Lecture 3-1: General-Purpose Machine Tools: Lathe Machines and Operations

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INTRODUCTION

- Machine tools are factory equipment used for producing machines, instruments, tools, and all kinds of spare parts.
- Therefore, the size of a country's stock of machine tools, and their technical quality and condition, characterize its industrial and technical potential fairly well.
- Metal cutting machine tools are mainly grouped into the following categories:
- General-purpose machine tools.
  - These are multipurpose machines used for a wide range of work.
- Special-purpose machine tools.
  - These are machines used for making one type of part of a special configuration, such as screw thread and gear cutting machines.
- Capstan, turret, and automated lathes.
- Numerical and computer numerical controlled machine tools.

INTRODUCTION

- In this chapter, the general-purpose machine tools are characterized and dealt with in brief.
- This group of machine tools comprises:
- lathes,
- drilling machines,
- milling machines,
- shapers,
- planers,
- slotters,
- boring machines,
- jig boring machines,
- broaching machines,
- microfinishing machines.

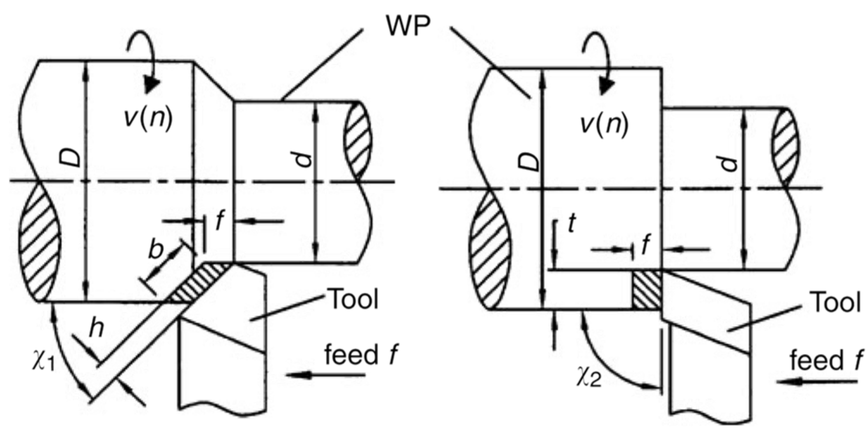
LATHE MACHINES AND OPERATIONS

- Lathes are generally considered to be the oldest machine tools still used in industry.
- About one third of the machine tools operating in engineering plants are lathe machines.
- Lathes are employed for turning external cylindrical, tapered, and contour surfaces; boring cylindrical and tapered holes, machining face surfaces, cutting external and internal threads, knurling, centering, drilling, counterboring, countersinking, spot facing and reaming of holes, cutting off, and other operations.
- Lathes are used in both job and mass production.

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

- In operations performed on lathes (turning operations), the primary cutting motion v (rotary) is imparted to the WP, and the feed motion f (in most cases straight along the axis of the WP) is imparted to a single-point tool.
- The tool feed rate f is usually very much smaller than the surface speed v of the WP.

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS



Basic machining parameters in turning.

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

- Basic machining parameters in turning include:

1. Cutting speed v

$$v = \frac{\pi D n}{1000} \text{ m/min}$$

where

D = initial diameter of the WP (mm)
n = rotational speed of the WP (rpm)

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

2. Rotational speed n

$$n = \frac{1000v}{\pi D} \text{ rpm}$$

3. Feed rate *f*, which is the movement of the tool cutting edge in millimeters per revolution of the WP (mm/rev).

4. Depth of cut t, which is measured in a direction perpendicular to the WP axis, for one turning pass.

$$t = \frac{D - d}{2} \text{ mm}$$

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

5. Undeformed chip cross-section area A_c

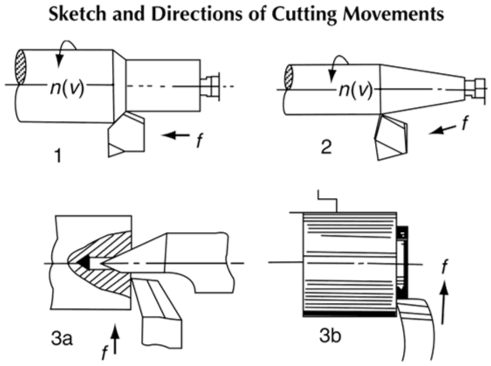
$$A_c = f \cdot t = h \cdot b \text{ mm}^2$$

where

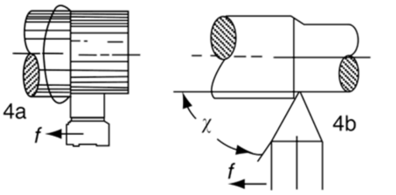
h = chip thickness in millimeters ($h = f \sin\chi$ mm)
b = contact length in millimeters
χ = cutting edge angle (setting angle)

LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

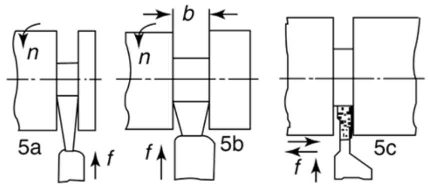
TABLE 3.1
Lathe Operations and Relevant Tools

Lathe Operation and Relevant Tool	Sketch and Directions of Cutting Movements
1. Cylindrical turning with a straight-shank turning tool 2. Taper turning with a straight-shank turning tool 3. Facing of a WP with: a. Facing tool while the WP is clamped by a half center b. Facing tool while the WP is mounted in a chuck	

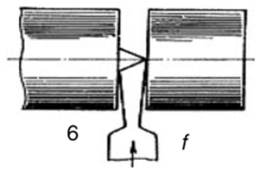
4. Finish turning with:
   a. Broad-nose finishing tool
   b. Straight finishing tool with a nose radius



5. Necking or recessing with:
   a. Recessing tool
   b. Wide recessing tool
   c. Wide recessing using narrow recessing tool

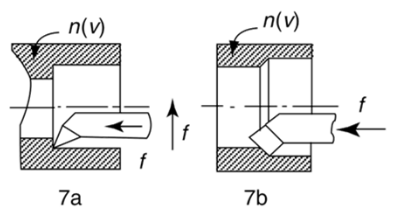


6. Parting off with parting-off tool

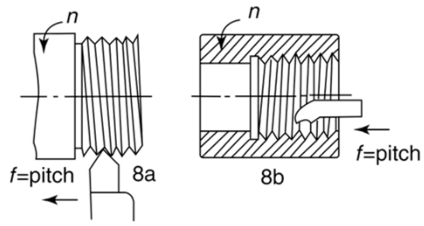


LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

7. Boring of cylindrical hole with:
   a. Bent rough-boring tool
   b. Bent finish-boring tool

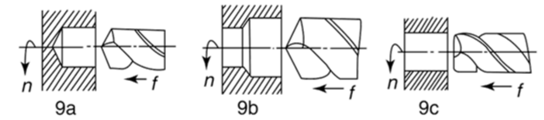


8. Threading with:
   a. External threading tool
   b. Internal threading tool

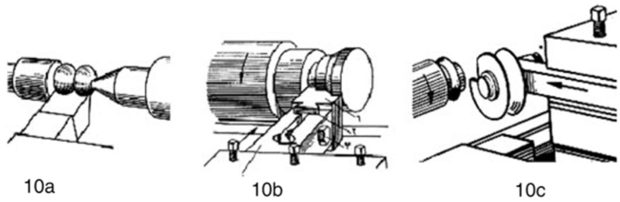


LATHE MACHINES AND OPERATIONS: TURNING OPERATIONS

9. Drilling and core drilling with a twist drill:
   a. Originating with a twist drill
   b. Enlarging with a twist drill
   c. Enlarging with a core drill



10. Forming with:
    a. Straight forming tool
    b. Flat dovetailed tool
    c. Circular form tool



LATHE MACHINES AND OPERATIONS: METAL CUTTING LATHES

Every engine lathe provides a means for traversing the cutting tool along the axis of revolution of the WP and at right angles to it.

Beyond this similarity, the lathe may embody other characteristics common to several classifications according to fields of application that ranges from manual to full automatic machining.

Metal cutting lathes may differ in size and construction.

Among these are the general-purpose machines that include universal engine lathes, plain turning lathes, facing lathes, and vertical turning and boring mills.

METAL CUTTING LATHES:

Universal Engine Lathes

- Universal engine lathes are widely employed in job and lot production, as well as for repair work.
- Parts of very versatile forms may be machined by this lathe.
- Its size varies from small bench lathes to heavy-duty lathes for machining parts weighing many tons.
- Figure 3.2 illustrates a typical universal engine lathe.

METAL CUTTING LATHES:

Universal Engine Lathes

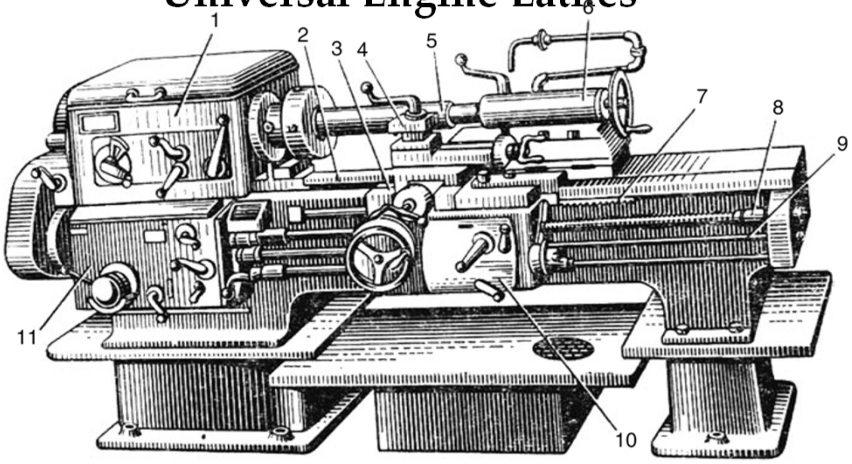


FIGURE 3.2 Typical engine lathe.

METAL CUTTING LATHES:

Universal Engine Lathes

- The bed (2) carries the headstock (1), which contains the speed gearbox.
- The bed also mounts the tailstock (6) whose spindle usually carries the dead center.
- The work may be held between centers, clamped in a chuck, or held in a fixture mounted on a faceplate.
- If a long shaft (5) is to be machined, it will be insufficient to clamp one end in a chuck; therefore, it is necessary to support the other end by the tailstock center.
- In many cases when the length of the shaft exceeds 10 times its diameter ($\ell > 10$ D), a steady rest or follower rest is used to support these long shafts.

METAL CUTTING LATHES:

Universal Engine Lathes

- Single-point tools are clamped in a square turret (4) mounted on the carriage (3).
- Tools such as drills, core drills, and reamers are inserted in the tailstock spindle after removing the center.
- The carriage (3), to which the apron (10) is secured, may traverse along the guideways either manually or powered.
- The cross slide can also be either manually or power traversed in the cross direction.
- Surfaces of revolution are turned by longitudinal traverse of the carriage.
- The cross slide feeds the tool in the cross direction to perform facing, recessing, forming, and knurling operations.
- Power traverse of the carriage or cross slide is obtained through the feed mechanism.

METAL CUTTING LATHES:

Universal Engine Lathes

- Rotation is transmitted from the spindle through change gears and the quick change feed gearbox (11) to either the lead screw (8) or feed rod (9).
- From either of these, motion is transmitted to the carriage. Powered motion of the lead screw is used only for cutting threads using a threading tool.
- In all other cases, the carriage is traversed by hand or powered from the feed rod. Carriage feed is obtained by a pinion and rack (7) fastened to the bed.
- The pinion may be actuated manually or powered from the feed rod. The cross slide is powered by the feed rod through a gearing system in the apron (10).
- During thread cutting, the half nuts (9) are closed by the lever (10) over the lead screw (1).

METAL CUTTING LATHES:

Universal Engine Lathes

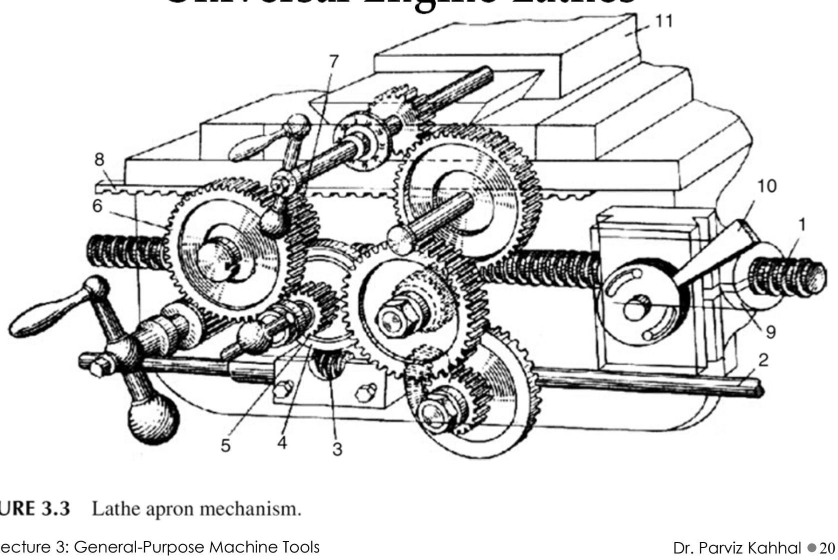


FIGURE 3.3 Lathe apron mechanism.

METAL CUTTING LATHES:

Universal Engine Lathes

- **Specifications of an Engine Lathe**
- Figure 3.4 shows the main dimensions that indicate the capacity of an engine lathe. These are:
- Maximum diameter D of work accommodated over the bed (swing over bed). According to most of national standards, D varies from 100 to 6300 mm, arranged in geometric progression φ = 1.26.
- Maximum diameter D_1 of work accommodated over the carriage.
- Distance between centers, which determines the maximum work length. It is measured with the tailstock shifted to its extreme right-hand position without overhanging.
- Maximum bore diameter of spindle, which determines the bar capacity (maximum bar stock).

METAL CUTTING LATHES:

Universal Engine Lathes

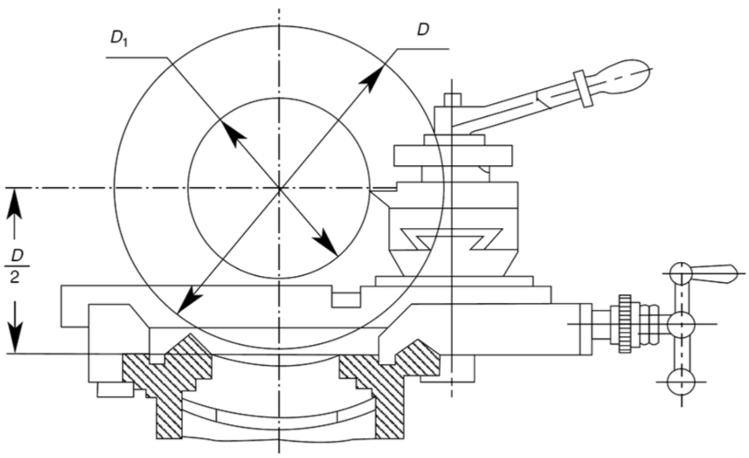


FIGURE 3.4 Main dimensions of an engine lathe.

METAL CUTTING LATHES:

Universal Engine Lathes

- In addition to these dimensions, other important specifications are:
- Number of spindle speeds and speed range
- Number of feeds and feed range
- Motor power and speed
- Overall dimensions and net weight

METAL CUTTING LATHES:

Universal Engine Lathes

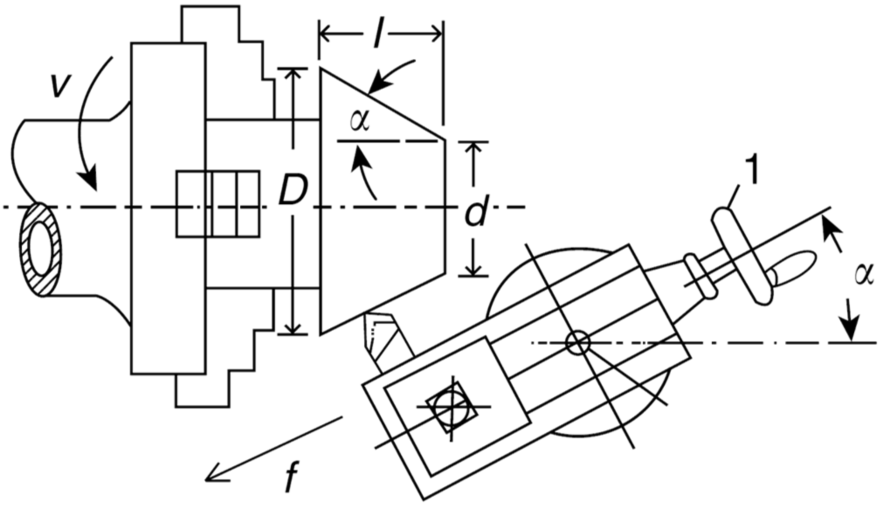
- ***Setting Up the Engine Lathe for Taper Turning***
- Tapered surfaces are turned by employing one of the following methods (Figure 3.5):

a) By swiveling the compound rest to the required angle α. Before performing the operation, the compound rest is to be clamped in this position. The tool is fed manually by rotating handle (1).

- This method is used for turning short internal and external tapers with large taper angles, while the work is commonly held in a chuck and a straight turning tool is used (Figure 3.5a).

METAL CUTTING LATHES:

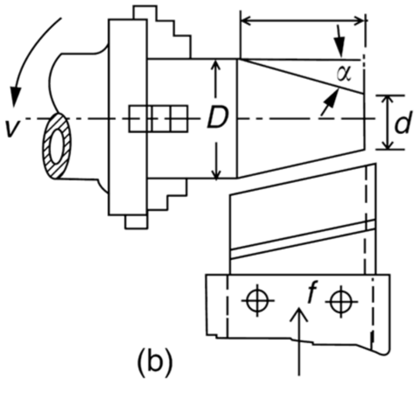
Universal Engine Lathes



METAL CUTTING LATHES:

Universal Engine Lathes

b) By using a straight-edge broad-nose tool. The tool of width that exceeds the taper being turned is cross-fed. The work is held in a chuck or clamped on a faceplate (Figure 3.5b).



(b)

METAL CUTTING LATHES:

Universal Engine Lathes

c) By setting over the tailstock.

- The angle of taper a should not exceed 8°. Since the turned surface is parallel to the spindle axis, the powered feed of the carriage can be used while the work is to be mounted between centers as shown in Figure 3.5c.
- Before turning cylindrical surfaces, it is a good practice to check whether the tailstock is not previously set over for taper turning; otherwise, tapered surfaces are produced.

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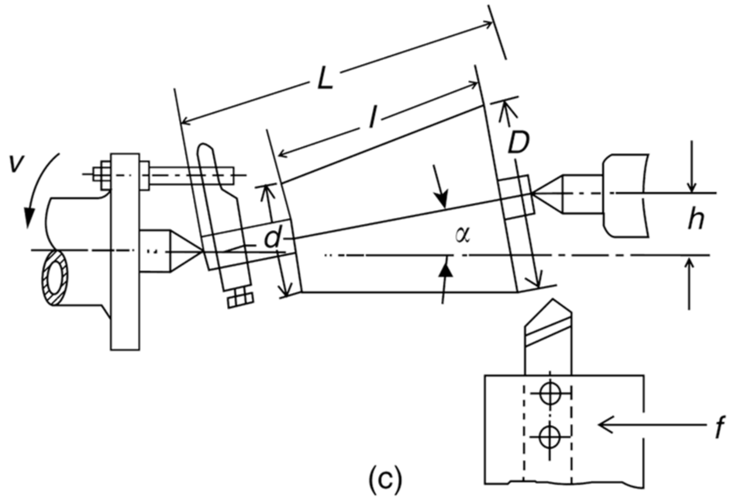
Universal Engine Lathes

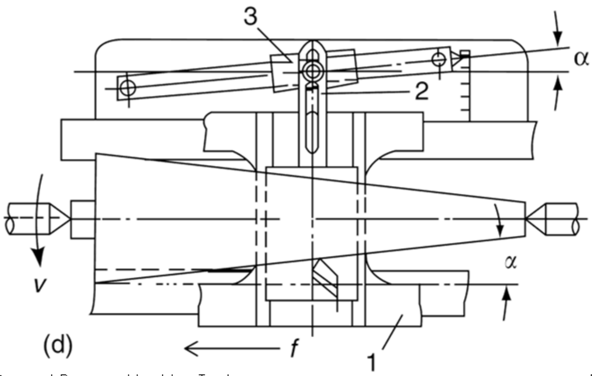


(c)

METAL CUTTING LATHES:

Universal Engine Lathes

d) By using a taper-turning attachment. This is best suited for long tapered work. The cross slide (1) is disengaged from the cross feed screw and is linked through the tie (2) to the slide (3) (Figure 3.5d).



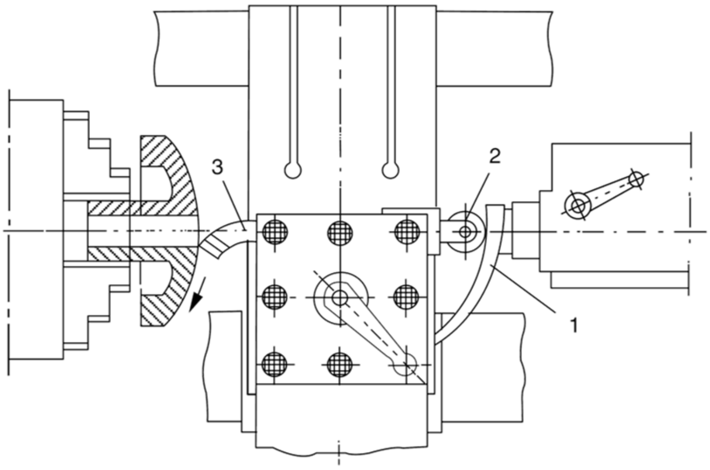
METAL CUTTING LATHES:

Universal Engine Lathes

- ***Setting Up the Engine Lathe for Turning Contoured Surfaces with a Tracer Device***
- Longitudinal contoured surfaces are produced using a tracer device similar to the taper-turning attachment, except that the template of the required profile is substituted by the guide bar.
- Disadvantages of such mechanical duplicating are the difficulties in making a template sufficiently accurate and strong enough to withstand the cutting force and the rapid wear of such templates.
- A mechanical tracer for turning spherical surfaces, shown in Figure 3.6, operates by similar principles.

METAL CUTTING LATHES:

Universal Engine Lathes



Turning of a spherical surface.

METAL CUTTING LATHES:

Universal Engine Lathes

- Accordingly, the template (1) is clamped in the tailstock spindle and a roller (2) is clamped in the square turret opposite the tool (3) and in contact with the template.
- If the cross feed is transmitted to the cross slide, the profile of the template will be produced on the WP.
- When much contour turning work is to be done with longitudinal feeds, a hydraulic tracer slide is often installed on engine lathe where the stylus sliding on the template does not carry the cutting force.

METAL CUTTING LATHES:

Universal Engine Lathes

- ***Setting Up the Engine Lathe for Cutting Screw Threads***
- In some cases when the machine has not a quick-change gearbox, or when the thread pitch to be cut is nonstandard, change gears must be used and setup on the quadrant as shown in Figure 3.7.

METAL CUTTING LATHES:

Universal Engine Lathes

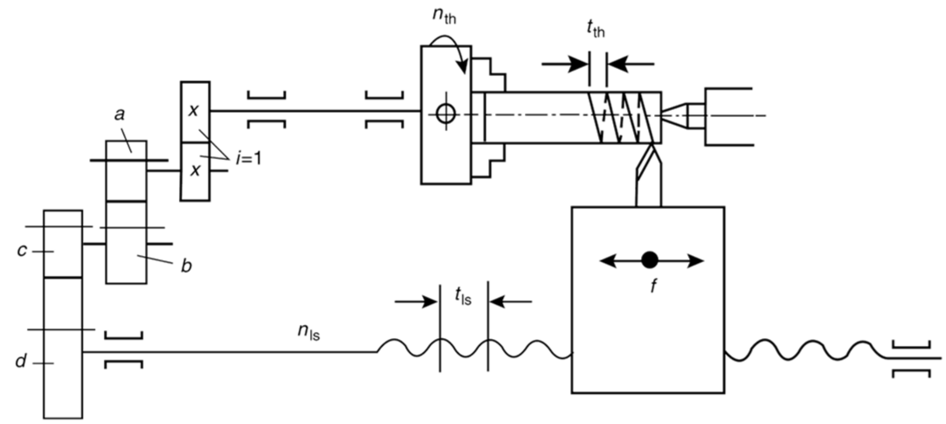


FIGURE 3.7 Setting up the engine lathe for thread cutting.

METAL CUTTING LATHES:

Universal Engine Lathes

- Because one revolution of the spindle provides the pitch t_{th} of the screw thread to be produced, the kinematic linkage is given by the following equation:

$$t_{\text{th}} = t_{\text{ls}} \cdot i_{\text{cg}}$$

$$i_{\text{cg}} = \frac{t_{\text{th}}}{t_{\text{ls}}} = \frac{a}{b} \times \frac{c}{d}$$

where

t_{ls} = pitch of the lead screw of the lathe
i_{cg} = gearing ratio of the quadrant
a, b, c, d = number of teeth of change gears

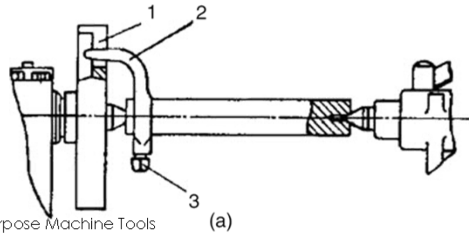
METAL CUTTING LATHES:

Universal Engine Lathes

- ***Holding the Work on Engine Lathe***
- WP fixation on an engine lathe depends mainly upon the geometrical features of the WP and the precision required. The WP can be held between centers, on a mandrel, in a chuck, or on a faceplate:

1. Holding the WP between centers

- A dog plate (1) and a lathe dog (2) are used (Figure 3.8a).
- It is an accurate method for clamping a long WP.

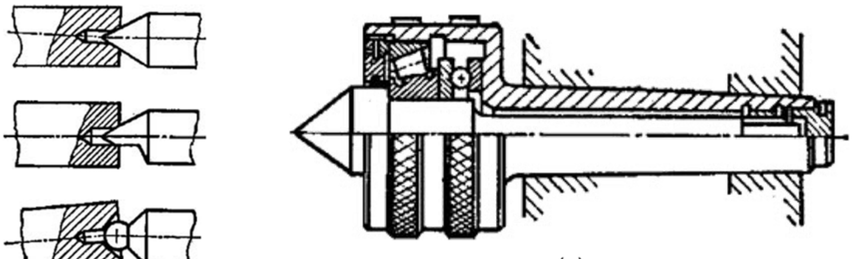


(a)

METAL CUTTING LATHES:

Universal Engine Lathes

- The tailstock center may be a dead center (Figure 3.8b), or a live center (Figure 3.8c), when the work is rotating at high speed. In such a case, rests are used to support long WPs to prevent their deflection under the action of the cutting forces.

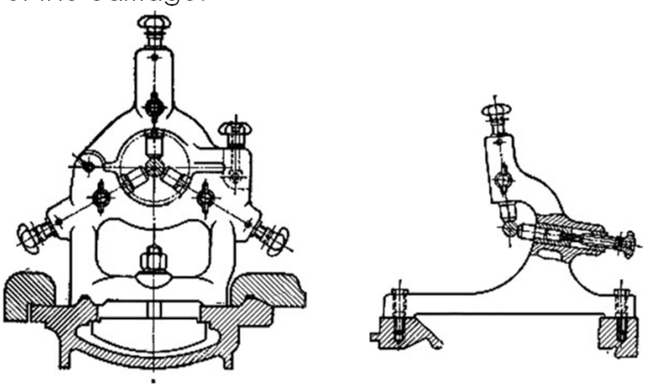


(c)

METAL CUTTING LATHES:

Universal Engine Lathes

- The steady rest (Figure 3.9a) is mounted on the guideways of the bed while the follower rest (Figure 3.9b) is mounted on the saddle of the carriage.



(a) Steady rest   (b) Follower rest

METAL CUTTING LATHES:

Universal Engine Lathes

2. Clamping hollow WPs on mandrels.

- Mandrels are used to hold WPs with previously machined holes. The WP to be machined (2) is tightly fitted on a conical mandrel, tapered at 0.001, and provided with center holes to be clamped between centers using a dog plate and a lathe dog (Figure 3.10a).
- The expanding mandrel (Figure 3.10b) consists of a conical rod (1), a split sleeve (2), and nuts (3 and 4).
- The work is held by expansion of a sleeve (2), as the latter is displaced along the conical rod (1) by nut (3).
- Nut (4) removes the work from the mandrel.
- There is a flat (5) on the left of the conical rod used for the setscrew of the driving lathe dog.

METAL CUTTING LATHES:

Universal Engine Lathes

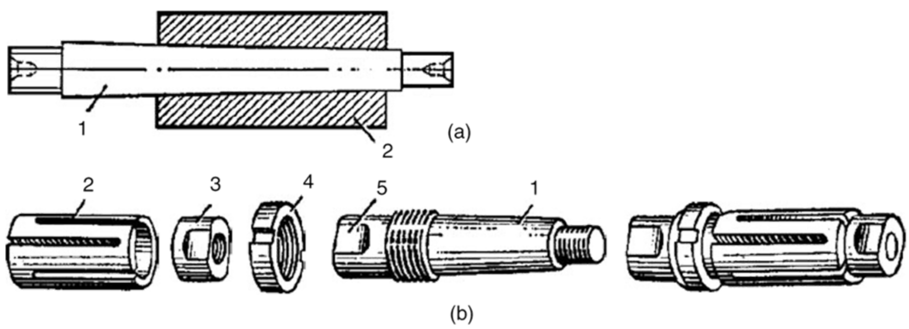


FIGURE 3.10 Mounting WPs on a mandrel.

METAL CUTTING LATHES:

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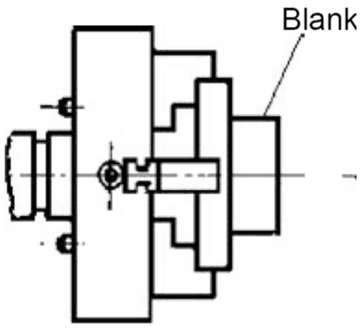
3. Clamping the WP in a chuck.

- The most commonly employed method of holding short work is to clamp it in a chuck (Figure 3.11a).



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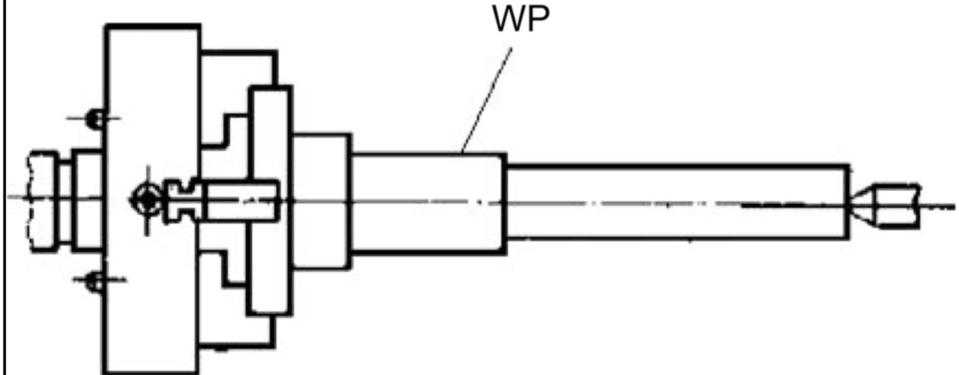
- If the work length is considerably large relative to its diameter, supporting the free end with the tailstock dead or live center *(Figure 3.11b) is also used.*



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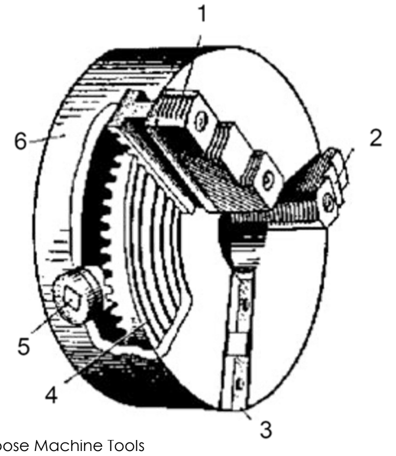
- Chucks may be universal (self-centering) of three jaws, which are expanded and drawn simultaneously (Figure 3.11c).



METAL CUTTING LATHES:

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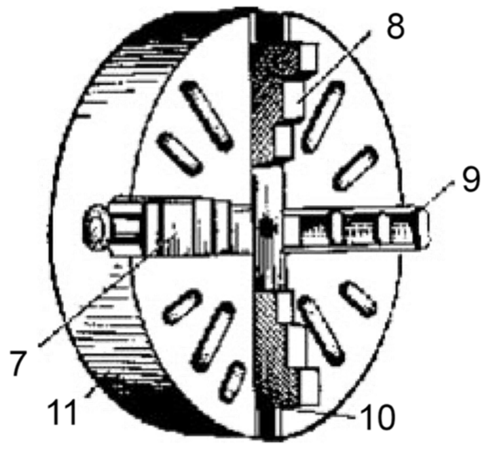
- they may be independent of four jaws (Figure 3.11d).



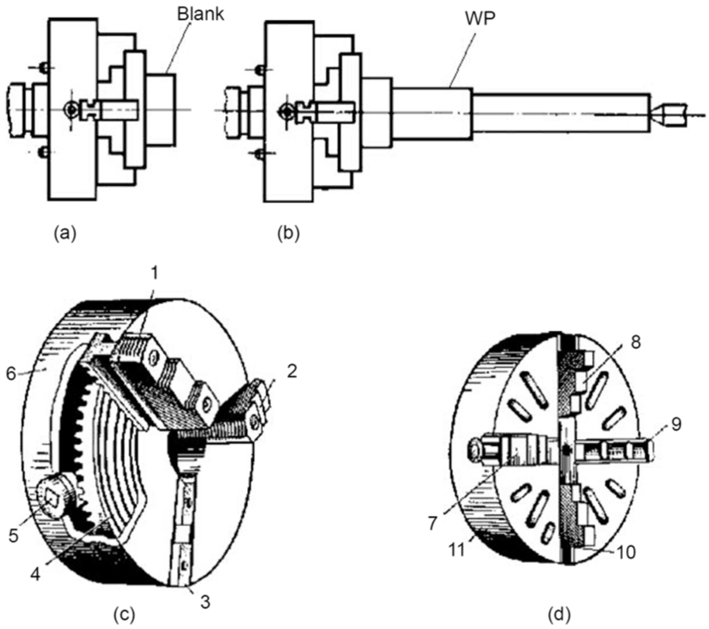


FIGURE 3.11 Clamping WPs in chucks: (a) Short WP, (b) long WP, (c) 3-jaw chuck, (d) 4-jaw chuck.

METAL CUTTING LATHES:

Universal Engine Lathes

- The three-jaw chucks are used to clamp circular and hexagonal rods, whereas the independent four-jaw chucks are especially useful in clamping irregular and nonsymmetrical WPs.
- Air-operated (pneumatic) chucks are commonly used in batch or mass production by increasing the degree of automation (Figure 3.12).
- The piston (1) is attached to a rod that moves it to the right or to the left depending on which chamber of the pneumatic cylinder is fed with compressed air.
- The end of the rod is connected to three levers (2), which expand jaws (3) in a radial direction to clamp orrelease the WP.

METAL CUTTING LATHES:

Universal Engine Lathes

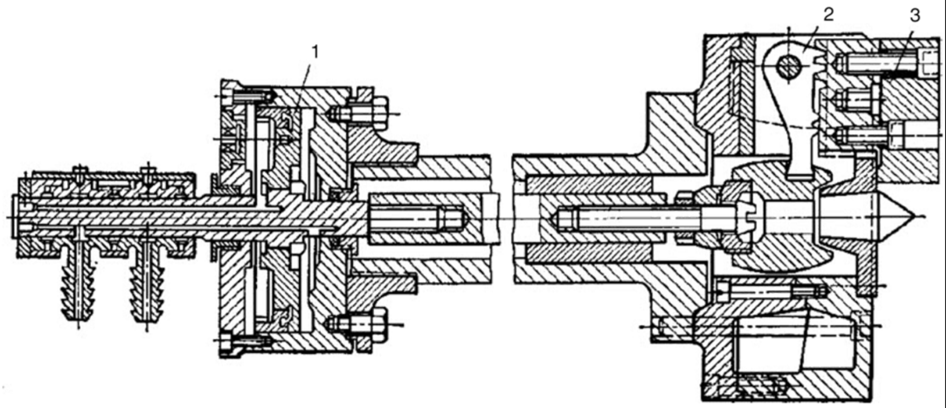


FIGURE 3.12 Pneumatic chuck.

METAL CUTTING LATHES:

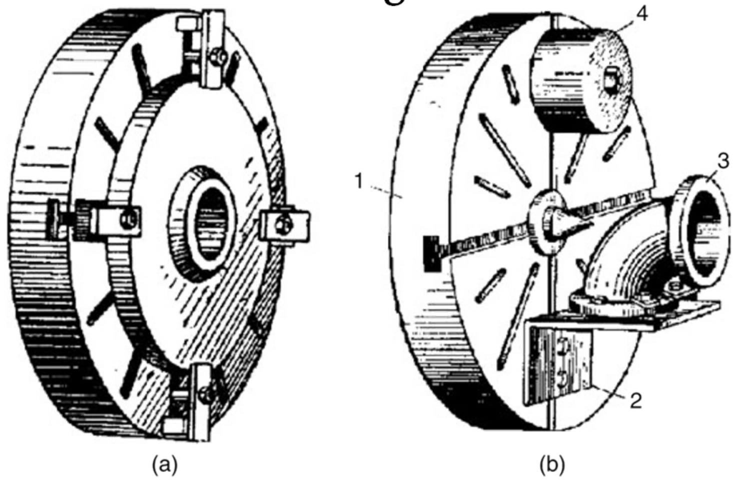
Universal Engine Lathes

4. Clamping the WP on a faceplate.

- Large WPs cannot be clamped in a chuck and are, therefore, mounted either directly on a faceplate (Figure 3.13a), or mounted on a plate fixture (2) that is attached to faceplate (1) (Figure 3.13b).
- The work (3) and angle plate (2) must be counterbalanced by using the counterweight (4) mounted at the opposite position on the faceplate.
- The plate fixture has been proved to be highly efficient in machining asymmetrical work of complex and irregular shape.

METAL CUTTING LATHES:

Universal Engine Lathes



Mounting WPs on faceplates.

Other Types of General-Purpose Metal Cutting Lathes

- These include plain turning lathes, facing lathes, and vertical turning and boring mills.
- Facing
- lathes, vertical turning and boring mills, and heavy-duty plain turning lathes are generally used for heavy work.
- They are characterized by low speeds, large feeds, and high cutting torques.

Other Types of General-Purpose Metal Cutting Lathes: Plain turning lathes

1. Plain turning lathes.

- Plain turning lathes differ from engine lathes in that they do not have a lead screw. They perform all types of lathe work except threading and chasing. The absence of the lead screw substantially simplifies the kinematic features and the construction of the feed gear trains.
- Their dimensional data are similar to those of engine lathes. Plain turning lathes are available in three different size ranges: small, medium, and heavy duty.
- Heavy-duty plain turning lathes have several common carriages that are powered either from a common feed rod, linked kinematically to the lathe spindle, or powered from a variable speed dc motor mounted on each carriage.
- The tailstock traverses along the guideway by a separate drive.

Other Types of General-Purpose Metal Cutting Lathes: Facing lathes.

2. Facing lathes.

- These are used to machine work of large diameter and short length in single-piece production and for repair jobs.
- These machines are generally used for turning external, internal, and taper surfaces, facing, boring, and so on.
- Facing lathes have relatively small length and large diameter of faceplates (up to 4 m).
- Sometimes, they are equipped with a tailstock.
- Its construction differs, to some extent, from the center lathe.

Other Types of General-Purpose Metal Cutting Lathes: Facing lathes.

- It consists of the base plate (1), headstock (4) with faceplate (5), bed (2), carriage (3), and tailstock (6) (Figure 3.14).
- The work is clamped on the faceplate using jaws, or clamps, and T-slot bolts.
- It may be additionally supported by the tailstock center.
- The feed gear train is powered from a separate motor to provide the longitudinal and transverse feeds.
- Facing lathes have been almost superseded by vertical turning and boring mills; however, because of their simple construction and low cost, they are still employed.

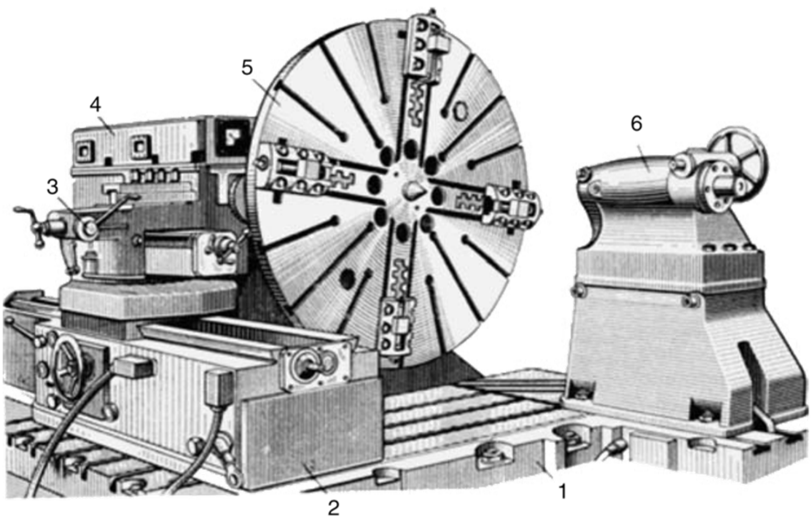


FIGURE 3.14 Facing lathe.

Other Types of General-Purpose Metal Cutting Lathes:

Vertical turning and boring mills.

- These machines are employed in machining heavy pieces of large diameters and relatively small lengths.
- They are used for turning and boring of cylindrical and tapered surfaces, facing, drilling, countersinking, counterboring, and reaming.
- In vertical turning and boring mills, the heavy work can be mounted on rotating tables more conveniently and safely as compared to facing lathes.
- The horizontal surface of the worktable excludes completely the overhanging load on the spindle of the facing lathes.
- This facilitates the application of high-velocity machining and, at the same time, enables high accuracy to be attained.
- These small machines are called vertical turret lathes. As their name implies, they are equipped with turret heads, which increase their productivity.