Machine Tools and Operations

Module 4

Source of Information

Text Book

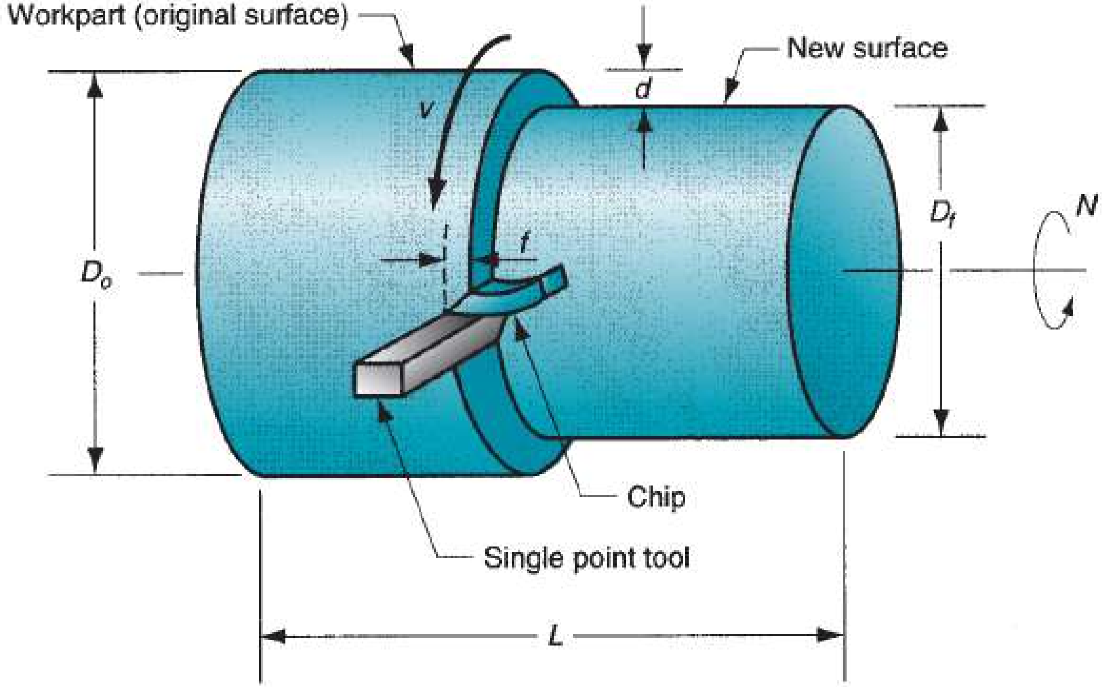
a. **S. Kapakjian** and **S.R. Schmid**, (2004), **Manufacturing Engineering and Technology**, 4th Edition, Pearson Education (Singapore) Pvt. Ltd.

b. **M. P. Groover**, **Fundamentals of Modern Manufacturing.**

Lathe

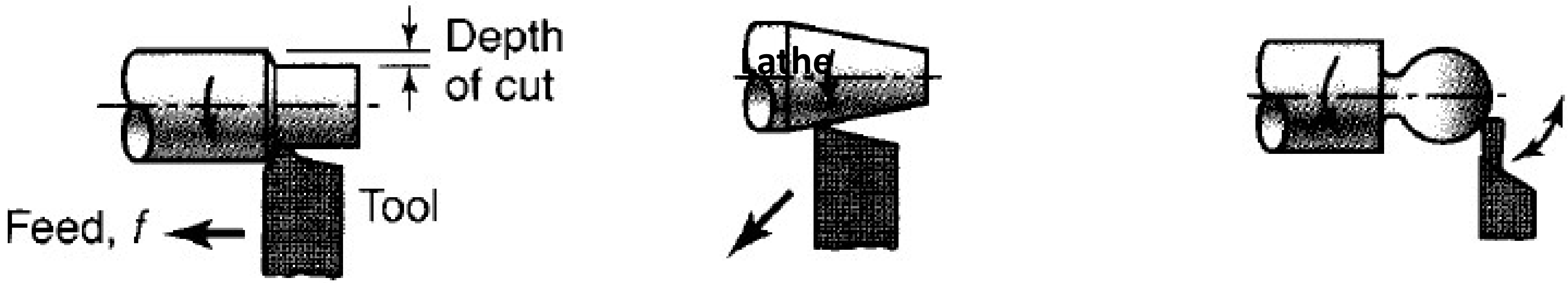
- **Turning** is a machining process in which a single-point tool removes material from the surface of a rotating workpiece.

1. Turning is traditionally carried out on a machine tool called a **lathe** which provides power to turn the part at a given rotational speed and to feed the tool at a specified rate and depth of cut.



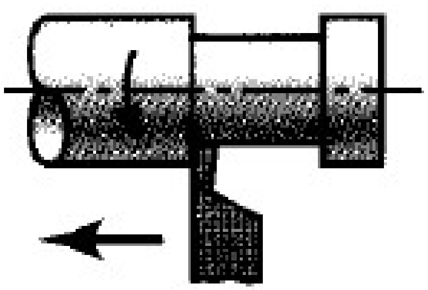
Lathe

- One of the most basic machining processes is turning, meaning that the part is rotated while it is being machined.
- Turning processes, which typically are carried out on a lathe or by similar machine tools, are outlined below.

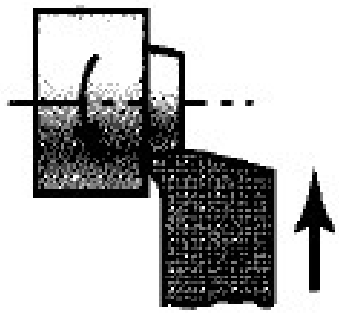


(a) Straight turning (b) Taper turning (c) Profiling

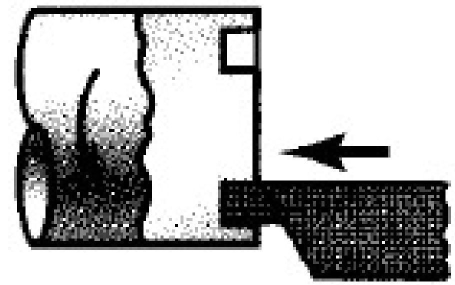
Lathe



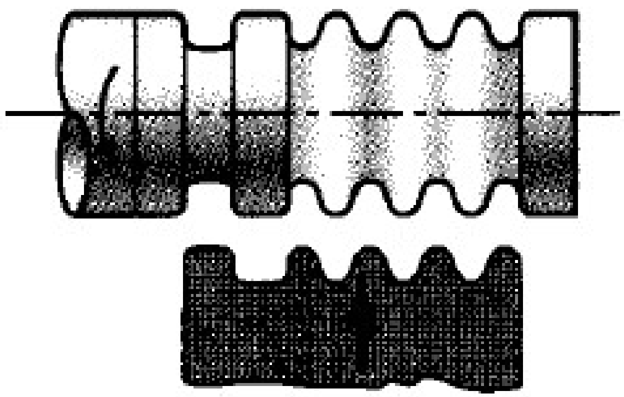
(d) Turning and external grooving



(e) Facing

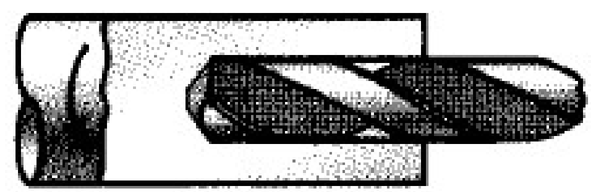


(f) Face grooving

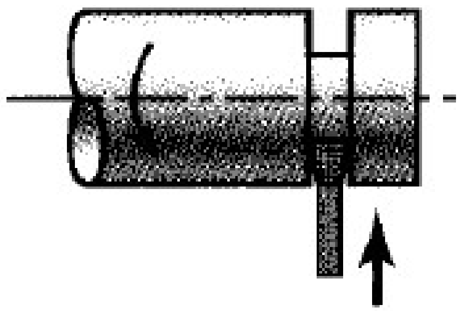


(g) Cutting with a form tool

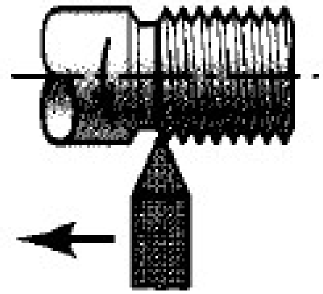
(h) Boring and internal grooving



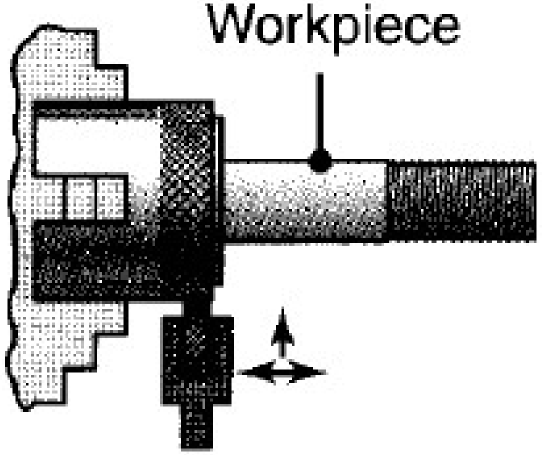
(i) Drilling



(j) Cutting off

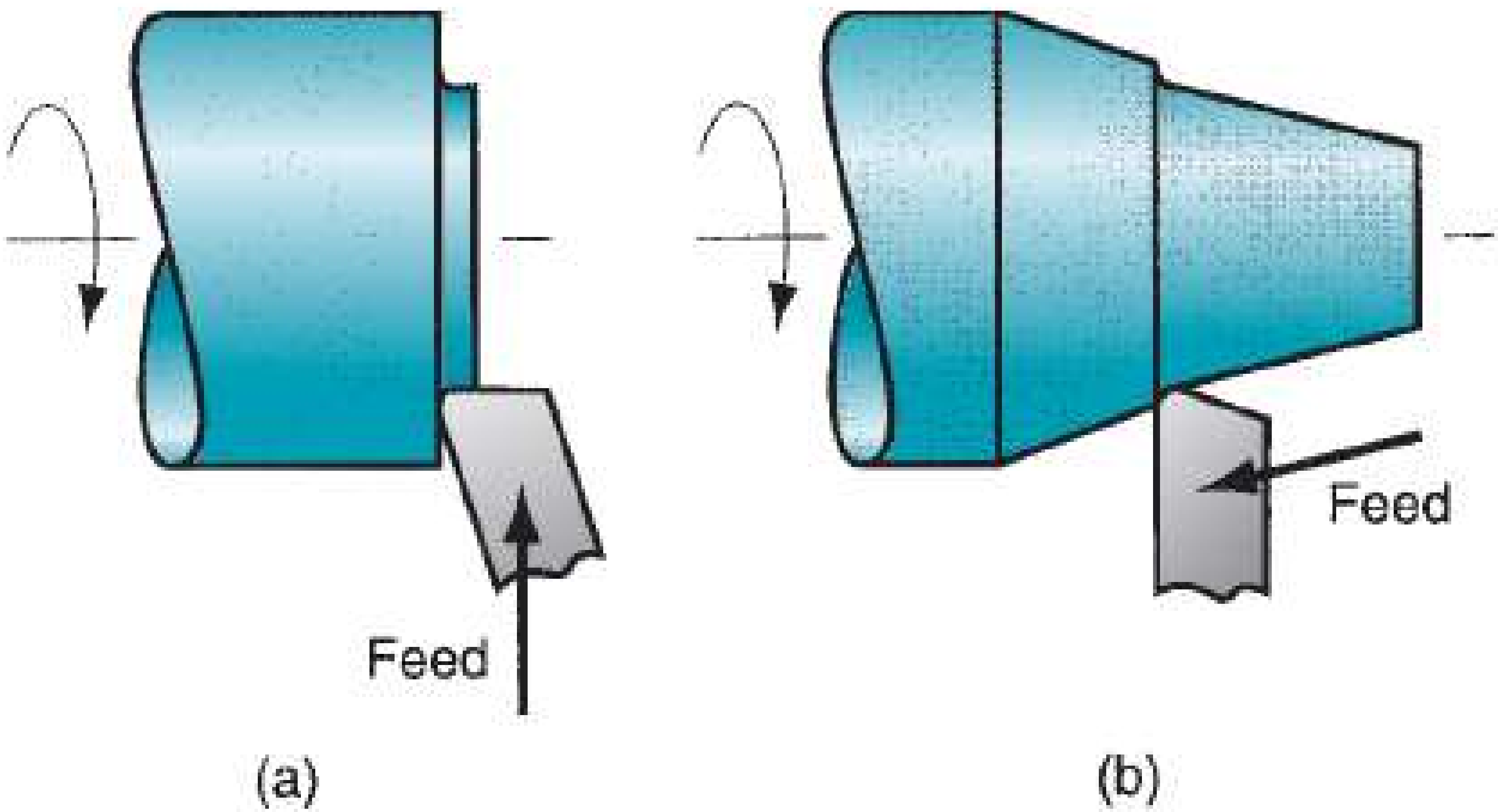


(k) Threading



(l) Knurling

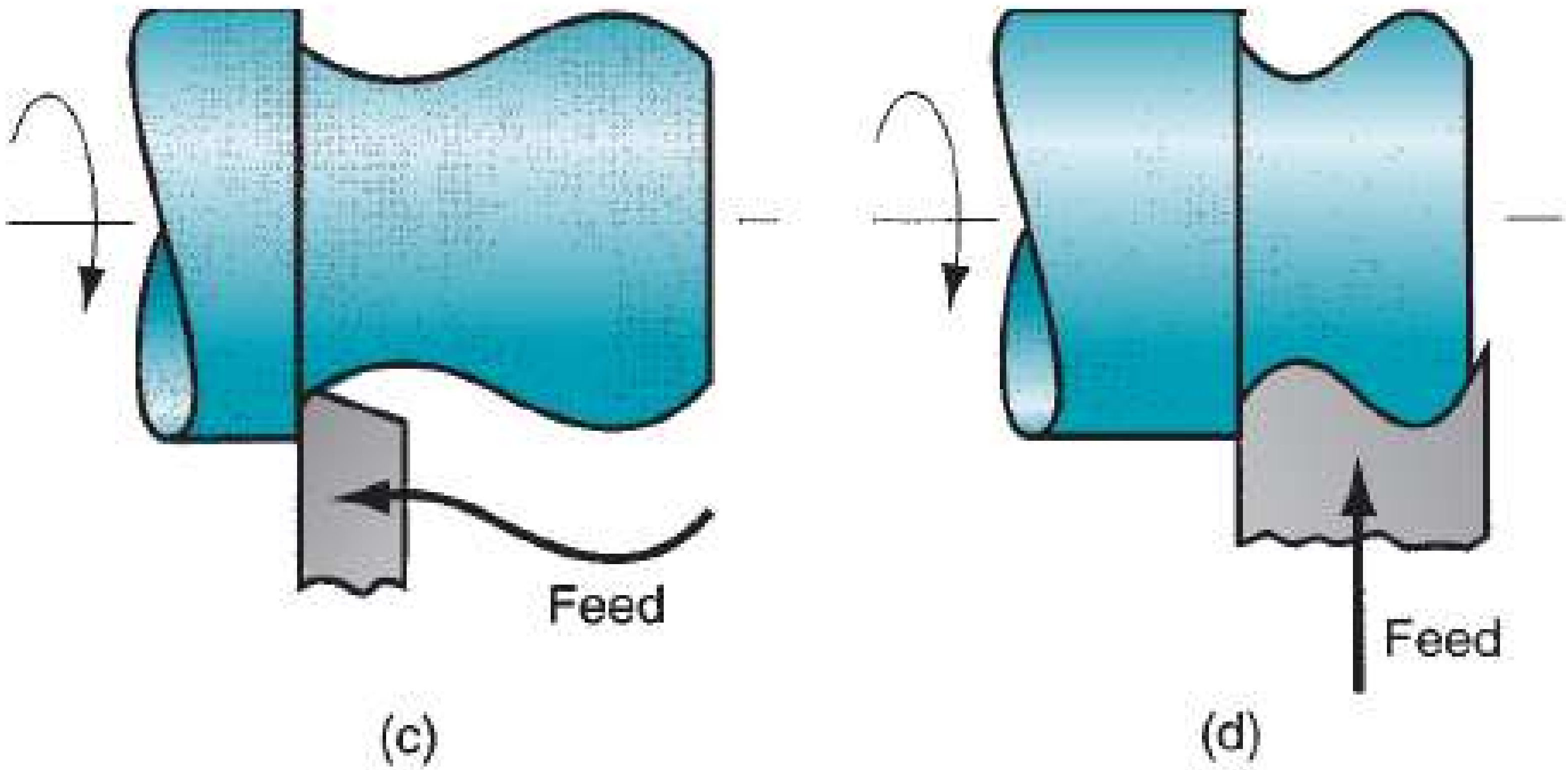
Operations Related to Turning



(a) **Facing.** The tool is fed radially into the rotating work on one end to create a flat surface on the end.

(b) **Taper turning** Instead of feeding the tool parallel to the axis of rotation of the work, the tool is fed at an angle, thus creating a tapered cylinder or conical shape.

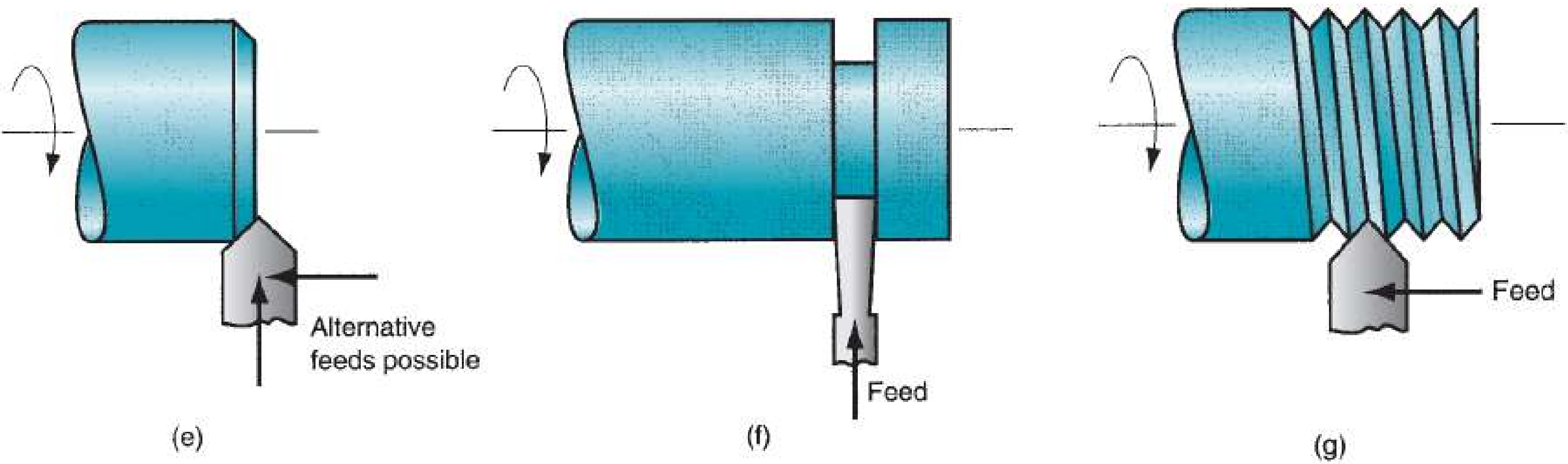
Operations Related to Turning



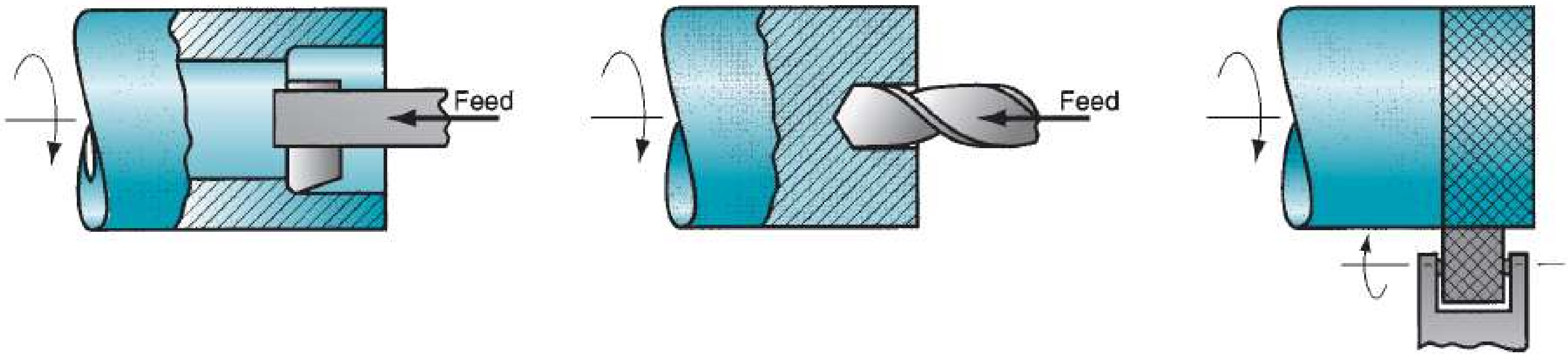
(c) **Contour turning**. Instead of feeding the tool along a straight line parallel to the axis of rotation as in turning, the tool follows a contour that is other than straight, thus creating a contoured form in the turned part.

(d) **Form turning**. In this operation, sometimes called forming, the tool has a shape that is imparted to the work by plunging the tool radially into the work.

Operations Related to Turning



(e) **Chamfering**. The cutting edge of the tool is used to cut an angle on the corner of the cylinder, forming what is called a ‘‘chamfer.’’
(f) **Cutoff**. The tool is fed radially into the rotating work at some location along its length to cut off the end of the part. This operation is sometimes referred to as parting.
(g) **Threading**. A pointed tool is fed linearly across the outside surface of the rotating workpart in a direction parallel to the axis of rotation at a large effective feed rate, thus creating threads in the cylinder.



(h) (i) (j)

(h) **Boring**. A single-point tool is fed linearly, parallel to the axis of rotation, on the inside diameter of an existing hole in the part.

(i) **Drilling**. Drilling can be performed on a lathe by feeding the drill into the rotating work along its axis. Reaming can be performed in a similar way.

(j) **Knurling**. This is not a machining operation because it does not involve cutting of material. Instead, it is a metal forming operation used to produce a regular crosshatched pattern in the work surface.

General Characteristics of Machining Processes and Typical Dimensional Tolerances

Process	Characteristics	Typical dimensional tolerances, ±mm
Turning	Turning and facing operations on all types of materials, uses single-point or form tools; engine lathes require skilled labor; low production rate (but medium-to-high rate with turret lathes and automatic machines) requiring less skilled labor	Fine: 0.025–0.13 Rough: 0.13
Boring	Internal surfaces or profiles with characteristics similar to turning; stiffness of boring bar important to avoid chatter	0.025
Drilling	Round holes of various sizes and depths; high production rate; labor skill required depends on hole location and accuracy specified; requires boring and reaming for improved accuracy	0.075
Milling	Wide variety of shapes involving contours, flat surfaces, and slots; versatile; low-to-medium production rate; requires skilled labor	0.013–0.025
Planing	Large flat surfaces and straight contour profiles on long workpieces, low-quantity production, labor skill required depends on part shape	0.08–0.13
Shaping	Flat surfaces and straight contour profiles on relatively small workpieces; low-quantity production; labor skill required depends on part shape	0.05–0.08
Broaching	External and internal surfaces, slots, and contours; good surface finish; costly tooling; high production rate; labor skill required depends on part shape	0.025–0.15
Sawing	Straight and contour cuts on flat or structural shapes; not suitable for hard materials unless saw has carbide teeth or is coated with diamond; low production rate; generally low labor skill	0.8

Rotational Speed (N)

- The rotational speed in turning is related to the desired cutting speed at the surface of the cylindrical workpiece by the equation

$$N = \frac{v}{\pi D_o}$$

- where **N** = rotational speed, ***rev/min***; **v** = cutting speed, ***m/min***); and $\mathbf{D_0}$ = original diameter of the part, ***m.***

Operating Parameters in *turning*

Depth of Cut (d)

- The turning operation reduces the diameter of the work from its original diameter D_0 to a final diameter D_f, as determined by the ***depth of cut*** **d**:

$$D_f = D_o - 2d$$

Feed (f)

- The feed in turning is generally expressed in ***mm/rev***. This feed can be converted to a linear travel rate in ***mm/min*** by the formula

$$f_r = Nf$$

➢ where f_r = feed rate, mm/min; and **f** = feed, mm/rev.

Machining Time (T_m)

- The time to machine from one end of a cylindrical work part to the other is given by

$$T_m = \frac{L}{f_r}$$

- where $\mathbf{T_m}$ = machining time, min; and L = length of the cylindrical work part, mm
- More direct computation of the machining time is provided by the following equation:

$$T_m = \frac{\pi D_o L}{f v}$$

Material removal rate (R_{MR})

The material-removal rate in turning is the volume of material removed per unit time, with the units of mm^3/min.

- The volumetric rate of material removal can be most conveniently determined by the following equation:

$$R_{MR} = vfd$$

➢ Where R_{MR} = material removal rate, **mm^3/min**. In using this equation, the units for **f** are expressed simply as **mm**, in effect neglecting the rotational character of turning.

➢ Also, care must be exercised to ensure that the units for speed are consistent with those for *f* and *d*.

Types of Lathe

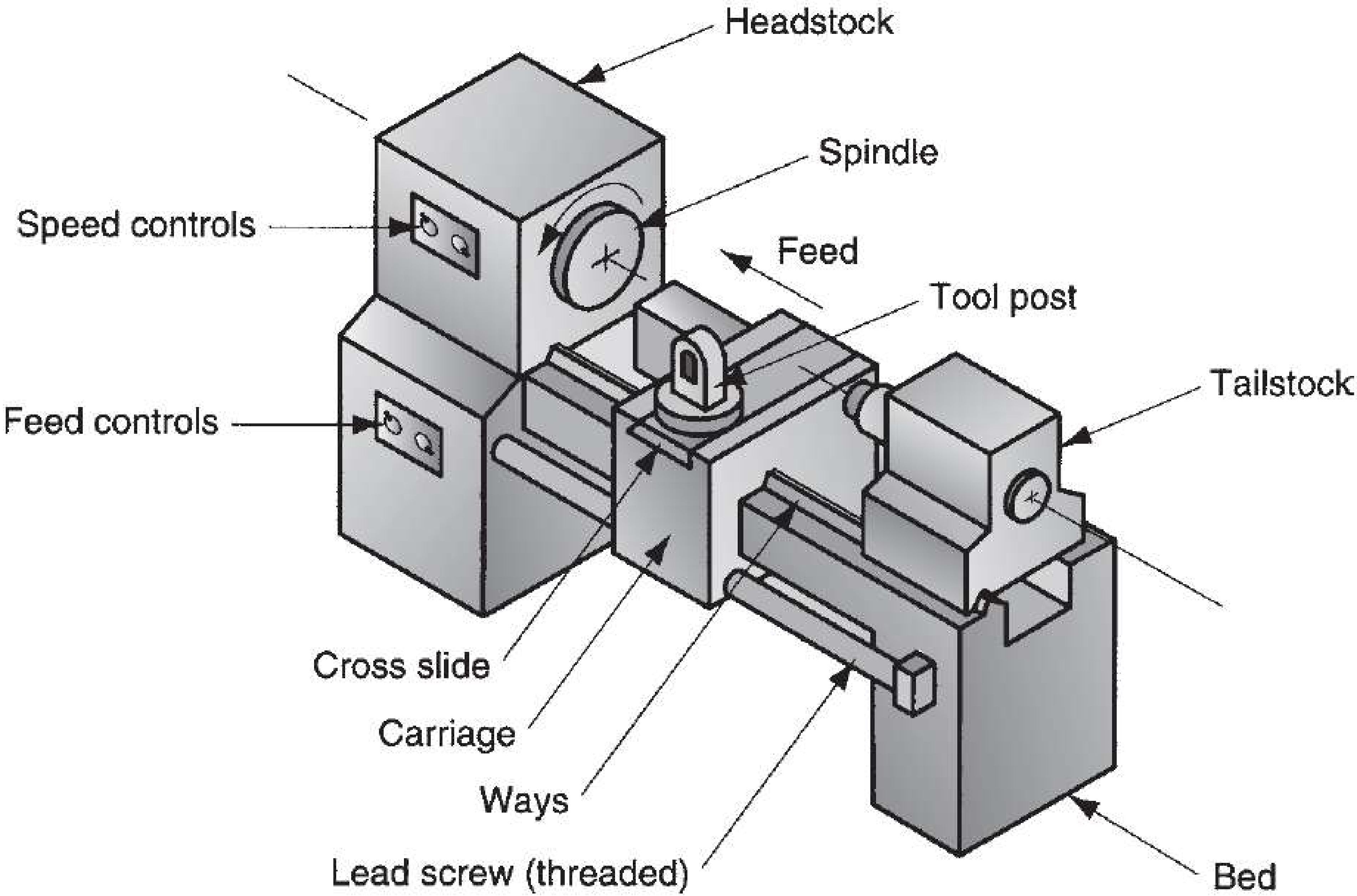
Some of the types of the lathes are…

- Engine lathe
- Bench Lathe
- Special purpose lathe
- Tracer lathe
- Automatic lathe
- Turret lathe
- Computer controlled lathe

Engine Lathe

- The **basic lathe** used for turning and related operations is an engine lathe.
- It is a **versatile** machine tool, manually operated, and widely used in **low and medium production**.
- The term engine dates from the time when these machines were **driven by steam engines**.

Engine Lathe



Engine Lathe

- The basic lathe used for turning and related operations is an **engine lathe**.
- The term engine dates from the time when these machines were driven by steam engines.
- The **headstock** contains the drive unit to rotate the **spindle**, which rotates the **work**.
- Opposite the headstock is the **tailstock**, in which a center is mounted to support the other end of the workpiece.
- The cutting tool is held in a **tool post** fastened to the **cross-slide**, which is assembled to the **carriage**.
- The carriage is designed to slide along the **ways** of the lathe in order to feed the tool parallel to the **axis of rotation**.
- The ways are built into the **bed** of the lathe, providing a rigid frame for the machine tool.

Engine Lathe

1. Horizontal turning machines: the spindle axis is horizontal
   - This is appropriate for the majority of turning jobs, in which the length of job is greater than the diameter.
2. Vertical turning machines: the spindle axis is vertical
   a. For jobs in which the diameter is large relative to length and the work is heavy, it is more convenient to orient the work so that it rotates about a vertical axis

Lathe designation: Swing & Maximum distance between centers

1. The **swing** is the maximum workpart diameter that can be rotated in the spindle, determined as twice the distance between the centerline of the spindle and the ways of the machine.
2. The **maximum distance between centers** indicates the maximum length of a workpiece that can be mounted between headstock and tailstock centers.

Bench Lathes

- Placed on a workbench or a table.
- Have low power,
- Usually operated by hand feed,
- Used to machine small work pieces.
- **Tool room lathes** have high precision, enabling the machining of parts to close dimensional tolerances.

Special-purpose Lathes

- Used for applications such as
  a. railroad wheels,
  b. gun barrels, and
  c. rolling-mill rolls

  with workpiece sizes as large as 1.7 m in diameter by 8 m in length and capacities of 450 kW

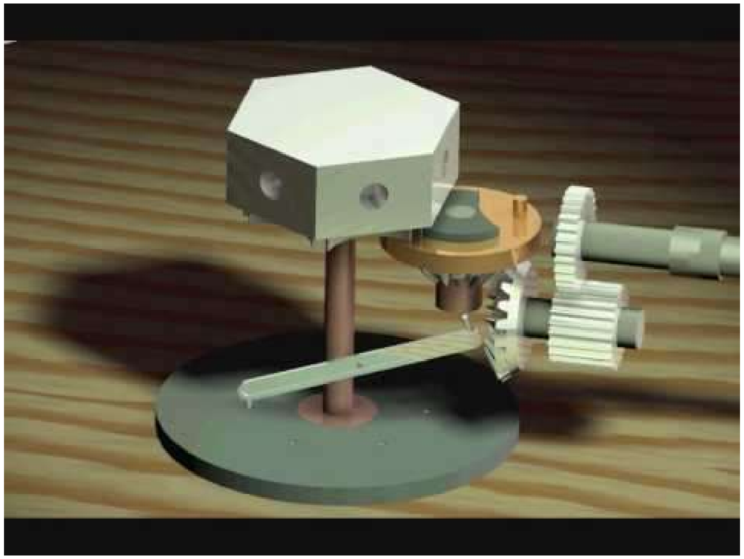
Tracer Lathes

- Also called a duplicating lathe or contouring lathe
- Have special attachments that are capable of turning parts with various contours
- The cutting tool follows a path that duplicates the contour of a template, similar to a pencil following the shape of a plastic stencil.

Automatic Lathes

- Suitable for medium- to high-volume production
- In a fully automatic lathe,
  - parts are fed and removed automatically,
- In semi-automatic machines,
  - parts are fed and removed manually.

- Several cutting tools (usually as many as six) are mounted on the hexagonal main ***turret***, which is rotated after each specific cutting operation is completed.
- Capable of performing multiple cutting operations, such as turning, boring, drilling, thread cutting, and facing
- Are versatile



Turret

Turret Lathe

Computer-controlled Lathes

- Movement and control of the machine tool and its components are achieved by computer numerical control (CNC)
- Generally are equipped with one or more turrets, and
- Each turret is equipped with a variety of tools and performs several operations on different surfaces of the workpiece

Computer-controlled Lathes

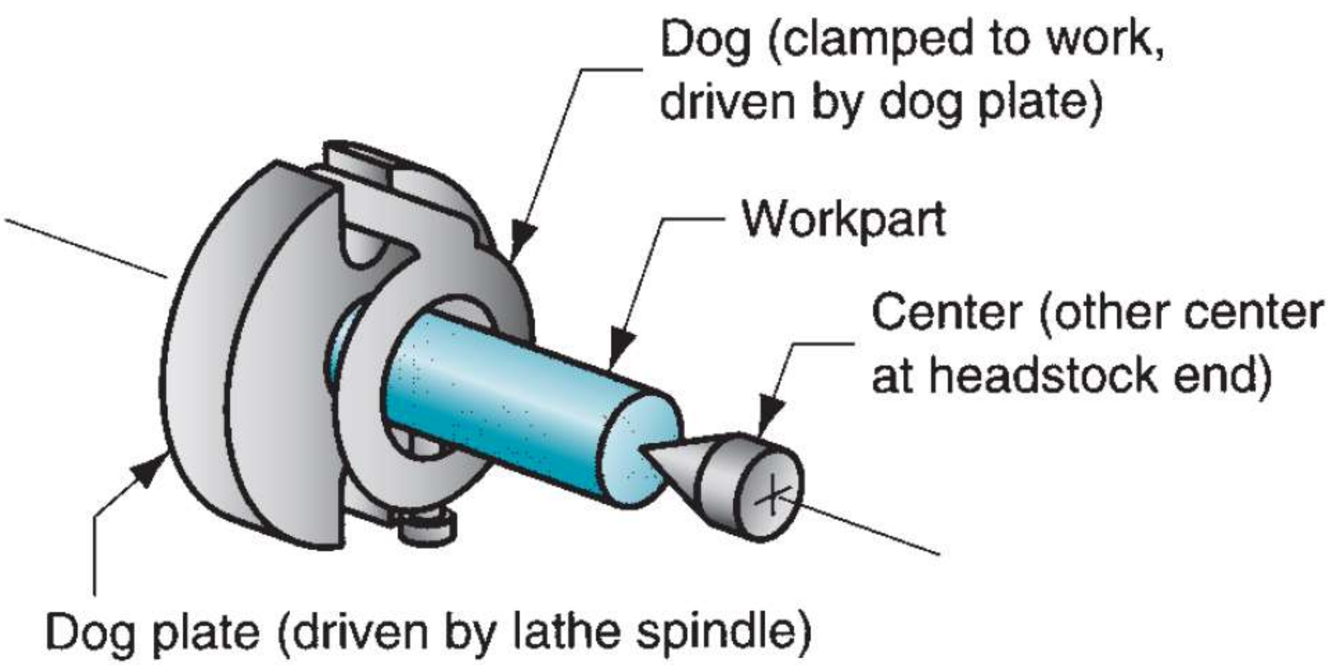
- They are equipped with automatic tool changers (ATCs).
- Their operations are reliably repetitive, maintain the desired dimensional accuracy,
- Require less skilled labor (once the machine is set up).
- They are suitable for low- to medium volume production.

Methods of Holding the Work in a Lathe

- These work holding methods consist of various mechanisms to grasp the work, centre and support it in position along the spindle axis, and rotate it.
- There are four common methods used to hold work parts in turning
  a. mounting the work between centres
  b. chuck,
  c. collet,
  d. face plate

a. mounting the work between centres

- **Between centers** refers to the use of two centers, one in the headstock and the other in the tailstock
- This method is appropriate for parts with large length-to-diameter ratios



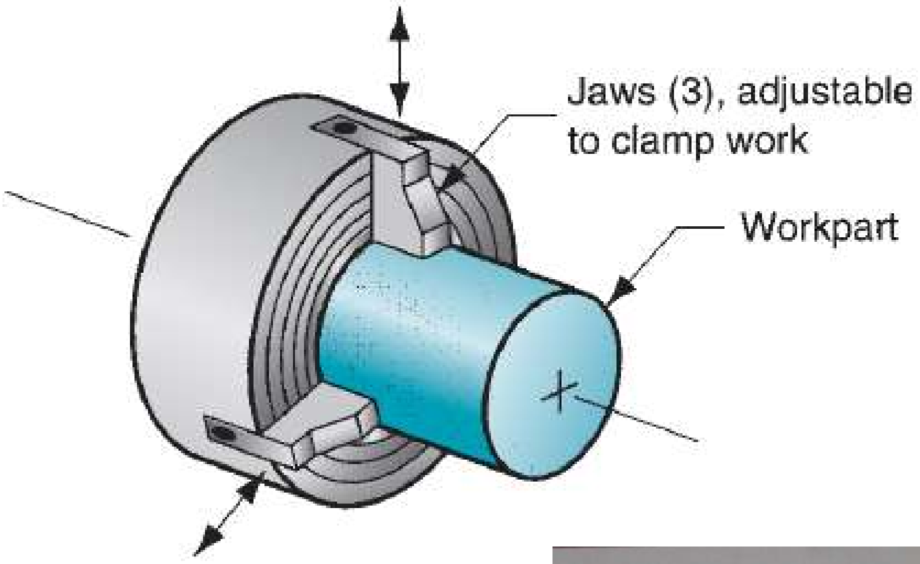
a. mounting the work between centres

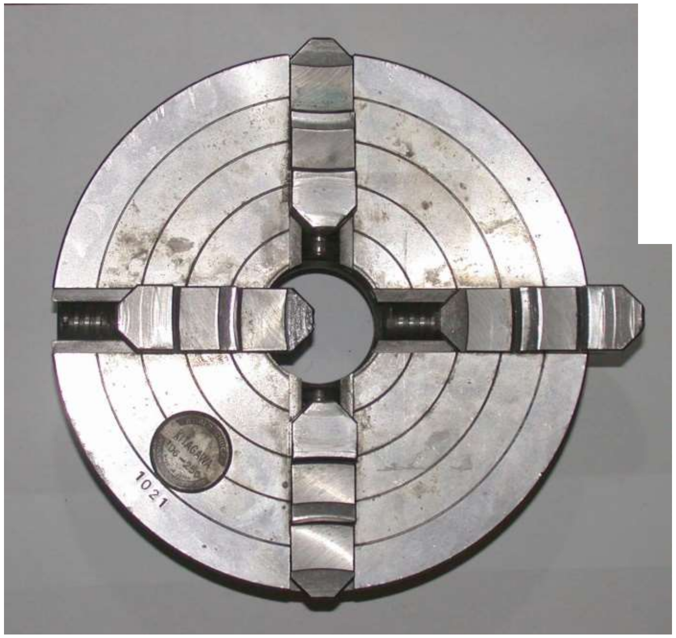
- At the headstock center, a device called a ***dog*** is attached to the outside of the work and is used to drive the rotation from the spindle.

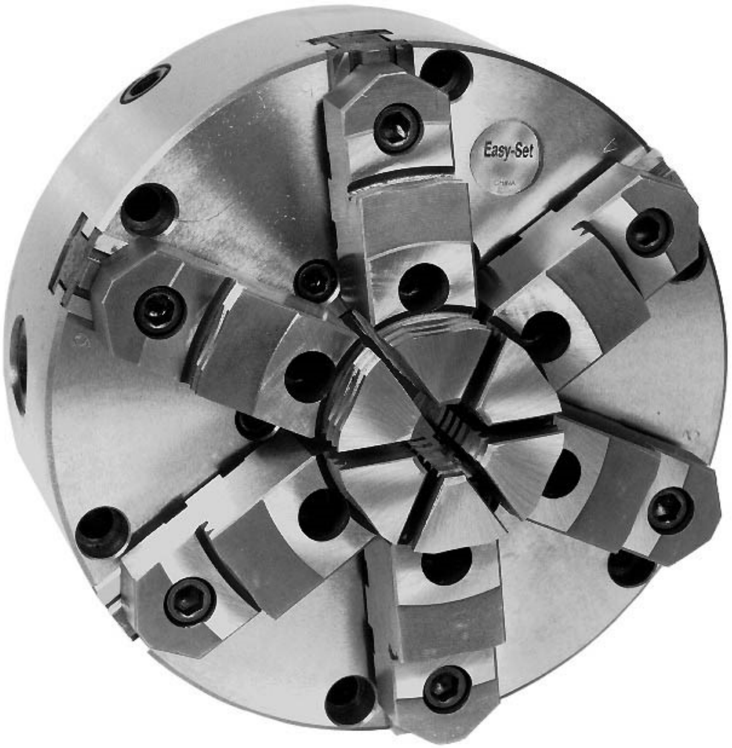
a. mounting the work between centres

- The tailstock center has a cone-shaped point which is inserted into a tapered hole in the end of the work.
- The tailstock center is either a ‘‘**live**’’ center or a ‘‘**dead**’’ center.
- A **live center** rotates in a bearing in the tailstock, so that there is no relative rotation between the work and the live center, hence, no friction between the center and the workpiece.
- A **dead center** is fixed to the tailstock, so that it does not rotate; instead, the workpiece rotates about it. Because of friction and the heat buildup that results, this setup is normally used at lower rotational speeds.
- The live center can be used at higher speeds.

b) Chuck





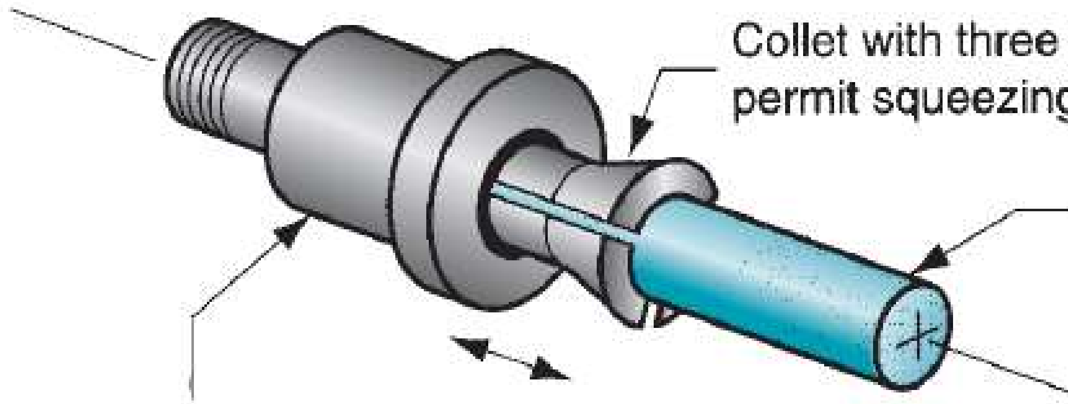


b) Chuck

- The **chuck** is available in several designs, with **three or four** jaws to grasp the cylindrical work part on its outside diameter.
- The jaws are often designed so they can also **grasp the inside diameter** of a tubular part.
- A **self-centering chuck** has a mechanism to move the jaws in or out simultaneously, thus centering the work at the spindle axis.
- Other chucks allow independent operation of each jaw.
- Chucks can be used with or without a tailstock center.
- For long workbars, the tailstock center is needed for support.

c) collet

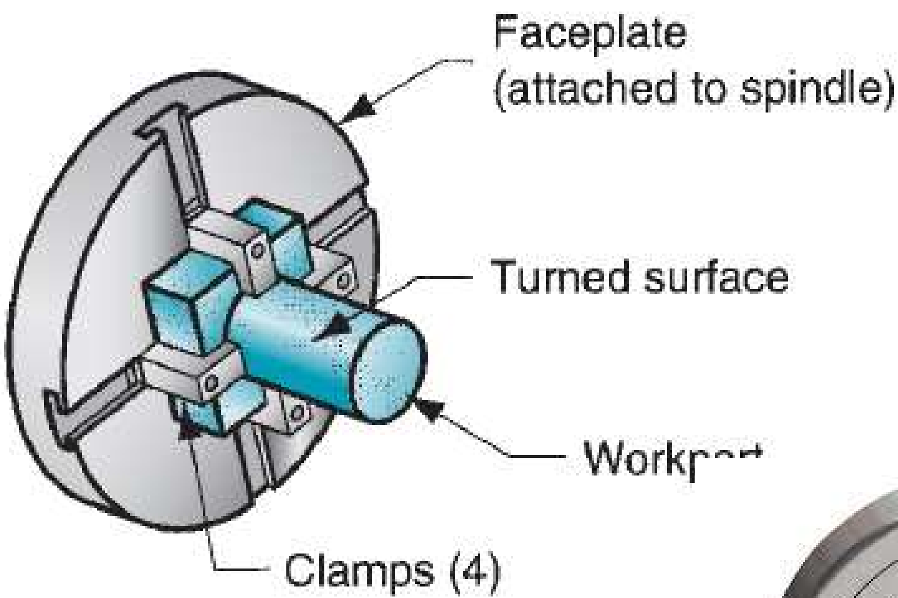
- A collet consists of a tubular bushing with longitudinal slits running over half its length and equally spaced around its circumference

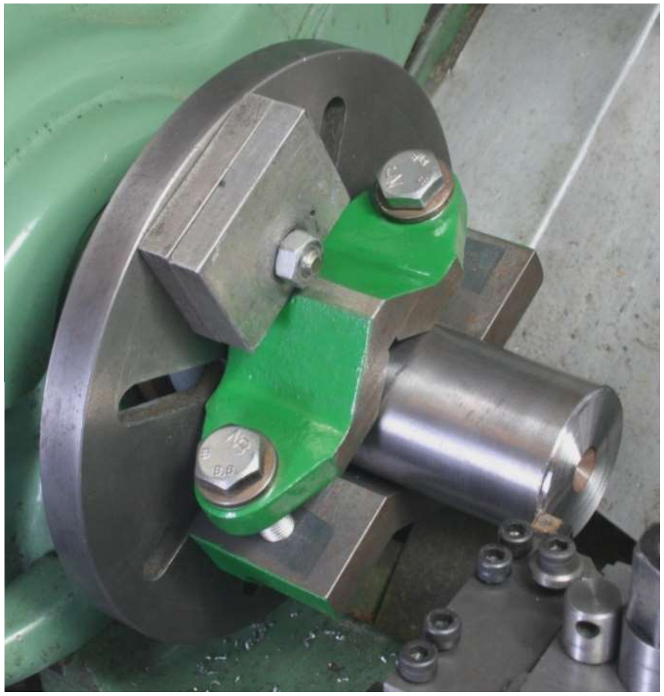


Advantage: the collet grips nearly the entire circumference of the part, making the device well suited particularly for parts with small cross sections.

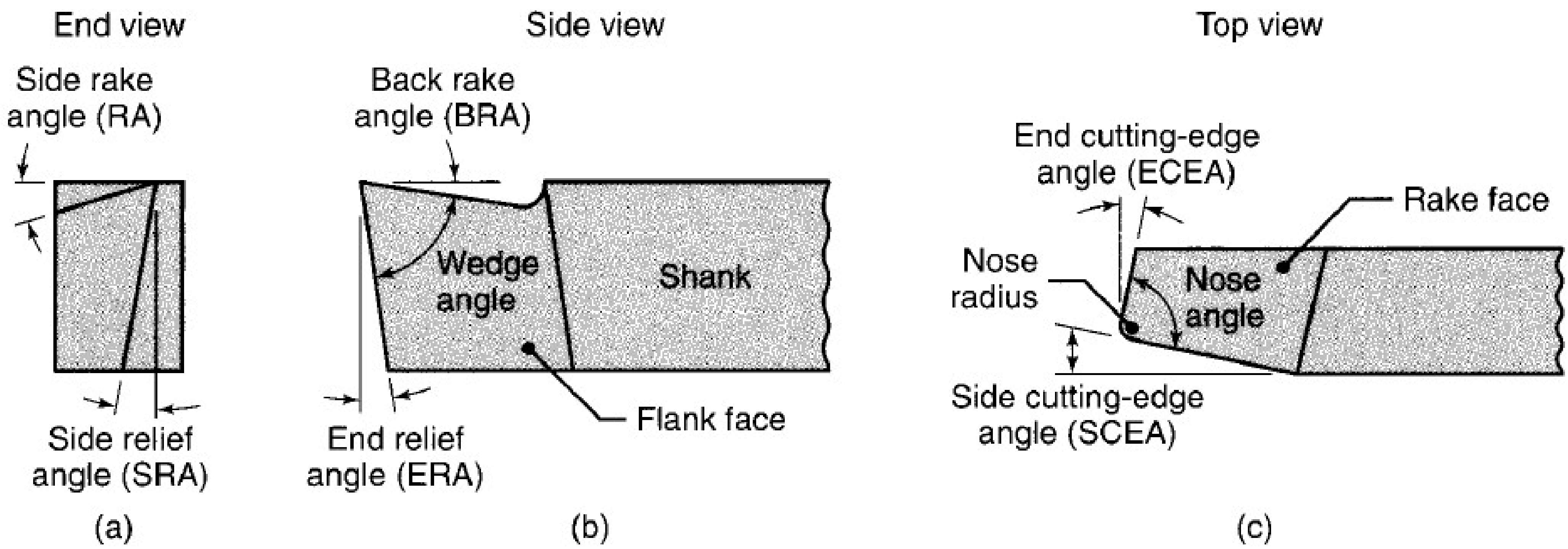
d) Face plate

- Is a workholding device that fastens to the lathe spindle and is used to grasp parts with irregular shapes.
- The faceplate is therefore equipped with the custom-designed clamps for the particular geometry of the part.





Tool Geometry

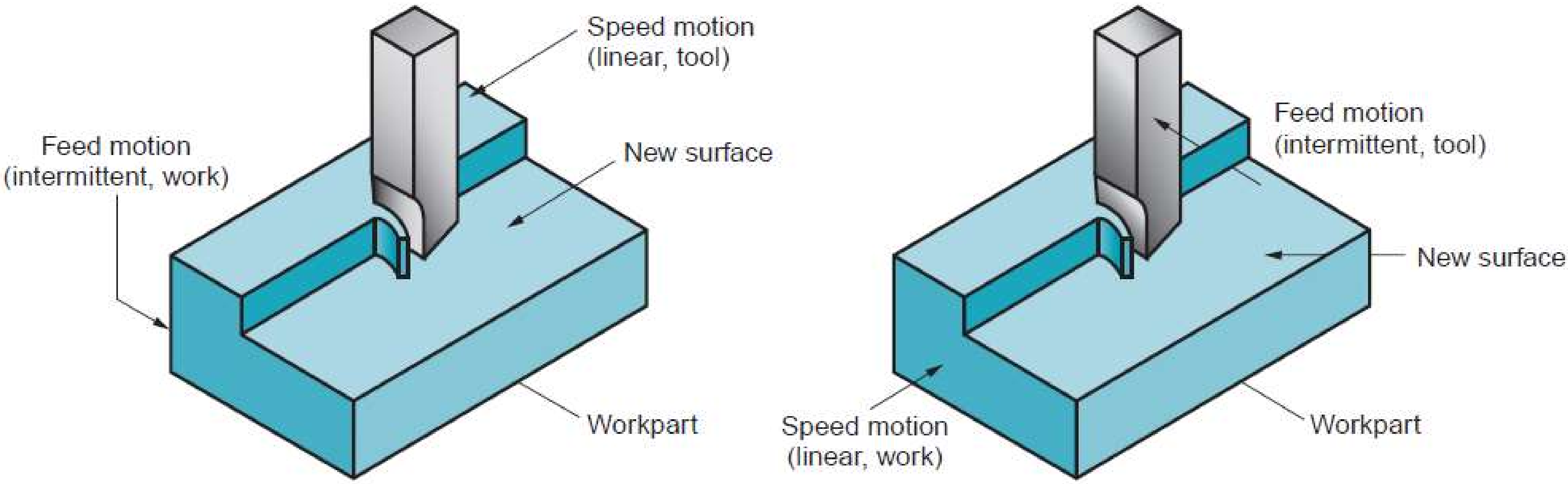


Tool Geometry

- **Side rake angle** is more important than the back rake angle, although the latter usually controls the direction of chip flow. For machining metals and using carbide inserts, these angles typically are in the range from -5° to 5°.
- **Cutting-edge angle** affects chip formation, tool strength, and cutting forces to various degrees. Typically, the cutting-edge angle is around 15°.
- **Relief angle** controls interference and rubbing at the tool-workpiece interface. If it is too large, the tool tip may chip off; if it is too small, flank wear may be excessive. Relief angles typically are 5 °.
- **Nose radius** affects surface finish and tool-tip strength. The smaller the nose radius (sharp tool), the rougher the surface finish of the workpiece and the lower the strength of the tool. However, large nose radii can lead to tool chatter

SHAPING AND PLANING

- Shaping and planing are similar operations, both involving the use of a single-point cutting tool moved linearly relative to the workpart.
- In conventional shaping and planing, **a straight, flat surface** is created by this action.
- In **shaping**, the speed motion is accomplished by moving the cutting tool; while in **planing**, the speed motion is accomplished by moving the workpart.
- Unlike turning, **interrupted cutting** occurs in shaping and planing, subjecting the tool to an **impact loading** upon entry into the work.
- These machine tools are limited to **low speeds** due to their start-and-stop motion

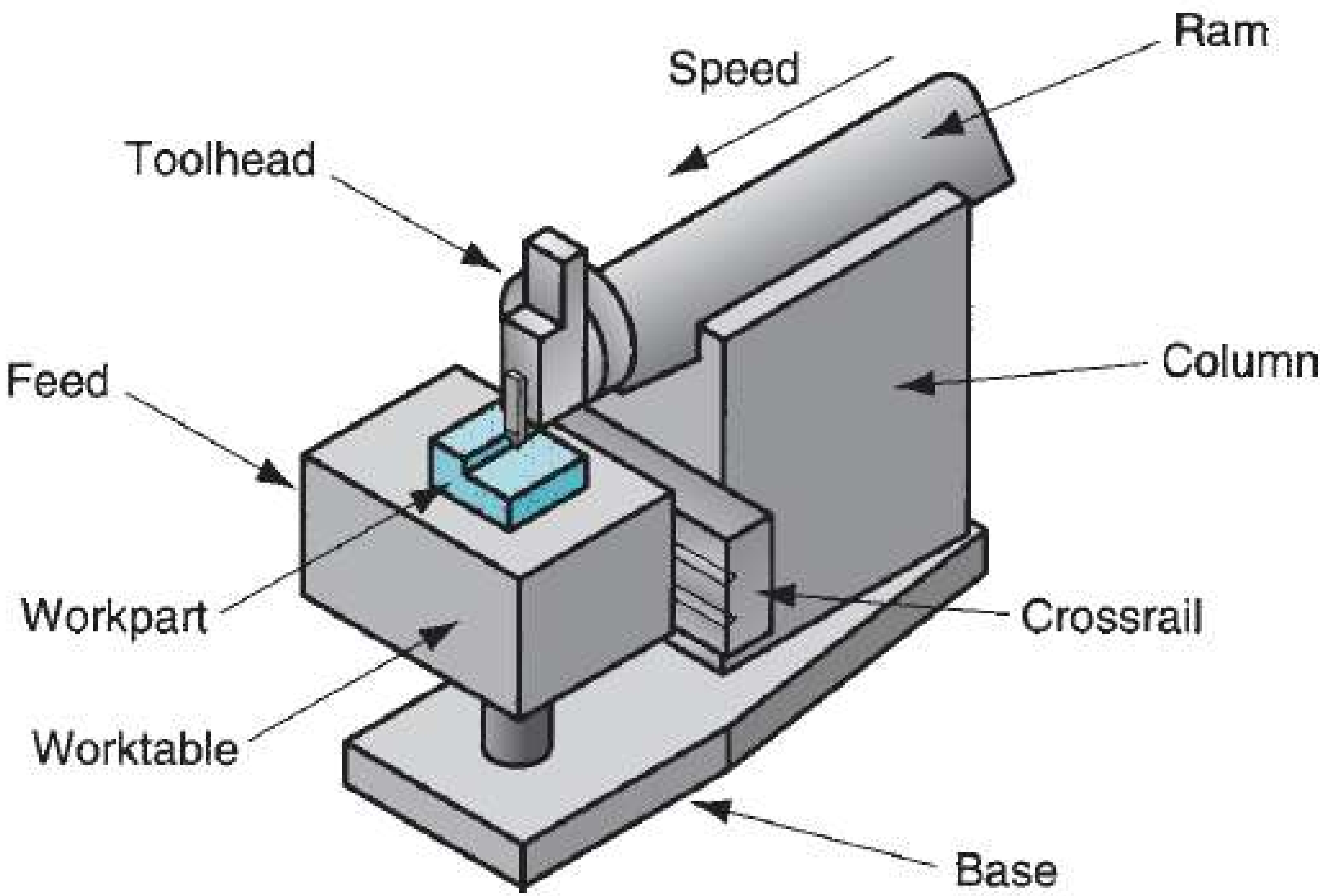


(a) Shaping

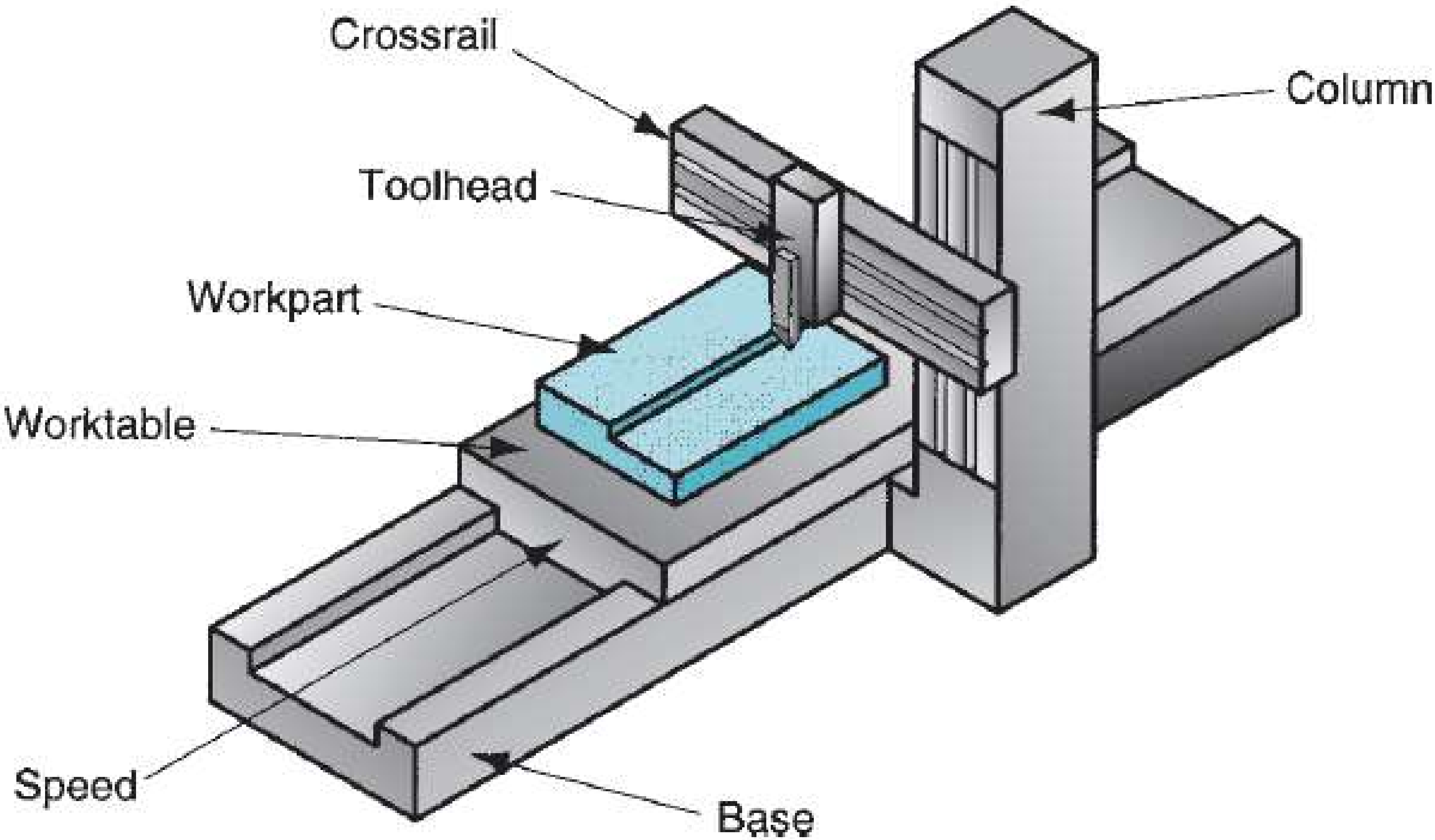
(b) Planing

Shaping

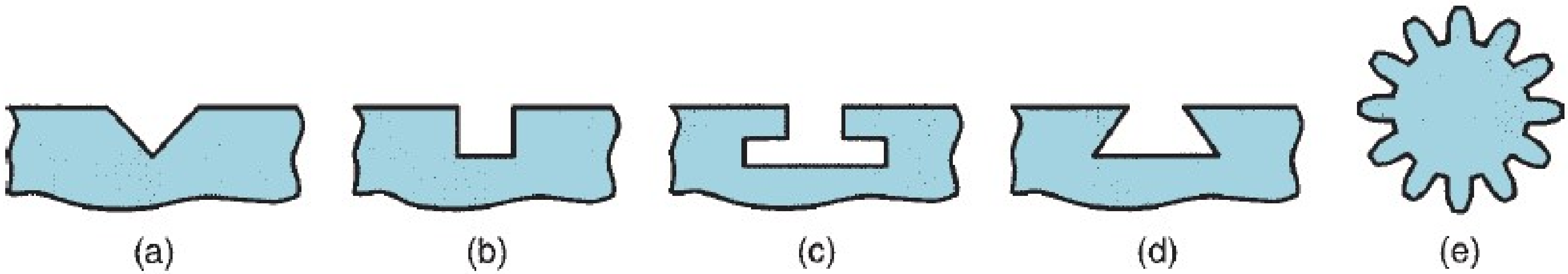
- performed on a machine tool called a **shaper**
- The components of the shaper include a **ram**, which moves relative to a **column** to provide the cutting motion, and a worktable that holds the part and accomplishes the **feed** motion.
- The motion of the ram consists of a **forward stroke** to achieve the cut, and a **return stroke** during which the tool is lifted slightly to clear the work and then reset for the next pass.
- On completion of each return stroke, the worktable is advanced laterally relative to the ram motion in order to **feed** the part.
- Feed is specified in **mm/stroke**
- The drive mechanism for the ram can be either hydraulic or mechanical
- Drives are designed to achieve higher speeds on the return (noncutting) stroke than on the forward (cutting) stroke.


Ram
Speed
Toolhead
Feed
Column
Workpart
Crossrail
Worktable
Base

Planing



- Shaping and planing can be used to machine shapes other than flat surfaces. The restriction is that the cut surface must be straight.
- This allows the cutting of **grooves, slots, gear teeth, and other shapes**



(a) V-groove, (b)square groove, (c) T-slot, (d) dovetail slot, and (e) gear teeth.

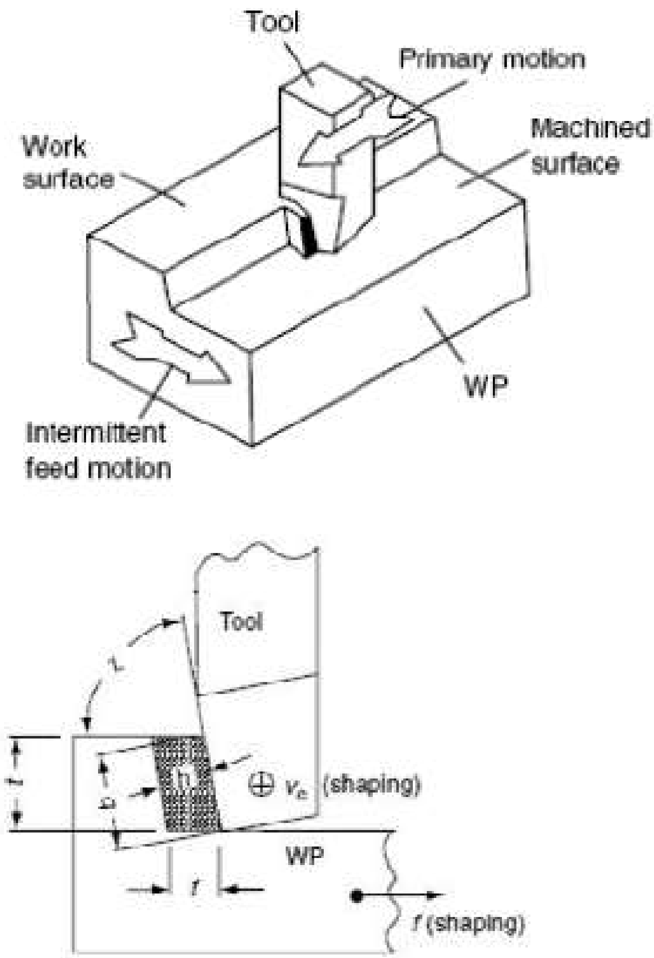
Slotting

- **Slotters** (Vertical shapers) are used to machine notches, keyways, and dies.
- Because of low production rates, only special-purpose shapers are in common use today.

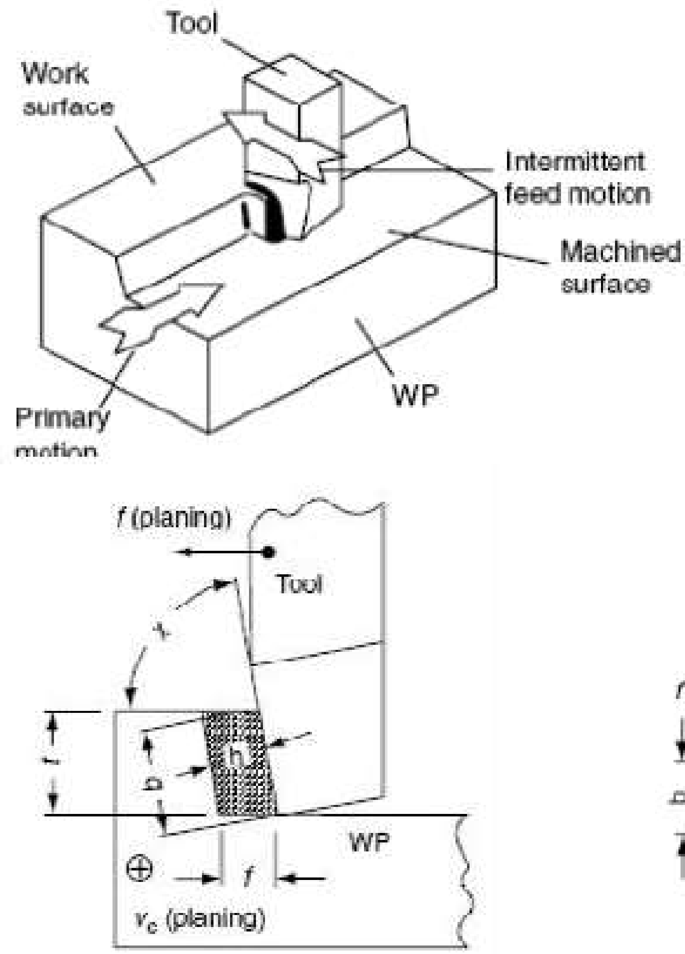
Difference among Shaper, Planer and Slotter

	Shaper	Planer	Slotter
1	The work is stationary and the tool on the ram is moved back and forth across the work.	The tool is stationary and the workpiece on the table travels back and forth under the tool	The work is held stationary and the tool on the ram is moved up and down across the work.
2	Used for shaping much smaller jobs	Meant for much larger jobs. Jobs as large as 6 metre wide and twice as long can be machined.	It is used for making slots in smaller jobs.
3	Is a light machine	It is a heavy duty machine.	Slotting is light machine
4	Can employ light cuts and finer feed.	Can employ heavier cuts and coarse feed.	Can employ light cuts and finer feed.
5	Uses one cutting tool at a time	Several tools can cut simultaneously.	Shaper uses one cutting tool at a time
6	Driven using quick- return link mechanism	The drive on the planer table is either by gears or by hydraulic means	The rams are either crank-driven or hydraulically driven.
7	It is less rigid and less robust	Better rigidity that give more accuracy on machined surfaces.	It is less rigid and less robust

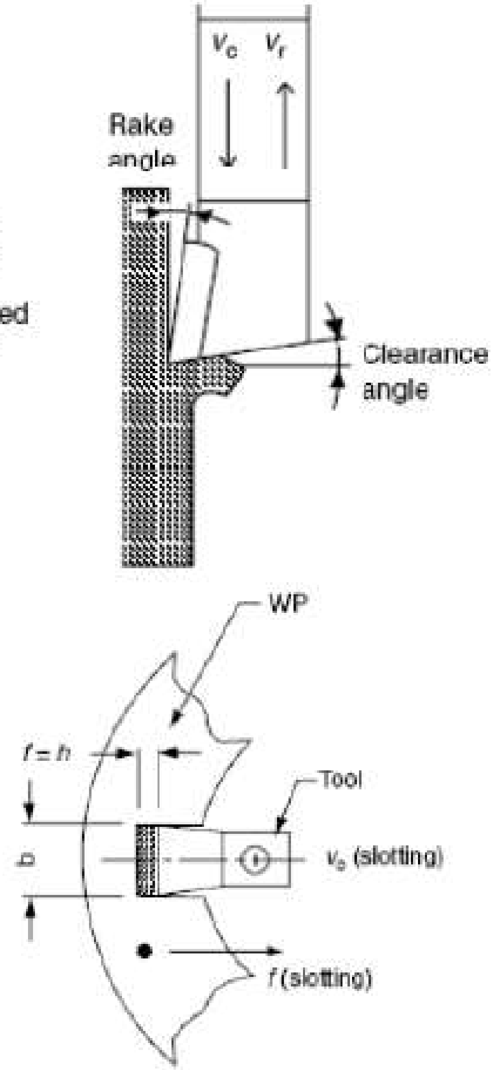
Difference among Shaper, Planer and Slotter



a) Shaping



b) Planning

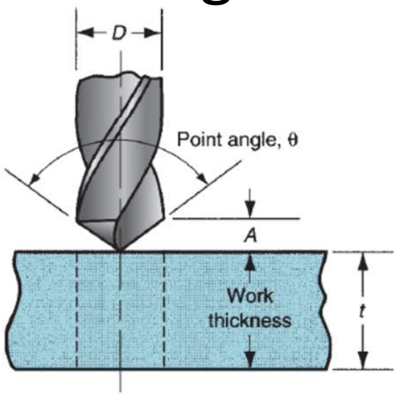


c) Slotting

Drilling and Related Operations

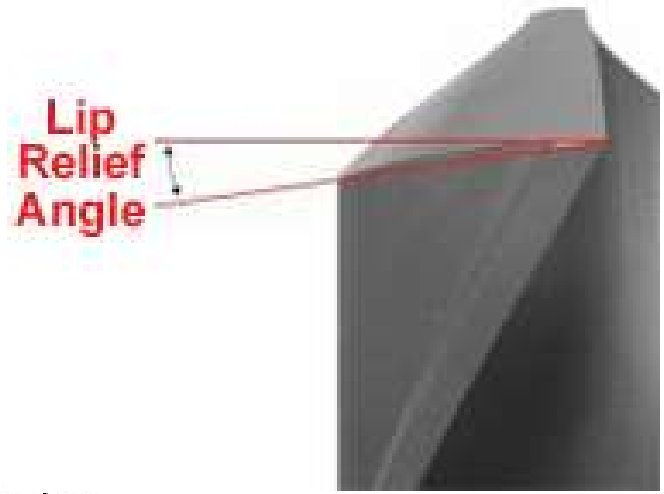
Drilling

- Drilling is a machining operation used to create a round hole in a workpart
- Drilling is usually performed with a rotating cylindrical tool that has **two cutting edges** on its working end.
- The tool is called a **drill** or **drill bit**
- The most common drill bit is the twist drill
- The rotating drill **feeds** into the stationary workpart to form a hole whose **diameter is equal to the drill diameter**.
- Drilling is customarily performed on a **drill press**, although other machine tools also perform this operation

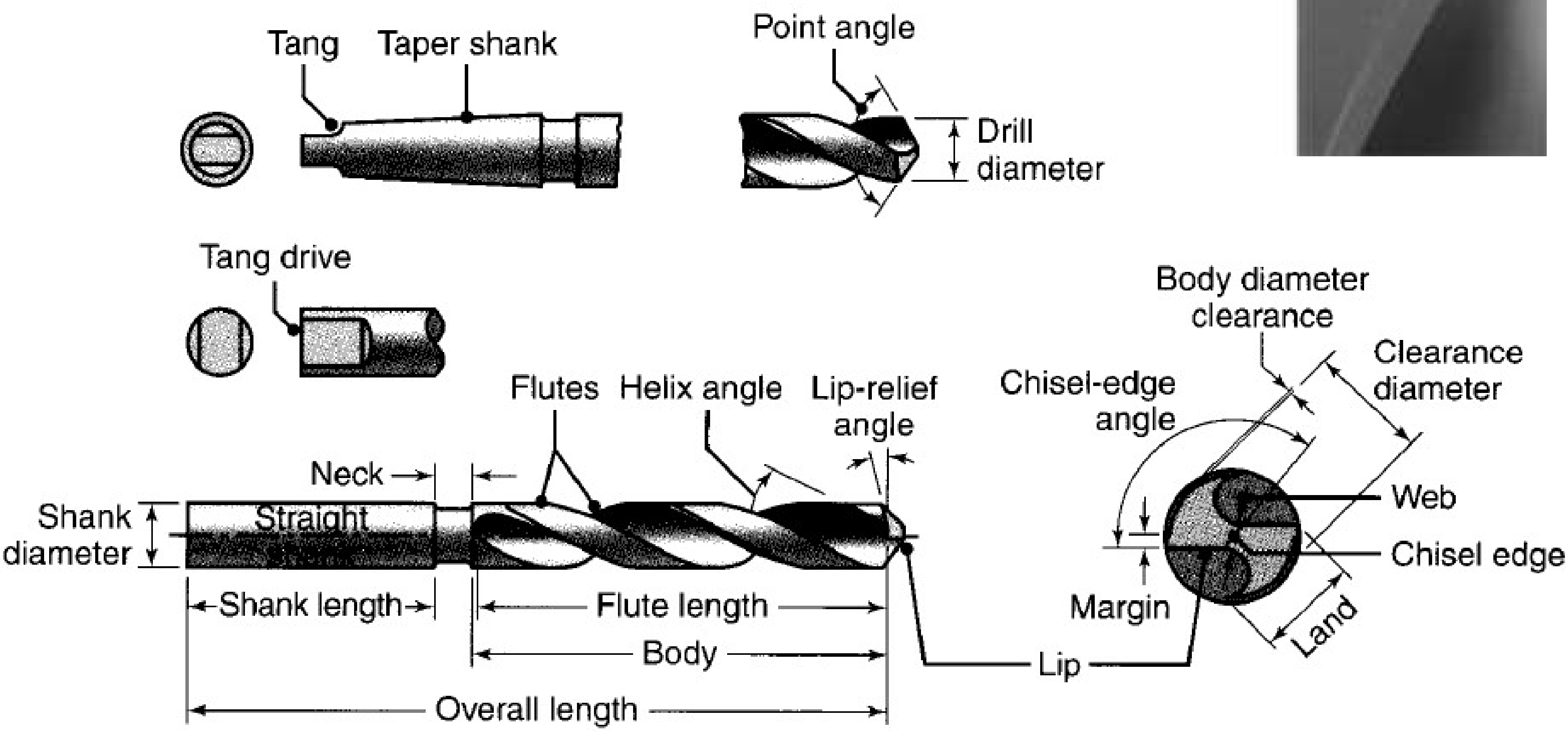


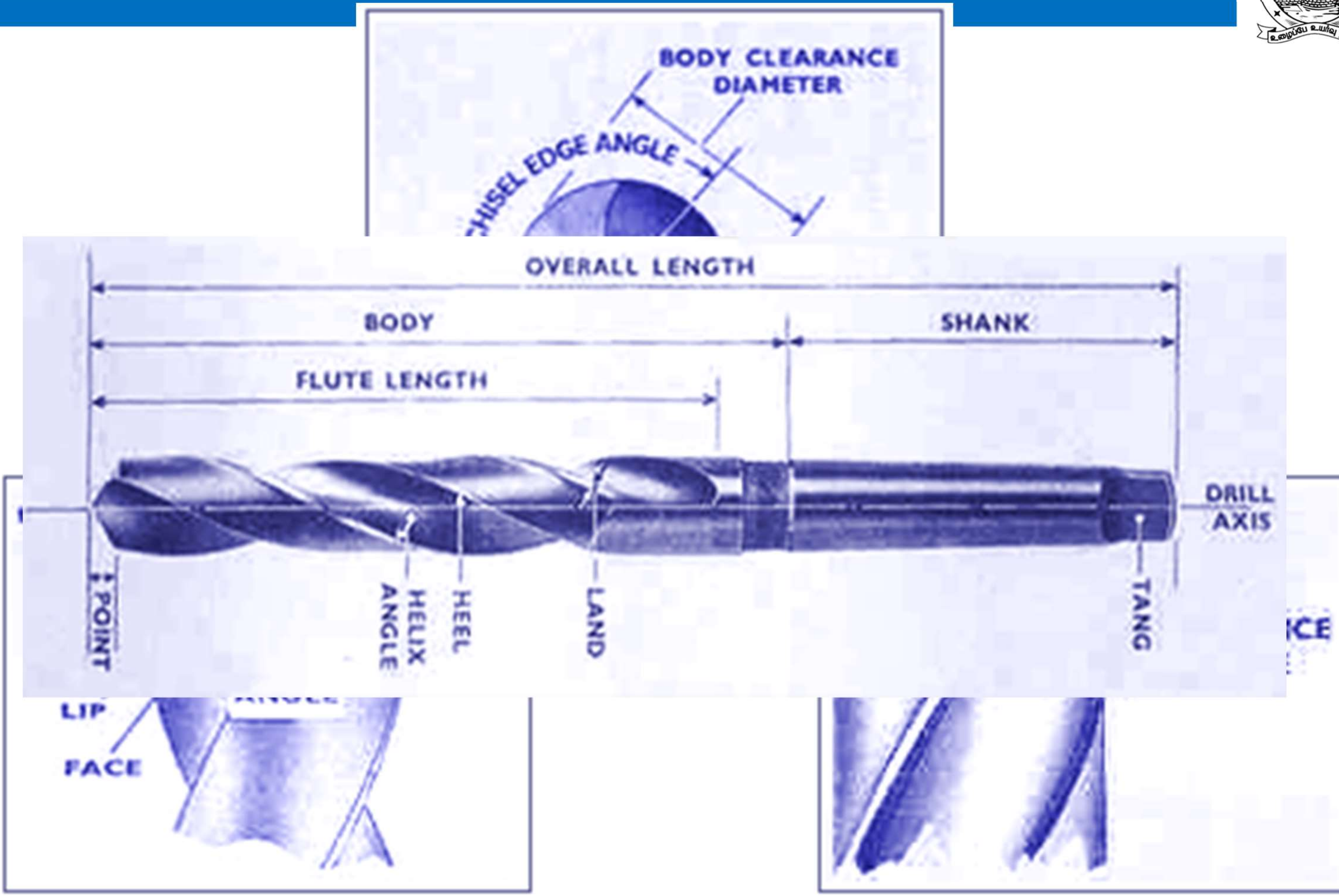
Drills

- Chisel-edge drill



Chisel-edge drill




BODY CLEARANCE
DIAMETER
EDGE ANGLE
OVERALL LENGTH
BODY
SHANK
FLUTE LENGTH
DRILL
AXIS
POINT
HELIX
ANGLE
HEEL
LAND
TANG
LIP
FACE

General Capabilities of Drilling and Boring Operations

Cutting tool	Diameter range (mm)	Hole depth/diameter	
		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

Drilling operation

- The chips that are produced within the hole move in a direction opposite to the forward movement of the drill.
- Thus, chip disposal and ensuring cutting-fluid effectiveness can present significant difficulties in drilling.
- Drills generally leave a burr on the bottom surface upon breakthrough, necessitating deburring operations

- Let ***N*** represent the spindle rev/min,

$$N = \frac{v}{\pi D}$$

where v = cutting speed, mm/min and D = the drill diameter, mm (in).

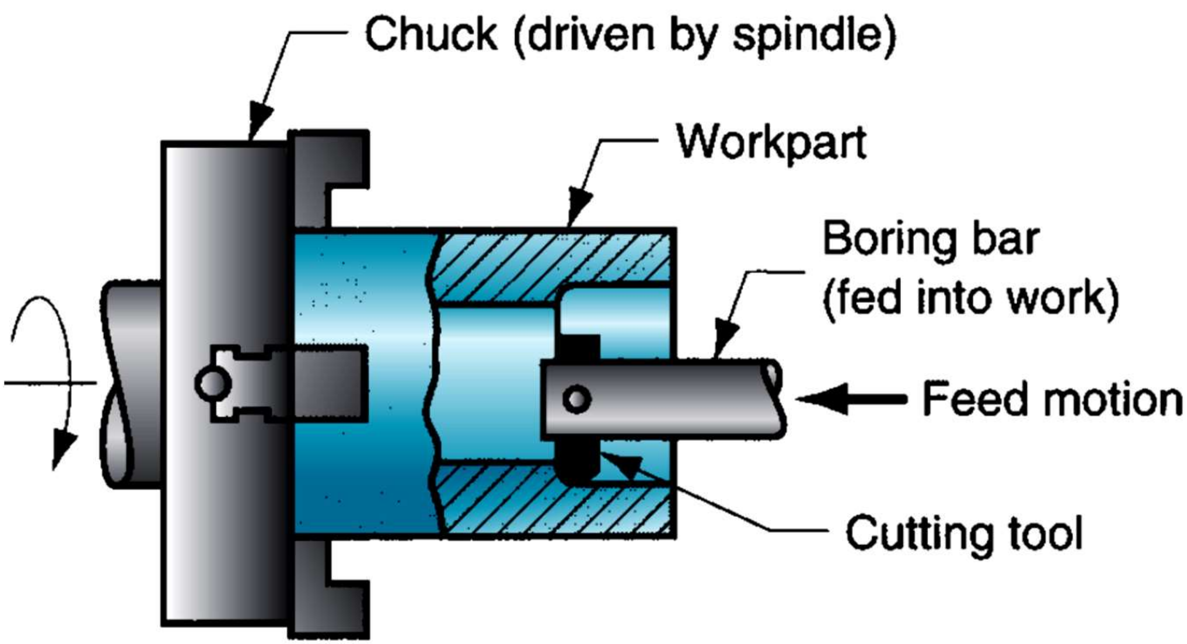
- Feed f in drilling is specified in mm/rev.
- Since there are (usually) two cutting edges at the drill point, the uncut chip thickness (chip load) taken by each cutting edge is half the feed. Feed can be converted to feed rate using the same equation as for turning: $f_r = Nf$

where f_r = feed rate, mm/min

Boring

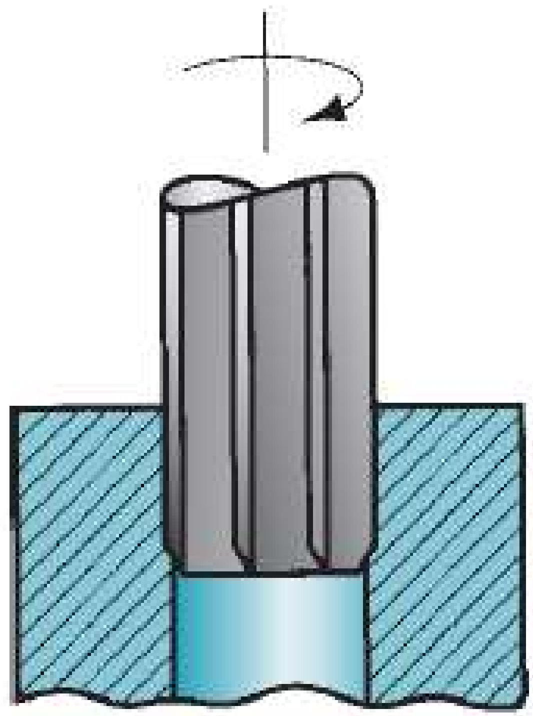
- Boring is similar to turning.
- It uses a **single-point tool** against a rotating workpart.
- The difference is that boring is performed on the inside diameter of an existing hole rather than the outside diameter of an existing cylinder. In effect, boring is an internal turning operation.

Boring Bar



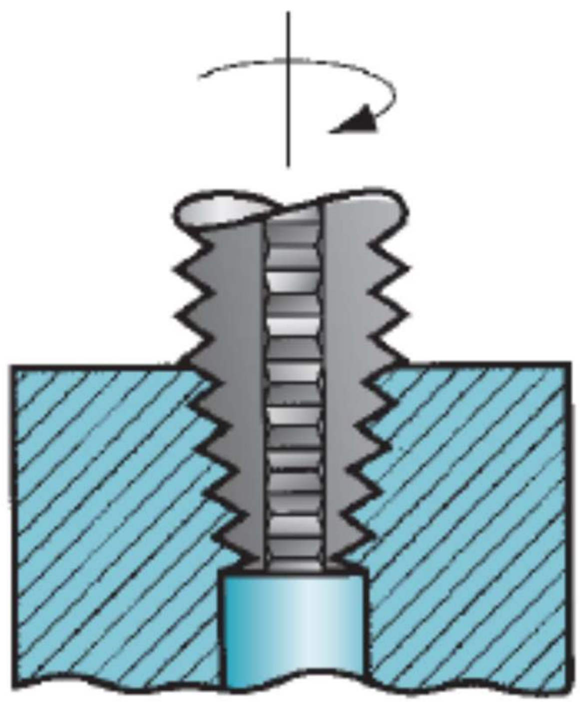
Reaming

- Reaming is used to provide a better tolerance on its diameter, and to improve its surface finish. The tool is called a reamer, and it usually has straight flutes.



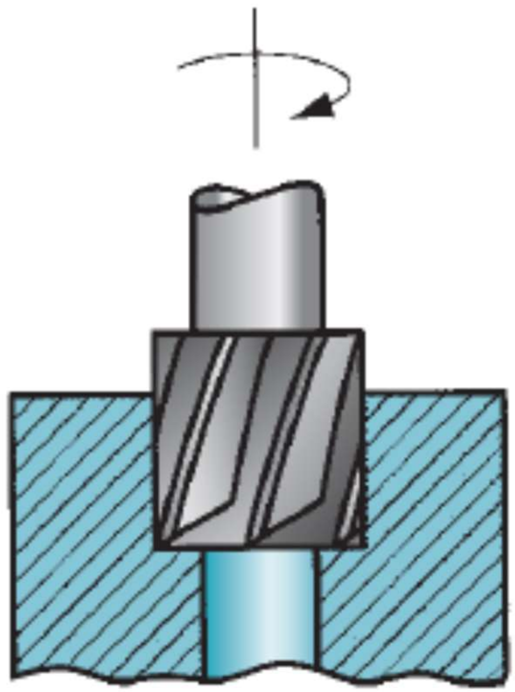
Tapping

- This operation is performed by a ***tap*** and is used to provide internal screw threads on an existing hole.



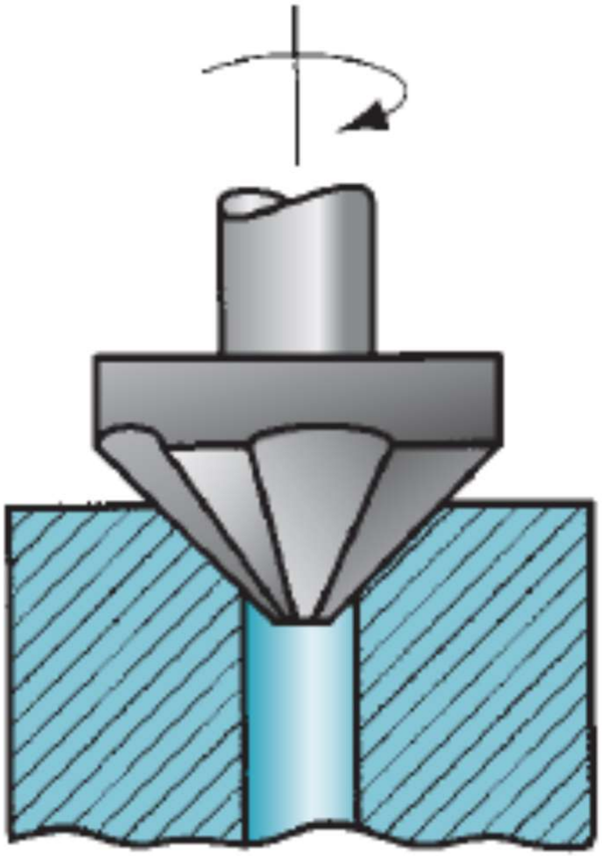
Counterboring

- Counterboring provides a stepped hole, in which a larger diameter follows a smaller diameter partially into the hole. A counterbored hole is used to seat bolt heads into a hole so the heads do not protrude above the surface.



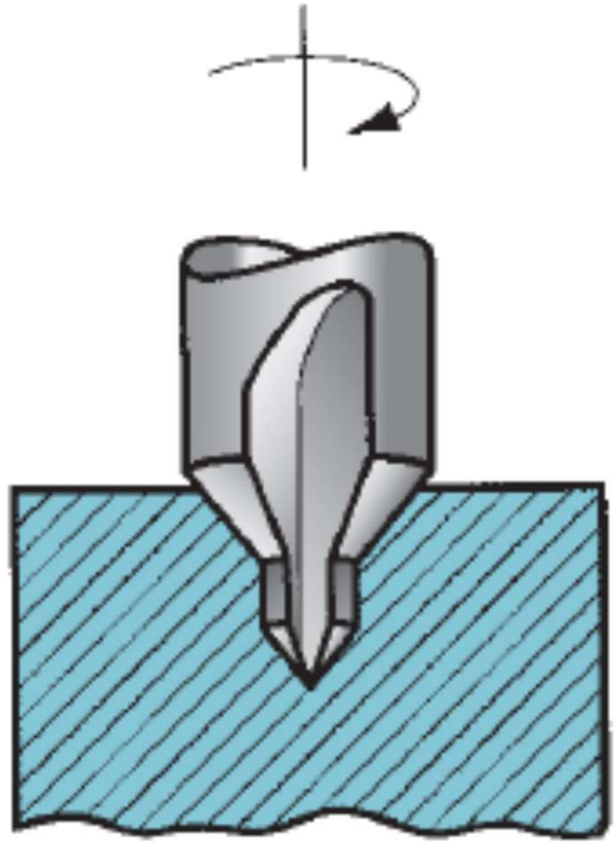
Countersinking

- This is similar to counterboring, except that the step in the hole is cone-shaped for flat head screws and bolts.



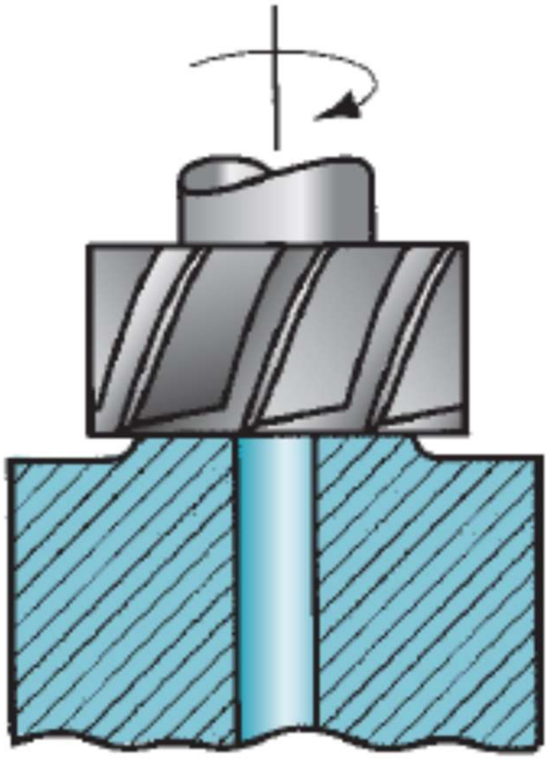
Centering

- Also called center drilling, this operation drills a starting hole to accurately establish its location for subsequent drilling. The tool is called a **center drill**.



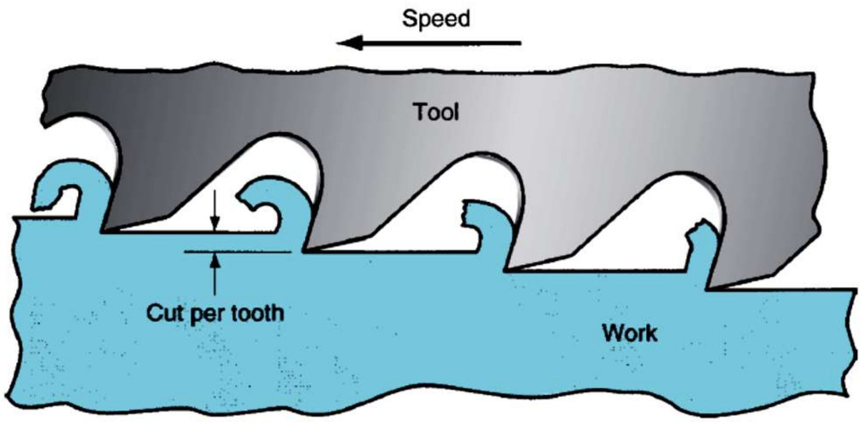
Spot facing

- Spot facing is similar to milling. It is used to provide a flat machined surface on the workpart in a localized area.



BROACHING

- Broaching is performed using a multiple-teeth cutting tool by moving the tool linearly relative to the work in the direction of the tool axis



1. The machine tool is called a *broaching machine*, and the cutting tool is called a *broach*.
2. Advantages include good surface finish, close tolerances, and a variety of work shapes.
3. Owing to the complicated and often custom shaped geometry of the broach, tooling is expensive.

CUTTING CONDITIONS IN TURNING

The rotational speed in turning is related to the desired cutting speed at the surface of the cylindrical workpiece by the equation

$$N = \frac{v}{\pi D_o} \tag{1}$$

where N = rotational speed, rev/min; v = cutting speed, m/min (ft/min); and D_o = original diameter of the part, m (ft).

The turning operation reduces the diameter of the work from its original diameter D_o to a final diameter D_f, as determined by the depth of cut d:

$$D_f = D_o - 2d \tag{2}$$

The feed in turning is generally expressed in mm/rev (in/rev). This feed can be converted to a linear travel rate in mm/min (in/min) by the formula

$$f_r = Nf \tag{3}$$

where f_r = feed rate, mm/min (in/min); and f = feed, mm/rev (in/rev).

The time to machine from one end of a cylindrical workpart to the other is given by

$$T_m = \frac{L}{f_r} \tag{4}$$

where T_m = machining time, min; and L = length of the cylindrical workpart, mm (in). A more direct computation of the machining time is provided by the following equation:

$$T_m = \frac{\pi D_o L}{f v} \tag{5}$$

where D_o = work diameter, mm (in); L = workpart length, mm (in); f = feed, mm/rev (in/rev); and v = cutting speed, mm/min (in/min). As a practical matter, a small distance is usually added to the workpart length at the beginning and end of the piece to allow for approach and overtravel of the tool. Thus, the duration of the feed motion past the work will be longer than T_m.

The volumetric rate of material removal can be most conveniently determined by the following equation:

$$R_{MR} = vfd \tag{6}$$

where R_{MR} = material removal rate, mm^3/min (in^3/min). In using this equation, the units for f are expressed simply as mm (in), in effect neglecting the rotational character of turning. Also, care must be exercised to ensure that the units for speed are consistent with those for f and d.

Example 1

A cylindrical Workpiece has *220 mm* in diameter and *800 mm* long is to be turned in an engine lathe.

Cutting conditions are as follows:

- Cutting speed = *3.15 m/s*
- Feed = *0.45 mm/rev*
- Depth of cut = *2.25 mm*

Determine -

(a) Cutting time

(b) Metal removal rate

Problem - 1

$D = 220\,mm$

$L = 800\,mm$

$v = 3.15\,m/s$

$f = 0.45\,mm/rev$

$d = 2.25\,mm$

① $T_M = \dfrac{\pi D L}{f v}$

$= \dfrac{\pi \times 220 \times 10^{-3}\,m \times 800 \times 10^{-3}\,m}{0.45 \times 10^{-3}\,\frac{m}{rev} \times 3.15\,\frac{m}{s}}$

$= \cancel{124\ sec}$

$= 390.06\,sec$

$\boxed{T_M = 6.501\,min}$

② $R_{MR} = v f d$

$= 3.15\,\frac{m}{sec} \times 0.45 \times 10^{-3}\,\frac{m}{rev} \times 2.25 \times 10^{-3}\,m$

$= 3.189 \times 10^{-6}\,m^3/sec$

$10^3\,mm = 1\,m$

$= 3.189 \times 10^{-6}\,(10^{+3}\,mm)^3/sec$

$\boxed{R_{MR} = 3.189 \times 10^{3}\,mm^3/sec}$

Problem 2

A machining process of tapered surface was carried out in a automatic lathe. The workpiece is *810 mm* long with minimum and maximum diameters of *120 mm* and *220 mm* at opposite ends. The automatic controls on the lathe permit the surface speed to be maintained at a constant value of *250 m/min* by adjusting the rotational speed as a function of workpiece diameter.

- Feed = *0.25 mm/rev*
- Depth of cut = *3.0 mm*

Determine:

(a) The time required to turn the taper and

(b) The rotational speeds at the beginning and end of the cut.

Problem - 2

$L = 810\,mm$

$D_{max} = 220\,mm$

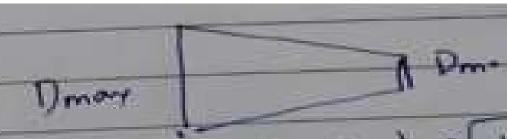
$D_{min} = 120\,mm$

$v = 250\,m/min$

$f = 0.25\,mm/rev$

$d = 3\,mm$

$$T_m = \frac{\pi D L}{f v} = \frac{A}{f v}$$



$$A = \pi (R_1 + R_2)\sqrt{h^2 + (R_1 - R_2)^2}$$

$$A = \pi (110 + 60)\sqrt{810^2 + (110 - 60)^2}$$

$$A = 433.42 \times 10^3\,mm^2$$

$$T_m = \frac{A}{f v} = \frac{433.42 \times 10^3}{0.25 \times 250 \times 10^3}$$

$$T_m = 6.934\,min$$

(b) At Begning

$$N = \frac{v}{\pi D_{min}} = \frac{250\,\frac{m}{min}}{\pi \times 120 \times 10^{-3}}$$

$$\boxed{N_{beg} = 663.14\,rev/min}$$

At End

$$N = \frac{v}{\pi D_{max}} = \frac{250}{\pi \times 220 \times 10^{-3}} = 361.71\,rev/min$$

$$\boxed{N_{end} = 361.71\,rev/min}$$

Problem 3

A workbar with *4.5 in* diameter and *52 in* length is chucked in an engine lathe and supported at the opposite end using a live center. A *46 in* portion of the length is to be turned to a diameter of *4.25 in* one pass at a speed of *450 ft/min*. The metal removal rate should be $6.75\ in^3/min$.

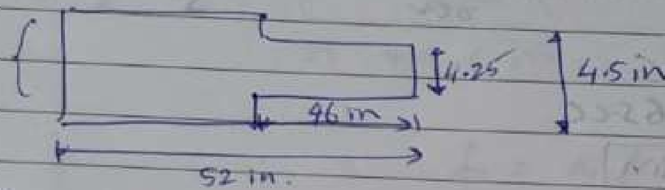
Determine

(a) The required depth of cut

(b) The required feed

(c) The cutting time

Problem 3:



$D = 4.5$ in

$L = 52$ in

Length 46 in to be made 4.25 in

$v = 450$ ft/min

$R_{MR} = 6.75\ in^3/min$

To find

(a) $d = ?$ (b) $f = ?$

(c) $T_m = ?$

(a) Depth of cut (d)

$$d = \left(\frac{4.5 - 4.25}{2}\right) = 0.125 \text{ in}$$

(b) feed (f) =

$$R_{MR} = v f d$$

$$f = \frac{R_{MR}}{v d}$$

$1 ft = 12 in$

$$= \frac{6.75\ in^3/min}{12 \times 450\ \frac{ft}{min} \times 0.125\ in}$$

$f = 0.01$ in/rev

$$\boxed{f = 0.01 \text{ in/rev}}$$

(c) Maching Time (T_m)

$$T_m = \frac{L}{f_r}$$

$$f_r = f\,N$$

$$N = \frac{V}{\pi D_o} = \frac{450\,\frac{ft}{min} \times 12\,in}{\pi \times 4.5\,in} = 381.97\ \frac{rev}{min}$$

$$\boxed{N = 381.97\ rev/min}$$

$$f_r = 0.01\ \frac{in}{rev} \times 381.97\ \frac{rev}{min}$$

$$\boxed{f_r = 3.81\ in/min}$$

$$T_m = \frac{46\ in}{3.81\ \frac{in}{min}}$$

$$\boxed{T_m = 12.04\ min}$$

Drilling operation

$$N = \frac{V}{\pi D}\ ;\quad f_r = Nf\ ;\quad T_m = \frac{t + A}{f_r}$$

N - Spindle speed RPM
V - Cutting sped
D - Drill diameter.
f_r = Feed rate
T_m - Maching Time.
A - Approach Allonce -
t = Work thickness.
θ = Drill point angle.

$$A = 0.5\,D \tan\left(90 - \frac{\theta}{2}\right)$$

d - Hole depth (mm)

$$R_{MR} = \frac{\pi D^2 f_r}{4}$$

Approach Allowance - It is the distance the drill must move into the work before reaching full diameter.

CUTTING CONDITIONS IN DRILLING

$$N = \frac{v}{\pi D}$$

where v = cutting speed, mm/min (in/min); and D = the drill diameter, mm (in).

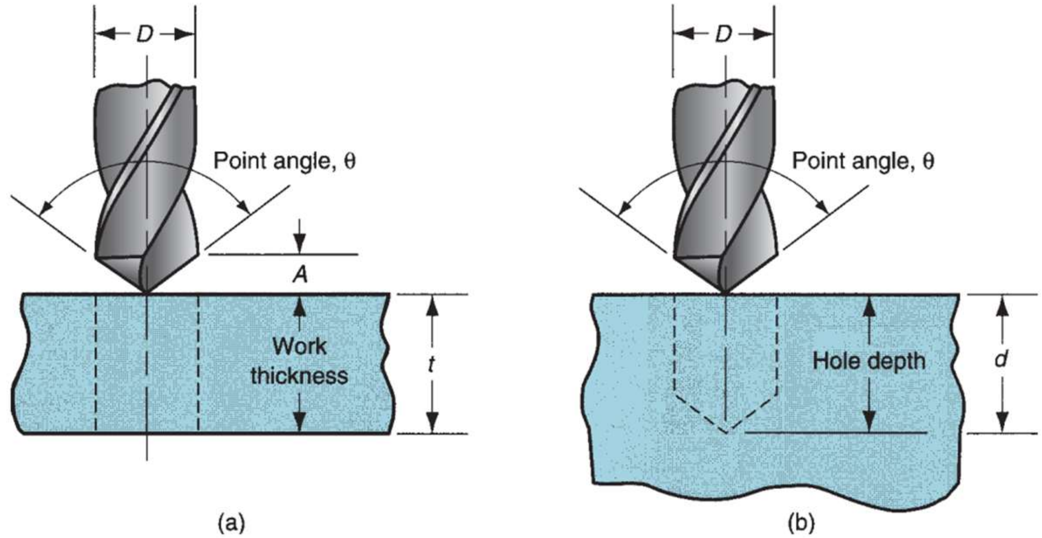
$$f_r = Nf$$

where f_r = feed rate, mm/min (in/min).

$$T_m = \frac{t + A}{f_r} \qquad A = 0.5\,D\tan\left(90 - \frac{\theta}{2}\right)$$

$$T_m = \frac{d + A}{f_r}$$

$$R_{MR} = \frac{\pi D^2 f_r}{4}$$



Two hole types: (a) through hole and (b) blind hole.

where T_m = machining (drilling) time, min; t = work thickness, mm (in); f_r = feed rate, mm/min (in/min); and A = an approach allowance that accounts for the drill point angle, representing the distance the drill must feed into the work before reaching full diameter,

A = approach allowance, mm (in); and θ = drill point angle.

Problem 4

A drilling operation is to be performed with a *12.7 mm* diameter twist drill in a steel work part. The hole is a blind hole at a depth of *60 mm* and the point angle is *118°*. The cutting speed is *25 m/min* and the feed is *0.30 mm/rev*.

Determine

(a) The cutting time to complete the drilling operation, and

(b) Metal removal rate during the operation, after the drill bit reaches full diameter.

(b) Ex 22.10

$D = 12.7\,mm$
$d = 60\,mm$
$\theta = 118°$
$v = 25\,m/min.$
$f = 0.30\,mm/rev$

(a) T_m (b) R_{MR} Note After drill bit reaches full diameter

(a) $T_m = \frac{L}{f_r}$

$f_r = N \cdot f$

Probl

$N = \frac{v}{\pi D} = \frac{25 \times 10^3\,mm/min}{\pi\ 12.7\,mm} = 626.59\ rev/min$

$f_r = 626.59\ \frac{rev}{min} \times 0.30\ \frac{mm}{rev} = 187.97\ mm/min$

$T_m = \frac{L}{f_r} = \frac{d}{f_r} = \frac{60\,mm}{187.97\,\frac{mm}{min}} = 0.319\ min$

$\boxed{T_m = 0.319\,min}$

(b) $R_{MR} = \frac{\pi}{4} D^2 f_r$

$= \frac{\pi}{4}(12.7\,mm)^2 \times 187.97\ mm/min$

$R_{MR} = 23811.45\ mm^3/min.$

$\boxed{R_{MR} = 23811.45\ mm^3/min.}$

$10^3 mm = 1\,m$

$(10^3)^3\ m^3$


THANK
YOU