* acts parallel to the hole axis
- Excessive thrust force can cause the drill to break, distort the workpiece and cause the workpiece to slip into the workholding fixture
- The thrust force depends on:

1. Strength of the workpiece material
2. Feed rate of drill
3. Rotational speed
4. Drill diameter
5. Drill geometry
6. Cutting fluid

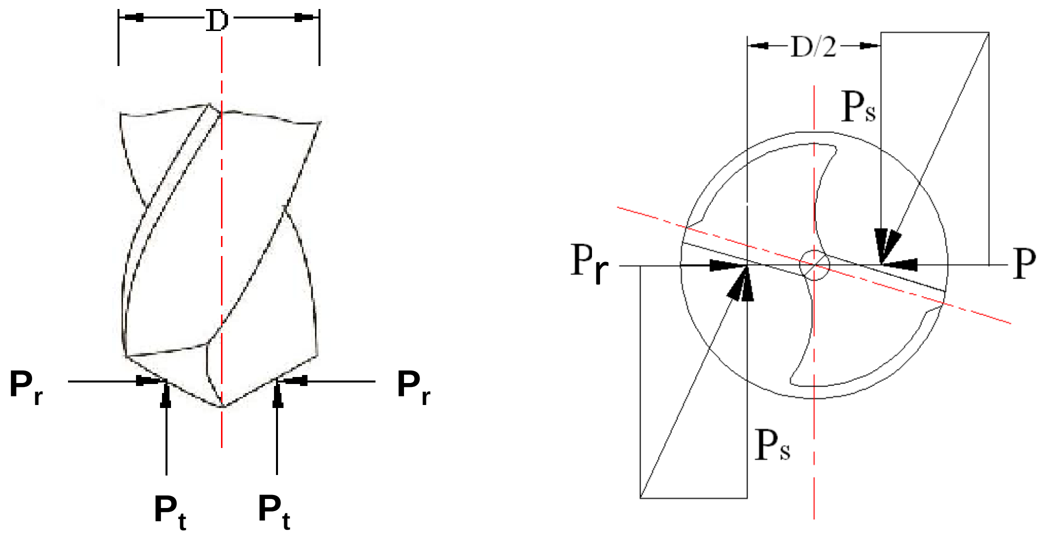


Figure 5.8: Cutting force components in drilling.

*** Source: *The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

Drilling, Drills, and Drilling Machines: Forces and Torque

Torque

- A knowledge of the *torque or moment* (M) in drilling is essential for estimating the power requirement. It depends on the main cutting force (Ps)
- Due to many factors involved, it is difficult to calculate
- Torque can be estimated from the data table

The main cutting force P_s

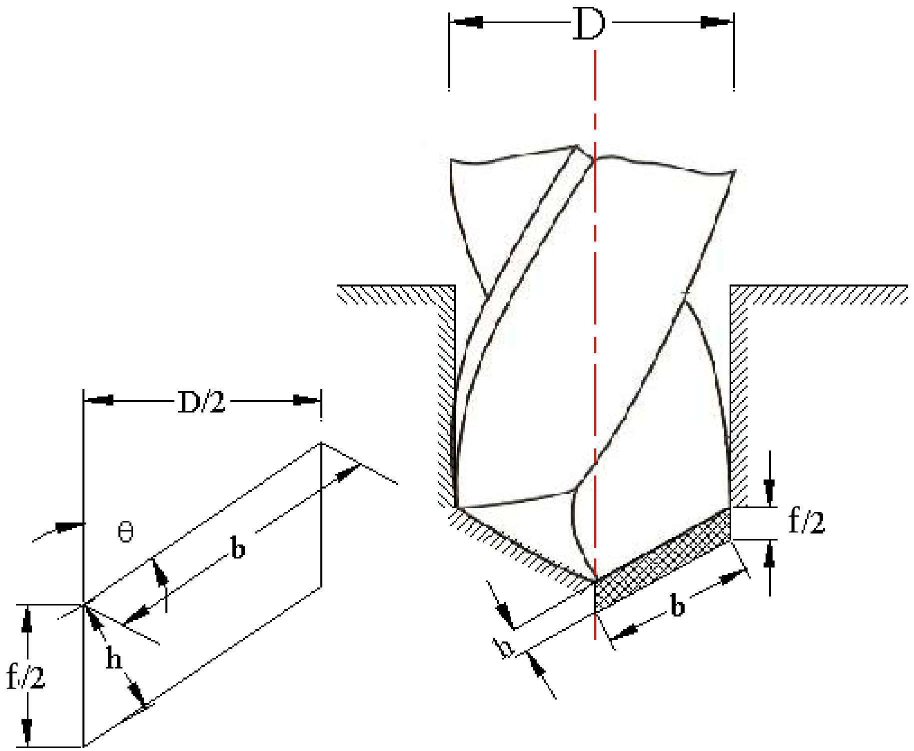
It is a horizontal force, acting on each lip in the direction of the cutting speed V, and can be calculated by the formula

$$P_s = K_s A$$

Where

Ks = specific cutting resistance (same at U_t) of the material to be drilled.

A = chip cross-section area = f/2 * D/2 or (D*f)/4 or b*h



* *Source: The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

The thrust force or the feed force ($P_t = P_f$)

The feed force P_t acts on each lip vertically upwards in the direction of the feed. It produces the penetration of the drill into the work.

The radial force P_r

The radial force acting on both lips towards the center are considered in the majority of cases to counterbalance each other.

Drilling torque

The required torque for drilling operation M, can be calculated if the main cutting force P_s and the drill diameter are known.

$$M = P_s \times D/2$$

$$M = Ks \times \frac{D \times f}{4} \times D/2$$

$$M = Ks \times \frac{D^2 \times f}{8}$$

The total drilling power

The total drilling power is equal to the main drilling power plus the feed power which is usually negligible if compared with main drilling power .

$$Power = 2P_s \times V / 2 + 2P_t \times f \times N$$

(After neglecting the power component from feed/thrust force)

$$= P_s \times V$$

$$P_{motor} = \frac{P_s \times V}{\eta_{mech}}$$

The machining time is:

$$t_m = \frac{L + (D/4)}{f \times N}$$

And material removal rate (MRR) is

$$MRR = V \times chipArea$$

$$MRR = V \times \frac{D \times f}{4}$$

Reaming and Reamers (Sec 23.6)

- *Reaming* is an operation used to:

1. Make existing hole dimensionally more accurate
2. Improve surface finish

- Most accurate holes in workpieces are produced by:

1. Centering
2. Drilling
3. Boring
4. Reaming

- For even better accuracy and surface finish, holes may be *burnished* or internally *ground* and *honed*

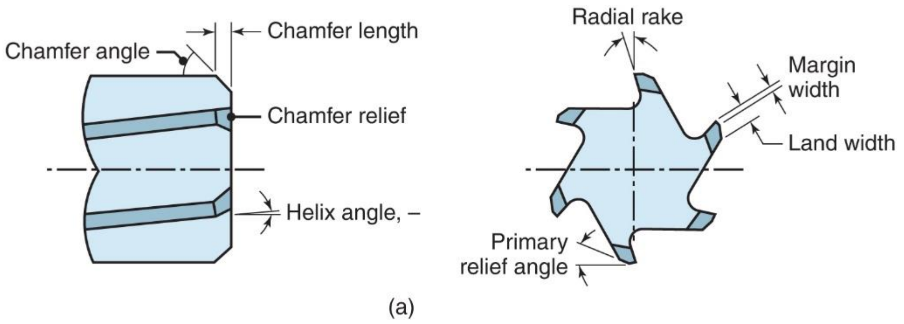


Figure 2327 -(a): Terminology for a helical reamer.

Source: Figure 23.27, Ch23, Textbook

Reaming and Reamers

https://www.youtube.com/watch?v=DuewffX4eDo

Reaming and Reamers

To meet quality requirements

Regarding both finish and accuracy (tolerances on diameter, roundness, straightness), reamers must have adequate support for the cutting edges, and reamer deflection must be minimal.

Boring and boring machines (Sec 23.4)

- Boring is similar to turning. It uses a single point cutting tool against a rotating workpiece.
- The difference is that boring is performed on the inside of an existing hole rather than the outside diameter of an existing cylinder.

First setup

In this setup the work is fixed to a rotating spindle, and the tool is attached to a boring bar that feeds the tool into the work, as shown in figure 5.11. The boring bar in this setup must be very stiff to avoid deflection and vibration during operation. (the boring bar is made of cemented carbide).

First setup

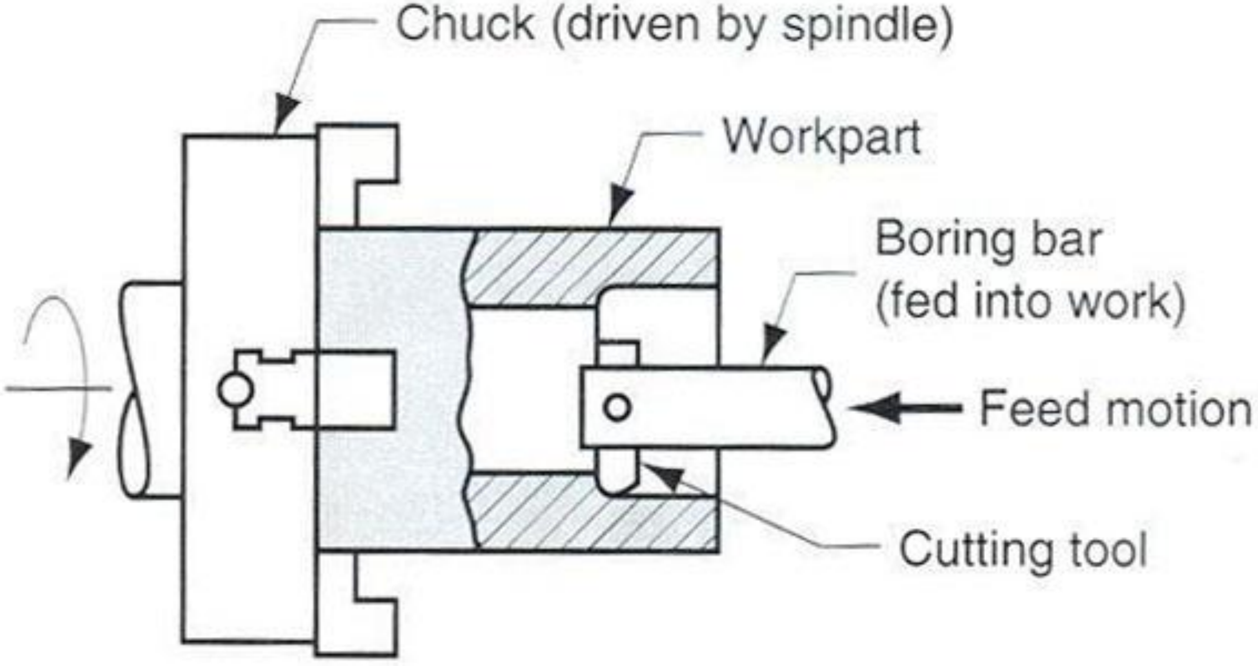


Figure 5.11: First setup of boring; boring bar is fed into a rotating workpiece.

***Source: The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

Second setup

In this setup the tool is mounted to a boring bar and the boring bar is supported and rotated between centers as shown in figure 5.12. The work is fastened to a feeding mechanism that feeds it past the tool. This setup can be used to perform boring operation on conventional engine lathe.

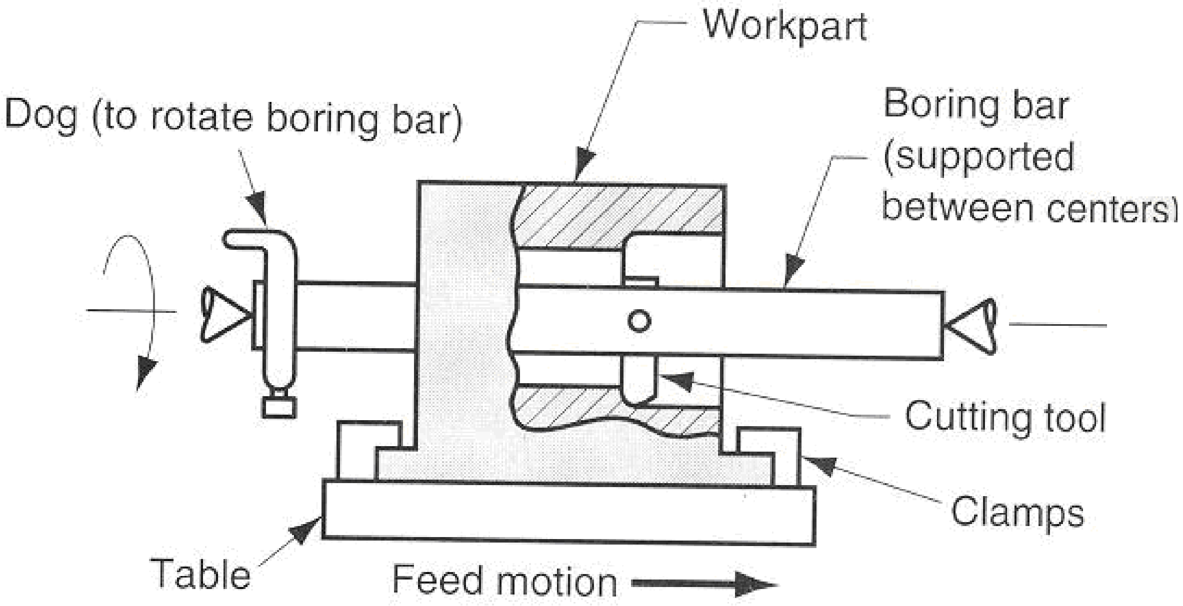


Figure 5.12: Second setup of boring; work is fed past a rotating boring bar.

*** *Source: The selection of Manufacturing Engineering Processes*. Prof. Saied Darwish, Industrial Engineering Department, King Saud University.

Vertical boring machine

A vertical boring machine is shown in figure 23.19. This machine is used for heavy work parts. Work parts up to 40 feet diameter can be machined on vertical boring machines. A **vertical boring mill** is similar to a lathe, has a vertical axis of workpiece rotation

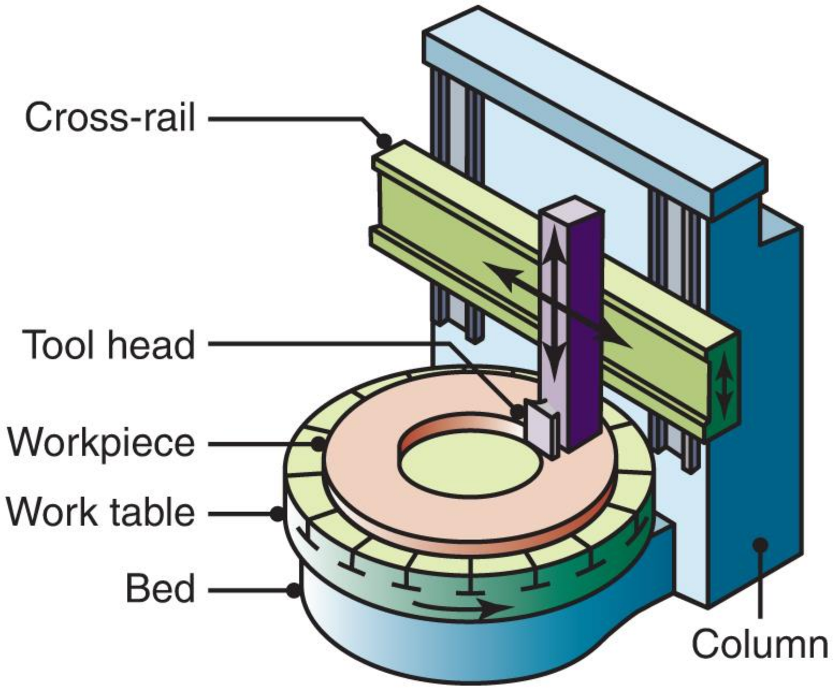


Figure 23.19: Schematic illustration of a vertical boring mill. Such a machine can accommodate workpiece sizes as large as 2.5 m (98 in.) in diameter.

https://www.youtube.com/watch?v=FNDziMNxPWY

https://www.youtube.com/watch?v=j9TQYO3MvVg

Source: Figure 23.19, Ch23, Textbook

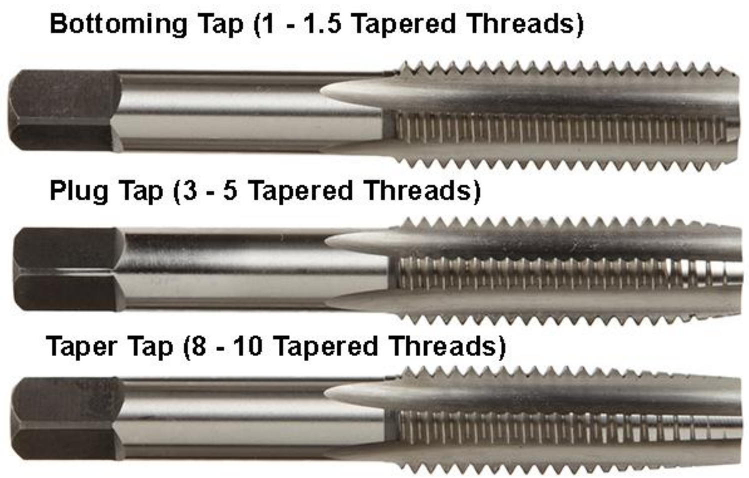
Boring and Boring Machines

Design Considerations for Boring:

1. Through holes should be specified
2. Greater the length-to-bore-diameter ratio, the more difficult it is to hold dimensions
3. Interrupted internal surfaces should be avoided

Tapping and Taps (Sec 23.7)

- **Internal threads** in workpieces can be produced by *tapping*
- A *tap* is a chip-producing threading tool with multiple cutting teeth
- *Tapered taps* are designed to reduce the torque required for the tapping of through holes
- *Bottoming taps* are for tapping blind holes to their full depth



Source: Figure 23.28, Ch23, Textbook

Tapping and Taps

- Tapping may be done by *hand* or with machines:

1. Drilling machines
2. Lathes
3. Automatic screw machines
4. Vertical CNC milling machines

- One system for the automatic tapping of nuts is shown

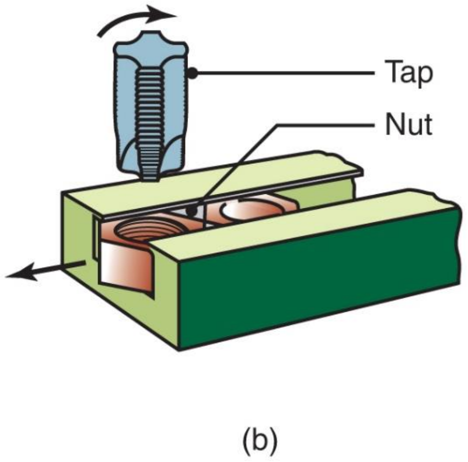


Figure 23.28 -(b): Tapping of steel nuts in production.

Internal and External threads:
https://www.youtube.com/watch?v=KVnN4jiB7Gk
https://www.youtube.com/watch?v=9IvWuXjCVbg

Source: Figure 23.28, Ch23, Textbook

Tapping and Taps

- Taps selection

  https://www.youtube.com/watch?v=gIbeVukDDmQ