

**Advanced Spring Design Case Study:
Cylindrical Compression Springs with Required Length, Coil Diameter, Stiffness, and Stress at Solid**

Suppose we have the following design constraints:

Music Wire

Closed/Ground Ends

Coil OD = 1"

Free Length = 2"

Spring Rate = 15 lbf/in

Corrected Stress % of Minimum Tensile Strength at Solid = 40%

The spring rate equation is

$$k = \frac{P}{f} = \frac{Gd^4}{8D^3N_a}$$

In this case, we have a known value for G (torsion modulus) and we also know the OD which is D+d, however we don't know D (mean coil diameter) or d (wire diameter). We also don't know the number of active coils. The rate can also be computed as the load to solid divided by the deflection to solid. The solid height is the product of the wire diameter and the total coils, neither of which are known.

The stress equation at a given load (P) is a function of the coil diameter and wire diameter.

$$S = \frac{8PD}{\pi d^3} K_w$$

Our goal is for the stress at solid to be 40% of the minimum tensile strength (MTS). The MTS is a function of the wire size, which we don't know.

$$\text{Tensile} = \left[P_0 \cdot d^{P_4} + P_1 \right] / \left[P_2 \cdot d^{P_4} + P_3 \right]$$

The Advanced Spring Design program uses an iterative process to solve this snarled mess of equations. We can use an initial guess for the wire diameter which is based on the given coil diameter.

Given that guess along with the known spring rate, the number of active coils is computed. From the number of coils, we get the solid height.

From the solid height, we get the load to solid.

From the load, we get the stress.

This process is repeated until a wire diameter is found which leads to the desired stress at solid.

Here is the ASD solution.

Compression Spring - Cylindrical - Round Wire

Material: Music Wire Buckling Constraints: End fixation not known.

Hand: Optional Right Left End Type: Closed Ground User-defined SN data

Grade: Commercial Precision Condition: Preset Peened Autoadjust Inactive Coils

Input / Output Scenarios: Power User Two Load One Load Rate Based Dimensional Min. Weight
 (Inputs for these five cases are indicated by green backgrounds)

Note: *Italicized labels* indicate optional inputs.

Wire Diameter	0.0797	in	Arbor Diameter	0.7022	in	Active Coils	4.967
Wire Dia. Tol. (+/-)	0.0005	in	Coil ID	0.8406	in	Total Coils	6.967
Wire Length	20.2406	in	Coil Mean Diameter	0.9203	in	Dead Coils	0.0000
Wire Weight	0.02869	lb	Coil OD	1.0000	in	Pitch	0.3706 in
Minimum Tensile Strength (MTS)	281733	psi	Coil Dia. Tol. (+/-)	0.0350	in	Pitch Angle	7.3043 deg
Spring Rate	15.0000	lbf/in	Min. Coil ID (Free)	0.8056	in	Free Length Tol. (+/-)	0.1305 in
Spring Index	11.5437		Shaft Diameter		in	Allowable Solid Length	in
Natural Frequency	267	Hz	Hole Diameter		in		

Wire Available: No Next Smaller Wire: 0.0790 Next Larger Wire: 0.0800 Estimated Cycle Life:

	Free	Cycle Load 1	Cycle Load 2	Other Load	At Solid	At Buckle	
Load	0				21.669		lbf
Load Tolerance (+/-)	0						lbf
Length	2.0000				0.5554		in
Deflection	0				1.4446		in
% of Max. Deflection	0				100		
Corrected Stress	0				112693		psi
Corrected % of MTS	0				40.0		

ASD shows a solution with 6.967 total coils and a wire size of 0.0797". At that point, it's a simple matter to change the wire diameter to the closest standard size of 0.08 and blank the At Solid Corrected Stress %.

Here is a 3D view of the spring.

