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JAPANESE INDUSTRIAL STANDARD

Helical compression and extension springs— Requirements for design

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Helical compression and extension springs -
Requirements for design

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1. Scope This Japanese Industrial Standard specifies the requirements for design of the cylindrically helical springs (hereafter, referred to as "springs") hot formed or cold formed using the material of circular section, among the compression helical springs and tension helical springs for general use.

Remarks 1. The standards cited in this Standard are given in Attached Table 1.

2. The units, numerical values and calculation formulae shown in { } in this Standard are in accordance with the traditional units, and are appended for informative reference.

Further, $1 \text{ N/mm}^2 = 1 \text{ MPa}$

2. Definitions For the main terms used in this Standard, the definitions in JIS B 0103 apply.

3. Materials The materials used for the springs shall be as given in Table 1. However, when springs are used for particular purposes, materials other than those may be used.

Further, the minimum values for the tensile strength of main materials are given in Informative reference Tables 1 and 2.

Table 1. Materials for springs

Type	Standard number	Symbol	Uses (Informative reference)						Remarks
			General use	Electric con-duction	Non-mag-netic	Heat resis-tance	Cor-ro-sion resis-tance	Fatigue resis-tance	
Spring steel	JIS G 4801	SUP 6 SUP 7 SUP 9 SUP 9 A SUP 10 SUP 11 A SUP 12 SUP 13	○						Used mainly for hot forming springs
Hard drawn steel wires	JIS G 3521	SW-B SW-C	○						Used mainly for cold forming springs
Piano wires	JIS G 3522	SWP	○					○	
Oil tempered carbon steel wires for mechanical spring	JIS G 3560	SWO	○						
Oil tempered carbon steel wires for valve spring	JIS G 3561	SWO-V						○	
Oil tempered chromium vanadium steel wires for valve spring	JIS G 3565	SWOCV-V				○		○	
Oil tempered silicon chromium steel wires for valve spring	JIS G 3566	SWOSC-V				○		○	
Oil tempered silicon manganese steel wires for mechanical spring	JIS G 3567	SWOSM	○						
Oil tempered silicon chromium steel wires for chemical spring	JIS G 3568	SWOSC-B	○			○			
Stainless steel wires for spring	JIS G 4314	SUS 302 SUS 304 SUS 304N1 SUS 316 SUS 631J1	○			○	○		
Brass wires	JIS H 3260	C 2600 W C 2700 W C 2800 W		○	○		○		
Nickel silver wires	JIS H 3270	C 7521 W C 7541 W C 7701 W		○	○		○		
Phosphor bronze wires		C 5102 W C 5191 W C 5212 W		○	○		○		
Copper-beryllium alloy wires		C 1720 W		○	○		○		

4. Designing calculation

4.1 Symbols The symbols used in spring designing calculation shall be as given in Table 2.

Table 2. Symbols

Symbol	Meaning of symbol	Unit
d	Diameter of material	mm
D_i	Coil inside diameter	mm
D_o	Coil outside diameter	mm
D	Mean diameter of coil $D = \frac{D_i + D_o}{2}$	mm
N_t	Total number of turns	—
N_a	Number of active turns	—
H_f	Free height (length)	mm
H_s	Solid height	mm
p	Pitch	mm
P_i	Initial tension	N, {kgf}
c	Spring index $c = \frac{D}{d}$	—
G	Modulus of transverse elasticity	N/mm ² , {kgf/mm ² }
P	Load acting on spring	N, {kgf}
δ	Deflection of spring	mm
k	Spring constant	N/mm, {kgf/mm}
τ_0	Torsional stress	N/mm ² , {kgf/mm ² }
τ	Corrected torsional stress	N/mm ² , {kgf/mm ² }
τ_i	Initial stress	N/mm ² , {kgf/mm ² }
χ	Stress correction factor	—
f	Frequency	Hz
U	Energy stored in spring	N·mm, {kgf·mm}
w	Weight per unit volume of material	N/mm ³ , {kgf/mm ³ }
W	Weight of moving part of spring	N, {kgf}
g	Acceleration ⁽¹⁾ of gravity	mm/s ²

Note (1) In Measurement Law, the acceleration of gravity is defined as 9806.65 mm/s².

4.2 Fundamental formulas used in the design of springs

4.2.1 In the case of compression springs and extension springs without initial tension

$$\delta = \frac{8N_a D^3 P}{Gd^4} \dots\dots\dots (1)$$

$$k = \frac{P}{\delta} = \frac{Gd^4}{8N_a D^3} \dots\dots\dots (2)$$

$$\tau_0 = \frac{8DP}{\pi d^3} \dots\dots\dots (3)$$

$$\tau_0 = \frac{Gd\delta}{\pi N_a D^2} \dots\dots\dots (4)$$

$$\tau = \chi \tau_0 \dots\dots\dots (5)$$

$$d = \sqrt[3]{\frac{8DP}{\pi \tau_0}} = \sqrt[3]{\frac{8\chi DP}{\pi \tau}} \dots\dots\dots (6)$$

$$N_a = \frac{Gd^4 \delta}{8D^3 P} = \frac{Gd^4}{8D^3 k} \dots\dots\dots (7)$$

$$U = \frac{P\delta}{2} = \frac{k\delta^2}{2} \dots\dots\dots (8)$$

4.2.2 In the case of extension springs with initial tension ($P > P_i$)

$$\delta = \frac{8N_a D^3 (P - P_i)}{Gd^4} \dots\dots\dots (1')$$

$$k = \frac{P - P_i}{\delta} = \frac{Gd^4}{8N_a D^3} \dots\dots\dots (2')$$

$$\tau_0 = \frac{8DP}{\pi d^3} \dots\dots\dots (3)$$

$$\tau_0 = \frac{Gd\delta}{\pi N_a D^2} + \tau_i \dots\dots\dots (4')$$

$$\tau = \chi \tau_0 \dots\dots\dots (5)$$

$$d = \sqrt[3]{\frac{8DP}{\pi \tau_0}} = \sqrt[3]{\frac{8\chi DP}{\pi \tau}} \dots\dots\dots (6)$$

$$N_a = \frac{Gd^4}{8D^3 k} = \frac{Gd^4 \delta}{8D^3 (P - P_i)} \dots\dots\dots (7')$$

$$U = \frac{(P + P_i) \delta}{2} \dots\dots\dots (8')$$

4.3 Matters to be taken into consideration in design of springs

4.3.1 Modulus of transverse elasticity The values of the modulus of transverse elasticity G used in the design of springs should preferably be in accordance with Table 3.

Table 3. Modulus of transverse elasticity: G Unit: $\text{N/mm}^2 \{ \text{kgf/mm}^2 \}$

Material		Value of G
Spring steel		$78 \times 10^3 \{8 \times 10^3\}$
Hard drawn steel wire		
Piano wire		
Oil tempered wire		
Stainless steel wires for spring	SUS 302	$69 \times 10^3 \{7 \times 10^3\}$
	SUS 304	
	SUS 304N1	
	SUS 316	
	SUS 631J1	$74 \times 10^3 \{7.5 \times 10^3\}$
Brass wire		$39 \times 10^3 \{4 \times 10^3\}$
Nickel silver wire		
Phosphor bronze wire		$42 \times 10^3 \{4.3 \times 10^3\}$
Copper-beryllium alloy wire		$44 \times 10^3 \{4.5 \times 10^3\}$

4.3.2 Number of active turns The number of active turns used in the design of springs shall be in accordance with the following:

- (1) In the case of compression springs The number of active turns of the compression springs shall be as follows.

$$N_a = N_t - (X_1 + X_2)$$

where, X_1, X_2 : respective number of end turns at both ends of coil

- (a) When only the coil end contacts with the next free coil
[Corresponding to (a) to (c) of Fig. 3.]

$$X_1 = X_2 = 1$$

Therefore, $N_a = N_t - 2$

- (b) When the coil end does not contact with the next coil and the length of end turn part is $3/4$ turns [corresponding to (e) to (g) of Fig. 3.]

$$X_1 = X_2 = 0.75$$

Therefore, $N_a = N_t - 1.5$

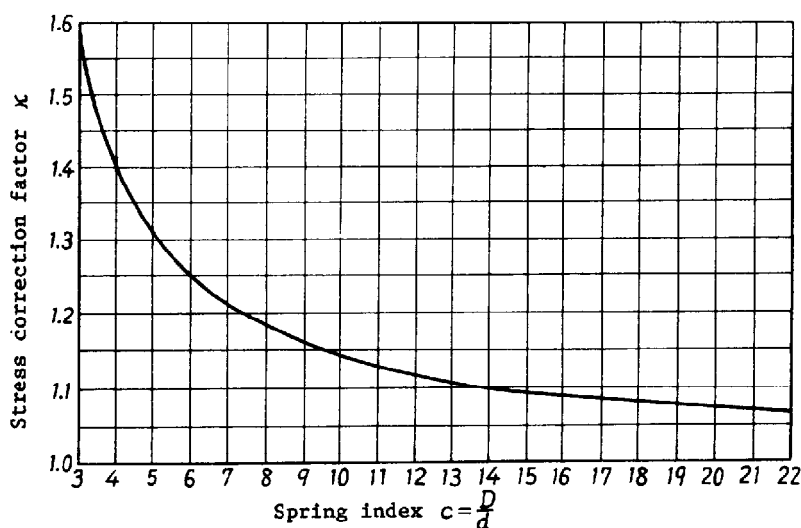
- (2) In the case of extension springs The active number of turns of the extension springs shall be as follows. However, the hook part is excluded.

$$N_a = N_t$$

4.3.3 Stress correction factors The stress correction factors in respect to the values of spring index c shall be in accordance with the following formula or Fig. 1.

$$x = \frac{4c-1}{4c-4} + \frac{0.615}{c} \dots\dots\dots (9)$$

Fig. 1. Stress correction factors: x



4.3.4 Solid height The solid height of the spring shall generally be calculated from the following approximate calculation formula. However, the solid height of the compression spring shall not be specified by the purchaser, generally.

$$H_s = (N_t - 1)d + (t_1 + t_2) \dots\dots\dots (10)$$

where, $(t_1 + t_2)$: sum of respective thicknesses at both end parts of coil

Further, for the compression springs of which both end parts are of (b), (c), (e) and (f) of Fig. 3 and when it is required to specify the solid heights particularly, the values obtained from the following formula are specified as the maximum value of solid height, however, care shall be taken for that, in some cases, it is liable to become larger than this value, according to the shapes of springs.

$$H_s = N_t \times d_{\max} \quad \dots\dots\dots(11)$$

where, $d_{\max}$: diameter for which the maximum value of the tolerance on d has been employed.

4.3.5 Initial tension of extension springs The initial tension P_i is generated in the solid-wound cold formed extension spring. In this case, the initial tension shall be calculated from the following formula:

$$P_i = \frac{\pi d^3}{8D} \tau_i \quad \dots\dots\dots(12)$$

Further, the initial stress τ_i , when it has been formed into solid-wound from the steel wires of piano wire, hard drawn wire and the like, and the low temperature annealing has not been processed, shall be within the range shaded with oblique lines of Fig. 2. However, the value of initial stress read from the range of the oblique lines of Fig. 2 shall be corrected as given in the following, according to the properties of material other than steel wires and the process of low temperature annealing.

- (1) In the case of the stainless steel wire, reduce 15 % from the initial stress of the steel wire.
- (2) In the case of the phosphor bronze wire, brass wire, nickel silver wire, etc., reduce 50 % from the initial stress of steel wire.
- (3) In the case where the low temperature annealing after forming is processed, reduction of 20 % to 35 % for the steel wires of piano wire, hard drawn steel wire, etc., and reduction of 15 % to 25 % for the stainless steel wire, for the value obtained in the above shall be made.

Fig. 2. Initial stress: τ_i (the value prior to low temperature annealing of spring formed by steel wire)

