sign convention — tension (+), compression (−)

(ductile): mat'l with more than 5% elongation at fracture (P.62)

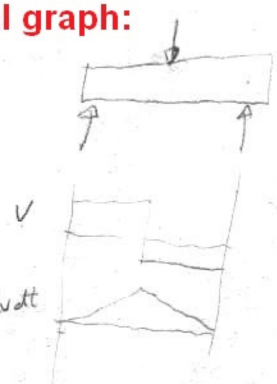
Stress analysis

Tension-compression $\sigma_{max} = P/A$ Torsion $\tau_{max} = Tr/J$

Bending $\sigma_{max} = \frac{Mc}{I}$ Bending rectangular: $\tau_{max} = \frac{3V}{2A}$

circular: $\tau_{max} = \frac{4V}{3A}$

typical graph:



Mohr's circle

$$\sigma_1, \sigma_3 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\tau_{max} = \frac{|\sigma_1 - \sigma_3|}{2} \qquad \sigma_1 > \sigma_3$$

sign convention τ_{xy} + CW, − CCW

$$\tan 2\phi = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

criteria (safest to unsafest)

(SAFE) Max Shear	Von Mises	Max Strain	(UNSAFE) Max Normal
$N = \frac{S_y}{2\tau_{max}}$	$N = \frac{S_y}{\sigma'}$	$N = \frac{S_y}{\sigma'}$	$N = \frac{S_y}{\vert\sigma_{max}\vert}$

$\sigma' = \sqrt{\sigma_1^2 + \sigma_3^2 - \sigma_1\sigma_3}$

$\sigma' = |\sigma_{max} - \nu\sigma_{min}|$ ← $\sigma_{max} = max(|\sigma_1|, |\sigma_3|)$, $\sigma_{min} = min(|\sigma_1|, |\sigma_3|)$ with their respective signs

$(= \sigma_1 - \nu(\sigma_3 + \sigma_2))$

For brittle mat'l: (Brittle Mat'l)

Coulomb-Mohr

$\sigma_3 < 0 \rightarrow \frac{1}{N} = \frac{\sigma_1}{S_{ut}} - \frac{\sigma_3}{S_{uc}}$

$\sigma_3 > 0 \rightarrow N = \frac{S_{ut}}{\sigma_1}$

Modified-Mohr

$\frac{-\sigma_3}{\sigma_1} > 1 \rightarrow \frac{1}{N} = \frac{\sigma_1}{S_{ut}} - \frac{\sigma_3}{S_{uc}} - \frac{\sigma_1}{S_{uc}}$

$\frac{-\sigma_3}{\sigma_1} < 1 \rightarrow N = \frac{S_{ut}}{\sigma_1}$

For impact:

Impact $I.F = \frac{F_i}{W} = 1 + \sqrt{1 + \frac{2h\eta}{\delta_{st}}} \Rightarrow M = f(F_i) \Rightarrow \sigma = \frac{Mc}{I}$

$= v_i \sqrt{\frac{\eta}{g\,\delta_{st}}}$ $\quad \eta = \frac{1}{1 + \frac{m_b}{3m}}$ $\quad m_b \rightarrow$ struck object, $m \rightarrow$ striking object

For notches:

Notches $\rightarrow \sigma = K_t \sigma_{nom}$ $\quad K_T \Rightarrow$ geometric factor (static) → Tables
− for ductile $K_T = 1$ (→ although use small d at notch for $\sigma = \frac{Mc}{I}$)

$\sigma = K_f \sigma_{nom}$ $\quad K_f \Rightarrow$ geometric factor (dynamic)

$\tau = K_{ts} \tau_{nom}$

$\tau = K_{fs} \tau_{nom}$

$K_f = 1 + q(K_t - 1)$ $\quad q = \left(1 + \frac{\sqrt{a}}{\sqrt{r}}\right)^{-1}$ $\quad \sqrt{a} \Rightarrow$ Table (P.390)
↳ for alternating stress see P.42 notes) ↳ notch radius (P.391)

SHAFT

For shaft:

Fatigue strength (S_f), Endurance limit (S_e) → P. 33-36 (notes)

$A_{95} \rightarrow$ Fig. 6-25 (P.377)

$C_{reliability} \rightarrow$ Table (P. 381) $\rightarrow N = \frac{S_e}{K_f \sigma_{nom}}$ (dynamic) $\quad N = \frac{S_y}{K_T \sigma_{nom}}$ (static) (K_T=1 ductile)

↳ σ_a (when $\sigma_m = 0$) (see otherside)

↳ critical sections → all steps + mid length of shaft
↳ use small ϕ to find $\sigma_{nom} = \frac{Mc}{I}$

For fatigue:

cumulative fatigue damage → P.66

Fatigue

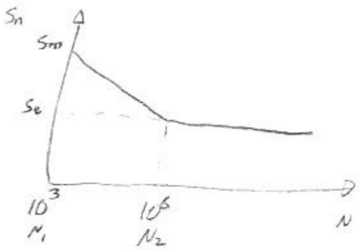
$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$ $\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$

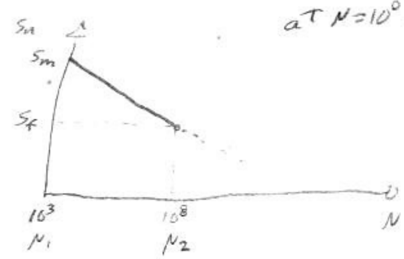
SAFETY Factor for fluctuating stress → P.43 (notes)

Equation for graph →

bending $S_m = 0.9\, S_{ut}$

axial loading $S_m = 0.75\, S_{ut}$





at $N = 10^0$ → $S_n = S_{ut}$

$$\log S_n = \log a + b \log N$$

$$S_n = a N^b$$

$z = \log N_1 - \log N_2$

$b = \frac{1}{z} \log\left[\frac{S_m}{S_e}\right]$ $\log a = \log S_m - 3b$

Fully reversed ($-F$ to F) $\sigma_m = 0$

Steps-> Find: K_T, S_{ut}, S_y, S_e', q, K_f, $\sigma_{a\,nom}$, σ_a ($K_f \sigma_{a\,nom}$), σ_1 & σ_3 (at critical location using σ_a), σ' (Von Mises), S_e, S_n (at given N from ...), $\Rightarrow N_f = \frac{S_n}{\sigma'}$

Repeated or fluctuating ($\sigma_m \neq 0$)

Steps-> Find: K_T, q, K_f, $\sigma_{a\,nom}$, σ_a, $\sigma_{m\,nom}$, σ_m (P.42 → $K_{fm} \sigma_{m\,nom}$ (P.42 notes)), S_{ut}, S_y, S_e', ($\tau_{a\,nom}$ $\tau_{a\,nom}$ $\tau_{m\,nom}$ $\tau_{m\,nom}$ etc), σ_a', σ_m', S_e, S_n $\Rightarrow N_f$ → see P.43 notes where $S_f = S_n$

$$\sigma_a' = \sqrt{\sigma_{xa}^2 + \sigma_{ya}^2 - \sigma_{xa}\sigma_{ya} + 3\tau_{xya}^2}$$

$$\sigma_m' = \sqrt{\sigma_{xm}^2 + \sigma_{ym}^2 - \sigma_{xm}\sigma_{ym} + 3\tau_{xym}^2}$$

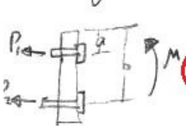
Screws + Fasteners → P.53

stress in threads → P.57

Self-locking screw if: $\mu \geq \frac{L}{\pi d_p}\cos\alpha$ ($\mu \geq \tan\lambda \cos\alpha$)

(opposite is back-driving: $\mu < \tan\lambda\cos\alpha$)

Fastener in shear → P.63



$n_1 P_1 a + n_2 P_2 b = M$

$\frac{P_1}{a} = \frac{P_2}{b}$

Gears: $d = \frac{N}{(P_d)_t}$ (teeth/in) $P_c = \frac{\pi d}{N}$ $P_c P_{d_t} = \pi$ $(P_d)_t = (P_d)_n \cos\psi$ (Helix angle)

load on gears: $F_t = \frac{2T}{d}$ $F_r = F_t \tan\phi$ $F = \frac{F_t}{\cos\phi}$

$c = \frac{d_p + d_g}{2} = \frac{N_p + N_g}{2(P_d)_t}$

standard → P.715

contact ratio $m_p = \frac{Z}{P_b} = \frac{N Z}{\pi d \cos\phi} = \frac{P_d Z}{\pi \cos\phi}$ → P.708

bending → P.74

$N = \frac{S_{fb}}{\sigma_b}$ → P.70

surface contact → P.75

$N = \frac{S_{fc}}{\sigma_c}$ → P.71