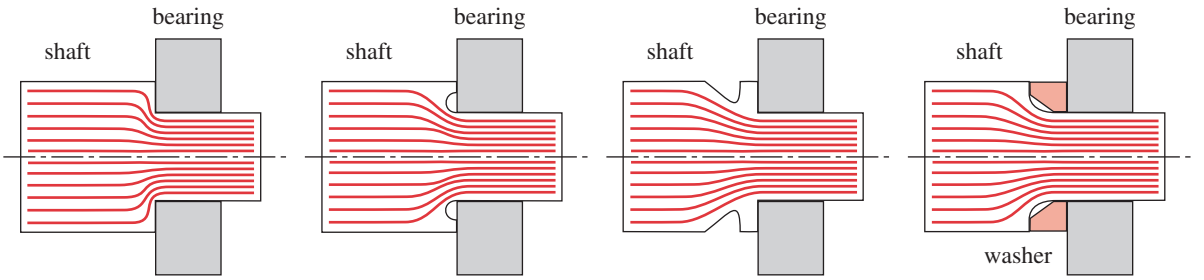


(a) Stress concentration at a sharp corner

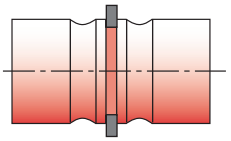
(b) Stress concentration reduced with radius

(c) Stress concentration reduced with groove

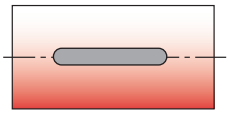
(d) Stress concentration reduced with washer

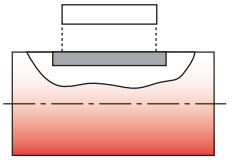
FIGURE 4-38

Design Modifications to Reduce Stress Concentrations at a Sharp Corner

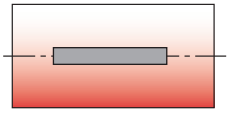


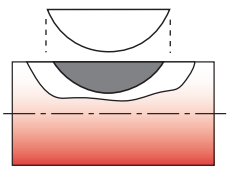
(a) Reliefs can reduce stress concentration around a snap-ring groove





(b) Slot for square key creates stress concentrations





(c) Slot for Woodruff key creates stress concentrations

FIGURE 4-39

Stress Concentrations in Shafts

concentrations, the strategy is to keep the force-flow lines within the solid (unthreaded) portion of the bolt.

These examples show the usefulness of the *force-flow analogy* in providing a means to qualitatively improve the design of machine parts for reduced stress concentration. The designer should attempt to minimize sharp changes in the contours of internal force-flow lines by suitable choice of part shape.

4.16 AXIAL COMPRESSION—COLUMNS

Section 4.7 discussed stress and deflection due to axial tension and developed equations for their calculation, which are repeated here for convenience.

$$\sigma_x = \frac{P}{A} \tag{4.7}$$

$$\Delta s = \frac{Pl}{AE} \tag{4.8}$$

When the axial load direction is reversed so as to put the member in compression, equation 4.7 alone may not be sufficient to determine the safe load for the member. It is now a column and may fail by buckling rather than by compression. Buckling occurs suddenly and without warning, even in ductile materials, and as such is one of the more dangerous modes of failure. You can demonstrate buckling for yourself by taking a common rubber eraser between the palms of your two hands and gradually loading it in axial compression. It will resist the load until at some point it suddenly buckles into a bowed shape and collapses. (If you are feeling stronger, you can do the same with an aluminum beverage can.)

Slenderness Ratio

A **short column** *will fail in compression* as shown in Figure 2-6, and its compressive stress can be calculated from equation 4.7. An **intermediate** or a **long column** *will fail by buckling* when the applied axial load exceeds some critical value. The compressive