8a.
Bending and Forming Tools

Nageswara Rao Posinasetti

Sheet metal operations

Stresses induced	Operations
Shearing	Shearing, blanking, piercing, trimming,
	shaving, notching, nibbling
Tension	Stretch forming
Compression	Coining, sizing, ironing, hobbing
Tension and compression	Drawing, spinning, bending, forming, embossing

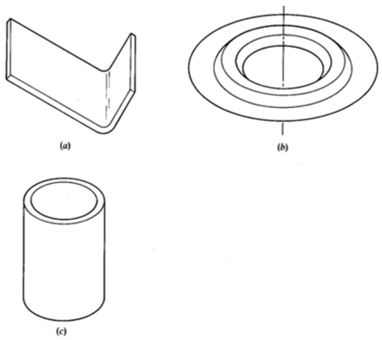


FIGURE 10-1
Basic operations for shaping sheet metal: (*a*) bending, (*b*) forming, (*c*) drawing.

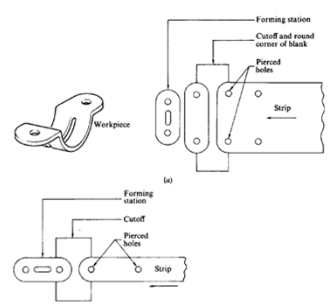


FIGURE 10-12
Feeding strip: (*a*) Material fed short way. Loose blanks difficult to feed into forming station. (*b*) Material fed long way. Blank is fed over forming station before cutoff.

Bending

- Bending refers to the operation of deforming a flat sheet around a straight axis where the neutral plane lies.
- The disposition of the stresses in a bent specimen is shown.
- Here, due to the applied forces, the top layers are in tension and bottom layers are in compression, as shown.

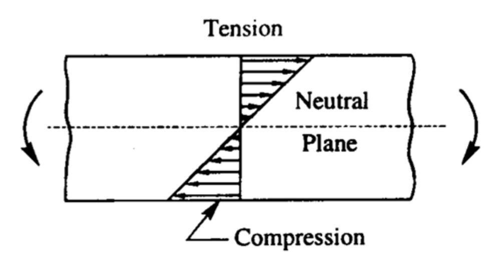


Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

Bending

- The plane with no stresses is called the neutral axis. The neutral axis should be at the centre when the material is elastically deformed.
- But when the material reaches the plastic stage, the neutral axis move downward, since the materials oppose compression much better than tension.

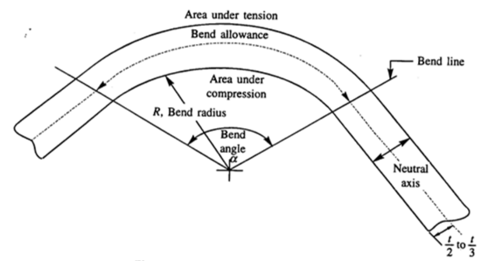


Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

Bend allowance

- Increased length of the sheet because of bending

Bending

- Bend allowance, B = α (R + K t)
- Where α = bend angle, radians
- R = inside radius of the bend, mm
- K = location of neutral axis from bottom surface
  - = 0.33 when R < 2 t
  - = 0.50 when R > 2 t
- t = sheet thickness, mm

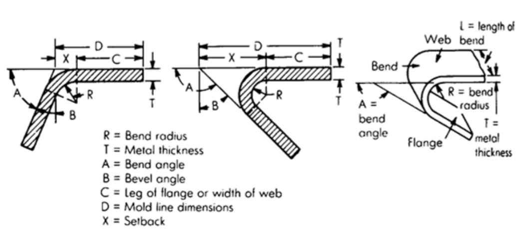


Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

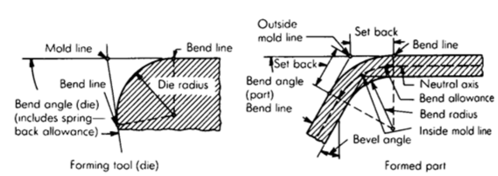


Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

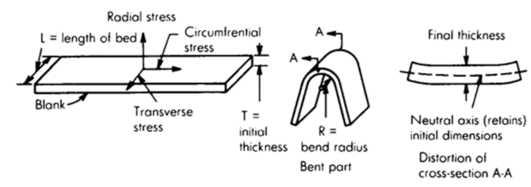


Figure 8-1. **Bending terms.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

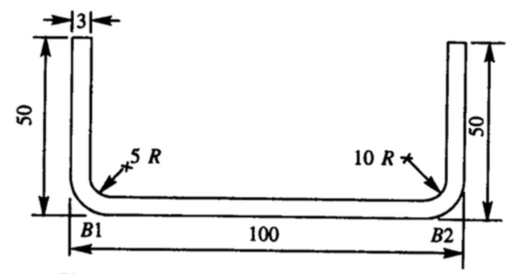


Fig. 21.20 Example for bending length calculation

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

- Since R < 2 t , K = 0.33
- Bend allowance = $\frac{90}{360} \times 2\pi(5 + 0.33 \times 3)$
  = 9.42 mm
- Since R > 2t , K = 0.50
- Bend allowance = $\frac{90}{360} \times 2\pi(10 + 0.5 \times 3)$
  = 18.06 mm
- Total length = 50 - (5+3)+ 9.42+ 100 - (10+3) + 18.06+50 - (10+3) = 185.48 mm

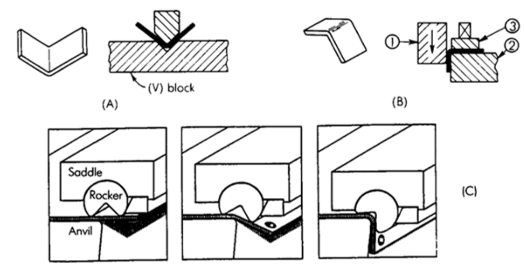


Figure 8-2. **Bending methods: (*A*) V bending; (*B*) edge bending; (*C*) rotary READY® Bender method. (*Courtesy, Ready Tools, Inc.*)**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

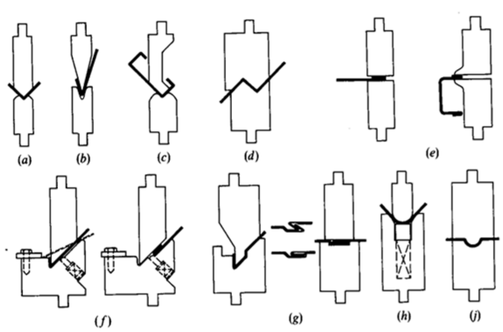


FIGURE 10-4
Typical press-brake bending and forming dies.

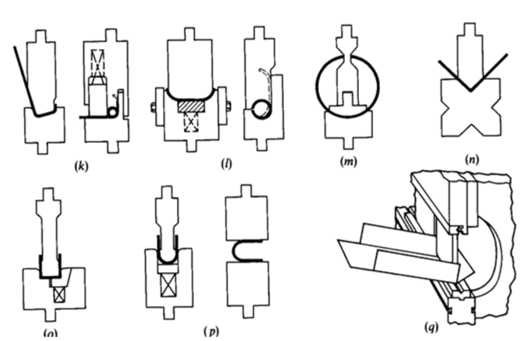


FIGURE 10-4
Typical press-brake bending and forming dies.

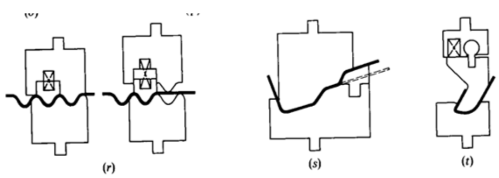
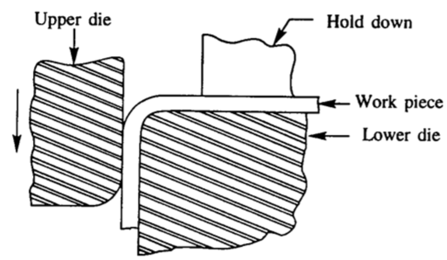
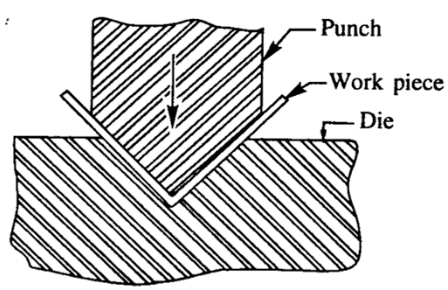


FIGURE 10-4
Typical press-brake bending and forming dies.



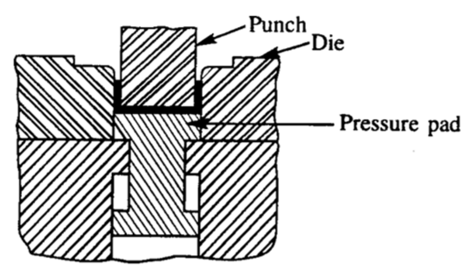
(a) Wiping die

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.



(b) V-die

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.



(c) U-die

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

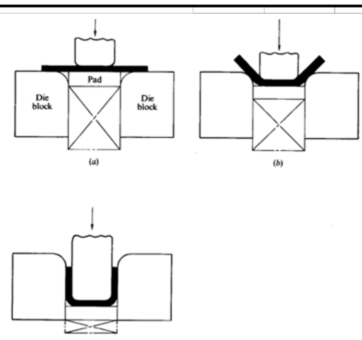


FIGURE 10-9
The principle of the U die (channel die).

Bend radius

- The outer layers which are under tension should not be stretched too much, otherwise there is likelihood of rupture taking place.
- The amount of stretching depends on the sheet thickness and the bend radius.
- Lower the bend radius, higher is the strain in this zone.
- Hence there is a minimum bend radius to be specified, depending on the material characteristics.

Bend radius

- Minimum bend radius = 0.5 t soft materials
  = t other materials
  = 3.0 t spring materials.

Bending force

- The bending load may be calculated from the knowledge of material properties and the die characteristics as shown below:

$$F_b = \frac{KLst^2}{W}$$

$$F_b = \frac{KLst^2}{W}$$

- Where F_b = bending force, tons
- K = 1.33 for die opening of 8t
- = 1.20 for die opening of 16t
- = 0.67 for U bending
- = 0.33 for a wiping die
- L = length of the bent part, in
- s = ultimate tensile strength, lb/in^2.
- t = blank thickness, in
- W = width between the contact points, in
  = 8t for V-bends

Estimate the force required for a 90 deg bending of St 50 steel of thickness 2 mm in a V die. The die opening can be taken as eight times the thickness. The length of the bent part is 1 m.

- Die opening, W = 8 × 2 = 16 mm.
- Ultimate tensile strength = 500 MPa.
- Bending force = $\frac{1.33 \times 1000 \times 500 \times 2^2}{16}$
-
- = 166.25 kN

- Calculate the bending force required for a C50 steel 1.5 mm sheet of width 1 m to be bent in a wiping die. The die radius used is 3 mm.
- C50 steel, ultimate tensile strength can be taken as 800 MPa.

Die opening, W = 1.5 + 3 + 3 = 7.5 mm

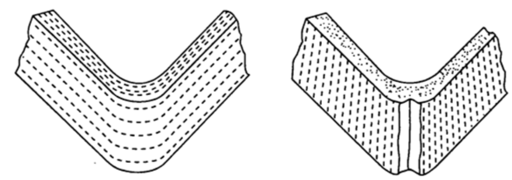
For a wiping die, K = 0.33

Bending force = $\frac{0.33 \times 1000 \times 800 \times 1.5^2}{7.5}$

= 79.20 kN

Bending direction

- Grain orientation
- As far as possible, the bending is to be done in a direction perpendicular to the grain direction in the metal.
- By virtue of the rolled sheets being used for bending, the grain direction usually is along the length axis, being the direction of rolling. There is a possibility of cracks appearing at the time of bending if the bending is done along the grains.



(a) Bent along grain (b) Bent across grain

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

Bending direction

- But if two bendings are to be done on the same sheet at right angles, then it may be desirable to make them at 45 deg to the grain direction so that the risk of cracking is minimised.

Spring back

- One of the principal concerns in bending is the spring back of the metal.
- Spring back in bending is difficult to estimate theoretically. But it is essential to compensate it, because the bend geometry gets affected by the spring back directly.
- The data relating to the most generally used configurations are available in handbooks.

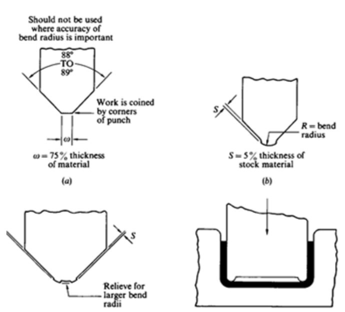


FIGURE 10-5
Methods of corner setting to prevent springback.

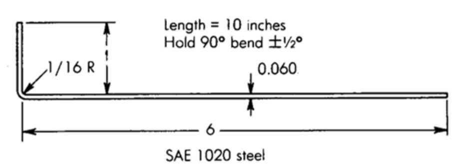


Figure 8-3. **Part bent in the die of *Figure 8-4*.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

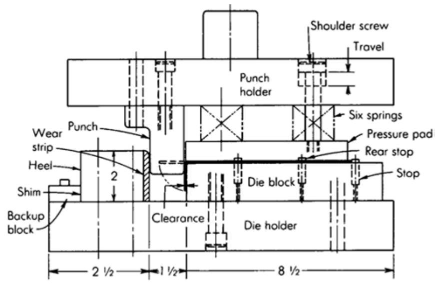


Figure 8-4. Die design for part of *Figure 8-3*.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Forming dies

- Solid form dies
- For parts Made of soft metal such as pipe strap
- Male and female templates are used.

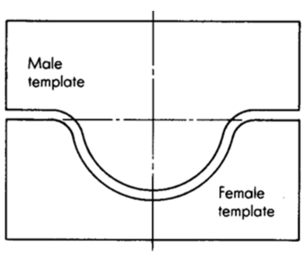
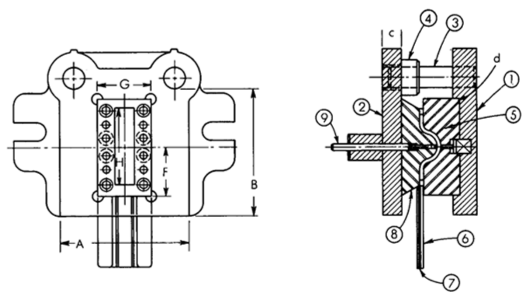


Figure 8-5. Templates for forming.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME



Solid form die

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

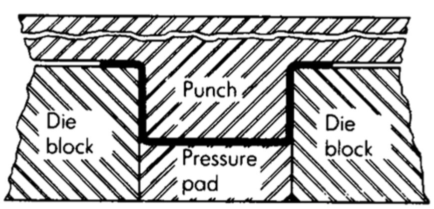


Figure 8-7. A pad-type form die.

For small radius corners

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Forming dies with Pressure pad

- For accurate dies

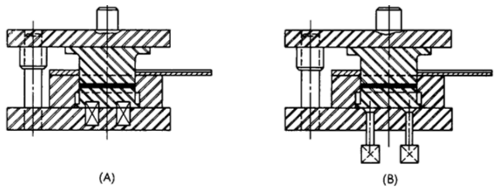


Figure 8-8. Pressure-pad-type form dies.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

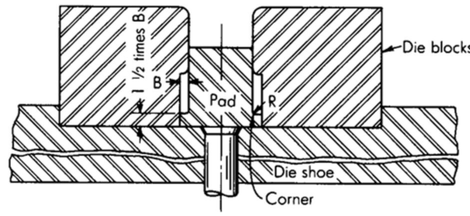


Figure 8-9. Pressure pad design.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

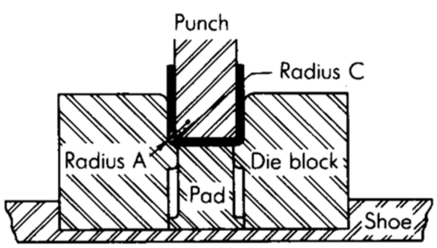


Figure 8-10. Radii considerations for form die design.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

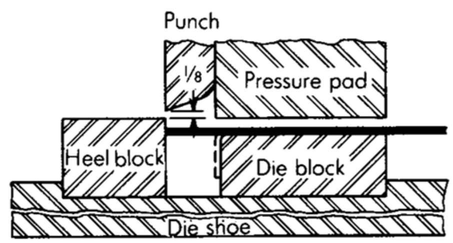


Figure 8-11. Die with a heel block and relieved punch.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Using Rubber and Urethane

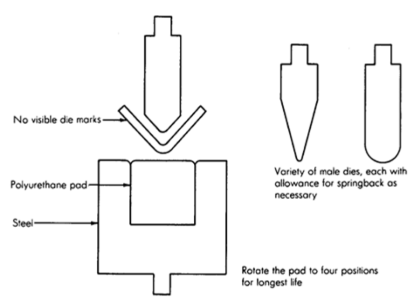


Figure 8-12. Rubber or polyurethane forming die and punches.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Embossing

- Embossing is the operation used in making raised figures on sheets with its corresponding relief on the other side.
- The process essentially involves drawing and bending of the metal.
- An example of the embossing operation is shown.

Embossing

- The die set consists essentially of a die and punch with the desired contours, so that when the punch and die meet the clearance between them is same as that of the sheet thickness.
- Embossing operation is generally used for providing dimples on sheets to increase their rigidity and for decorative sheet work used for panels in houses and religious places.

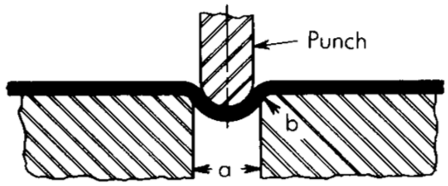


Figure 8-13. **An embossing die.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

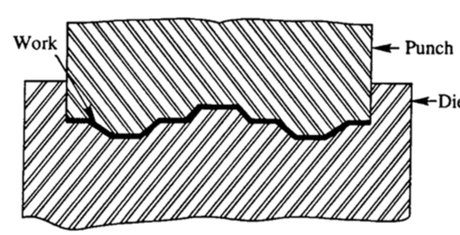
Coining

- Coining is essentially a cold forging operation except for the fact that the flow of the metal occurs only at the top layers and not the entire volume.
- The coining die consists of the punch and die which are engraved with the necessary details required on both sides of the final object.

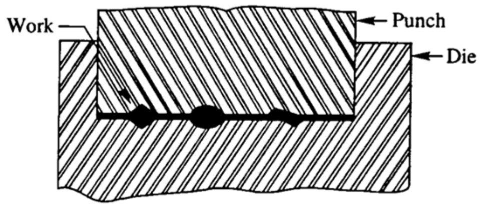
Coining

- The pressures involved in coining are very high, of the order of 1600 MPa because of the very fine details that are normally desired in coining.
- The type of impression obtained on both sides would be different unlike the embossing.
- Coining is used for making coins, medals and similar articles, and for impressions on decorative items.

Embossing



Coining



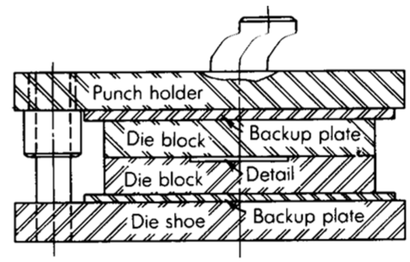


Figure 8-25. **A coining die.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

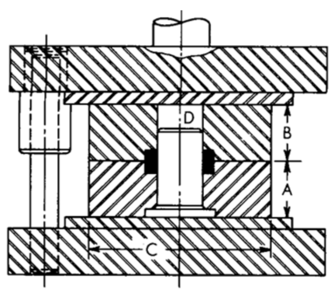


Figure 8-26. **A swaging die.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

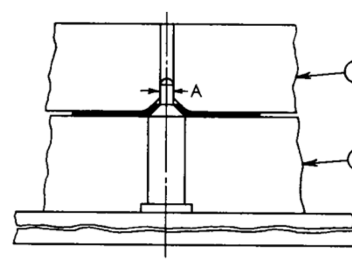


Figure 8-27. **A forming die for countersunk holes.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

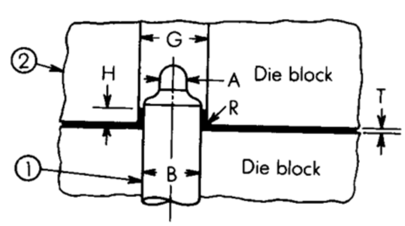


Figure 8-28. **A die for punching and countersinking a hole.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

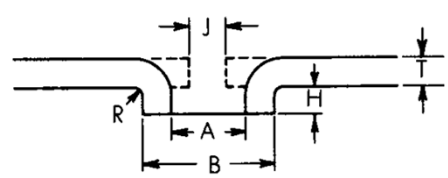


Figure 8-29. **Hole flange design.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

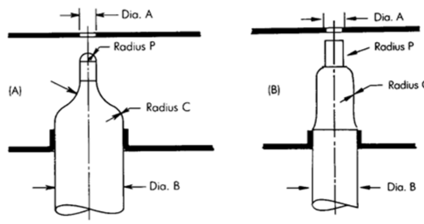


Figure 8-30. (*A*) Two-station flanging punch design; (*B*) Single-station flanging punch design.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME