lus follows the contour of the template. The stylus arm actuates a control valve regulating the flow of oil into a cylinder incorporated in the tool slide base. A piston connected to the tool slide is moved in or out by the flow of oil to the cylinder. This movement causes the tool slide (and toolbit) to move in or out as the carriage moves along, duplicating the profile of a template on the workpiece.

Advantages of a Tracer Attachment

- Intricate forms, difficult to produce by other means, can be readily produced.
- Various forms, tapers, and shoulders can be produced in one cut.
- Duplicate parts can be produced rapidly and accurately.
- Accuracy and finish of the part do not depend on the skill of the operator.

Hints on the Use of a Tracer Attachment

1. The toolbit point and stylus should have the same form and radius.
2. The radius on the toolbit should be smaller than the smallest radius on the template.
3. The stylus must be set to the point on the template giving the smallest diameter of the work.
4. The centerline of the template must be parallel to the ways of the lathe.
5. The form of the template must be smooth.
6. No angle larger than 30°, or the equivalent radius, should be incorporated in the form of the template.
7. Duplicate parts produced between centers must be the same length and have the center holes drilled to the same depth.
8. Duplicate parts held in a chuck should project the same distance from the chuck jaws.
9. The included angle of the tool point should be less than the smallest angle on the template.

REVIEW QUESTIONS

KNURLING

1. Define the process of knurling.
2. Explain how to set up the knurling tool.
3. Why is it important not to disengage the feed during the knurling operation?

GROOVING

4. For what purposes are grooves used?
5. How can the depth of the cut be gaged during grooving?
6. What should be done to prevent the cutting tool from binding in a deep groove?

FORM TURNING

7. Name three methods by which form turning may be done on a lathe.
8. Briefly describe the procedure for turning a ½-in. (13-mm) radius on the end of a workpiece.
9. What is a template?
10. What types of templates may be used with a tracer lathe?
11. List three advantages of a tracer lathe or tracer attachment.
12. List six points to observe when using a tracer lathe.

UNIT 54

Tapers and Taper Turning

A *taper* may be defined as a uniform change in the diameter of a workpiece measured along its axis. Tapers in the inch system are expressed in taper per foot, taper per inch, or degrees. Metric tapers are expressed as a ratio of 1 mm per unit of length; for example, 1:20 taper would have a 1-mm change in diameter in 20 mm of length. A taper provides a rapid and accurate method of aligning machine parts and an easy method of holding tools such as twist drills, lathe centers, and reamers.

Machine tapers (those used on machines and tools) are now classified by the American Standards Association as *self-holding tapers* and *steep* or *self-releasing tapers.*

OBJECTIVES

After completing this unit you will be able to:
1. Identify and state the purpose of self-holding and self-releasing tapers
2. Cut short, steep tapers using the compound rest
3. Calculate and cut tapers on work between centers by offsetting the tailstock
4. Calculate and machine tapers with a taper attachment

SELF-HOLDING TAPERS

Self-holding tapers, when seated properly, remain in position because of the wedging action of the small taper angle. The most common forms of self-holding tapers are the Morse, the Brown and Sharpe, and the ¾-in.-per-foot machine taper. See Table 54-1.

The smaller sizes of self-holding tapered shanks are provided with a tang to help drive the cutting tool. Larger sizes employ a tang drive with the shank held in by a key or a key drive with the shank held in with a draw bolt.

STEEP TAPERS

Steep tapers (self-releasing) have a 3½ in. taper per foot (tpf). This was formerly called the standard milling machine taper. It is used mainly for alignment of milling machine arbors and accessories. A steep taper has a key drive and uses a draw-in bolt to hold it securely in the milling machine spindle.

STANDARD TAPERS

Although many of the tapers referred to in Table 54-1 are taken from the Morse and Brown and Sharpe taper series, those not listed in this table are classified as nonstandard machine tapers.

The *Morse taper,* which has approximately ⅝-in. *tpf,* is used for most drills, reamers, and lathe center shanks. Morse tapers are available in eight sizes ranging from #0 to #7.

The *Brown and Sharpe taper,* available in sizes from #4 to #12, has approximately 0.502-in. *tpf,* except #10 which has a taper of 0.516-in./ft. This self-holding taper is used on Brown and Sharpe machines and drive shanks.

The *Jarno taper,* 0.600-in. *tpf,* was used on some lathe and drill spindles in sizes from #2 to #20. The taper number indicates the large diameter in eighths of an inch and the small diameter in tenths of an inch. The taper length is indicated by the taper number divided by two.

The *standard taper pins* used for positioning and holding parts together have ¼-in. *tpf.* Standard sizes in these pins range from #6/0 to #10.

LATHE SPINDLE NOSE TAPERS

Two types of tapers are used on lathe spindle noses. The *Type D-1* has a very short tapered section (3-in. *tpf*) and is used on cam-lock spindles (Fig. 54-1). The *Type L* lathe spindle nose has a taper of 3½-in./ft and has a considerably longer taper than the Type D-1. The chuck or drive plate is held on by a threaded lock ring fitted on the spindle behind

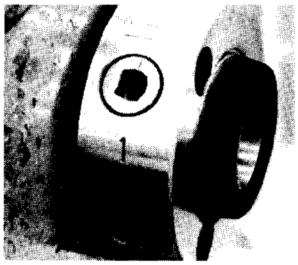
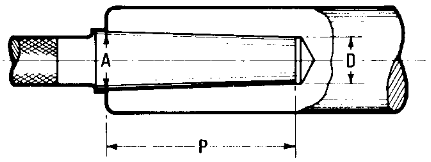


Figure 54-1 *Tapered lathe spindle nose Type D-1.*

Table 54-1 Basic Dimensions of Self-Holding Tapers



Number of Taper	Taper per Foot	Diameter at Gage Line (*A*)	Diameter at Small End (*D*)	Length (*P*)	Series Origin
0.239	0.502	0.2392	0.200	15/16	
0.299	0.502	0.2997	0.250	1 3/16	Brown and Sharpe taper series
0.375	0.502	0.3752	0.3125	1 1/2	
0*	0.624	0.3561	0.252	2	
1	0.5986	0.475	0.369	2 1/8	
2	0.5994	0.700	0.572	2 9/16	
3	0.6023	0.938	0.778	3 3/16	
4	0.6233	1.231	1.020	4 1/16	Morse taper series
4 1/2	0.624	1.500	1.266	4 1/2	
5	0.6315	1.748	1.475	5 3/16	
6	0.6256	2.494	2.116	7 1/4	
7	0.624	3.270	2.750	10	
200	0.750	2.000	1.703	4 3/4	
250	0.750	2.500	2.156	5 1/2	
300	0.750	3.000	2.609	6 1/4	
350	0.750	3.500	3.063	7	
400	0.750	4.000	3.516	7 3/4	
450	0.750	4.500	3.969	8 1/2	3/4-in.-*tpf* series
500	0.750	5.000	4.422	9 1/4	
600	0.750	6.000	5.328	10 3/4	
800	0.750	8.000	7.141	13 3/4	
1000	0.750	10.000	8.953	16 3/4	
1200	0.750	12.000	10.766	19 3/4	

*Taper #0 is not a part of the self-holding taper series. It has been added to complete the Morse taper series.

the taper nose. A key drive is employed in this type of taper (Fig. 54-2).

TAPER CALCULATIONS

To machine a taper, particularly by the tailstock offset method, it is often necessary to make calculations to ensure accurate results. Since tapers are often expressed in *taper*

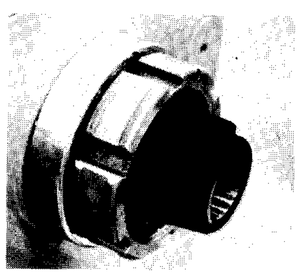


Figure 54-2 *Tapered lathe spindle nose Type L.*

per foot, taper per inch, or *degrees,* it may be necessary to calculate any of these dimensions.

TO CALCULATE THE *tpf*

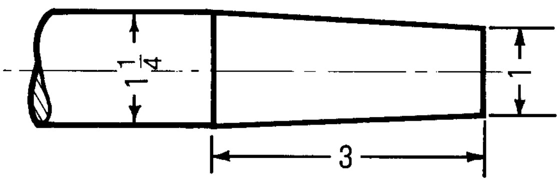


Figure 54-3 *The main part of an inch taper.*

To calculate the *tpf* it is necessary to know the large diameter, the small diameter, and the length of taper. The *tpf* can be calculated by applying the following formula.

$$tpf = \frac{(D - d)}{\text{length of taper}} \times 12$$

To calculate the *tpf* for the workpiece in Fig. 54-3

$$tpf = \frac{(1\frac{1}{4} - 1)}{3} \times 12$$
$$= \frac{1}{4} \times \frac{1}{3} \times 12$$
$$= 1$$

TO CALCULATE THE TAILSTOCK OFFSET

When calculating the tailstock offset, the *tpf* and the total length of the work must be known (Fig. 54-4).

$$\text{Tailstock offset} = \frac{tpf \times \text{length of work}}{24}$$

$$tpf = \frac{(1\frac{1}{8} - 1)}{3} \times 12$$
$$= \frac{1}{8} \times \frac{1}{3} \times 12$$
$$= 1/2 \text{ in.}$$

$$\text{Tailstock offset} = \frac{1/2 \times 6}{24}$$
$$= \frac{1}{2} \times \frac{1}{24} \times 6$$
$$= 1/8 \text{ in.}$$

A simplified formula can be used to calculate the tailstock offset if the taper per inch is known:

$$\text{Taper per inch} = \frac{\text{taper per foot}}{12}$$

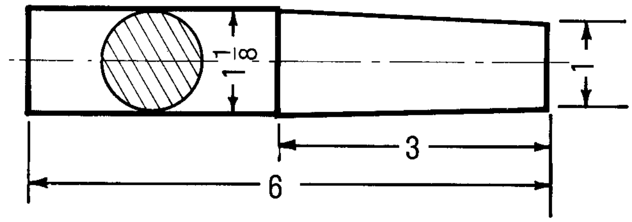


Figure 54-4 *Dimensions of a workpiece having a taper.*

$$\text{Tailstock offset} = \frac{\text{taper per inch} \times \text{OL}}{2}$$

where OL = overall length of work.

In cases where it is not necessary to find the *tpf*, the following simplified formula can be used to calculate the amount of tailstock offset.

$$\text{Tailstock offset} = \frac{\text{OL}}{\text{TL}} \times \frac{(D - d)}{2}$$

OL = overall length of work
TL = length of the tapered section
D = diameter at the large end
d = diameter at the small end

For example, to find the tailstock offset required to cut the taper for the work in Fig. 54-4

$$\text{Tailstock offset} = \frac{6}{3} \times \frac{1}{8} \times \frac{1}{2}$$
$$= 1/8 \text{ in.}$$

INCH TAPER ATTACHMENT OFFSET CALCULATIONS

Most tapers cut on a lathe with the taper attachment are expressed in *tpf*. If the *tpf* of the taper on the workpiece is not given, it may be calculated by using the following formula:

$$tpf = \frac{(D - d) \times 12}{\text{TL}}$$

EXAMPLE

Calculate the *tpf* for a taper with the following dimensions: large diameter (D), 1⅜ in.; small diameter (d), $^{15}/_{16}$ in.; length of tapered section (TL), 7 in.

$$tpf = \frac{(1\text{-}3/8 - 15/16) \times 12}{7}$$
$$= \frac{7/16 \times 12}{7}$$
$$= 3/4 \text{ in.}$$

METRIC TAPERS

Metric tapers are expressed as a ratio of 1 mm per unit of length. In Fig. 54-5 the work would taper 1 mm in a distance of 20 mm. This taper would then be expressed as a ratio of 1:20 and would be indicated on a drawing as "taper = 1:20."

Since the work tapers 1 mm in 20 mm of length, the diameter at a point 20 mm from the small diameter (d) will be 1 mm larger ($d + 1$).

Some common metric tapers are:

Milling machine spindle	1:3.429
Morse taper shank	1:20 (approx.)
Tapered pins and pipe threads	1:50

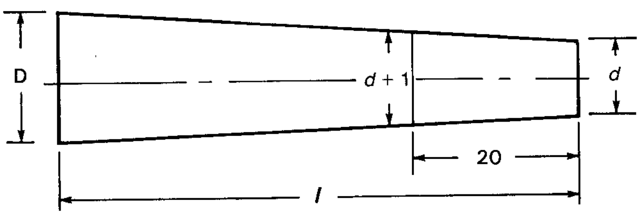


Figure 54-5 *Characteristics of a metric taper.*

Metric Taper Calculations

If the small diameter (d), the unit length of taper (k), and the total length of taper (l) are known, the large diameter (D) may be calculated.

In Fig. 54-6, the large diameter (D) will be equal to the small diameter plus the amount of taper. The amount of taper for the unit length (k) is $(d + 1) - (d)$ or 1 mm. Therefore the amount of taper per millimeter of unit length = $1/k$.

The *total amount of taper* is the taper per millimeter ($1/k$) multiplied by the total length of taper (l);

$$\text{Total taper} = \frac{1}{k} \times l \quad \text{or} \quad \frac{l}{k}$$

$$D = d + \text{total amount of taper}$$

$$= d + \frac{l}{k}$$

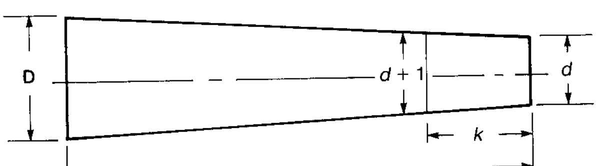


Figure 54-6 *Dimensions of a metric taper.*

EXAMPLE

Calculate the large diameter D for a 1:30 taper having a small diameter of 10 mm and a length of 60 mm.

SOLUTION

Since the taper is 1:30, $k = 30$

$$D = d + \frac{l}{k}$$

$$= 10 + \frac{60}{30}$$

$$= 10 + 2$$

$$= 12 \text{ mm}$$

METRIC TAILSTOCK OFFSET CALCULATIONS

If the taper is to be turned by offsetting the tailstock, the amount of offset is calculated as follows. See Fig. 54-7.

$$\text{Offset} = \frac{D - d}{2 \times l} \times L$$

D = large diameter
d = small diameter
l = length of taper
L = length of work

EXAMPLE

Calculate the tailstock offset required to turn a 1:30 taper × 60 mm long on a workpiece 300 mm long. The small diameter of the tapered section is 20 mm.

SOLUTION

$$D = d + \frac{l}{k}$$

$$= 20 + \frac{60}{30}$$

$$= 20 + 2$$

$$= 22 \text{ mm}$$

$$\text{Tailstock offset} = \frac{D - d}{2 \times l} \times L$$

$$= \frac{22 - 20}{2 \times 60} \times 300$$

$$= \frac{2}{120} \times 300$$

$$= 5 \text{ mm}$$

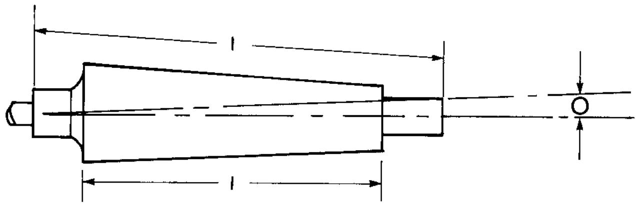


Figure 54-7 *Metric taper turning by the tailstock offset method.*

METRIC TAPER ATTACHMENT OFFSET CALCULATIONS

When the taper attachment is used to turn a taper, the amount the guide bar is set over may be determined as follows:

1. If the angle of taper is given on the drawing, set the guide bar to one-half the angle (Fig. 54-8).
2. If the angle of taper is not given on the drawing, use the following formula to find the amount of guide bar setover.

$$\text{Guide bar setover} = \frac{D - d}{2} \times \frac{\text{GL}}{l}$$

D = large diameter of taper
d = small diameter of taper
l = length of taper
GL = length of taper attachment guide bar

EXAMPLE

Calculate the amount of setover for a 500-mm-long guide bar to turn a 1:50 × 250-mm-long taper on a workpiece. The small diameter of the taper is 25 mm.

SOLUTION

$$D = d + \frac{l}{k}$$

$$= 25 + \frac{250}{50}$$

$$= 30 \text{ mm}$$

$$\text{Guide bar setover} = \frac{D - d}{2} \times \frac{\text{GL}}{l}$$

$$= \frac{30 - 25}{2} \times \frac{500}{250}$$

$$= \frac{5}{2} \times 2$$

$$= 5 \text{ mm}$$

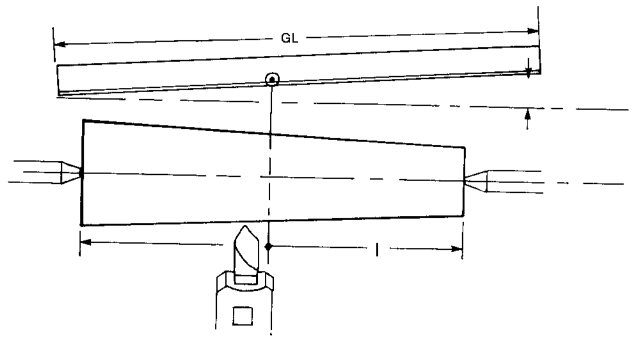


Figure 54-8 *Metric taper turning by the taper attachment method.*

TAPER TURNING

Taper turning on a lathe can be performed on work held between centers or in a lathe chuck. There are three methods of producing a taper:

1. By offsetting the tailstock
2. By means of a taper attachment set to the proper *tpf* or the proper taper angle of the workpiece; on inch tapers by means of the taper attachment set to the *tpf* or taper angle of the workpiece; or on metric tapers by calculating the guide bar offset
3. By adjusting the compound rest to the angle of the taper

The method used to machine any taper depends on the work length, taper length, taper angle, and number of pieces to be machined.

THE TAILSTOCK OFFSET METHOD

The tailstock offset method is generally used to cut a taper when no taper attachment is available. This involves moving the tailstock center out of line with the headstock center. However, the amount that the tailstock may be offset is limited. This method will not permit steep tapers to be turned or standard tapers to be turned on the end of a long piece of work.

Methods of Offsetting the Tailstock

The tailstock may be offset by three methods:

1. By using the graduations on the end of the tailstock (visual method)
2. By means of the graduated collar and feeler gage
3. By means of a dial indicator

To Offset the Tailstock by the Visual Method

1. Loosen the tailstock clamp nut.
2. Offset the upper part of the tailstock by loosening one

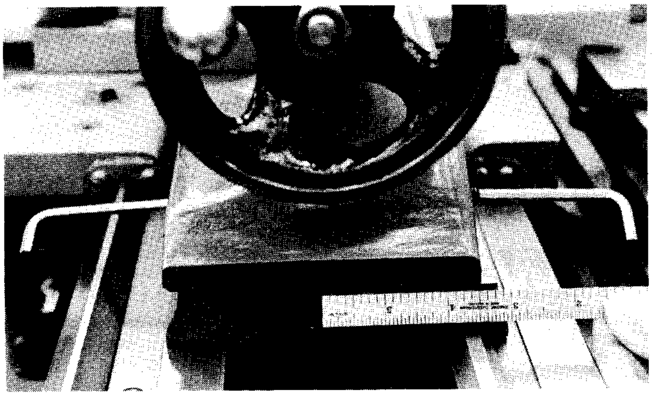


Figure 54-9 *Measuring the amount of offset with a rule.*

setscrew and tightening the other until the required amount is indicated on the graduated scale at the end of the tailstock (Fig. 54-9).

NOTE: Before machining the work make sure that both setscrews are snugged up to prevent any lateral movement of the tailstock.

To Offset the Tailstock Accurately

The tailstock may be accurately offset by using a dial indicator (Fig. 54-10).

1. Adjust the tailstock spindle to the distance it will be used in the machining setup and lock the tailstock spindle clamp.
2. Mount a dial indicator in the toolpost with the plunger in a horizontal position and on center.
3. Using the crossfeed handle, move the indicator so that it registers approximately 0.020 in. (0.50 mm) on the work, and set the indicator and crossfeed graduated collars to 0.
4. Loosen the tailstock clamp nut.
5. With the tailstock adjusting setscrews, move the tailstock until the required offset is shown on the dial indicator.
6. Tighten the tailstock setscrew that was loosened, being sure that the indicator reading does not change.
7. Tighten the tailstock clamp nut.

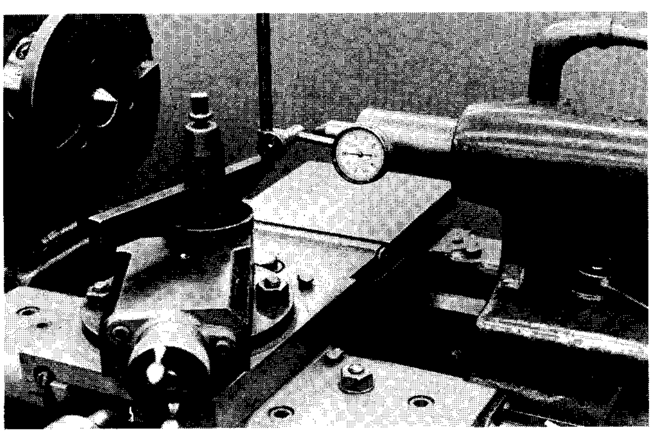


Figure 54-10 *Offsetting a tailstock using a dial indicator. (Courtesy Kostel Enterprises Limited.)*

The tailstock may also be offset fairly accurately by using a feeler gage between the toolpost and the tailstock spindle in conjunction with the crossfeed graduated collar (Fig. 54-11).

To Turn a Taper by the Tailstock Offset Method

1. Loosen the tailstock clamp nut.
2. Offset the tailstock the required amount.
3. Set up the cutting tool as for parallel turning.

NOTE: The cutting tool *must* be on center.

4. Starting at the small diameter, take successive cuts until the taper is 0.050- to 0.060-in. (1.27- to 1.52-mm) oversize.
5. Check the taper for accuracy using a taper ring gage, if required (see Taper Ring Gages, Unit 14).
6. Finish-turn the taper to the size and fit required.

TAPER TURNING USING THE TAPER ATTACHMENT

The use of a taper attachment for taper turning provides several advantages:

1. The lathe centers remain in alignment preventing the distortion of centers on the workpiece.
2. The setup is simple and permits changing from taper to parallel turning with no time lost to align the centers.
3. The length of the workpiece does not matter, since duplicate tapers may be turned on any length of work.

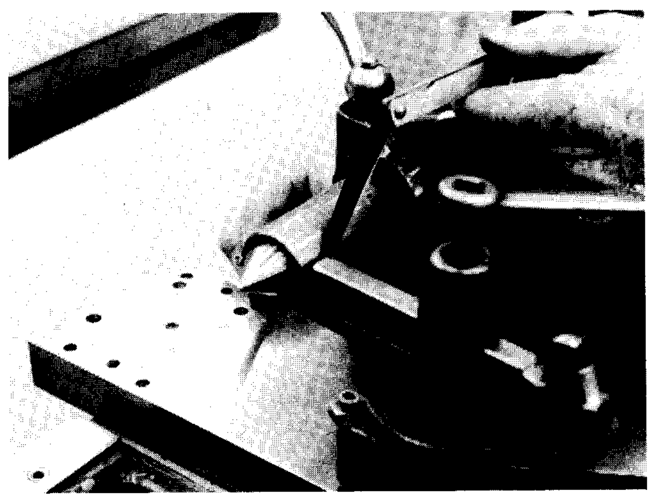


Figure 54-11 *Offsetting a tailstock using the crossfeed graduated collar and a feeler.*

4. Tapers may be produced on work held between centers, in a chuck, or in a collet.
5. Internal tapers can be produced by this method.
6. Metric taper attachments are graduated in millimeters and degrees, while inch attachments are graduated in both degrees and inches of *tpf.* This eliminates the need of lengthy calculations and set up.
7. A wider range of tapers may be produced.

There are two types of taper attachments:

1. The plain taper attachment (Fig. 54-12)
2. The telescopic taper attachment (Fig. 54-13)

When using the *plain taper attachment,* remove the binding screw which holds the cross-slide to the crossfeed screw nut. The binding screw is then used to connect the sliding block to the slide of the taper attachment. With the plain taper attachment, the depth of cut is made by using the compound rest feed handle.

When a *telescopic taper attachment* is used, the crossfeed screw is not disengaged and the depth of cut can be set by the crossfeed handle.

To Cut a Taper Using a Telescopic Taper Attachment

1. Clean and oil the guide bar B (Fig. 54-13).
2. Loosen the lock screws D^1 and D^2 and offset the end of the guide bar the required amount or, for inch attachments, set the bar to the required taper in degrees or *tpf.*
3. Tighten the lock screws.
4. Set up the cutting tool on center.
5. Set the workpiece in the lathe and mark the length of taper.
6. Tighten the connecting screw G on the sliding block E.

NOTE: If a plain taper attachment is being used, remove the binding screw in the cross-slide and use it to connect the sliding block and the connecting slide. The compound rest must also be set at right angles to the lathe bed.

7. Move the carriage until the center of the attachment is opposite the length to be tapered.
8. Lock the anchor bracket A to the lathe bed.
9. Take a cut 1/16 in. (1.5 mm) long, stop the lathe, and check the end of the taper for size.
10. Set the depth of the roughing cut to 0.050 to 0.060 in. (1.27 to 1.52 mm) oversize, and machine the taper.

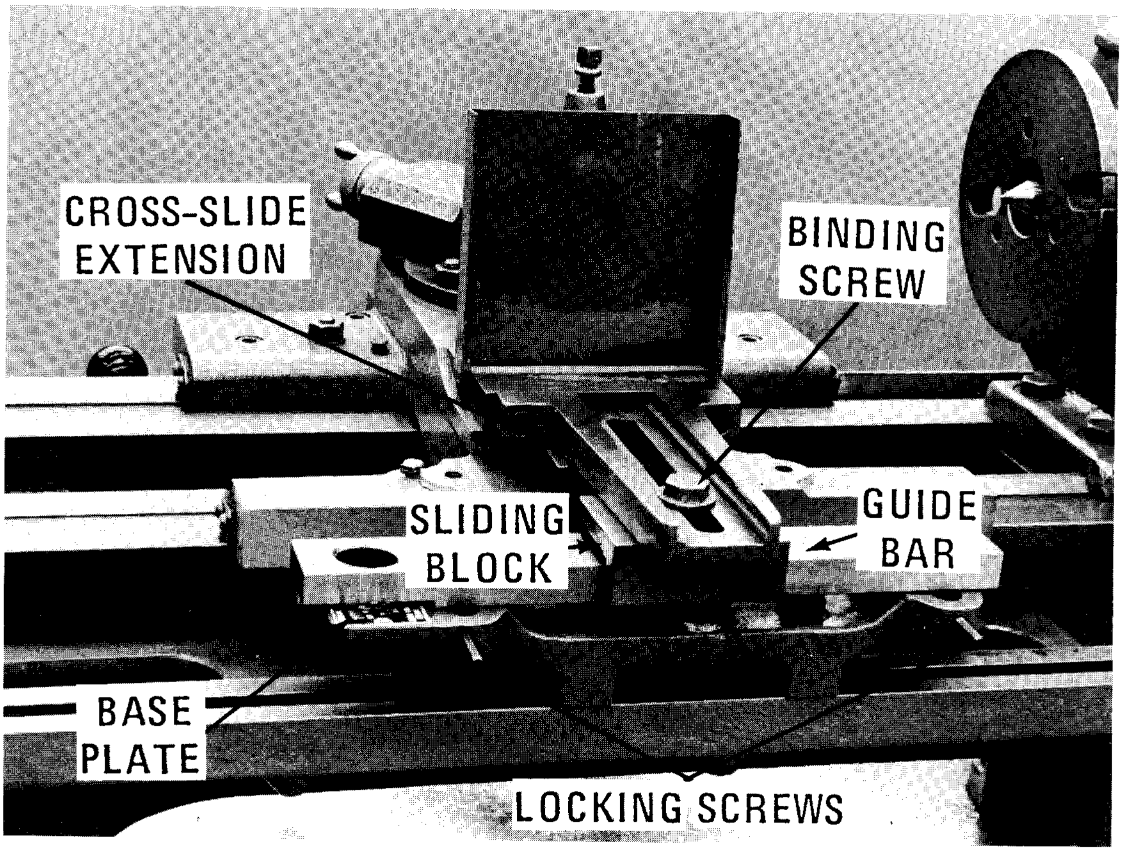


Figure 54-12 *The parts of a plain taper attachment.*

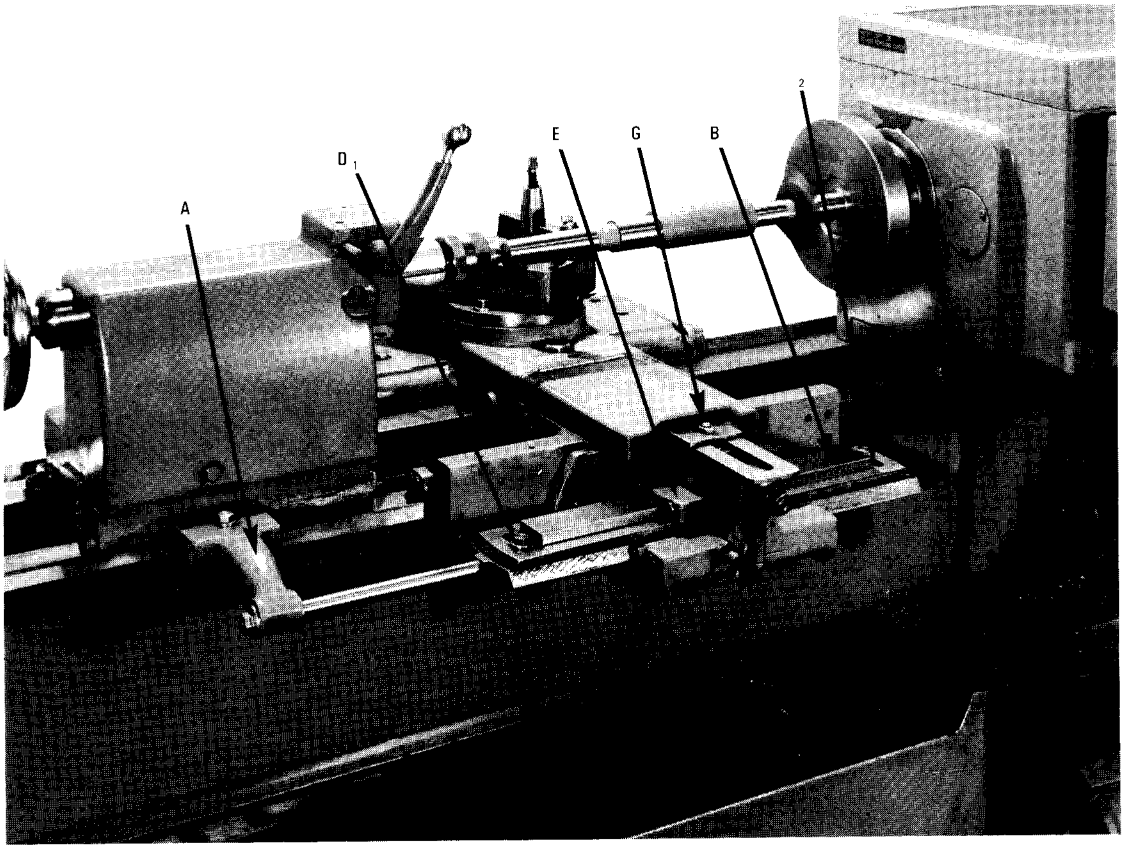


Figure 54-13 *The telescopic taper attachment.*

NOTE: Start the feed about ½ in. (13 mm) before the start of the cut to remove any play in the taper attachment.

11. Readjust the taper attachment if necessary, take a light cut, and recheck the taper fit.
12. Finish-turn and fit the taper to a gage.

When standard tapers must be produced on a piece of work, a taper plug gage may be mounted between centers and the taper attachment adjusted to this angle by using a dial indicator mounted on center in the toolpost.

When an *internal taper* is cut, the same procedure is followed, except that the guide bar is set to the side of the centerline opposite to that used when turning an external taper.

When mating external and internal tapers must be cut, it is advisable first to machine the internal taper to a plug gage. The external taper is then fitted to the internal taper.

TAPER TURNING USING THE COMPOUND REST

To produce short or steep tapers stated in degrees, the compound rest method is used. The tool must be fed in by hand, using the compound rest feed handle. Proceed as follows:

1. Refer to the drawing for the amount of taper required in degrees. However, if the angle on the drawing is not given in degrees, calculate the compound rest setting as follows:

$$\text{Tan } \frac{1}{2} \text{ angle} = \frac{tpf}{24} \quad \text{or} \quad \frac{tpi}{2}$$

For example, for the workpiece illustrated in Fig. 54-3, the calculations would be:

$$tpf = \frac{1}{4} \times \frac{12}{3}$$
$$= 1 \text{ in.}$$
$$\text{Tan angle} = \frac{1}{24}$$
$$= 0.04166$$

By referring to the trigonometric tables in any handbook, it is found that one-half the angle of this taper (and the compound rest setting) is 2°23′. If a set of trigonometry tables is not available, use the simplified formula to calculate the angle of the taper and the compound rest setting. Tan angle = $tpf \times 2°23'$.

2. Loosen the compound rest lock screws.

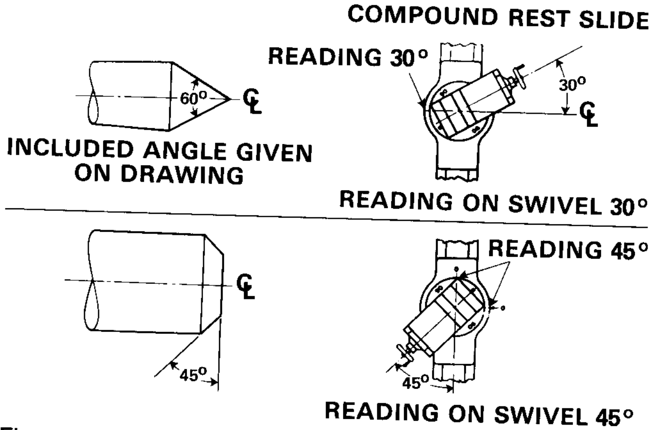


Figure 54-14 *Direction to swing the compound rest for cutting various angles.*

3. Swivel the compound rest as follows:
   a. Where included angles are given on a drawing, swivel the compound rest to one-half the angle (Fig. 54-14 top).
   b. Where angles are given on one side only (Fig. 54-14 bottom), swivel the compound rest to that angle.
4. Tighten the compound rest lock screws using only two-finger pressure on the wrench to avoid stripping the lock screw threads.
5. Set the cutting tool to center with the toolholder at right angles to the taper to be cut.
6. Tighten the toolpost securely.
7. Back off the top slide of the compound rest so that there will be enough travel to machine the length of the taper.
8. Move the carriage to position the cutting tool near the start of the taper and then lock the carriage.
9. Rough turn the taper by feeding the cutting tool using the *compound rest feed handle* (Fig. 54-15).
10. Check the taper for accuracy and readjust the compound rest setting if necessary.
11. Finish turn and check the taper for size and fit.

CHECKING A TAPER

Inch tapers can be checked by scribing two lines exactly 1 in. apart on the taper and carefully measuring the taper at these points with a micrometer (Fig. 54-16). The difference in readings will indicate the *tpi* of the workpiece. Tapers may be more accurately checked by using a sine bar (see Unit 13).

To obtain a more accurate taper, a taper ring gage is used to check external tapers. A taper plug gage is used to check internal tapers (see Unit 14).

The *taper micrometer* (Fig. 54-17) quickly and accurately measures tapers while the workpiece is still in the machine. This instrument includes an adjustable anvil and a 1 in. sine bar attached to the frame, which is adjusted by the micrometer thimble. The micrometer reading indicates the *tpi*, which can be readily converted to *tpf* or angles. The anvil can be adjusted to accommodate a wide range of work sizes.

Taper micrometers are available in various models for measuring internal tapers and dovetails (Fig. 54-18), and in bench models incorporating two indicators for quickly checking the accuracy of tapered parts.

The advantages of taper micrometers are:

- The taper accuracy can be checked while the workpiece is still in the machine.
- They provide a quick and accurate means of checking tapers.

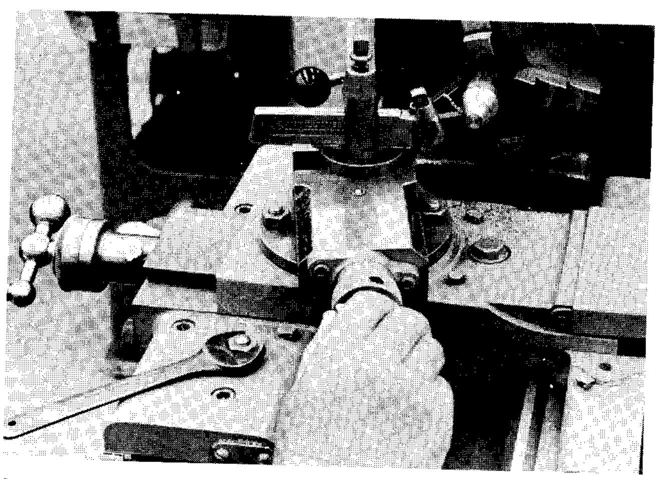


Figure 54-15 *Cutting a short taper using a compound rest.*

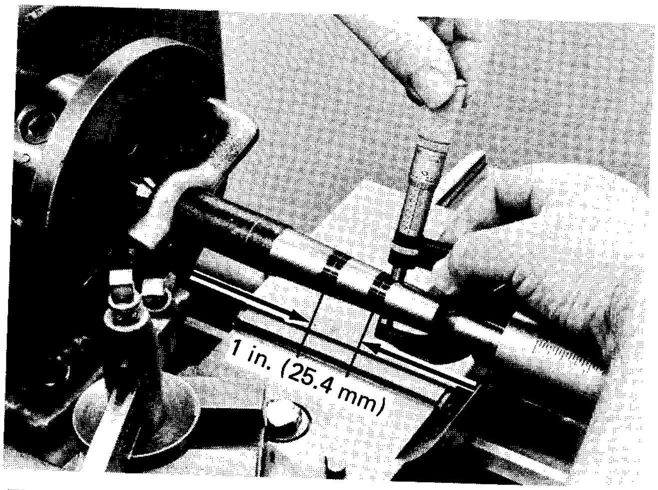


Figure 54-16 *Checking the accuracy of a taper with a micrometer.*

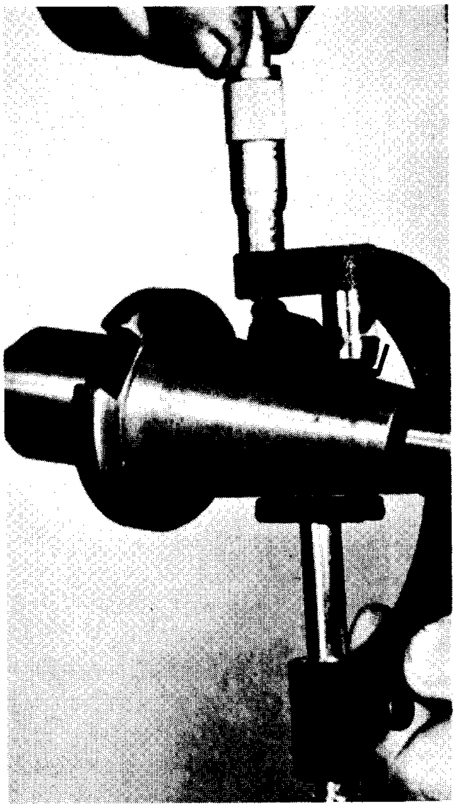


Figure 54-17 *Using a taper micrometer to check an external taper. (Courtesy Taper Micrometer Corporation.)*

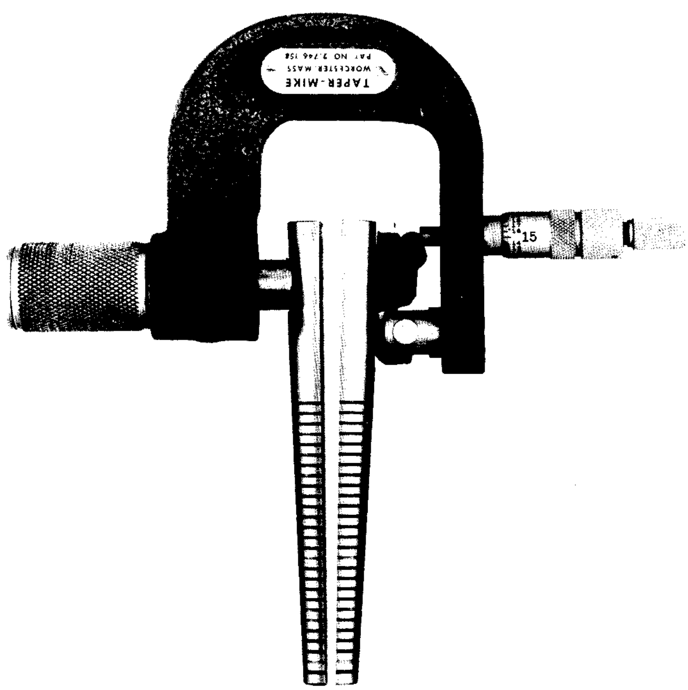


Figure 54-18 *A taper micrometer for measuring internal tapers. (Courtesy Taper Micrometer Corporation.)*

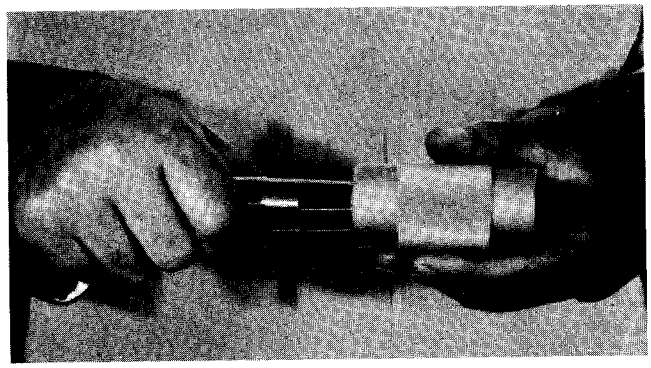


Figure 54-19 *Checking the accuracy of a taper using chalk lines.*

- They are simple to operate.
- The need for costly gaging equipment is eliminated.
- They can be used for measuring external tapers, internal tapers, and dovetails.

TO FIT AN EXTERNAL TAPER

1. Make three equally spaced lines with chalk or mechanics blue along the taper (see Unit 14, Taper Ring Gages).
2. Insert the taper into the ring gage and turn *counterclockwise* for one-half turn (Fig. 54-19).

CAUTION: Do not force the taper into the ring gage.

3. Remove the workpiece and examine the chalk marks. If the chalk has spread along the whole length of the taper, the taper is correct. If the chalk lines are rubbed from only one end, the taper setup must be adjusted.
4. Make a slight adjustment to the taper attachment and, taking trial cuts, machine the taper until the fit is correct.

TO CHECK A METRIC TAPER

1. Check the drawing for the taper required.
2. Clean the tapered section of the work and apply layout dye.
3. Lay out two lines on the taper, which are the same distance apart as the second number in the taper ratio. For example, if the taper was 1:20, the lines would be 20 mm apart.

NOTE: If the work is long enough, lay out the lines at double or triple the length of the tapered section and increase the difference in diameters by the appropriate amount. For instance, on a 1:20 taper the lines may be laid out 60 mm apart or three times the unit length of the taper. Therefore the difference in diameters would then be 3 × 1, or 3 mm. This will give a more accurate check of the taper.

4. Measure the diameters carefully with a metric micrometer at the two lines. The difference between these two diameters should be 1 mm for each unit of length.

5. If necessary, adjust the taper attachment setting to correct the taper.

REVIEW QUESTIONS

TAPERS

1. Define a *taper.*
2. Explain the difference between self-holding and steep tapers.
3. State the *tpf* for the following tapers:
   a. Morse
   b. Brown and Sharpe
   c. Jarno
   d. Standard taper pin
4. Describe the type D-1 and type L spindle nose and state where each is used.

TAPER CALCULATIONS

5. Calculate the *tpf* and tailstock offset for the following work:
   a. $D = 1.625$ in., $d = 1.425$ in., TL = 3 in., OL = 10 in.
   b. $D = 7/8$ in., $d = 7/16$ in., TL = 6 in., OL = 9 in.
6. Calculate the tailstock offset for the following using the simplified tailstock offset formula:
   a. $D = 3/4$ in., $d = 17/32$ in., TL = 6 in., OL = 18 in.
   b. $D = 7/8$ in., $d = 25/32$ in., TL = 3½ in., OL = 10½ in.
7. Explain what is meant by a metric taper of 1:50.
8. Calculate the large diameter of a 1:50 taper having a small diameter of 15 mm and a length of 75 mm.
9. Calculate the tailstock offset required to turn a 1:40 taper × 100 mm long on a workpiece 450 mm long. The small diameter is 25 mm.

TAPER TURNING

10. Name three methods of offsetting the tailstock for taper turning.
11. List the advantages of a taper attachment.
12. List the main steps required to cut an external taper using the taper attachment.
13. Describe a taper micrometer and state its advantages.
14. Explain in point form how to fit an external taper.
15. Calculate the amount of setover for a 480-mm-long guide bar to turn a 1:40 taper × 320 mm long on a workpiece. The small diameter of the taper is 37.5 mm.
16. At what angle should the compound rest be set to machine a workpiece with a large diameter of 1¼ in., small diameter of ¾ in., length of taper of 1 in.?

UNIT 55

Threads and Thread Cutting

Threads have been used for hundreds of years for holding parts together, making adjustments to tools and instruments, and for transmitting power and motion. A thread is basically an inclined plane or wedge that spirals around a bolt or nut. Threads have progressed throughout the ages from the early screws, which were filed by hand, to the highly accurate ball screws used on the precision machine tools of today. Although the purpose of a thread is basically the same as when the early Romans developed it, the art of producing threads has continually improved. Today threads are mass produced by taps, dies, thread rolling, thread milling, and grinding to exacting standards of accuracy and quality control. Thread cutting is a skill that every machinist should possess because it is still necessary to cut threads on an engine lathe, especially if a special size or form of thread is required.