

7.D5 This problem calls for us to explain the procedure by which a cylindrical rod of 1040 steel may be deformed so as to produce a given final diameter (8.9 mm), as well as a specific minimum tensile strength (825 MPa) and minimum ductility (12%EL). First let us calculate the percent cold work and attendant tensile strength and ductility if the drawing is carried out without interruption. From Equation 7.8

$$\begin{aligned} \%CW &= \frac{\pi \left(\frac{d_0}{2}\right)^2 - \pi \left(\frac{d_d}{2}\right)^2}{\pi \left(\frac{d_0}{2}\right)^2} \times 100 \\ &= \frac{\pi \left(\frac{11.4 \text{ mm}}{2}\right)^2 - \pi \left(\frac{8.9 \text{ mm}}{2}\right)^2}{\pi \left(\frac{11.4 \text{ mm}}{2}\right)^2} \times 100 = 40\%CW \end{aligned}$$

At 40%CW, the steel will have a tensile strength on the order of 900 MPa (130,000 psi) [Figure 7.19(b)], which is adequate; however, the ductility will be less than 9%EL [Figure 7.19(c)], which is insufficient.

Instead of performing the drawing in a single operation, let us initially draw some fraction of the total deformation, then anneal to recrystallize, and, finally, cold-work the material a second time in order to achieve the final diameter, tensile strength, and ductility.

Reference to Figure 7.19(b) indicates that 17%CW is necessary to yield a tensile strength of 825 MPa (122,000 psi). Similarly, a maximum of 19%CW is possible for 12%EL [Figure 7.19(c)]. The average of these extremes is 18%CW. If the final diameter after the first drawing is d'_0 , then

$$18\%CW = \frac{\pi \left(\frac{d'_0}{2}\right)^2 - \pi \left(\frac{8.9 \text{ mm}}{2}\right)^2}{\pi \left(\frac{d'_0}{2}\right)^2} \times 100$$

And, solving for d'_0 , yields

$$d'_0 = \frac{8.9 \text{ mm}}{\sqrt{1 - \frac{18\%CW}{100}}} = 9.83 \text{ mm (0.387 in.)}$$