1. Turning and Related Operations

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

The tool is fed linearly in a direction parallel to the axis of rotation to generate a cylindrical geometry, as illustrated in Figure 1.1.

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.

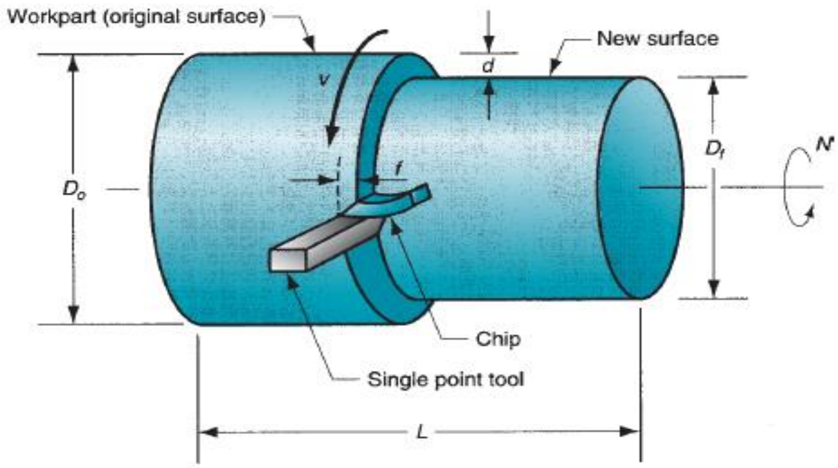

FIGURE 1.1 Turning operation.

1.1 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

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

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:

$$D_f = D_o - 2d$$

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

$$f_r = Nf$$

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

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

Where T_m = machining time, min; and L = length of the cylindrical workpart, mm (in).

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:

$$R_{MR} = vfd$$

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 workpart 200 mm in diameter and 700 mm long is to be turned in an engine lathe. Cutting conditions are as follows: cutting speed is 2.30 m/s, feed is 0.32 mm/rev, and depth of cut is 1.80 mm. Determine (a) cutting time, and (b) metal removal rate.

Solution:

(a) N = v/(πD) = (2.30 m/s)/ 0.2 π = 3.66 rev/s

f_r = Nf = 6.366(.3) = 1.17 mm/s

T_m = L/f_r = 700/1.17 = 598 s = 9.96 min

(b) R_{MR} = vfd = (2.30 m/s)(10^3)(0.32 mm)(1.80 mm) = 1320 mm^3 /s

Example 2:

In a production turning operation, the foreman has decreed that a single pass must be completed on the cylindrical workpiece in 5.0 min. The piece is 400 mm long and 150 mm in diameter. Using a feed = 0.30 mm/rev and a depth of cut = 4.0 mm, what cutting speed must be used to meet this machining time requirement?

Solution:

T_m = L/f_r = L/ Nf = πD_oL/vf.

v = πD_oL/fT_m

v = π(0.4)(0.15) / (0.30)(10^{-3})(5.0) = 0.1257(10^3) m/min = 125.7 m/min

2.2. Operations Related to Turning

A variety of other machining operations can be performed on a lathe in addition to turning; these include the following, illustrated in Figure 1.2:

(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.

(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.

(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) ***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 cross- hatched pattern in the work surface.

Most lathe operations use single-point tools.

Turning, facing, taper turning, contour turning, chamfering, and boring are all performed with single-point tools.

A threading operation is accomplished using a single-point tool designed with a geometry that shapes the thread.

Certain operations require tools other than single-point.

Drilling is accomplished by a drill bit.

Knurling is performed by a knurling tool, consisting of two hardened forming rolls, each mounted between centers.

The forming rolls have the desired knurling pattern on their surfaces.

To perform knurling, the tool is pressed against the rotating workpart with sufficient pressure to impress the pattern onto the work surface.

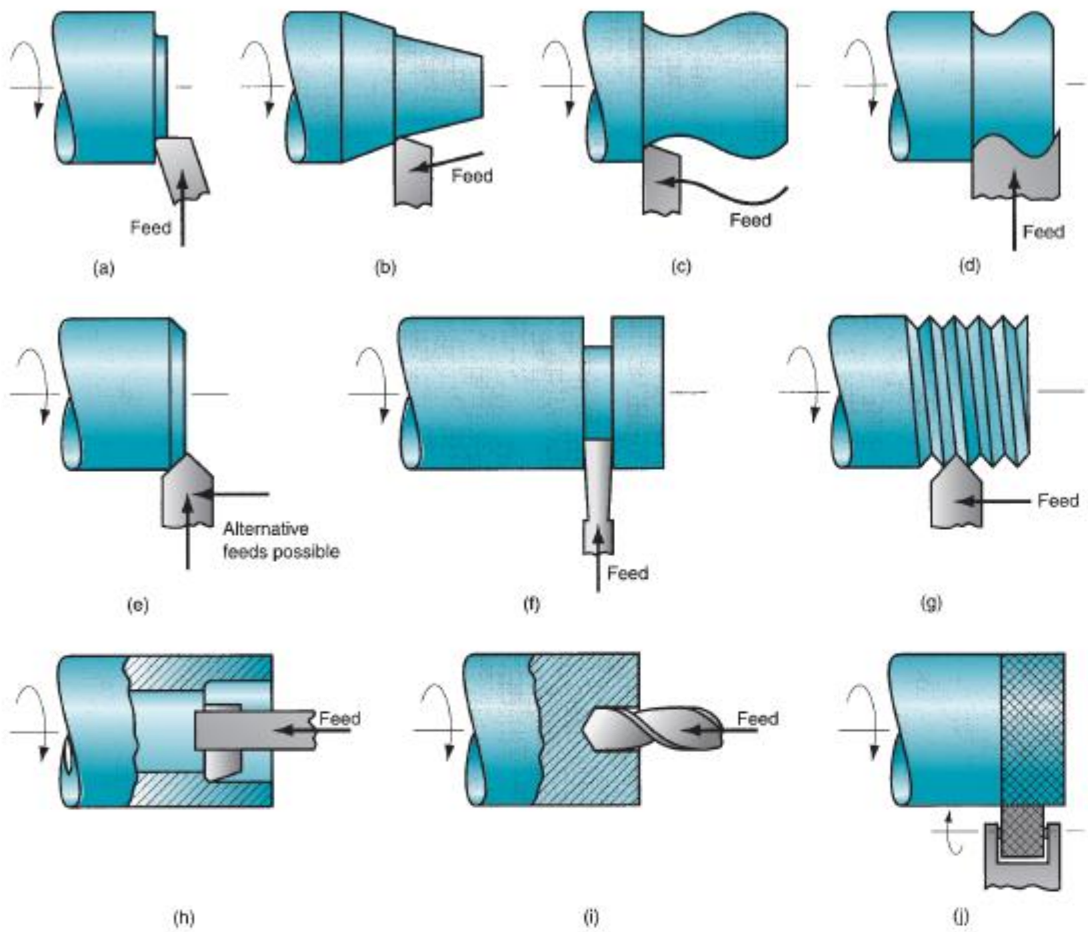

FIGURE 1.2 Machining operations other than turning that are performed on a lathe: (a) facing, (b) taper turning, (c) contour turning, (d) form turning, (e) chamfering, (f) cutoff, (g) threading, (h) boring, (i) drilling, and (j) knurling.

1.3 The 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 Technology Figure 1.3 is a sketch of an engine lathe showing its principal components.

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.

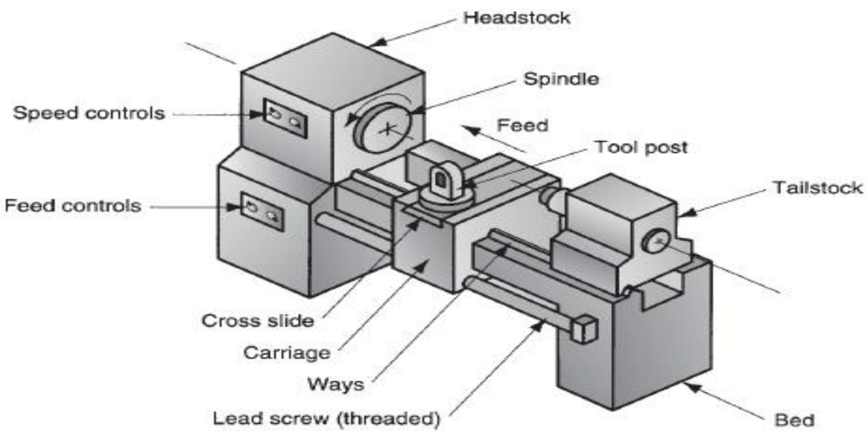

FIGURE 1.3 Diagram of an engine lathe, indicating its principal components

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 like tracks along which the carriage rides, and they are made with great precision to achieve a high degree of parallelism relative to the spindle axis.

The ways are built into the bed of the lathe, providing a rigid frame for the machine tool.

The carriage is driven by a lead screw that rotates at the proper speed to obtain the desired feed rate.

The cross-slide is designed to feed in a direction perpendicular to the carriage movement.

Thus, by moving the carriage, the tool can be fed parallel to the work axis to perform straight turning; or by moving the cross-slide, the tool can be fed radially into the work to perform facing, form turning, or cutoff operations.

The conventional engine lathe and most other machines described in this section are horizontal turning machines; that is, the spindle axis is horizontal.

This is appropriate for the majority of turning jobs, in which the length is greater than the diameter.

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; these are vertical turning machines.

The size of a lathe is designated by swing and maximum distance between centers.

The swing is the maximum workpart diameter that can be rotated in the spindle, deter- mined as twice the distance between the centerline of the spindle and the ways of the machine.

The actual maximum size of a cylindrical workpiece that can be accommodated on the lathe is smaller than the swing because the carriage and cross-slide assembly are in the way.

The maximum distance between centers indicates the maximum length of a workpiece that can be mounted between headstock and tailstock centers.

For example, a 350 mm x 1.2 m (14 in x 48 in) lathe designates that the swing is 350 mm (14 in) and the maximum distance between centers is 1.2 m (48 in).

1.4 Methods of Holding the Work in a Lathe

There are four common methods used to hold workparts in turning.

These workholding methods consist of various mechanisms to grasp the work, center and support it in position along the spindle axis, and rotate it.

The methods, illustrated in Figure 1.4, are (a) mounting the work between centers, (b) chuck, (c) collet, and (d) face plate.

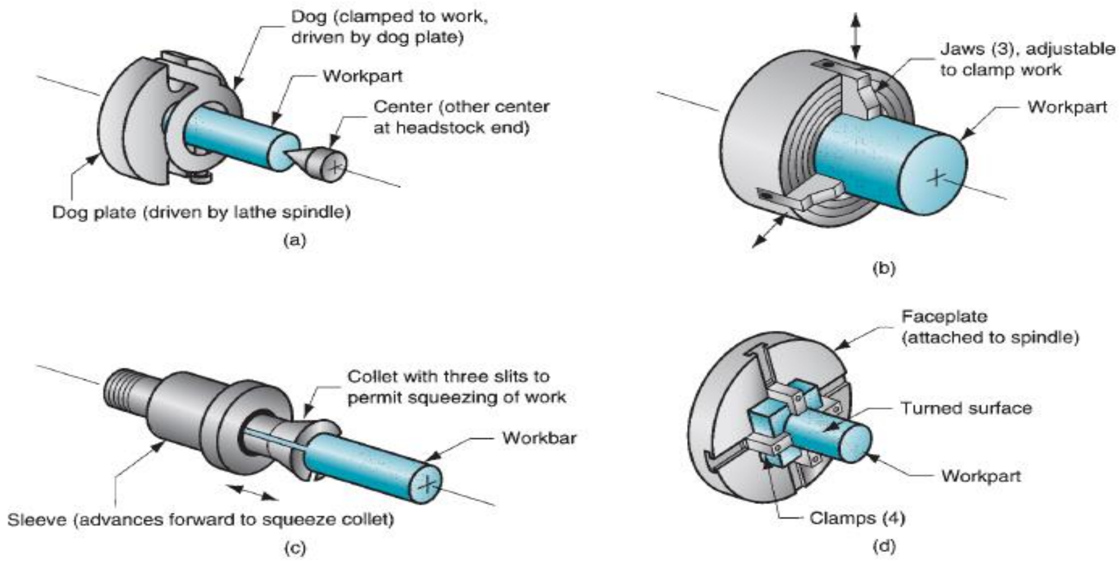

FIGURE 1.4 Four workholding methods used in lathes: (a) mounting the work between centers using a dog, (b) three-jaw chuck, (c) collet, and (d) faceplate for noncylindrical workparts.

Holding the work between centers refers to the use of two centers, one in the headstock and the other in the tailstock, as in Figure 1.4(a).

This method is appropriate for parts with large length-to-diameter ratio, 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.

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.

In contrast, 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.

The chuck, Figure 1.4(b), is available in several designs, with three or four jaws to grasp the cylindrical workpart 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 parts with low length-to-diameter ratios, holding the part in the chuck in a cantilever fashion is usually sufficient to withstand the cutting forces, for long workbars, the tailstock center is needed for support.

A collet consists of a tubular bushing with longitudinal slits running over half its length and equally spaced around its circumference, as in Figure 1.4(c).

The inside diameter of the collet is used to hold cylindrical work such as bar stock.

Owing to the slits, one end of the collet can be squeezed to reduce its diameter and provide a secure grasping pressure against the work.

Because there is a limit to the reduction obtainable in a collet of any given diameter, these workholding devices must be made in various sizes to match the particular workpart size in the operation.

A face plate, Figure 1.4(d), is a workholding device that fastens to the lathe spindle and is used to grasp parts with irregular shapes.

Because of their irregular shape, these parts cannot be held by other work holding methods.

The faceplate is therefore equipped with the custom-designed clamps for the particular geometry of the part.