Autodesk Inventor Engineer s Handbook

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Engineer s Handbook

Shaft Generator

Calculation formulas

These formulas are used to solve either a shaft (with one or more sections) or a beam (with one constant section) with multiple supports and loads.

The shaft/beam axis is aligned with the Z axis. If the impact of the material density is included in the calculation, the gravity vector is aligned with the Y axis.

Shear forces:

$$T(z) = -\int q(z)dz + \sum_{0}^{n} F$$

Bending moments:

$$M_B(z) = \int T(z)dz + \sum_{0}^{n} M_B$$

Deflection angle:

$$\varphi(z) = -\int \frac{M_B(z)}{E * J(z)}\, dz + \varphi(0) + \frac{\beta}{G * S(z)}$$

where:

E modulus of elasticity in tension

J moment of inertia

G modulus of rigidity

β shear displacement ratio

Deflection:

$$y(z) = \int \varphi(z)\, dz + y(0)$$

Bending stress:

$$\sigma_B(z) = \frac{M_B(z)}{W_B(z)}$$

Shear stress:

$$\tau_S(z) = \frac{T(z)}{S(z)}$$

Torsion stress:

$$\tau(z) = \frac{M_{torq}(z)}{W_{torq}(z)}$$

Tension stress:

$$\sigma_T(z) = \frac{\sum_0^n F_z}{S(z)}$$

Reduced stress:

$$\sigma_{red} = \sqrt{(\sigma_B + \sigma_T)^2 + \alpha * (\tau^2 + {\tau_S}^2)}$$

where:

σ_B bending stress

σ_T tension stress

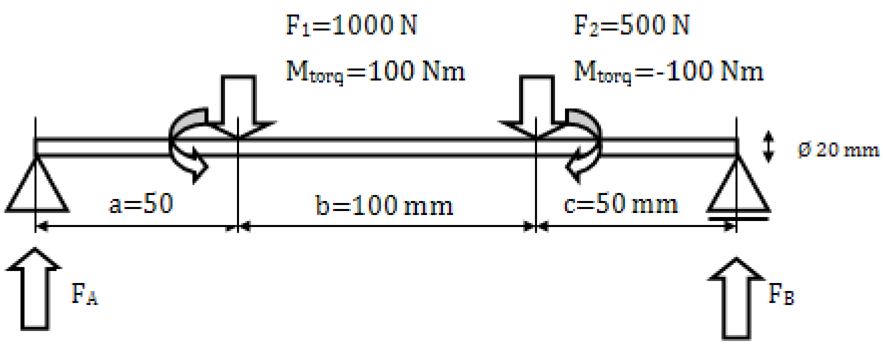
τ torsion stress

τ_S shear stress

αα = 3 for HMH

α = 4 for Tresca-Guest

Sample Calculation



Modulus of elasticity E = 210 000 MPa

Modulus of rigidity G = 81 000 MPa

Shear displacement ratio β = 1.118

Mode of reduced stress: HMH

Do not include the material density.

Support Forces:

$$F_A = \frac{F_1 * (b+c) + F_2 * b}{a+b+c} = \frac{1000 * 150 + 500 * 50}{200} = \underline{875\ N}$$

$$F_B = \frac{F_1 * a + F_2 * (a+c)}{a+b+c} = \frac{1000 * 50 + 500 * 150}{200} = \underline{625\ N}$$

Maximal shear stress:

$$\tau_{S\ max} = \frac{F_a}{\frac{\pi * d^2}{4}} = \frac{875}{\frac{\pi * 0.02^2}{4}} = \underline{2.78521\ MPa}$$

Maximal torsion stress:

$$\tau = \frac{M_{torq}}{W_{torq}} = \frac{M_{torq}}{\frac{\pi * d^3}{16}} = \underline{63.662\ MPa}$$

Maximal moment:

$$M_{B\,max} = F_A * a = 875 * 0{,}05 = \underline{43{,}75\ Nm}$$

Maximal bending stress:

$$\sigma_{B\,max} = \frac{M_{B\,max}}{W_B} = \frac{M_{B\,max}}{\frac{\pi * d^3}{32}} = \frac{43{,}75}{\frac{\pi * 0.02^3}{32}} = \underline{55.7042\ MPa}$$

Maximal reduced stress:

$$\sigma_{red} = \sqrt{(\sigma_B + \sigma_T)^2 + \ \alpha * (\tau^2 + {\tau_S}^2)}$$

$$\sigma_{red} = \sqrt{55.7^2 + 3 * (63.66^2 + 2.785^2)} \ = \underline{123.632\ MPa}$$

Angle of twist:

$$\alpha = \frac{180}{\pi} * \frac{M_{torq} * l}{G * J_{torq}} = \frac{180}{\pi} * \frac{M_{torq} * l}{G * \frac{\pi * d^4}{32}}$$

$$\alpha = \frac{180}{\pi} * \frac{100 * 0.1}{81 * 10^9 * \frac{\pi * 0.02^4}{32}} = \underline{0.45°}$$

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