Autodesk Inventor Engineer s Handbook

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Spring Generator

Belleville Spring Generator

Basic calculation of Belleville springs

The calculation is carried out in metric or English units. With the ANSI standard set, the calculation is performed in English units.

The calculation is done in XY and XZ planes and their quadratic sum is made.

Calculated Parameters

Unloaded height of truncated cone of free spring

h = H - t [mm, in]

where:

Hunloaded spring height [mm, in]

t spring material thickness [mm, in]

Diameter ratio

$$\delta = \frac{D}{d} \quad [-]$$

where:

Douter spring diameter [mm, in]

d inner spring diameter [mm, in]

Calculation factor α

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

Calculation factor β

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

Calculation factor 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 (at 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 factor [-]

D outside spring diameter [mm, in]

Force exerted by the spring at the 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]

μ Poisson's ratio [-]

α calculation factor [-]

D outside spring diameter [mm, in]

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

Maximum pressure stress in the spring at the 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]

μ Poisson's ratio [-]

α calculation factor [-]

D outside spring diameter [mm, in]

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

γ calculation factor [-]

Total spring number in a set

$\chi = n\ i$ [-]

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 [-]

Stroke (deflection) of a spring set

$z = i\ s$ [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

$F = n F_1$ [N, lb]

where:

n spring number in a set with unidirectional mounting [-]

F_1 force exerted by one washer [N, lb]

Length of spring set in unloaded state

$L_0 = i (h + n t)$ [mm, in]

where:

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

i spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting [-]

n spring number in a set with unidirectional mounting [-]

t spring material thickness [mm, in]

Length of loaded spring set

$L = L_0 - z$ [mm, in]

where:

L_0 length of spring set in unloaded state [mm, in]

z stroke (deflection) of spring set [mm, in]

Review of all used variables:

d inner spring diameter [mm, in]
D outside spring diameter [mm, in]
F_1 force exerted by one washer [N, lb]
E spring modulus of elasticity [MPa, psi]
t spring material thickness [mm, in]
s working deflection of a spring [mm, in]
μ Poisson's ratio [-]

i spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting [-]
n spring number in a set with unidirectional mounting [-]
H unloaded spring height [mm, in]

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