The bolt connects 2 flanges (torque load)

Serious bolt failures often occur in the operation of machines and machinery. In some cases, this phenomenon occurs even when the designer is convinced of sufficient safety of the bolted connection (given the external load conditions). The failure is most often caused by the underestimation of the limit state of the bolt connection or by the lack of reliable data for a thorough analysis of the strength conditions of the connection. These are especially experimentally obtained data, which are necessary both for the theoretical calculation and for the determination of the optimal design of the bolt connection.

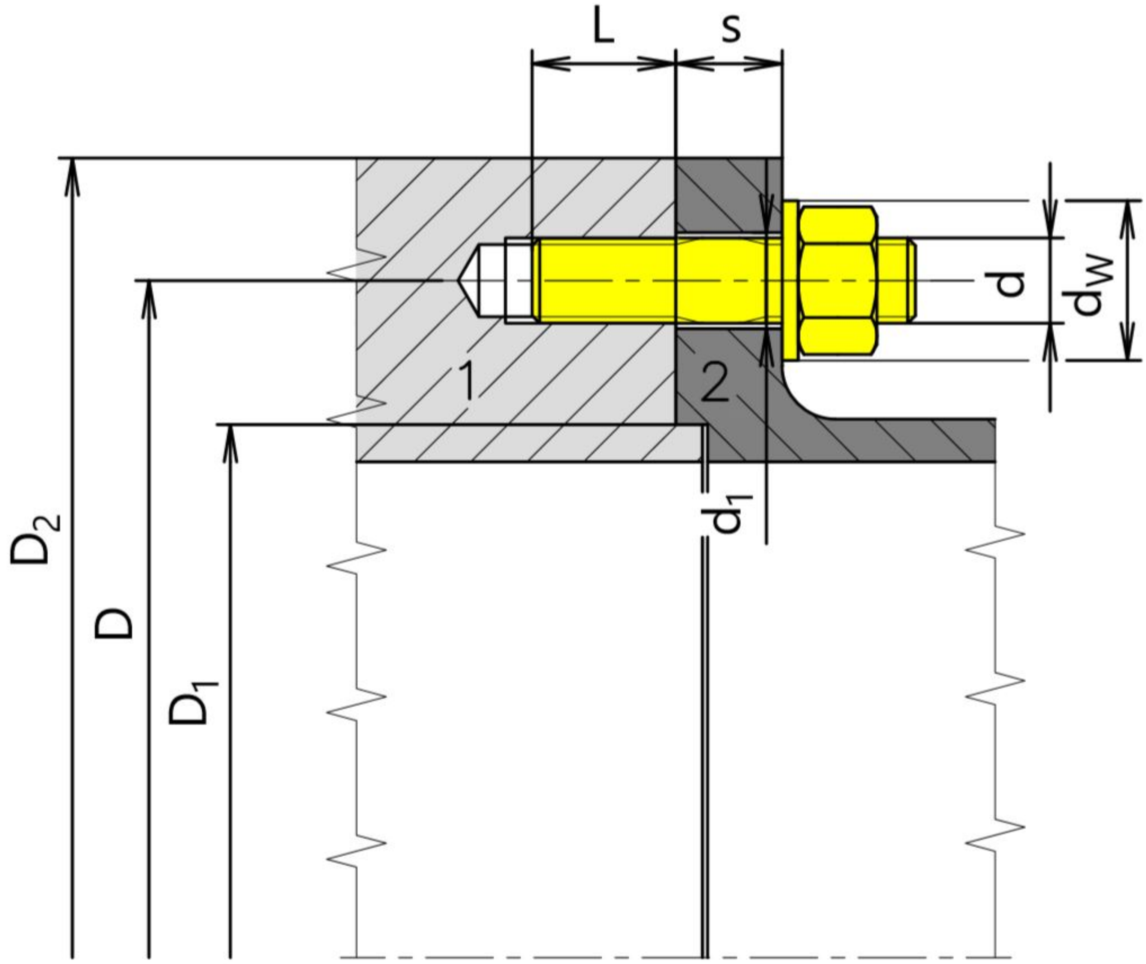

Fig. 1 the bolt connects 2 flanges (torque load)

Axial stress the bolt:

$$\sigma = \frac{F_{Bmax}}{\frac{\pi}{4}\left(\frac{d_{b2}+d_{b3}}{2}\right)^2}$$

σ	axial stress the bolt	[MPa]
F_{Bmax}	maximum axial force in the bolt	[N]
d_{b2}	medium diameter	[mm]
d_{b3}	smaller external thread diameter	[mm]

Shear stress the bolt:

$$\tau = \frac{M}{\frac{\pi}{16}\left(\frac{d_{b2}+d_{b3}}{2}\right)^3}$$

τ	shear stress the bolt	[MPa]
M	the bolt tightening torque	[Nm]
d_{b2}	medium diameter	[mm]
d_{b3}	smaller external thread diameter	[mm]

Bending stress the bolt:

$$\sigma_B = \frac{M_B}{\frac{\pi}{32}\left(\frac{d_{b2}+d_{b3}}{2}\right)^3}$$

σ_B	bending stress the bolt	[MPa]
M_B	bending moment the bolt	[Nm]
d_{b2}	medium diameter	[mm]
d_{b3}	smaller external thread diameter	[mm]

Bending moment the bolt:

$$M_B = \frac{d_{B3}^2 * F_{Bmax} * arc\psi * \sqrt{E*\pi}}{8\sqrt{F_{Bmax}} * tanh\left(\frac{8s}{d_{B3}^2} * \sqrt{\frac{F_{Bmax}}{E*\pi}}\right)}$$

M_B	bending moment the bolt	[Nm]
d_{b3}	smaller external thread diameter	[mm]
F_{Bmax}	maximum axial force in the bolt	[N]
ψ	angular displacement of perpendicular contact surface of the bolt head [rad]	
E	Young's modules	[MPa]
s	flange thickness	[mm]

Maximal shear stress (Tresca) the bolt:

$$\sigma_{tresca} = \sqrt{\sigma^2 + \sigma_B^2 + 4\tau^2} \le \sigma_{Call}$$

σ_{tresca}	maximal shear stress (Tresca) the bolt	[MPa]
σ	axial stress the bolt	[MPa]
σ_B	bending stress the bolt	[MPa]
τ	shear stress the bolt	[MPa]
σ_{Call}	allowable combined stress	[MPa]

Allowable combined stress:

$$\sigma_{Call} = \frac{R_{p0,2T}}{S_F} * C_c$$

σ_{Call}	allowable combined stress	[MPa]
$R_{p0,2T}$	the minimum yield strength or 0,2% proof strength at calculation temperature	[MPa]
S_F	safety factor	[]
C_c	coefficient according to load	[]

Coefficient according to load:

load	[]
Unidirectional load, non-impact load	0,8
Unidirectional load, with a small impact load	0,7
Unidirectional load, with a big impact load	0,6
Alternating load, with a small impact load	0,45
Alternating load, with a big impact load	0,25

Bearing stress the bolt:

$$p_t = \frac{4F_{Bmax}}{\frac{L}{P} * \pi * (d^2 - d_{b1}^2)} \leq \sigma_{all(t)}$$

p_t	bearing stress the bolt	[MPa]
F_{Bmax}	maximum axial force in the bolt	[N]
L	thread length of thread in threaded hole	[mm]
P	thread pitch	[mm]
d	thread	[mm]
d_{b1}	minor diameter	[mm]
$\sigma_{all(t)}$	allowable bearing stress the thread	[MPa]

Allowable bearing stress the thread:

$$\sigma_{all(t)} = \frac{0{,}9R_{p0,2T}}{S_F} * C_c$$

$\sigma_{all(t)}$	allowable bearing stress the thread	[MPa]
$R_{p0,2T}$	the minimum yield strength or 0,2% proof strength at calculation temperature	[MPa]
S_F	safety factor	[]
C_c	coefficient according to load	[]

Bearing stress the washer:

$$p = \frac{4F_{Bmax}}{\pi * (d_w^2 - d_1^2)} \leq \sigma_{all}$$

p	bearing stress the washer	[MPa]
F_{Bmax}	maximum axial force in the bolt	[N]
d_w	washer diameter	[mm]
d_1	the bolt nominal diameter	[mm]
σ_{all}	allowable bearing stress	[MPa]

Allowable bearing stress:

$$\sigma_{all} = \frac{0{,}9R_{p0,2T}}{S_F} * C_c$$

σ_{all}	allowable bearing stress	[MPa]
$R_{p0,2T}$	the minimum yield strength or 0,2% proof strength at calculation temperature	[MPa]
S_F	safety factor	[]
C_c	coefficient according to load	[]

Shear stress the thread:

$$\tau_t = \frac{3F_{Bmax}}{2\pi * d_{b1} * \frac{L}{P} * \left(P - \frac{H}{2}\tan 30\right)} \leq \tau_{all(t)}$$

τ_t	shear stress the thread	[MPa]
F_{Bmax}	maximum axial force in the bolt	[N]
d_{b1}	minor diameter	[mm]
L	thread length of thread in threaded hole	[mm]
P	thread pitch	[mm]
H	height of basic triangle	[mm]
$T_{all(t)}$	allowable shear stress the thread	[MPa]

Allowable shear stress the thread:

$$\tau_{all(t)} = \frac{0{,}4R_{p0,2T}}{S_F} * C_c$$

$T_{all(t)}$	allowable shear stress the thread	[MPa]
$R_{p0,2T}$	the minimum yield strength or 0,2% proof strength at calculation temperature	[MPa]
S_F	safety factor	[]
C_c	coefficient according to load	[]

Height of basic triangle:

$$H = \frac{\sqrt{3}}{2}P$$

H	height of basic triangle	[mm]
P	thread pitch	[mm]

Bending stress the thread:

$$\sigma_t = \frac{3F_{Bmax} * (d - d_{b1})}{2\pi * d_{b1} * \frac{L}{P} * \left(P - \frac{H}{2}\tan 30\right)^2} \leq \sigma_{Ball(t)}$$

σ_t	bending stress the thread	[MPa]
F_{Bmax}	maximum axial force in the bolt	[N]
d	thread	[mm]
d_{b1}	minor diameter	[mm]

L	thread length of thread in threaded hole	[mm]
P	thread pitch	[mm]
H	height of basic triangle	[mm]
$\sigma_{Ball(t)}$	allowable bending stress the thread	[MPa]

Allowable bending stress the thread:

$$\sigma_{Ball(t)} = \frac{0{,}6R_{p0,2T}}{S_F} * C_c$$

$\sigma_{Ball(t)}$	allowable bending stress the thread	[MPa]
$R_{p0,2T}$	the minimum yield strength or 0,2% proof strength at calculation temperature	[MPa]
S_F	safety factor	[]
C_c	coefficient according to load	[]

Literature:

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