ZS is normal to *CD*, so its equation can be written and solved simultaneously with that of the line *CD* to find the coordinates of point *S* and the length *ZS*, which are

$$\sigma'_{m@S} = \frac{S_{ut}\left(S_f{}^2 - S_f\sigma'_a + S_{ut}\sigma'_m\right)}{S_f{}^2 + S_{ut}{}^2}$$

$$\sigma'_{a@S} = -\frac{S_f}{S_{ut}}\left(\sigma'_{m@S}\right) + S_f$$

$$ZS = \sqrt{\left(\sigma'_m - \sigma'_{m@S}\right)^2 + \left(\sigma'_a - \sigma'_{a@S}\right)^2} \qquad (6.18f)$$

To establish a ratio for the safety factor, swing point *S* about point *Z* to be coincident with line *OZS'* at point *S'*. The safety factor is the ratio *OS'/OZ*.

$$OZ = \sqrt{\left(\sigma'_a\right)^2 + \left(\sigma'_m\right)^2}$$

$$N_f = \frac{OZ + ZS}{OZ} \qquad (6.18g)$$

There is also the possibility that point *S* may lie on line *DE* instead of *CD*, in which case equation 6.16*d* (p. 384) should be substituted for 6.16*c* in the above solution.

Case 4 gives a more conservative safety factor than case 3. The same approach can be used to obtain safety-factor expressions for stress-component combinations in the left half-plane of the modified-Goodman diagram. Also, if the diagram is drawn to scale, rough estimates of the safety factors can be scaled from it. The *TKSolver* file GOODMAN supplied with this text calculates all the safety factors defined in equations 6.18 (p. 388) for any supplied values of σ'_a and σ'_m, and it plots the modified-Goodman diagram and the stress line *OZ* extended so that the failure intercept can be seen.

Design Steps for Fluctuating Stresses

A set of design steps similar to those listed for the fully reversed case can be defined for the case of fluctuating stresses:

1 Determine the number of cycles of loading *N* that the part will experience over its expected service life.

2 Determine the amplitude of the applied alternating loads (mean to peak) and of the mean load. (See Chapter 3 and equations 6.1, p. 329.)

3 Create a tentative part-geometry design to withstand the applied loads based on good engineering practice. (See Chapters 3 and 4.)

4 Determine any geometric stress-concentration factors K_t at notches in the part's geometry. Try, of course, to minimize these through good design. (See Section 4.15 on p. 193.)