results plotted as a series of S-N curves. For design purposes, it is more useful to know how the mean stress affects the permissible alternating stress amplitude for a given life (number of cycles). This is usually accomplished by plotting the allowable stress amplitude for a specific number of cycles as a function of the associated mean stress. At zero mean stress, the allowable stress amplitude is the effective fatigue limit for a specified number of cycles. As the mean stress increases, the permissible amplitudes steadily decrease until, at a mean stress equal to the ultimate tensile strength of the material, the permissible amplitude is zero.

The two straight lines and the curve shown in Fig. 20 represent the three most widely used empirical relations. The straight line joining the alternating fatigue strength to the tensile strength is the modified Goodman law (Eq 2). Goodman’s original law, which is no longer used, included the assumption that the alternating fatigue limit was equal to one-third of the tensile strength; this has since been modified to the relation shown in Fig. 20, using the alternating fatigue strength determined experimentally. Gerber found that the early experiments of Wöhler fitted closely to a parabolic relation, and this is known as Gerber’s parabola (curve, Fig. 20). Gerber’s law is given in Eq 3. The third relation, known as Soderberg’s law (Eq 4), is given in Fig. 20 by the straight line joining the alternating fatigue strength to the static yield strength. For many purposes it is essential that the static yield strength not be exceeded, and this relation is intended to fulfill the conditions that neither fatigue failure nor yielding occurs. The relations may be written mathematically as:

\[ S_a = S \left[ 1 - \left( \frac{S_m}{S_y} \right)^2 \right] \quad (Eq 2) \]

\[ S_a = S \left[ 1 - \left( \frac{S_m}{S_t} \right)^n \right] \quad (Eq 3) \]

\[ S_a = S \left[ 1 - \left( \frac{S_m}{S_y} \right)^n \right] \quad (Eq 4) \]

where \( S_a \) is the alternating stress associated with a mean stress \( S_m \), \( S \) is the alternating fatigue strength, \( S_t \) is the tensile strength, and \( S_y \) is the yield strength.

An understanding of the Goodman, or constant-life, diagram has resulted in many varied and useful treatments for improving fatigue life. According to a constant-life diagram, increased tension decreases the fatigue life and increased compression increases it. Because most cracks originate at the surface of the part, placing the surface under compressive stress should be beneficial. Recognition of this has resulted in development of such surface treatments as nitriding, carburizing, shot peening, surface rolling, and overstressing. When these treatments are properly applied, the sur-