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Nested helical compression springs of round wire
(To be used in conjunction with ESDU 82008)

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NESTED HELICAL COMPRESSION SPRINGS OF ROUND WIRE (TO BE USED IN CONJUNCTION WITH ESDU 82008)

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NESTED HELICAL COMPRESSION SPRINGS OF ROUND WIRE
(To be used in conjunction with ESDU 82008*)

1. NOTATION

c	spring index = $D/d = (D_i + d)/d = (D_o - d)/d$		
D	mean diameter of individual spring = $D_i + d = D_o - d$	m	in
D_i	inside diameter of spring	m	in
D_o	outside diameter of spring	m	in
d	wire diameter	m	in
e	clearance factor (see Sketch 1.1)		
G	shear modulus of spring material	N/m^2	lbf/in^2
K	efficiency factor (see Section 3.5)		
L	initially loaded length of spring in series nest (see Sketch 1.2)	m	in
L_c	closed length of spring (see ESDU 82008)	m	in
L_c'	closed length of working coils = nd	m	in
N	number of springs in nest		
n	number of effective or working coils in spring		
P	axial load	N	lbf
q	shear stress at inner surface of coils (including curvature correction factor)	N/m^2	lbf/in^2
S	rate or stiffness	N/m^2	lbf/in^2
U, V, W	functions of spring parameters (see Table 3.1)		
y	deflection from initially loaded length of spring in series nest (see Sketch 1.2)	m	in
α	function of c and e involved in definition of U and V (see Table 3.1)		
δ	deflection of spring from free length	m	in

* ESDU 82008, "Elastic stresses and deflections of helical compression and tension springs of round wire."

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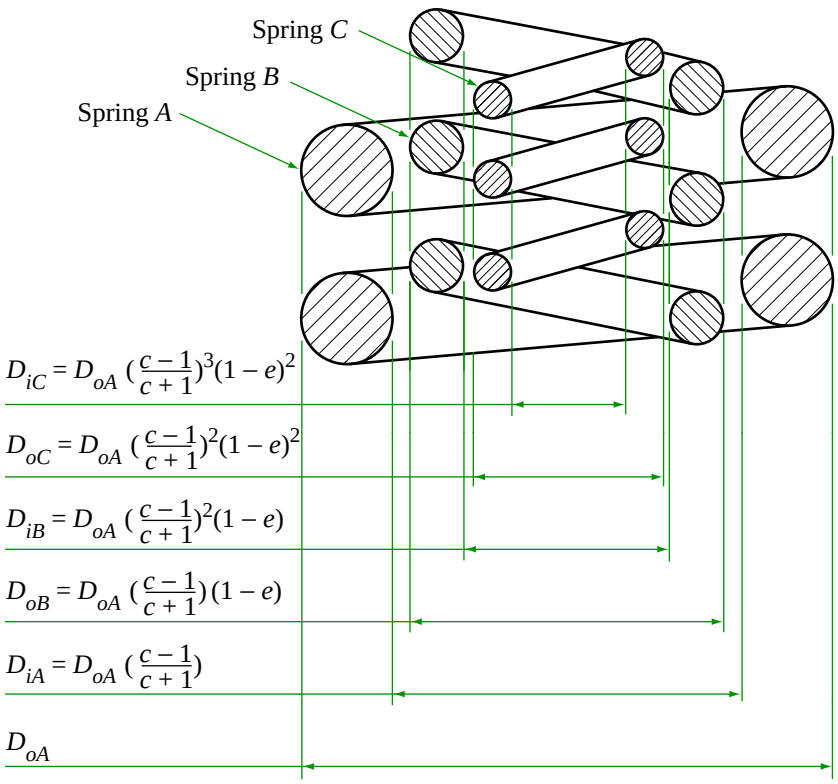
Suffixes

A, B, C	refer to first, second and third springs, respectively, working from outer spring inwards
n	refers to nest (rather than an individual spring)

Both SI and British units are quoted but any coherent systems of units may be used.



Sketch 1.1 Part section of nest of three springs in parallel

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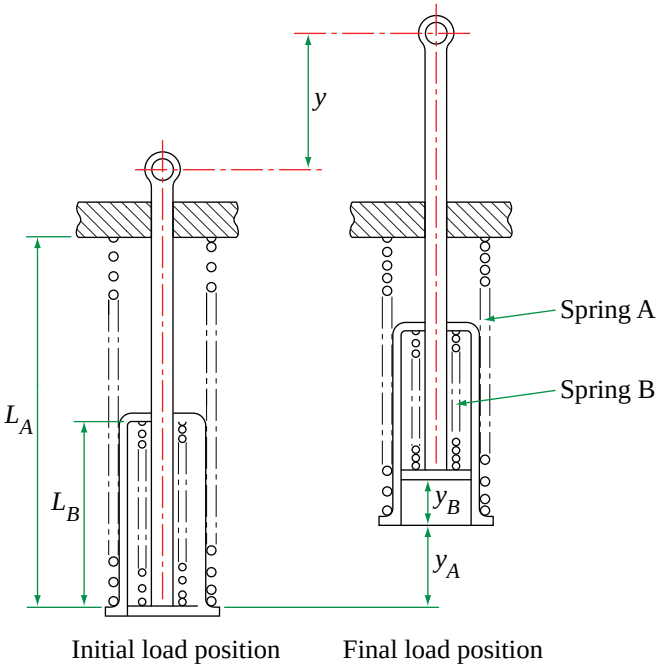

Sketch 1.2 Nested springs in series

2. NOTES

This Item provides data for the design of helical compression springs of round wire acting in combination. The major dimensions of each spring may be determined by using the design methods presented here; however, ESDU 82008 should be referred to for detail design and for information on cyclic loading, buckling, *et cetera*. Usually, nested springs are mounted concentrically, as illustrated in Sketches 1.1 and 1.2. This is the most effective way of using the available housing space and is the subject of the design processes in this Item. Occasionally, however, springs may be arranged differently; one spring mounted on top of another for example. In such instances not all of the equations in the Item will be applicable.

3. PARALLEL NESTED SPRINGS

If the design space for a single spring is such that a parallel nest of two or more springs can be accommodated in its place then, with careful design, a reduction in the working stress of each spring below that of the single spring can be obtained. Alternatively, a greater load capacity or smaller housing volume may be achieved for the same working stress. These benefits are maximised if the solid length and the stress per unit deflection of every spring in the nest are equal. These conditions imply that the index of each spring is the same and provides the starting point for the design process which is set out in the following section. Practical conditions often necessitate slight deviations from this initial, simple approach and these are discussed in Section 3.4. Section 3.6 deals with the special case of the direct replacement of a single spring with a parallel nest.

3.1 Determination of Spring Index

The major requirements of a spring nest may be expressed as a spring rate, a required deflection, an allowable stress (dependent on the material) and an outside diameter. Additionally, the closed length of the nest is usually known, in which case L_c' may be used as an approximate value for the closed length. The precise closed length varies with the type of end coil formation (see ESDU 82008). The basic equations

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relating these parameters, given in ESDU 82008, may be combined to give the three non-dimensional expressions set out in Table 3.1. These are labelled U, V and W for convenience of reference. Figures 1, 2 and 3 present these expressions as functions of the spring index, c, and the number of springs in the nest, N, for a practical value of clearance factor, e, of 0.05. Notes on e and N are given in Sections 3.2 and 3.3, respectively. Depending on the known design parameters, one of U, V or W may be calculated and c for the springs of the nest found from the appropriate figure.

TABLE 3.1 General Functions for Nested Springs

Function in terms of design parameters	*Equation number*	*N*	*Function in terms of c and α (see Equation (3.4))*
Rate function: U $= \dfrac{GD_{oA}^2}{L_c' S_n}$	(3.1)	1	$= 8c^3(1+c)^2$
		2	$= \dfrac{8c^3(1+c)^2}{(1+\alpha)}$
		3	$= \dfrac{8c^3(1+c)^2}{(1+\alpha+\alpha^2)}$
Load function: V $= \dfrac{qD_{oA}^2}{P}$	(3.2)	1	$= \dfrac{8c(c+0.2)(1+c)^2}{\pi(c-1)}$
		2	$= \dfrac{8c(c+0.2)(1+c)^2}{\pi(c-1)(1+\alpha)}$
		3	$= \dfrac{8c(c+0.2)(1+c)^2}{\pi(c-1)(1+\alpha+\alpha^2)}$
Deflection function: W $= \dfrac{G\delta}{L_c' q}$	(3.3)	1, 2, 3	$= \dfrac{\pi c^2(c-1)}{(c+0.2)}$

$$\alpha = \frac{(1-e)^2(c-1)^2}{(1+c)^2}. \tag{3.4}$$

Once c is known, n and d may be calculated for each spring and, subsequently, Equations (3.5) and (3.6) may be used to evaluate the individual spring rates and shear stresses.

$$S = \frac{Gd}{8nc^3}, \tag{3.5}$$

$$q = \frac{8P}{\pi d^2} \times \frac{c(c+0.2)}{(c-1)}. \tag{3.6}$$

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