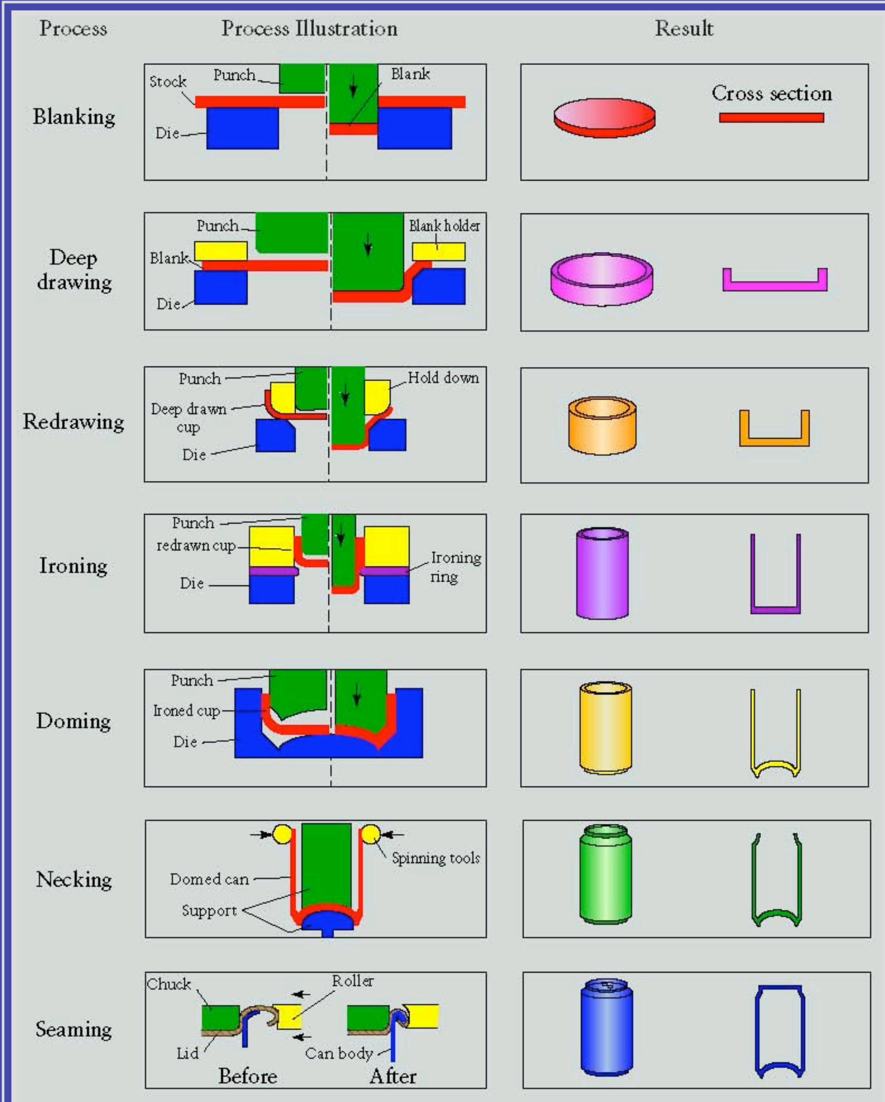

Metal-Forming Process for Food and Beverage Containers

FIGURE 7.76 The metal-forming process used to manufacture two-piece beverage cans.

Deep-drawing Process

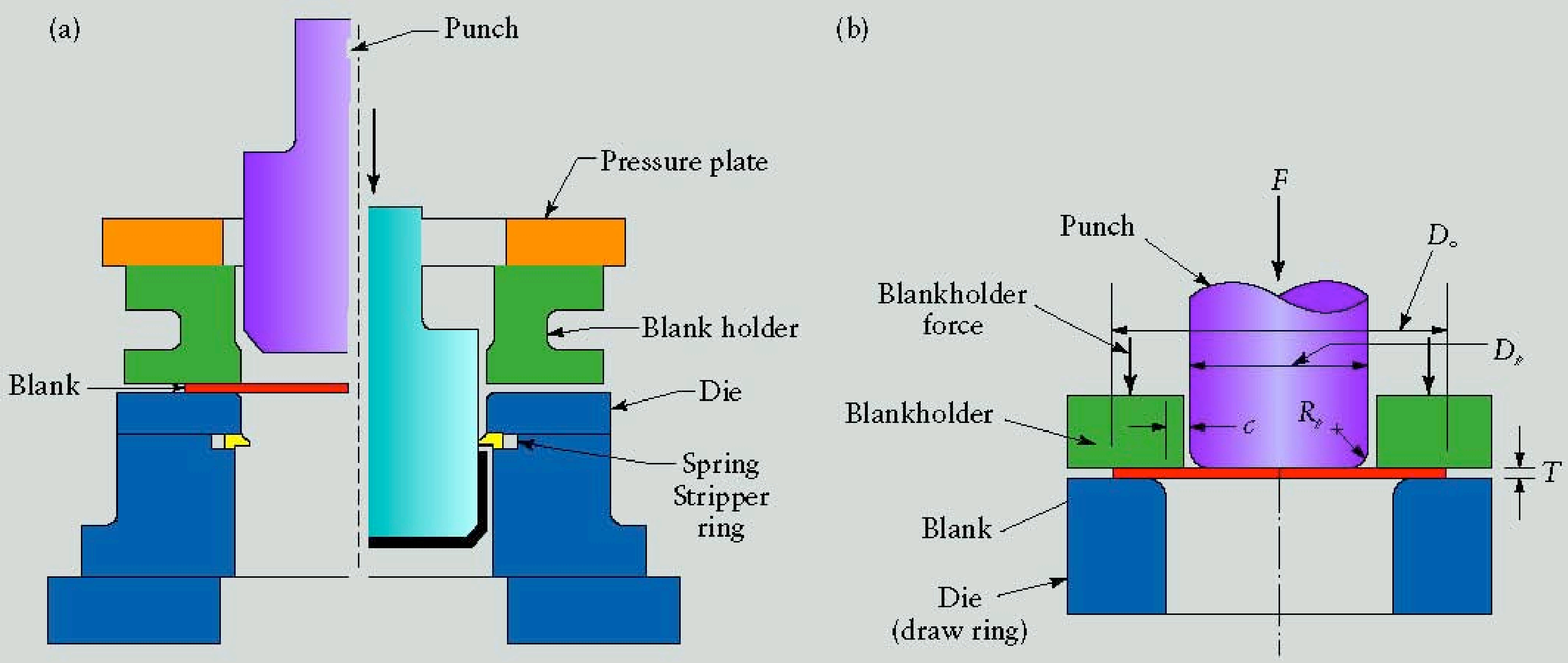

FIGURE 7.50 (a) Schematic illustration of the deep-drawing process. This procedure is the first step in the basic process by which aluminum beverage cans are produced today. The stripper ring facilitates the removal of the formed cup from the punch. (b) Variables in deep drawing of a cylindrical cup. Only the punch force in this illustration is a dependent variable; all others are independent variables, including the blankholder force.

Deformation in Flange and Wall in Deep Drawing

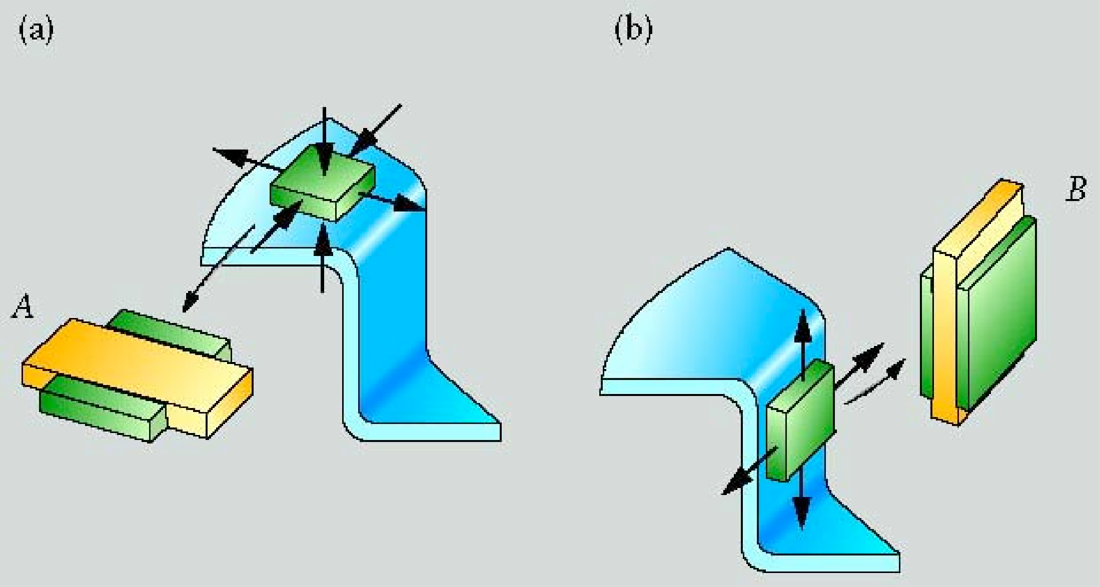

FIGURE 7.51 Deformation of elements in (a) the flange and (b) the cup wall in deep drawing of a cylindrical cup.

Deep Drawing

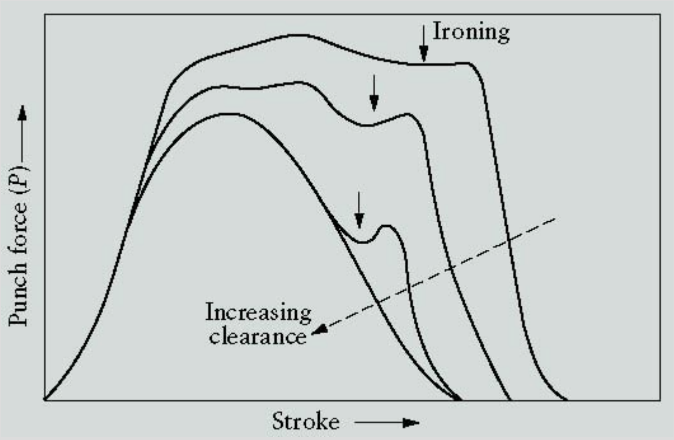

FIGURE 7.60 Schematic illustration of the variation of punch force with stroke in deep drawing. Note that ironing does not begin until after the punch has traveled a certain distance and the cup is formed partially. Arrows indicate the beginning or ironing.

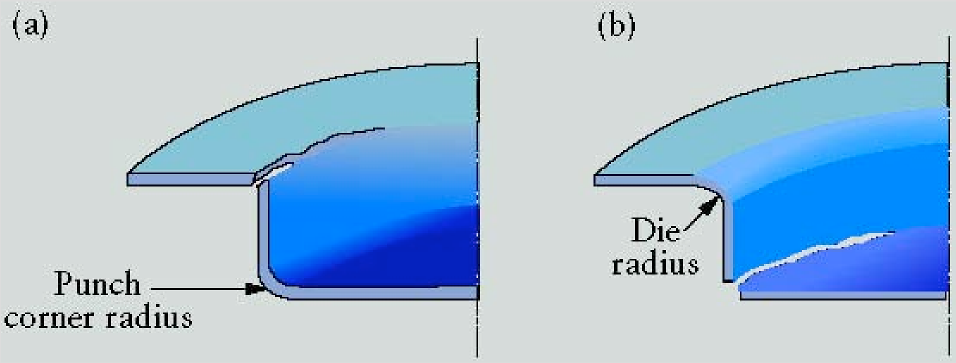

FIGURE 7.61 Effect of die and punch corner radii in deep drawing on fracture of a cylindrical cup. (a) Die corner radius too small. The die corner radius should generally be 5 to 10 times the sheet thickness. (b) Punch corner radius too small. Because friction between the cup and the punch aids in the drawing operation, excessive lubrication of the punch is detrimental to drawability.

Ironing Process

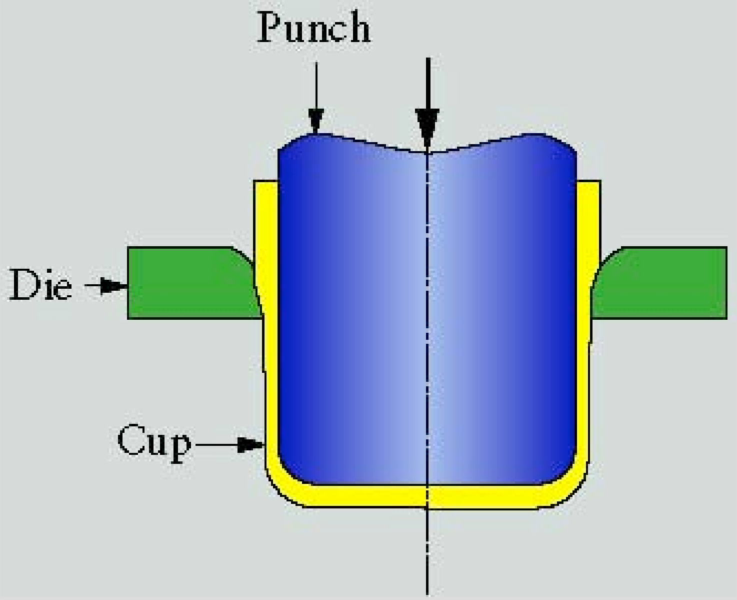

FIGURE 7.54 Schematic illustration of the ironing process. Note that the cup wall is thinner than its bottom. All beverage cans without seams (known as two-piece cans) are ironed, generally in three steps, after being deep drawn into a cup. (Cans with separate tops and bottoms are known as three-piece cans.)

Normal Anisotropy

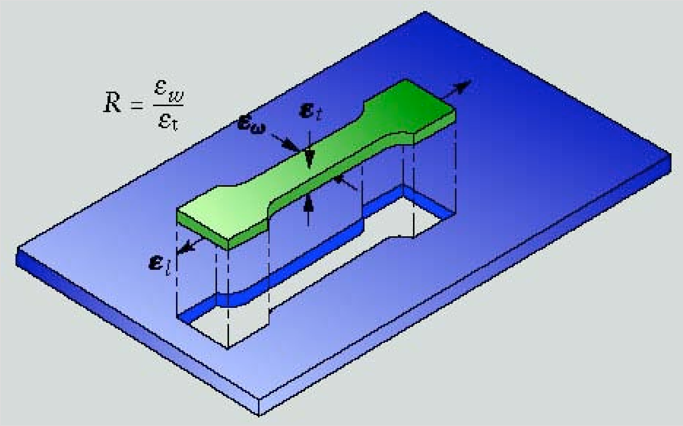

FIGURE 7.55 Definition of the normal anisotropy ratio, *R*, in terms of width and thickness strains in a tensile-test specimen cut from a rolled sheet. Note that the specimen can be cut in different directions with respect to the length, or rolling direction, of the sheet.

Drawing Operations

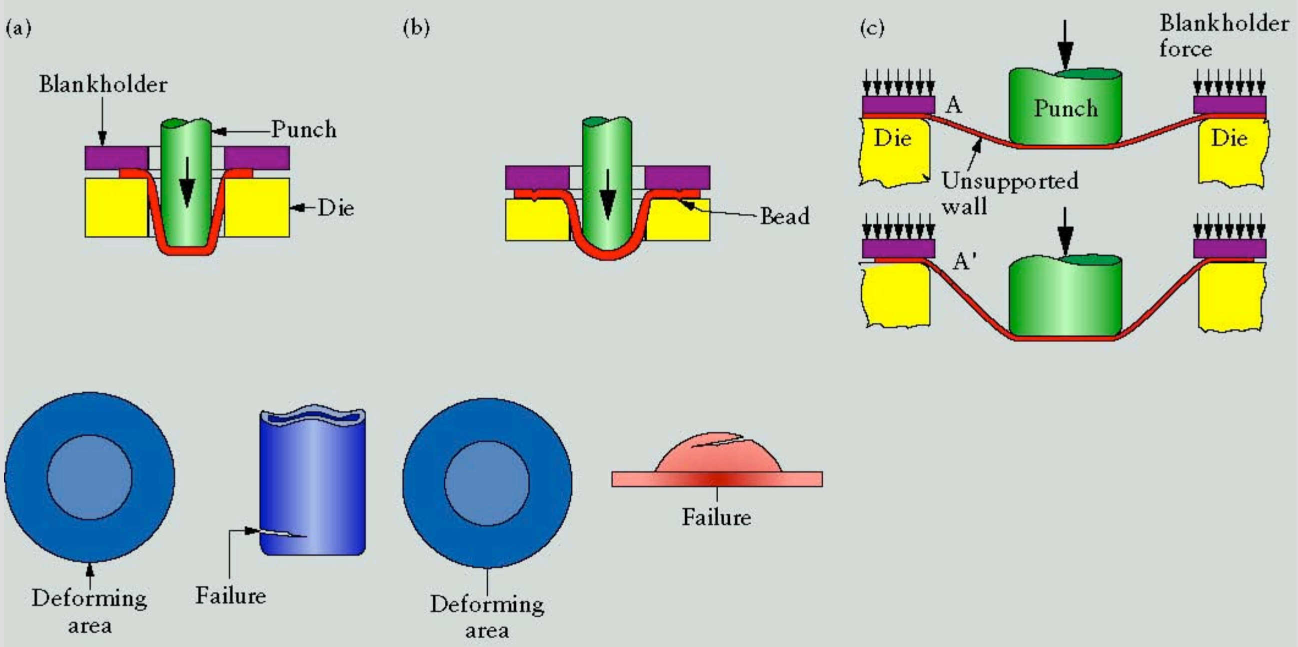

FIGURE 7.52 Examples of drawing operations: (a) pure drawing and (b) pure stretching. The bead prevents the sheet metal from flowing freely into the die cavity. (c) Possibility of wrinkling in the unsupported region of a sheet in drawing. *Source*: After W. F. Hosford and R. M. Caddell.

Draw Bead

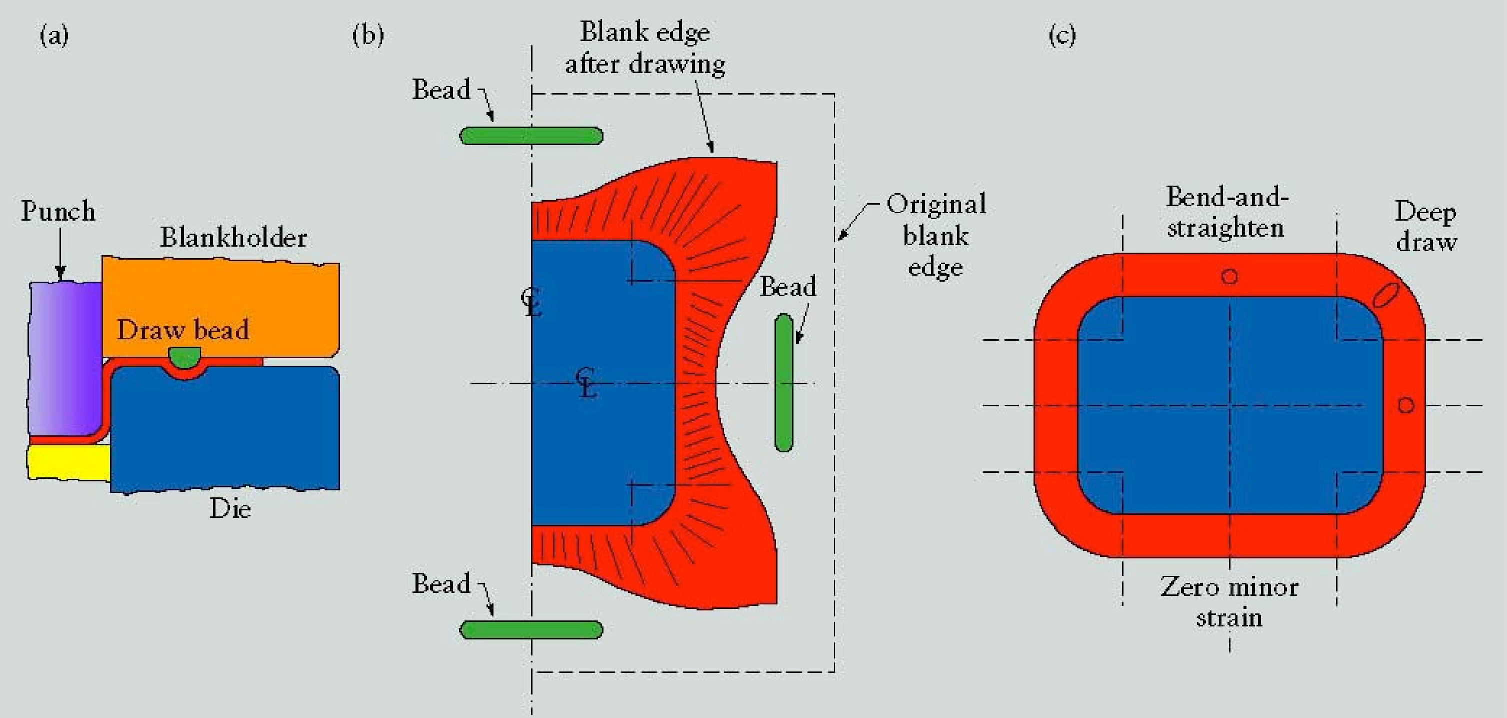

FIGURE 7.53 (a) Schematic illustration of a draw bead. (b) Metal flow during drawing of a box-shaped part, using beads to control the movement of the material. (c) Deformation of circular grids in drawing. (See Section 7.13.) *Source*: After S. Keeler.

Tractrix Die Profile

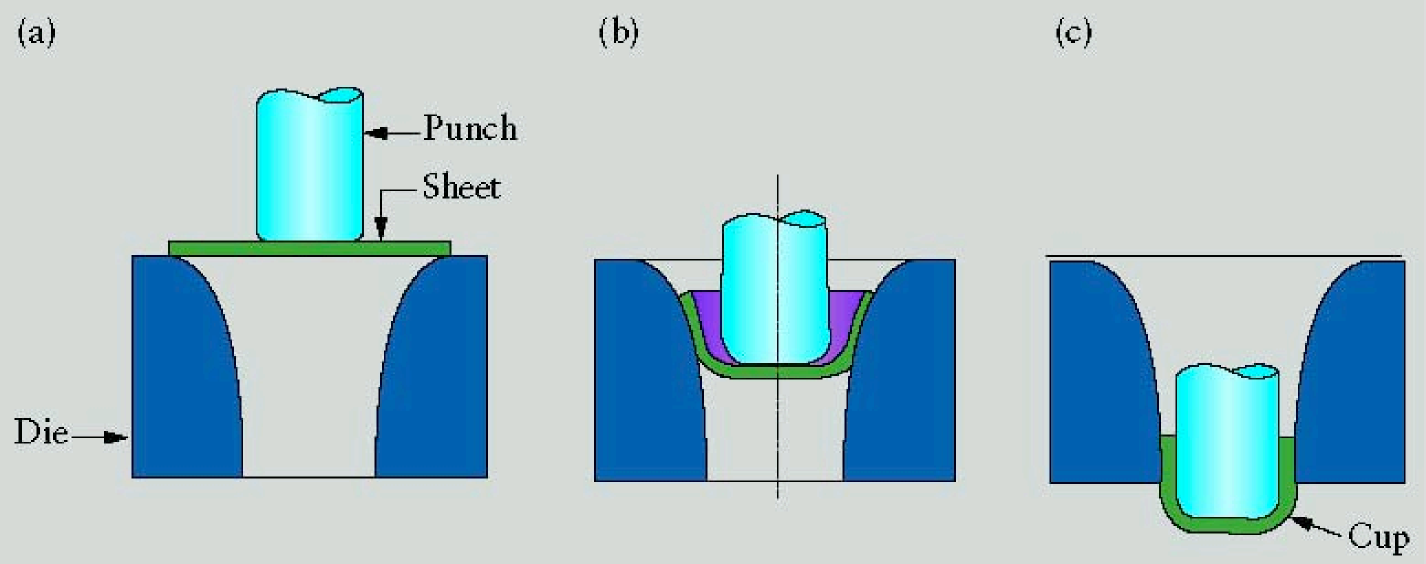

FIGURE 7.63 Deep drawing without a blankholder, using a *tractrix* die profile. The *tractrix* is a special curve, the construction for which can be found in texts on analytical geometry or in handbooks.

Ironing Process

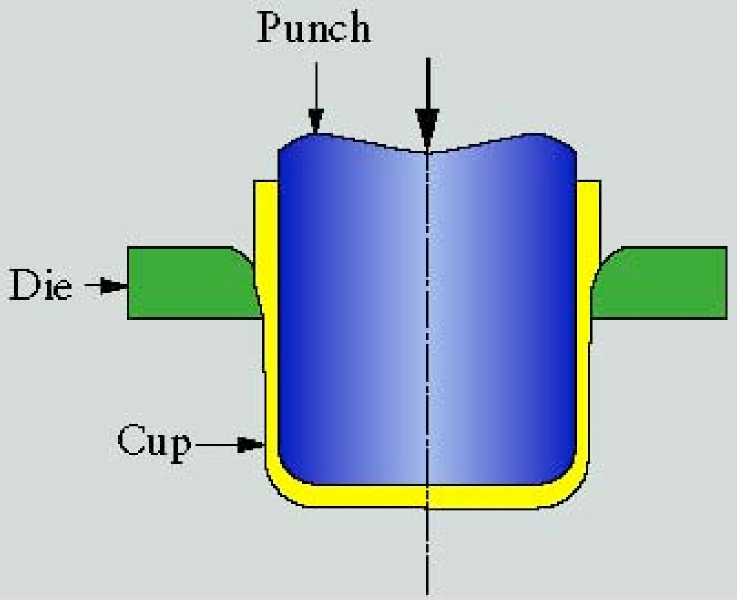

FIGURE 7.54 Schematic illustration of the ironing process. Note that the cup wall is thinner than its bottom. All beverage cans without seams (known as two-piece cans) are ironed, generally in three steps, after being deep drawn into a cup. (Cans with separate tops and bottoms are known as three-piece cans.)

Normal Anisotropy

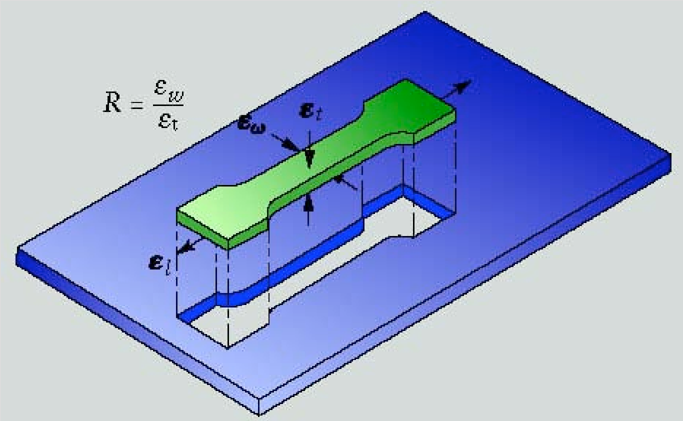

FIGURE 7.55 Definition of the normal anisotropy ratio, *R*, in terms of width and thickness strains in a tensile-test specimen cut from a rolled sheet. Note that the specimen can be cut in different directions with respect to the length, or rolling direction, of the sheet.

Effect of Average Normal Anisotropy

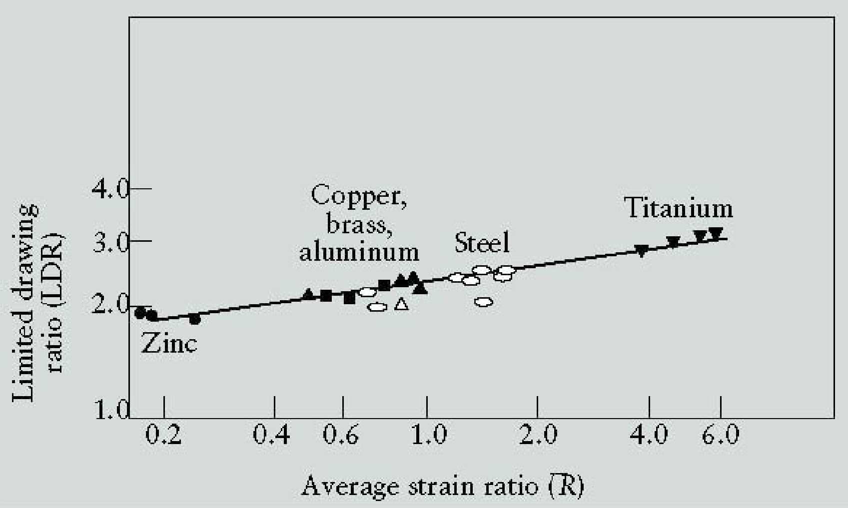

FIGURE 7.58 Effect of average normal anisotropy, *R*, on limiting drawing ratio (LDR) for a variety of sheet metals. Zinc has a high *c/a* ratio (see Figure 3.2c), whereas titanium has a low ratio. *Source*: After M. Arkinson.

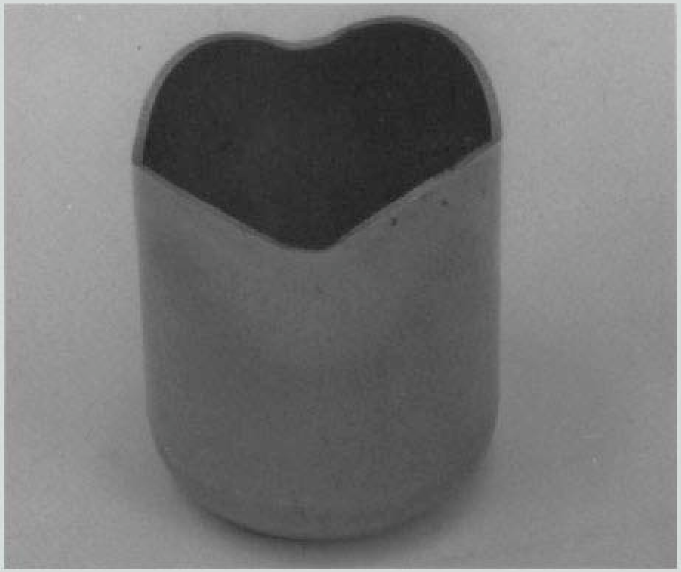

FIGURE 7.59 Earing in a drawn steel cup, caused by the planar anisotropy of the sheet metal.

Deep Drawing

Figure 14-2 Drawing failures by necking at bottom of cup wall. With very low friction, the failure site tends to move onto the punch radius as shown at the right. From D. J. Meuleman, Ph.D. thesis, Univ. of Michigan (1980).

Figure 14-3 Wrinkling in a partially drawn cup due to insufficient hold-down force. From D. J. Meuleman, *ibid*.

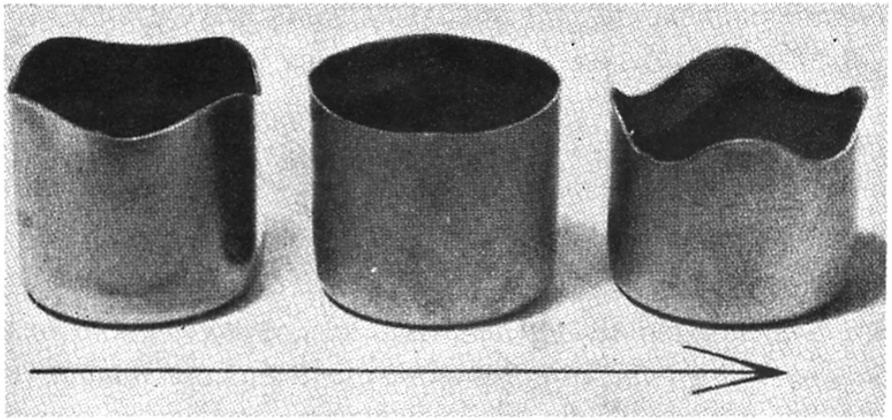

Figure 14-12 Earing behavior of cups made from three different copper sheets. Arrow indicates rolling direction of the sheets. From D. V. Wilson and R. D. Butler, *J. Inst. Met.*, 90 (1961–2), pp. 473–83.

W.F. Hosford and R.M. Caddell, *Metal Forming*, 2nd Ed., Prentice-Hall, Inc., Edgewood Cliffs, NJ, 1993.

Deep Drawing

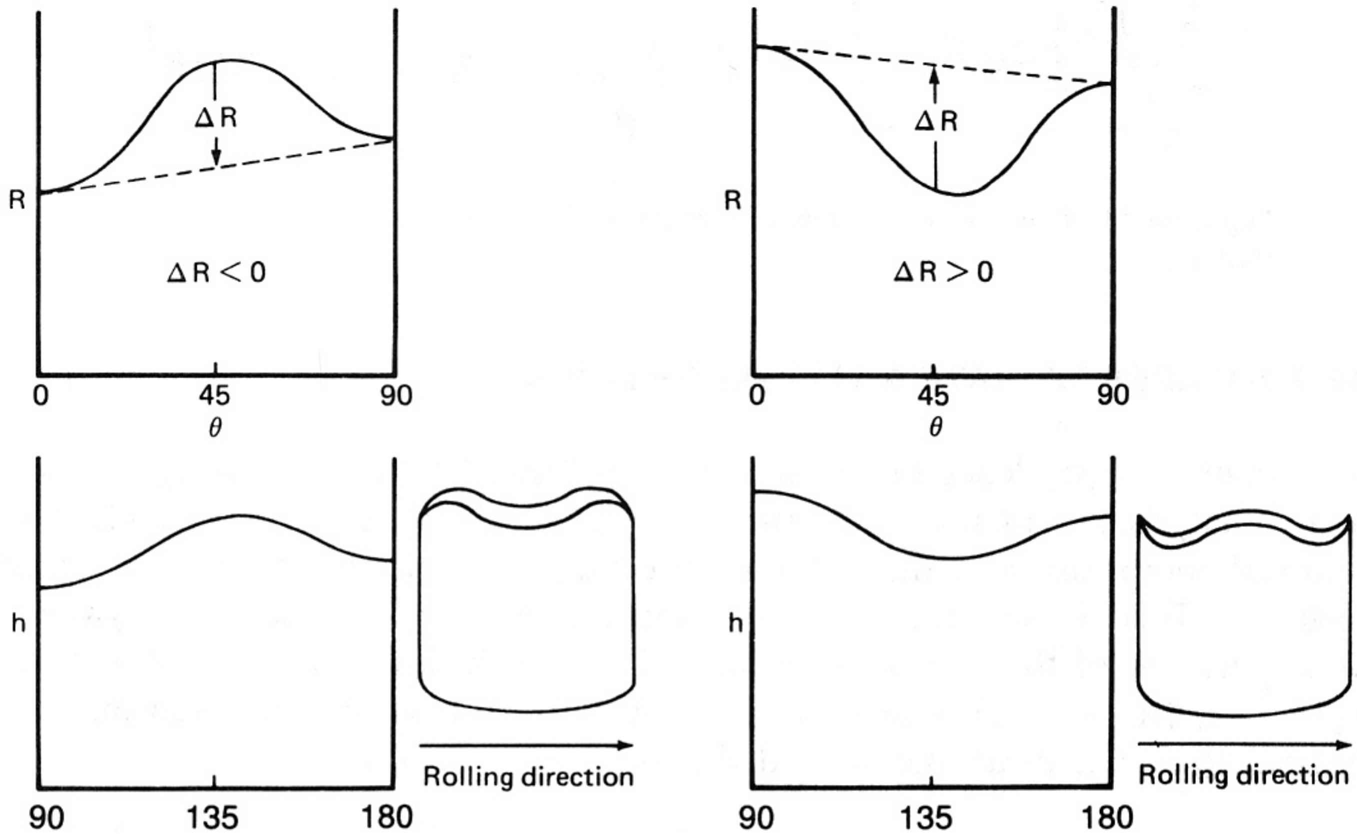

Figure 14-13 Relation of earing to angular variations of *R*. Here, *h* is the wall height.

W.F. Hosford and R.M. Caddell, *Metal Forming*, 2nd Ed., Prentice-Hall, Inc., Edgewood Cliffs, NJ, 1993.