Stainless Steel Springs

TAIYO Stainless Spring Co., Ltd.

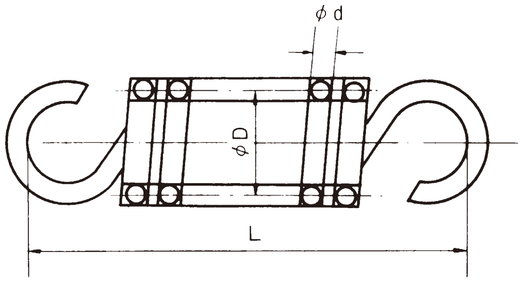
We have corrected the existing defects of surface treatments given to springs made from steel or alloyed metal, as well as other various mechanistic faults. As a result, we are proud to provide products that have earned customers' trust and praise. We hope that you will also appreciate our superior products and technology.

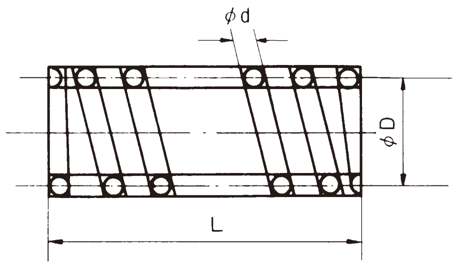
Elastic Coefficient \ Type of Material	SUS304	SUS631	Piano Wire	Nickel Silver Wire	Phosphor Bronze Wire
Shear Modulus (G)	73,550N/mm^2	76,492N/mm^2	78,453N/mm^2	38,246N/mm^2	41,188N/mm^2
Young's Modulus (E)	186,320N/mm^2	196,133N/mm^2	205,940N/mm^2	101,989N/mm^2	107,873N/mm^2

Mechanical Properties of Age-Hardened High-Tension Stainless Steel SUS631 - Precipitation Hardening

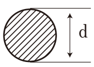
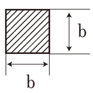
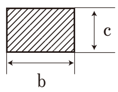
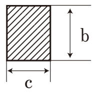
HRC	Treatment	Pre-Hardening Mechanical Properties				Post-Hardening Mechanical Properties			
		Tensile Test		Bend Test		Tensile Test		Flexural Strength Test	Hardness
		Tensile Strength N/mm^2	Elongation %	Bend Angle	Inside Radius	Tensile Strength N/mm^2	Elongation %	Threshold Limit Kb N/mm^2	HRC
22	R.H	892 - 1,030	8 - 13	180°	2 × Material Thickness	1,481	6 - 12	588	47
38	C.H	1,206 or over	6 - 10	180°		1,589	5 - 9	834	51

General Formula for Spring Design





d: Wire diameter D: Mean diameter N: Number of active coils W: Axial load δ: Deflection
G: Shear modulus (Stainless Steel Wire = approx. 70,000N/mm^2)

Finding...			 b≦2C	 b>2C
Deflection from load	$\delta=\frac{8WND^3}{Gd^4}$	$\delta=\frac{5.6WND^3}{Gb^4}$	$\delta=\frac{2.79WND^3(b^2+c^2)}{Gb^3c^3}$	$\delta=\frac{2.35WND^3}{Gc^3(b-0.63c)}$
Deflection from shear stress	$\delta=\frac{\pi fsND^2}{Gd}$	$\delta=\frac{2.35fsND^2}{Gb}$	$\delta=\frac{3.5fsND^2(b^2+c^2)}{Gbc(2b+c)}$	$\delta=\frac{2.9fsND^2b^2}{Gc(2b+c)(b-0.63c)}$
Shear stress from load	$fs=\frac{8WD}{\pi d^3}$	$fs=\frac{2.38WD}{b^3}$	$fs=\frac{0.8WD(2b+c)}{b^2c^2}$	$fs=\frac{0.8WD(2b+c)}{b^2c^2}$
Shear stress from deflection	$fs=\frac{\delta Gd}{\pi ND^2}$	$fs=\frac{0.425\delta Gb}{ND^2}$	$fs=\frac{0.28\delta G(2b^2c+bc^2)}{ND^2(b^2+c^2)}$	$fs=\frac{0.34\delta Gc(2b+c)(b-0.63c)}{ND^2b^2}$
Load from estimated shear stress	$W=\frac{fs\pi d^3}{8D}$	$W=\frac{0.42fsb^3}{D}$	$W=\frac{1.25fsb^2c^2}{D(2b+c)}$	$W=\frac{1.23fsb^2c^2}{D(2b+c)}$
Load from deflection	$W=\frac{\delta d^4G}{8ND^3}$	$W=\frac{\delta Gb^4}{5.6ND^3}$	$W=\frac{\delta Gb^3c^3}{2.79ND^3(b^2+c^2)}$	$W=\frac{\delta Gc^3(b-0.63c)}{2.35ND^3}$
The number of active coils	$N=\frac{\delta Gd^4}{8WD^3}$	$N=\frac{\delta Gb^4}{5.6WD^3}$	$N=\frac{\delta Gb^3c^3}{2.79WD^3(b^2+c^2)}$	$N=\frac{\delta Gc^3(b-0.63c)}{2.35WD^3}$

With respect to tension springs. the initial tension is set to 0.

Initial tension calculations

$$\delta=\frac{\pi(fs-fso)ND^2}{Gd}$$ Po: Initial tension fso : Residual stress $\left(\frac{G}{100c}\right)$ c: Spring index $\left(\frac{D}{d}\right)$

$$Po=\frac{\pi fsod^3}{8D} \qquad fs=\frac{\delta Gd}{\pi ND^2}+fso$$

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Tensile Strength of Stainless Steel Wires for Springs (Type-B)

<table>
<tr><th>Wire Diameter</th><th>Tensile Strength N/mm²</th><th>Wire Diameter</th><th>Tensile Strength N/mm²</th><th>Wire Diameter</th><th>Tensile Strength N/mm²</th></tr>
<tr><th>mm</th><th>Hard Drawn Steel Wires</th><th>mm</th><th>Hard Drawn Steel Wires</th><th>mm</th><th>Hard Drawn Steel Wires</th></tr>
<tr><td>0.10</td><td rowspan="6">2,150 – 2,400</td><td>0.45</td><td rowspan="4">1,950 – 2,200</td><td>1.80</td><td rowspan="2">1,650 – 1,900</td></tr>
<tr><td>0.12</td><td>0.50</td><td>2.00</td></tr>
<tr><td>0.14</td><td>0.55</td><td>2.30</td><td rowspan="2">1,550 – 1,800</td></tr>
<tr><td>0.16</td><td>0.60</td><td>2.60</td></tr>
<tr><td>0.18</td><td>0.65</td><td rowspan="5">1,850 – 2,100</td><td>2.90</td><td rowspan="4">1,450 – 1,700</td></tr>
<tr><td>0.20</td><td>0.70</td><td>3.20</td></tr>
<tr><td>0.23</td><td rowspan="6">2,050 – 2,300</td><td>0.80</td><td>3.50</td></tr>
<tr><td>0.26</td><td>0.90</td><td>4.00</td></tr>
<tr><td>0.29</td><td>1.00</td><td>4.50</td><td rowspan="4">1,350 – 1,600</td></tr>
<tr><td>0.32</td><td>1.20</td><td rowspan="2">1,750 – 2,000</td><td>5.00</td></tr>
<tr><td>0.35</td><td>1.40</td><td>5.50</td></tr>
<tr><td>0.40</td><td>1.60</td><td>1,650 – 1,900</td><td>6.00</td></tr>
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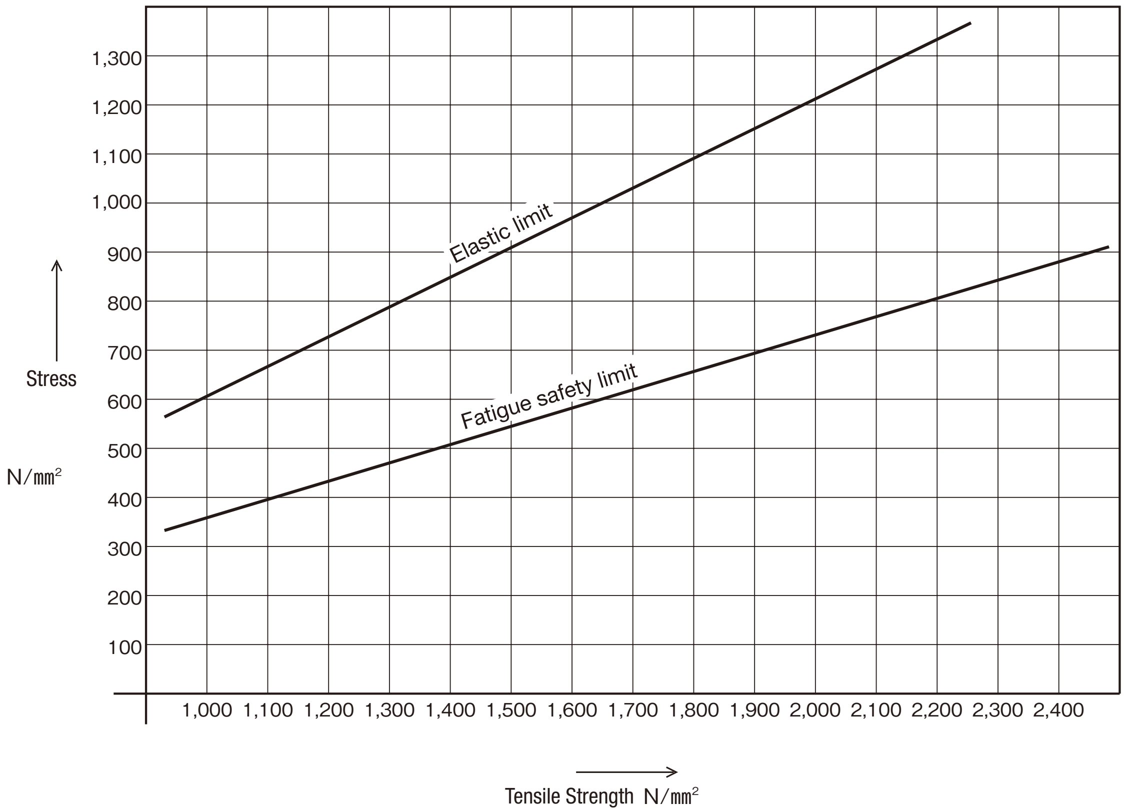
Spring Elastic Limit and Fatigue Safety Limit vs. Tensile Strength



Disc Springs

Disc springs (Belleville washers) are formed springs with a center hole. Disc springs are able to withstand heavy loads within a small area. Disc springs may be used independently or in combination to achieve desired loading capacities and spring characteristics.

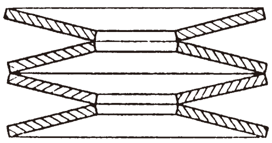
1. Usage Examples

1) Single usage

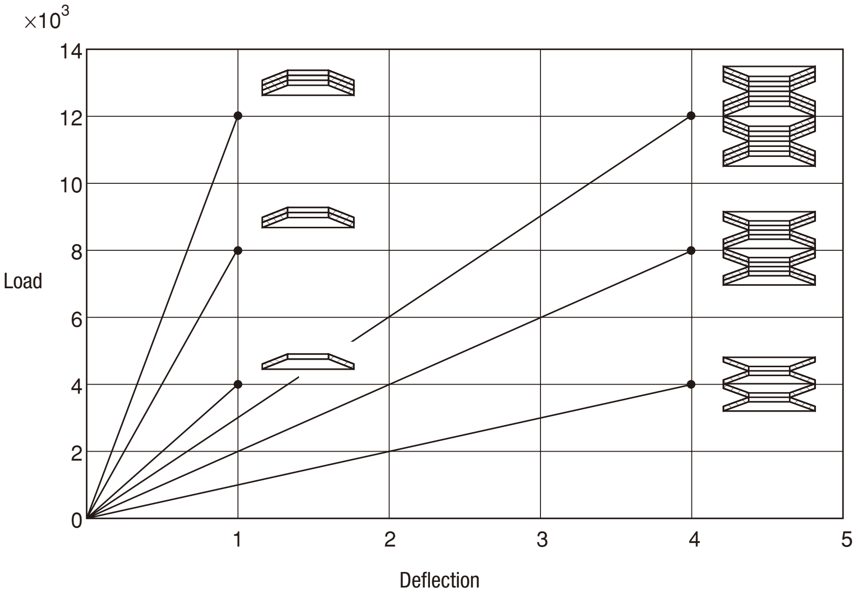
2) Stacking in parallel

Suitable for applications that require high loading capacity with small deflection. Loading capacity increases in proportion to the number of disc springs stacked.

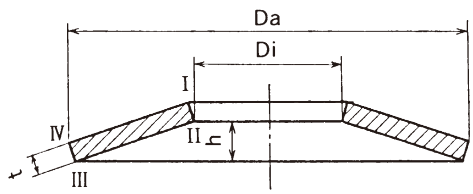
3) Stacking in series



Suitable for applications that require lower loading capacity with greater deflection. Deflection increases in proportion to the number of disc springs stacked.



Load/deflection characteristics of disc spring stacking



2. Disc Spring Calculation

1) Load and deflection calculations

$$P = \frac{4E}{1-\mu^2} \cdot \frac{t^4}{\alpha Da^2} \cdot \frac{f}{t} \left[\left(\frac{h}{t} - \frac{f}{t}\right) \left(\frac{h}{t} - \frac{f}{2t}\right) + 1 \right]$$

$$= 905{,}000 \; \frac{t^4}{\alpha Da^2} \cdot \frac{f}{t} \left[\left(\frac{h}{t} - \frac{f}{t}\right) \left(\frac{h}{t} - \frac{f}{2t}\right) + 1 \right] \text{N}$$

$$\alpha = \frac{1}{\pi} \; \frac{\left(\frac{\delta - 1}{\delta}\right)^2}{\frac{\delta + 1}{\delta - 1} - \frac{2}{\log_e \delta}}$$

	(Spring Steels)
E : Young's modulus	206,000 N/mm²
μ : Poisson's ratio	0.3
$4E/1-\mu^2$:	905,000 N/mm²
f : Deflection	
α : Calculation coefficient of the diameter ratio Da/Di	
δ : Da/Di	

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2) Static Loading and Stress

$$\sigma I = 905{,}000\ \frac{t^2}{\alpha \cdot Da^2} \cdot \frac{f}{t}\left[-\beta\left(\frac{h}{t}-\frac{f}{2t}\right)-\gamma\right]$$

β, γ : Calculation coefficient on diameter ratio Da/Di

$$\beta = \frac{1}{\pi} \cdot \frac{6}{\log_e \delta}\left(\frac{\delta-1}{\log_e \delta}-1\right)$$

$$\gamma = \frac{1}{\pi} \cdot \frac{6}{\log_e \delta} \cdot \frac{\delta-1}{2}$$

The following values serve as the allowable range of calculational stress "σI" at the point I.

1,900 to 2,500 N/mm^2 when f=0.75h

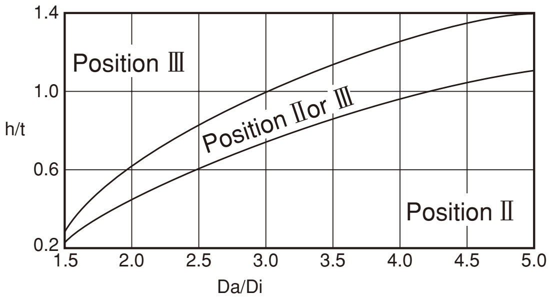
2,500 to 3,200 N/mm^2 when f=h

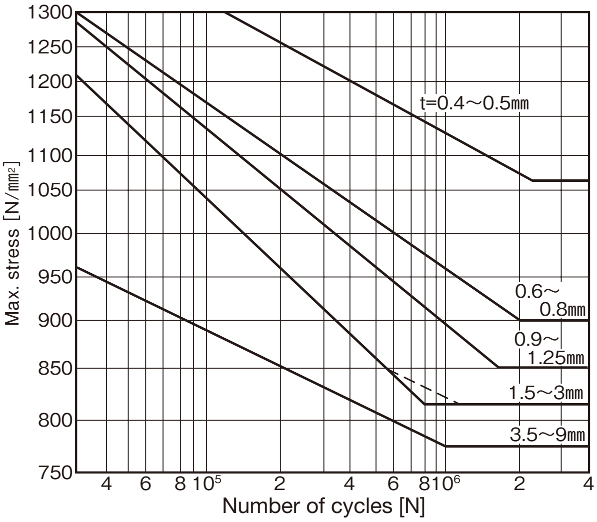
3) Dynamic Loading and Stress

$$\sigma II = 905{,}000\ \frac{t^2}{\alpha \cdot Da^2} \cdot \frac{f}{t}\left[-\beta\left(\frac{h}{t}-\frac{f}{2t}\right)+\gamma\right]$$

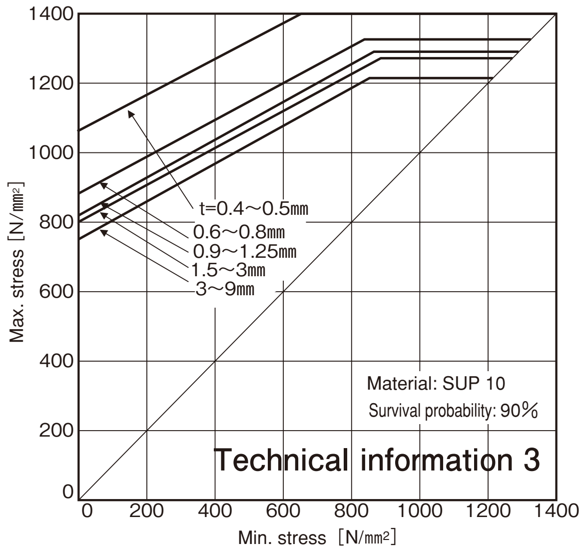
$$\sigma III = 905{,}000\ \frac{t^2}{\alpha \cdot Da^2} \cdot \frac{f}{t} \cdot \frac{1}{\delta}\left[(2\gamma-\beta)\left(\frac{h}{t}-\frac{f}{2t}\right)+\gamma\right]$$

Find the stress range that occurs in "Position II or III" in the diagram to the right and calculate the value of stress using the formula above.
Since the number of stress cycles before fracture depends on maximum stress or stress amplitude, carefully determine the permissible stress.
A fatigue test result example is shown in the diagrams below.





S-N curve of pulsating fatigue test (SUP10; survival probability is 90%)



Permissible stress for dynamic loading [2×106 times]

Reference: Japan Society for Spring Research (SSR), *Spring*, Tokyo: Maruzen Co., Ltd. 1995-2004.

Wave Washers

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Wave washers are ring-shaped, thin metal washers made with wave-like forms designed to achieve spring characteristics against compression; this enables gaining load capacity in limited spaces.

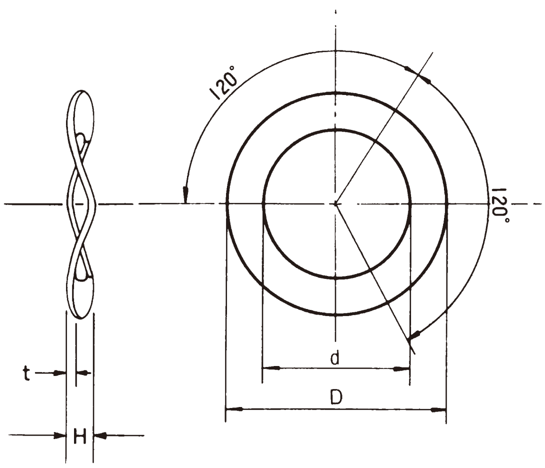
Our Wave Washers comply with JASO F302 Automotive Standard - Wave Washers (Wave Washers for Adjustments).

Calculations for Wave Washers

In wave washer calculations, a significant difference between calculated values and measured values usually exists. The number of waves or the inside-to-outside diameter ratio considerably affects the calculation, as well as the nonlinear change of spring rate of wave washers that occurs when close to their solid height, which makes it difficult to determine values at given points. If a wave washer is assumed to be a continuous beam and its number of waves is 3 or more, the following equation is given to describe the relation between deflection (δ) and load (W), and the stress(σ):

$$K = \frac{W}{\delta} = \frac{Ebt^3N^4}{1.94(dm)^3} \qquad \sigma = \frac{12EtN^2\delta}{\pi^2(dm)^2}$$

K : Spring Rate (N/mm)
W : Load (N)
δ : Deflection (mm)
E : Young's Modulus (N/mm^2)
b : Width (mm) $= \frac{D-d}{2}$
t : Thickness (mm)
N : Number of Waves
dm : Mean diameter (mm) $= \frac{D+d}{2}$
σ : Bend stress (N/mm^2)
D : External diameter (mm)
d : Internal diameter (mm)



Nevertheless, it is recommended to prepare and test a prototype to verify the calculated values.

- Free Height (H) in this Guide is calculated with the above formula with the stress at its solid height set as 4,000 N/mm^2.
- For actual applications, it is recommended to stay within the stress that ensures the free height. The suggested value of stress is 1800 N/mm^2.
- Attention shall be paid in use cases with greater stress, because the free height may be reduced as the spring settles.

Reference: Society of Automotive Engineers of Japan, *JASO F302 Automotive Standard - Wave Washers*