Buckling of Compression Springs

A compression spring is loaded as a column and can buckle if it is too slender. A slenderness ratio was developed for solid columns in Chapter 4. That measure is not directly applicable to springs due to their much different geometry. A similar slenderness factor is created as the aspect ratio of free length to mean coil diameter L_f / D. If this factor is > 4 the spring may buckle. Gross buckling can be prevented by placing the spring in a hole or over a rod. However, rubbing of the coils on these guides will take some of the spring force to ground through friction and reduce the load delivered at the spring end.

Just as with solid columns, the end constraints of the spring affect its tendency to buckle. If one end is free to tip as shown in Figure 14-13*a*, the spring will buckle with a smaller aspect ratio than if it is held against parallel plates at each end as shown in Figure 14-13*b*.

The ratio of the spring's deflection to its free length also affects its tendency to buckle. Figure 14-14 shows a plot of two lines that depict the stability of the two end-constraint cases of Figure 14-13. Springs with aspect ratio-deflection ratio combinations to the left of these lines are stable against buckling.

Compression-Spring Surge

Any device with both mass and elasticity will have one or more natural frequencies, as was discussed in Chapter 10 relative to shaft vibrations. Springs are no exception to this rule and can vibrate both laterally and longitudinally when dynamically exited near their natural frequencies. If allowed to go into resonance, the waves of longitudinal vibrations, called surging, cause the coils to impact one another. The large forces from both the excessive coil deflections and impacts will fail the spring. To avoid this condition, the spring should not be cycled at a frequency close to its natural frequency. Ideally, the natural frequency of the spring should be greater than about 13 times that of any applied forcing frequency.

The natural frequency ω_n or f_n of a helical compression spring depends on its boundary conditions. Fixing both ends is the more common and desirable arrangement, as its f_n will be twice that of a spring with one end fixed and the other free. For the fixed-fixed case:

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$$\omega_n = \pi \sqrt{\frac{kg}{W_a}} \quad \text{rad/sec} \qquad\qquad f_n = \frac{1}{2}\sqrt{\frac{kg}{W_a}} \quad \text{Hz} \tag{14.12a}$$

where k is the spring rate, W_a is the weight of the spring's active coils, and g is the gravitational constant. It can be expressed either as angular frequency ω_n or linear frequency f_n. The weight of the active coils can be found from

$$W_a = \frac{\pi^2 d^2 D N_a \gamma}{4} \tag{14.12b}$$

where γ is the material's weight density. For total spring weight substitute N_t for N_a.

Substituting equations 14.7 (p. 797) and 14.12*b* into 14.12*a* gives