Bolted Joint Stiffness, Joint Constant and Bolt Load

Bolt and member stiffness of a bolted joint (frustum method), the joint constant, and the bolt load, member load and separation load for a preload and external load.

Method: Shigley's Mechanical Engineering Design (Budynas and Nisbett); ch. 8 (k_m = 0.5774 π E d / (2 ln(5(0.5774 l + 0.5 d)/(0.5774 l + 2.5 d))), F_b = F_i + C P)

Input parameters

Unit system: SI

Parameter	Value	Unit
Bolt nominal diameter	12.000	mm
Tensile stress area of the thread	84.300	mm²
Grip length (members clamped)	40.000	mm
Modulus of the bolt	207.00	GPa
Modulus of the members (same material)	207.00	GPa
Preload	40.000	kN
External tensile load on the joint	20.000	kN
Threaded length within the grip 0 if the grip is all plain shank. The threaded part uses the tensile stress area A_t.	0	mm

Calculated results

Parameter	Value	Unit
Bolt stiffness (shank and threaded lengths in series)	585,279	N/mm
Member stiffness (30° frustum, washer face 1.5 d)	2,235,068	N/mm
Joint constant k_b/(k_b + k_m)	20.752	%
Bolt load F_i + C P (P once separated)	44.150	kN
Member clamp load F_i − (1 − C) P (0 once separated)	24.150	kN
External load to separate the joint	50.474	kN

Formula and method

$$k_b = \frac{A_d A_t E_b}{A_d l_t + A_t (l - l_t)}, \quad A_d = \frac{\pi d^2}{4}, \quad k_m = \frac{0.5774 \pi E_m d}{2 \ln \frac{5(0.5774\, l + 0.5d)}{0.5774\, l + 2.5d}}$$

$$C = \frac{k_b}{k_b + k_m}, \quad F_b = F_i + CP, \quad F_m = F_i - (1 - C)P \ \ (P \le P_0), \quad F_b = P,\ F_m = 0 \ \ (P > P_0), \quad P_0 = \frac{F_i}{1 - C}$$

Variables

d	Bolt nominal diameter	m
A_t	Tensile stress area of the thread	m²
l	Grip length (members clamped)	m
E_b	Modulus of the bolt	Pa
E_m	Modulus of the members (same material)	Pa
F_i	Preload	N
P	External tensile load on the joint	N
l_t	Threaded length within the grip	m
A_d	Shank (nominal) area π d²/4	m²
k_b	Bolt stiffness (shank and threaded lengths in series)	N/m

k_m	Member stiffness (30° frustum, washer face 1.5 d)	N/m
C	Joint constant k_b/(k_b + k_m)	-
F_b	Bolt load F_i + C P (P once separated)	N
F_m	Member clamp load F_i − (1 − C) P (0 once separated)	N
P_0	External load to separate the joint	N

Method and standards

Spring model of bolt and clamped members.

Assumptions and limits

- Same-material members; elastic.
- Bolt stiffness: plain shank (area A_d) over the grip less the threaded length, and the threaded length in the grip at the tensile stress area A_t, in series.
- Once the external load exceeds P_0 the joint is open: the bolt carries P and the member clamp load is zero.

References

- Shigley's Mechanical Engineering Design (Budynas and Nisbett)
- ch. 8 (k_m = 0.5774 π E d / (2 ln(5(0.5774 l + 0.5 d)/(0.5774 l + 2.5 d))), F_b = F_i + C P)

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This calculator online

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