Tie Calcs


- M10 → $d = 10\,mm$
  $= 0.01\,m$

- assuming coarse thread

* considering failure due to UTS.

$$\sigma_u = \frac{HV}{0.3} = \frac{330}{0.3} = 1100\ MPa$$

* considering failure due to tension:

$$\sigma = \frac{P}{A}$$

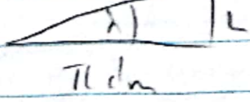
$$\therefore P = \sigma_u A$$
$$= 1100\ MPa \times \frac{\pi}{4}(10\,mm)^2$$
$$= 86.39\ kN$$

∴ hence at it's UTS load, the max force experienced by the M10 bolt is 86.39 kN

* to find torque to raise:
→ given that we are lifting the load:

$$T = \frac{W d_m}{2} \cdot \frac{f \pi d_m + L\cos\alpha_n}{\pi d_m \cos\alpha_n - fL}$$

Values:
$w = 86.39\ kN$ (P calcs)
$d_m = d - P/2 = 10\,mm - \frac{1.5\,mm\ (P)}{2} = 9.25\,mm$ (table 10.2)
$f = 0.02$
$L = 1.5\ mm$
$\cos\alpha_n \approx 0.406$




$$\therefore \lambda = \tan^{-1}\left(\frac{L}{\pi d_m}\right) = \tan^{-1}\left(\frac{1.5\,mm}{\pi \times 9.25\,mm}\right)$$
$$= 2.95°$$

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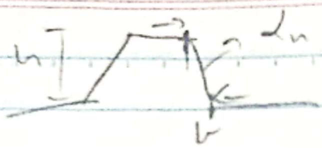
$\tan \alpha_n = \frac{b}{h_t}$ (figure 10.7)



$= \frac{p - \left(\frac{2p}{4}\right)}{d - d_r}$

$= \frac{p - \frac{p}{2}}{d - d_r}$ $\quad \tan \alpha_n = \frac{1.5mm / 2}{10mm - 8.16mm}$

$= \frac{\frac{p}{2}}{d - d_r}$ $\quad \tan \alpha_n = 0.407$

$\therefore \alpha_n \simeq 66°$

$$f \geq \frac{L \cos \alpha_n}{\pi d_m} \geq \frac{1.5mm \times 0.406}{\pi \times 9.25mm} \geq 0.021 \text{ (from eqtn 10.7)}$$

$\therefore T = 40.41$ Nm of torque to fail at $\sigma_{UTS}$

* considering failure due to thread stripping

$$F_{bolt} \simeq \frac{\pi}{4}(0.9d)^2 S_y$$

$$F_{nut} \simeq \pi d(0.75t)(0.58S_y) \rightarrow t = 0.47d$$

$$\simeq \pi d(0.3525d)(0.58S_y)$$

$$\simeq 0.325\pi d^2(0.58S_y)$$

(eqtn 10.45)

considering SAE class:

* $d \in [1.1, 36]$ mm $= 10$mm
* $S_y = 1100$ MPa

$$\therefore F_{bolt} = \frac{\pi}{4}(0.9(10mm))^2(1100 \text{ MPa}) = 69.98 \simeq 70kN$$

$$F_{nut} = 0.325\pi(10mm)^2(0.58)(1100 \text{ MPa}) = 65.141 \simeq 65.1kN$$

$$\therefore T = \frac{Wd_m}{2} \cdot \frac{f\pi d_m + L\cos\alpha_n}{\pi d_m \cos\alpha_n - fL}$$

$T_{bolt} = 32.73$ Nm

$T_{nut} = 30.47$ Nm

consider failure soon after initial tightening:

$F_{it} = K_i \cdot A_t \cdot S_p$ (eqtn 10.11)

considering SAE 12.9 class bolt:

$d = 10\,mm$ ($\in [1.6, 36]$)
$K_i = 0.9$
$S_p = 970\,MPa$ } → table 10.5
$A_t = 58\,mm^2$ (stress area) → table 10.2

$\therefore F_{it} = 0.9 \times 970\,MPa \times 58.0\,mm^2$
$= 50634\,N$
$= 50.63\,kN$

→ $T_{it} = 0.2 F_{it} d$ (eqtn 10.13)
$= 0.2(50634\,N)(10\times10^{-3}\,m)$
$= 101.27\,Nm$

hence different failure conditions:
- → UTS: $F = 86.4\,kN$ → $T = 40.41\,Nm$
- → thread stripping (bolt): $F = 70\,kN$ → $T = 32.73\,Nm$
- → thread stripping (nut): $F = 65.1\,kN$ → $T = 30.47\,Nm$
- → initial tightening: $F = 50.63\,kN$ → $T = 101.27\,Nm$

* stresses at UTS:

$\sigma_{UTS} = 1100\,MPa$

* stresses due to torsion:

$\tau = \frac{16T}{\pi d^3}$ (4.3, 4.4 pg 435)

$\therefore \tau_{UTS} = \frac{16 \times 40.41\,Nm}{\pi(10\times10^{-3}\,m)^3} = 205806440\,Pa = 205.8\,MPa$

$\tau_{TS,Bolt} = \frac{16 \times 32.73\,Nm}{\pi(10\times10^{-3}\,m)^3} = 166692521\,Pa = 166.7\,MPa$

$\tau_{TS,Nut} = \frac{16 \times 30.47\,Nm}{\pi(10\times10^{-3}\,m)^3} = 155182436\,Pa = 155.2\,MPa$

$\tau_{it} = \frac{16 \times 101.27\,Nm}{\pi(10\times10^{-3}\,m)^3} = 515763874\,Pa = 515.8\,MPa$

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* stresses due to thread bearing compression

$$\sigma = \frac{4P}{\pi(d^2 - d_i^2)} \cdot \frac{p}{t}$$

$P = 70\ kN$ (bolt) / $65.1\ kN$ (nut)

$p = 1.5\ mm$

$d = 10\ mm$

$d_i = 9.23\ mm$

$t = 40$

$\therefore \sigma_{bolt} = 225.72\ MPa$

$\therefore \sigma_{nut} = 209.9\ MPa$

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