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Springs Washer Belleville Equation

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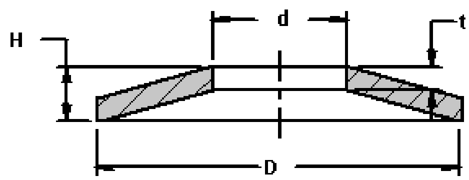
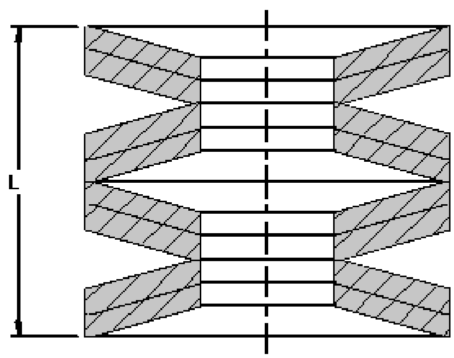
Springs Washer Belleville Equation

A Belleville spring or washer is formed into a conical or cone shaped geometry. The slight or aggressive conical shape gives the washer a spring characteristic and action. Belleville washers are typically used as springs where the spring action is used to apply a pre-load or flexible quality to a bolted joint. The equations below will determine the various characteristics including the applied load of a Belleville spring or washer.

Springs Washer Belleville Equation / Formula





Unloaded height of truncated cone of free spring

$$h = H - t \text{ [mm, in]}$$

Where:

H = unloaded spring height [mm, in]
t = spring material thickness [mm, in]

Diameter Ratio

$$\delta = \frac{D}{d}$$

Where:

D = outer spring diameter [mm]
d = inner spring diameter [mm]

Calculation coefficient α

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

Calculation coefficient β

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

Calculation coefficient γ

$$\gamma = \frac{\delta - 1}{\pi} \cdot \frac{3}{\ln \delta}$$

Limit Washer Deflection

$s_m = h$ [mm, in]

Where:

h = unloaded height of truncated cone of free spring [mm, in]

Force at Maximum Spring Deflection and Limit Deflection:

$$F_{max} = \frac{4E \cdot t^3 \cdot s_m}{(1 - \mu^2) \cdot \alpha \cdot D^2} \quad [N, lb]$$

Where:

E = Spring modulus of elasticity [MPa, psi]
t = Spring material thickness [mm, in]
s_m = limit spring deflection [mm, in]
μ = Poisson's ratio
α = calculation coefficient
D = outside spring diameter [mm, in]

Force Exerted by the Spring at s Deflection:

$$F = \frac{4E \cdot t^4}{(1 - \mu^2) \cdot \alpha \cdot D^2} \cdot \frac{s}{t} \cdot \left[\left(\frac{h}{t} - \frac{s}{t}\right) \cdot \left(\frac{h}{t} - \frac{s}{2t}\right) + 1\right] \quad [N, lb]$$

Where:

E = spring modulus of elasticity [MPa, psi]
t = spring material thickness [mm, in]
s = working deflection of a spring [mm, in]
Poisson's ratio
α = calculation coefficient
D = outside spring diameter [mm, in]
h = unloaded height of truncated cone of free spring [mm, in]

Maximum Pressure Stress in Spring at s Deflection:

$$\sigma = \frac{4E \cdot t \cdot s}{(1 - \mu^2) \cdot \alpha \cdot D^2} \cdot \left[\beta \cdot \left(\frac{h}{t} - \frac{s}{2t}\right) + \gamma\right] \quad [MPa, psi]$$

Where:

E = spring modulus of elasticity [MPa, psi]
t = spring material thickness [mm, in]
s = working deflection of a spring [mm, in]
= Poisson's ratio
α = calculation coefficient
D = outside spring diameter [mm, in]
β = calculation coefficient
h = unloaded height of truncated cone of free spring [mm, in]
γ = calculation coefficient

Total Springs in a Set or Stack up

$$\chi = n\, i$$

Where:

n = spring number in a set with unidirectional mounting
i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting

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Stroke of Deflection of a Spring Set (Stack up)

$$z = i\, s \quad \text{[mm, in]}$$

Where:

i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting
s = working deflection of a spring [mm, in]

Force Exerted by a Spring Set (Stack up)

$$F = n\, F_1 \quad \text{[N, lb]}$$

Where:

n = spring number in a set with unidirectional mounting
F_1 = force exerted by one washer [N, lb]

Height of Spring Stack up Unloaded

$$L_0 = i\,(h + n\, t) \quad \text{[mm, in]}$$

Where:

i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting
h = unloaded height of truncated cone of free spring [mm, in]
n = spring number in a set with unidirectional mounting
t = spring material thickness [mm, in]

Height of Loaded Spring Stack up

$$L = L_0 - z \quad \text{[mm, in]}$$

L_0 = Height of spring set in unloaded state [mm, in]
z = stroke (deflection) of spring set [mm, in]

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