Compression Spring Design and General Considerations

There are a number of design considerations to consider when working with compression springs. Let us first consider stress, set and weight as important considerations in establishing a custom spring design which need to be understood at the outset.
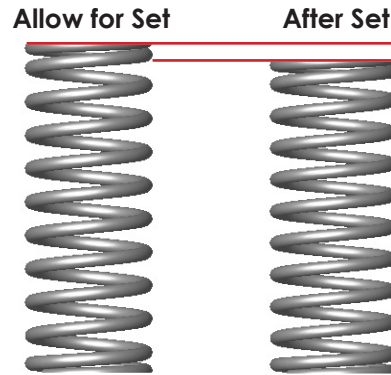
Compression Spring Stress

The dimensions, along with the load and deflection requirements, determine the stresses in the spring. When a compression spring is loaded, the coiled wire is stressed in torsion. The stress is greatest at the surface of the wire; as the spring is deflected, the load varies, producing a range of operating stress. Stress and stress range govern the life of the spring. The higher the stress range, the lower the maximum stress must be to attain comparable life. Relatively high stresses may be used when the stress range is low or if the spring is subjected solely to static loads.

In designing compression springs the space allotted governs the dimensional limits of a spring with regard to allowable solid height and outside and inside diameters. These dimensional limits, together with the load and deflection requirements, determine the stress level. It is extremely important to consider carefully the space allotted to insure that the spring will function properly to begin with, thereby avoiding costly design changes. Wider outside diameters will reduce stress as will increasing the length by increasing the number of coils. Given an outside diameter, using smaller wire sizes will further reduce stress; however, the result will be lighter compression loads.

> "It is extremely important to consider carefully the space allotted to insure that the spring will function properly..."

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Compression Spring Set

When a compression spring is compressed and released, it is supposed to return to its original height and, on further compressions, the load at any given point should remain constant at least w ithin the load limits specified. When a spring is made and then compressed the first time, if the stress in the wire is high enough at the point the spring is compressed to, the spring will not return to its original height (i.e., it will get shorter). This is referred to as "taking a set", or "setting". When a custom spring is supplied longer than spec fied to compensate for length loss when compressed in assembly, this is referred to as "Allow for Set". This is usually recommended for large quantity orders to reduce cost. Once the spring is compressed the first time and takes this set, the spring will generally not take any significant additional set on subsequent compressions.

Allow for Set   **After Set**

Compression Spring Weight

For cost and manufacturing purposes, it is useful to calculate the weight of springs to determine raw material use and shipping requirements. For manufacturing purposes, it is easier to work with a unit quantity of 1000 springs, so the weight per 1000 springs is the standard ratio to figure.

Additonal Design Considerations

After stress, set and weight we can look at some general considerations where the following design
procedure (and associated formulas) should be used for all compression spring designs.

1. Select the appropriate material for the spring design. Take note of the shear modulus (G) and tensile strength (TS), as these numbers will be used in future calculations.

2. Calculate the mean diameter (Dm) and inside diameter (ID) of the spring using the outside diameter (OD) and wire diameter (d). Compare the ID of the spring to any work over rod requirements. Remember to incorporate the low side of the OD (or ID) tolerance when examining the work over rod requirements.

$$D_m \text{ (in)} = OD - d$$
$$ID \text{ (in)} = OD - 2d$$

3. The diameter of a compression spring will increase when compressed. This increase is a function of the pitch (p). Calculate the OD expansion and compare this to any work in hole requirements. Remember to incorporate the high side of the OD tolerance when examining the work in hole requirements.

$$OD_{Expansion} = \left[\sqrt{D_m^2 + \tfrac{p^2 - d^2}{\pi^2}} + d \right] - OD$$

4. Calculate the pitch (and therefore coils per inch) and the spring index. Verify that the pitch of the spring is not greater than the OD, as this will result in coiling difficulties. Also, take note of the spring index. Details of this calculation can be found at Spring-i-pedia.com

5. Once the spring rate (R) and number of active coils (NA) has been established, calculate the number of total coils (NT). (This does not apply to designs that are based on physical dimensions.)

Formula for N_T based on End Type			
Open	**Open/Ground**	**Closed**	**Closed/Ground**
N_A	$N_A + 1$	$N_A + 2$	$N_A + 2$

6. Calculate the solid height (SH) and verify that any customer requirements are satisfied and that any load heights are above solid height. Allow a 5% variation to the nominal solid height value to calculate the maximum solid height.

Formula for N_T based on End Type			
Open	**Open/Ground**	**Closed**	**Closed/Ground**
N_A	$N_A + 1$	$N_A + 2$	$N_A + 2$

7. If the design has load requirements, the stress at these load heights must be calculated and compared against the tensile strength of the material. If the percent stress at any load height is greater than 40% then a set operation or allow for set should be considered. If the percent stress is greater than 60%, a set operation would be inadequate and a re-design must be considered. Stress, Corrected Stress, Wahl Correction Factor and Percentage Stress will need to be calculated – see Spring-i-pedia.com

8. Unless the working range is specifically known, the stress at solid height must be examined. If the percent stress at solid height is greater than 40% then a set operation or allow for set should be considered. If the percent stress is greater than 60%, a re-design must be considered. Again, see Spring-i-pedia.com for details of the calculation.

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9. Tolerances should be assigned to all required design criteria. Commercial tolerances should be used whenever possible to reduce cost. Tighter tolerances could be possible; however, should be compared against the calculated process capability (CPC) for manufacturability.

Diameter Tolerances - OD Commercial Tolerance Chart:

0.025" to .039" O.D. ± .002"	0.851" to 1.125" O.D. ± .020"
0.040" to .118" O.D. ± .003"	1.126" to 1.218" O.D. ± .025"
0.119" to .250" O.D. +.003"/-.005"	1.219" to 1.460" O.D. ± .030"
0.251" to .299" O.D. ± .005"	1.461" to 1.687" O.D. ± .040"
0.300" to .500" O.D. ± .008"	1.688" to 2.000" O.D. ± .055"
0.501" to .850" O.D. ± .015"	

CPC Values

$$OD_{CPC} = (2/3)OD\ Tol_c$$

Free length tolerances, Rate tolerances and Load tolerances should all be calculated according to formulae to be found at Spring-i-pedia.com.

Squareness - a tolerance of 3° maximum is standard. For any requirements that call for tighter squareness requirements, particular attention must be given to costs associated with coiling and grinding setup.

Number of Coils - generally speaking, the number of coils is not a dimension that will have a tolerance placed on it for manufacturing purposes. It is generally preferred to put a tolerance on the spring rate, which indirectly controls the number of coils.

Designing a custom spring is a well-known and understood process for manufacturers who are engaged in it every day, so we would recommend that time spent in discussion with a manufacturer's spring engineer would be very worthwhile prior to committing to a particular specification

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