Introduzione:

CRITERI DI RESISTENZA STATICA

→ Dato un generico stato di sforzo, come possiamo capire se è critico o meno per un componente?
→ Abbiamo bisogno di uno "strumento" che ci permette di ~~[illegible]~~ quantificare la criticità dello stato di sforzo rispetto alle caratteristiche del materiale che si vuole adottare.

Equazione di verifica:

$$\underbrace{\sigma^*} \leq \sigma_{amm} = \frac{\sigma_{lim}}{\eta}$$

Sforzo di confronto o sforzo equivalente

σ_{lim} ← Proprietà del materiale

η ← Coefficiente di sicurezza

Il calcolo dello sforzo equivalente viene svolto attraverso l'utilizzo di un criterio di resistenza ~~[illegible]~~ che dipende dal materiale utilizzato:

MATERIALI DUTTILI

↳ Criterio di Guest - Tresca

$$\tau_{max} \leq \tau_{amm} = \frac{\tau_{lim}}{\eta} \quad \text{dove} \quad \tau_{lim} = \tau_{sn} = \frac{\sigma_{sn}}{2}$$

$$\tau_{max} = \frac{\sigma_I - \sigma_{III}}{2} \leq \tau_{amm} = \frac{\sigma_{sn}}{2}\frac{1}{\eta}$$

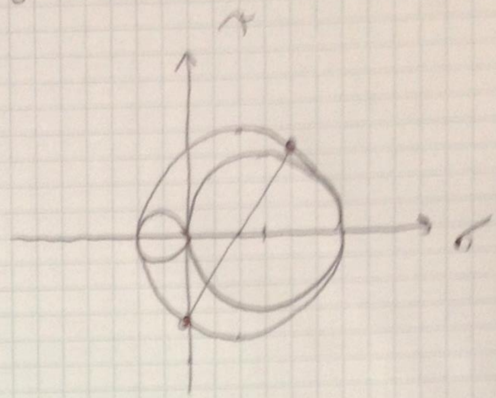
$$\Rightarrow \boxed{\sigma^*_{GT} = \sigma_I - \sigma_{III} \leq \sigma_{amm} = \frac{\sigma_{sn}}{\eta}}$$

Scritta anche come: $\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min}$

↳ Criterio di Von Mises

$$\boxed{\sigma_{VM}^* = \sqrt{\sigma_I^2 + \sigma_{II}^2 + \sigma_{III}^2 - \sigma_I\sigma_{II} - \sigma_{II}\sigma_{III} - \sigma_{III}\sigma_I}}$$

Caso tipico $\leftarrow \square \rightarrow \sigma$, τ



Formule semplificate:

$$\sigma_I = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma_{II} = 0$$

$$\sigma_{III} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$\sigma^*_{GT} = \sigma_I - \sigma_{II} = \sqrt{\sigma^2 + 4\tau^2}$$

$\Rightarrow$

$$\sigma^*_{VM} = \sqrt{\sigma^2 + 3\tau^2}$$

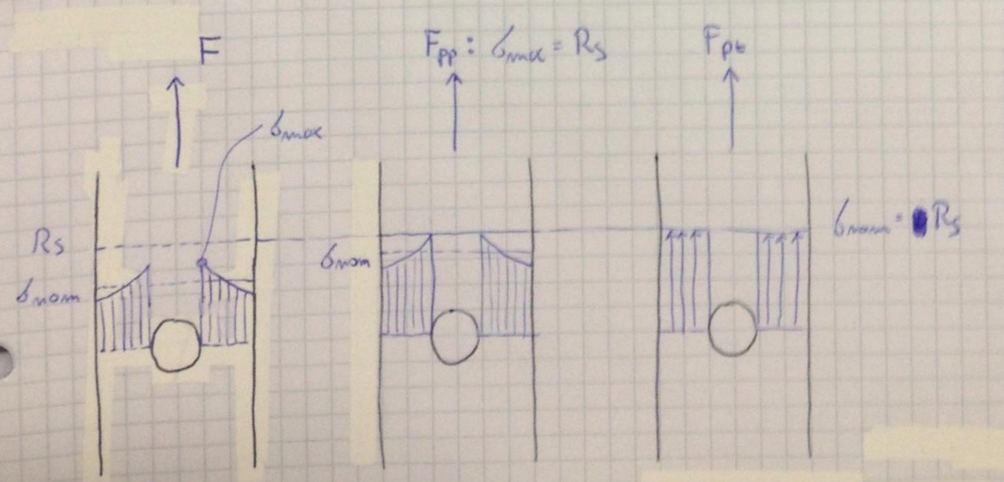
MATERIALI FRAGILI

↳ Galileo, Rankine, Navier

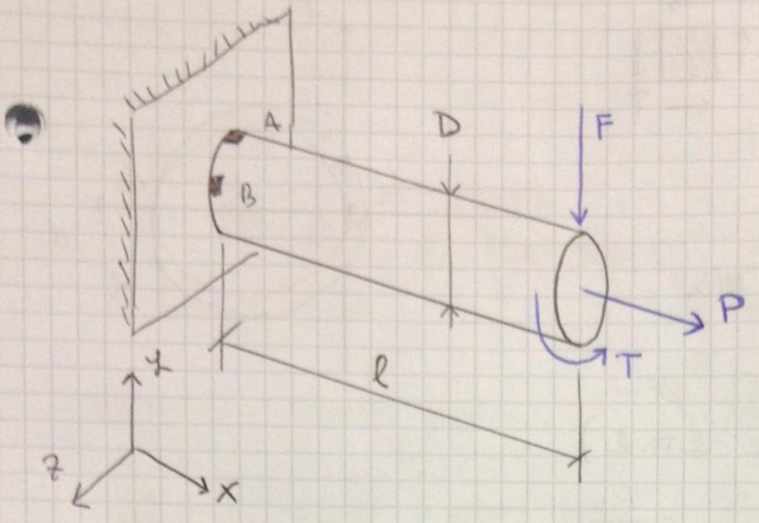
Il cedimento si verifica quando uno degli sforzi principali diventa uguale allo sforzo di rottura a trazione σ_m^t (R_m^t) o a compressione (σ_m^t o σ_m^c)

$$\sigma^*_{GRN} = \sigma_I \leq \frac{R_m^t}{\eta}$$

$$\sigma^*_{GRN} = \sigma_{III} \geq \frac{R_m^c}{\eta}$$



Spiegazione che gli σ_{nom} si trovano nella sezione "minore"



$D = 20\ mm$

$l = 100\ mm$

$F = 550\ N$

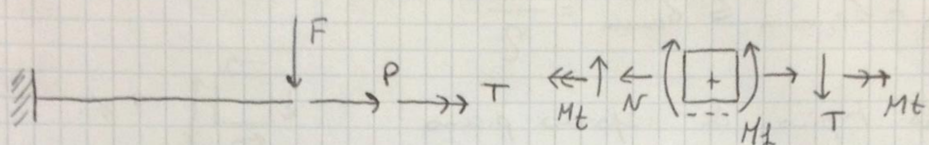
$P = 8000\ N$

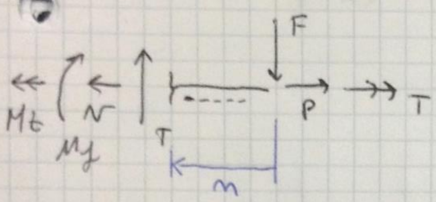
$T = 30\ Nm$

Materiale: acciaio Fe430

$R_m = 430\ MPa$

$R_s = 275\ MPa$



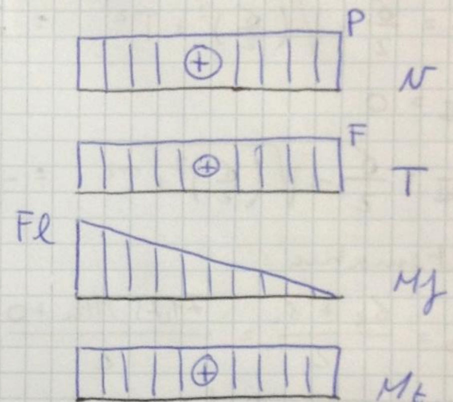


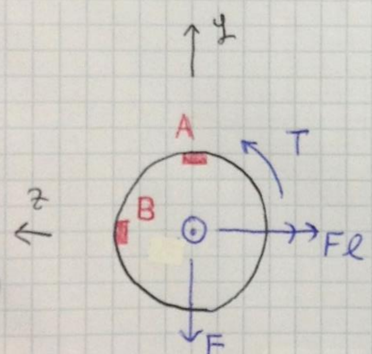
$N = P$

$T = F$

$M_f = -Fm$

$M_t = T$





Punto A:

$$\sigma_{x,N} = \frac{P}{A} = \frac{P}{\frac{\pi D^2}{4}} = \frac{8000\ N}{\frac{\pi\, 20^2\ mm^2}{4}} = 25{,}47\ MPa$$

$$\sigma_{x,M_f} = \frac{M_f\, D/2}{J} = \frac{M_f\, D/2}{\frac{\pi D^4}{64}} = 70\ MPa$$

$\sigma_{x,tot}: 95{,}47\ MPa$

$$\tau_{xz} = \frac{T\, D/2}{J_p} = \frac{T\, D/2}{\frac{\pi D^4}{32}} = \frac{30\ N\cdot m \cdot 10^3\ mm/m \cdot \frac{20\ mm}{2}}{\frac{\pi\ 20^4\ mm^4}{32}} = 19{,}1\ MPa$$

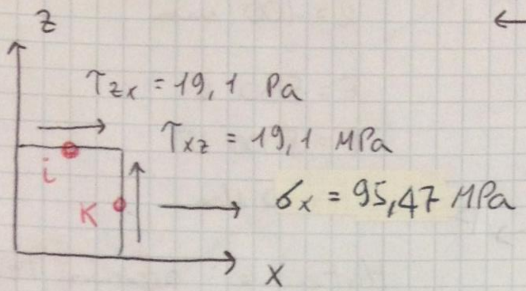
Punto B:

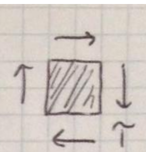
$\sigma_{x,N} = 25{,}47\ MPa$

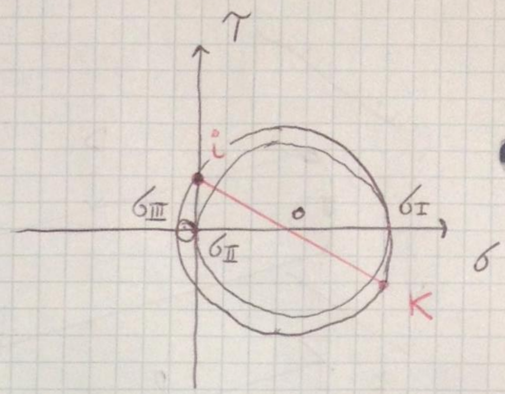
$\tau_{xy_{Mt}} = 19{,}1\ MPa$ $\qquad \tau_{xy_{F}} = \frac{4}{3}\frac{F}{A} = \frac{4}{3}\frac{550\ N}{\frac{\pi D^2}{4}} = 2{,}33\ MPa$

$\tau_{xy} = 21{,}43\ MPa$

Punto A:

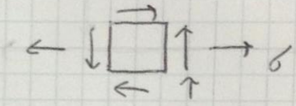






Guest-Tresca (materiali duttili)

$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} \leq \sigma_{amm} = \frac{R_s}{\eta}$$

Per questo caso tipico di sforzo piano: 

$$\sigma_I = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = 99,15 \text{ MPa}$$

$$\sigma_{II} = 0$$

$$\sigma_{III} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = -4,77$$

Alternativa:

$$\sigma_0 = \frac{\sigma_K + \sigma_i}{2} = \frac{95,47 \text{ MPa} + 0}{2} = 47,74 \text{ MPa}$$

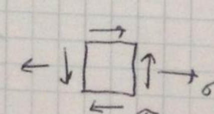
Raggio cerchio $(\sigma_I - \sigma_{III})$:

$$\overline{OK} = \sqrt{\tau_K^2 + (\sigma_K - \sigma_0)^2} = 51,41 \text{ MPa}$$

$\sigma_I = \sigma_0 + \overline{OK} = 99,15$ MPa $\qquad \sigma_{II} = \sigma_0 - \overline{OK} = -3,67$ MPa

$$\sigma^*_{GT} = \sigma_I - \sigma_{III} = 99,15 \text{ MPa} - (-3,67) \text{ MPa} = 102,8 \text{ MPa}$$

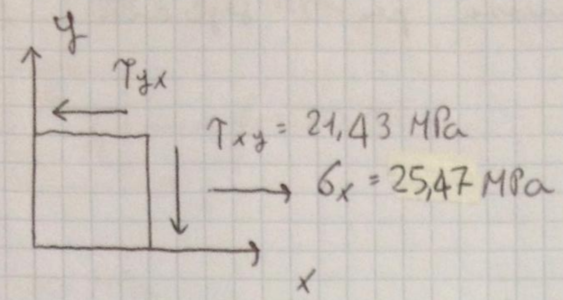
$$\sigma^*_{GT} \leq \sigma_{amm} = \frac{R_s}{\eta_{GT}} \rightarrow \eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = \frac{275 \text{ MPa}}{102,8 \text{ MPa}} = 2,68 > \eta_{duttili} = 1,5$$

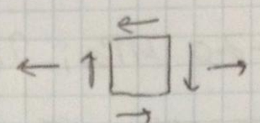
Alternativa calcolo σ^*_{GT}: caso di sforzo piano 

$$\sigma^*_{GT} = \sqrt{\sigma^2 + 4\tau^2} = 102,83 \text{ MPa}$$

$$\sigma^*_{VM} = \sqrt{\sigma^2 + 3\tau^2} = 101,04 \text{ MPa} \qquad \sigma^*_{VM} \leq \frac{R_s}{\eta_{VM}} \rightarrow \eta_{VM} = 2,72 > \eta_{duttili} = 1,5$$

Punto B:



Stato di sforzo piano: 

$$\sigma^*_{GT} = \sqrt{\sigma^2 + 4\tau^2} = 49{,}85 \text{ MPa} \leq \frac{R_s}{\eta_{GT}} \rightarrow \eta_{GT} = 5{,}52$$

$$\sigma^*_{VM} = \sqrt{\sigma^2 + 3\tau^2} = 45 \text{ MPa} \leq \frac{R_s}{\eta_{VM}} \rightarrow \eta_{VM} = 6{,}11$$

Barra di acciaio duttile con snervamento $R_s = 345$ MPa.
Calcolare i coefficienti di sicurezza per i seguenti stati di sforzo:

1) $\sigma_x = 80$ MPa ; $\sigma_y = 40$ MPa

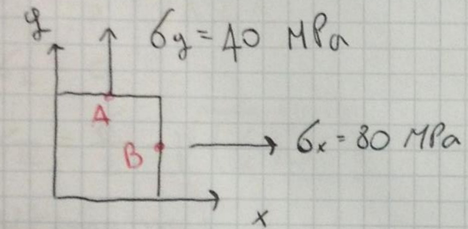
2) $\sigma_x = 80$ MPa ; $\sigma_y = -60$ MPa

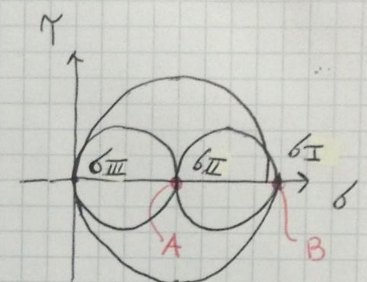
3) $\sigma_x = -40$ MPa ; $\sigma_y = -70$ MPa ; $\tau_{xy} = -35$ MPa

4) $\sigma_x = 80$ MPa ; $\sigma_y = 25$ MPa ; $\tau_{xy} = 10$ MPa

Ripetere i calcoli con una ghisa con $R_{m,t} = 200$ MPa e $R_{m,c} = -690$ MPa

Es. 1





$\sigma_I = 80$ MPa
$\sigma_{II} = 40$ MPa
$\sigma_{III} = 0$ MPa

Guest - Tresca : $\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = \sigma_I - \sigma_{III} = 80$ MPa

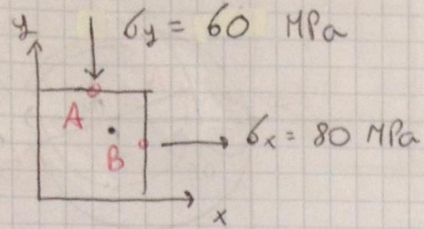
$\sigma^*_{GT} = 80 \text{ MPa} \leq \sigma_{amm} = \dfrac{R_s}{\eta_{GT}}$ $\qquad \eta_{GT} = \dfrac{R_s}{\sigma^*_{GT}} = \dfrac{345 \text{ MPa}}{80 \text{ MPa}} = 4{,}31$

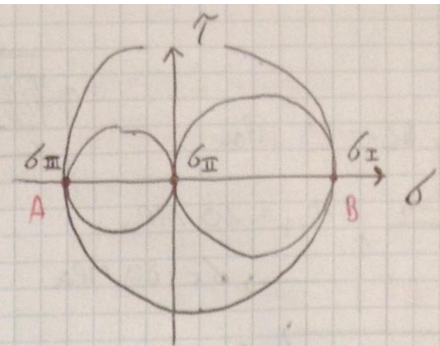
Von Mises : $\sigma^*_{VM} = \sqrt{\sigma_I^2 + \sigma_{II}^2 + \sigma_{III}^3 - \sigma_I\sigma_{II} - \sigma_{II}\sigma_{III} - \sigma_{III}\cdot\sigma_I} =$

$= \sqrt{\sigma_I^2 + \sigma_{II}^2 - \sigma_I\sigma_{II}} = 69{,}3$ MPa

$\sigma^*_{VM} = 69{,}3 \text{ MPa} \leq \sigma_{amm} = \dfrac{R_s}{\eta_{VM}} \longrightarrow \eta_{VM} = \dfrac{R_s}{\sigma^*_{VM}} = 4{,}98$

Es. 2





$\sigma_I = 80$ MPa

$\sigma_{II} = 0$ MPa

$\sigma_{III} = -60$ MPa

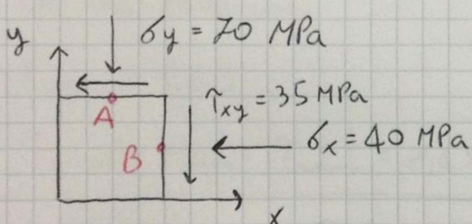
$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = 80\text{ MPa} - (-60\text{ MPa}) = 140\text{ MPa}$$

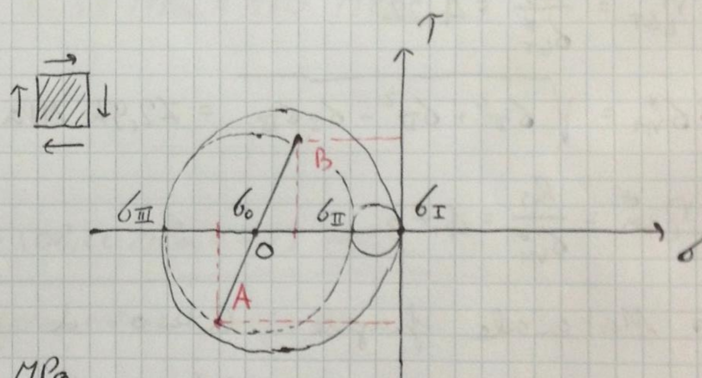
$$\sigma^*_{GT} = \frac{R_s}{\eta_{GT}} \rightarrow \eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = 2{,}46$$

$$\sigma^*_{VM} = \sqrt{\sigma_I^2 + \cancel{\sigma_{II}^2} + \sigma_{III}^2 - \cancel{\sigma_I \sigma_{II}} - \cancel{\sigma_{II} \sigma_{III}} - \sigma_{III}\sigma_I} = 121{,}7\text{ MPa}$$

$$\eta_{VM} = \frac{R_s}{\sigma^*_{VM}} = 2{,}83$$

Es. 3





$$\sigma_0 = \frac{\sigma_B + \sigma_A}{2} = \frac{-40-70}{2} = -55\text{ MPa}$$

$$\overline{OB} = \sqrt{(\sigma_B - \sigma_0)^2 + \tau_B^2} = 38{,}08\text{ MPa}$$

$\sigma_I = 0$; $\sigma_{II} = \sigma_0 + \overline{OB} = -16{,}92$ MPa ; $\sigma_{III} = \sigma_0 - \overline{OB} = -93{,}08$ MPa

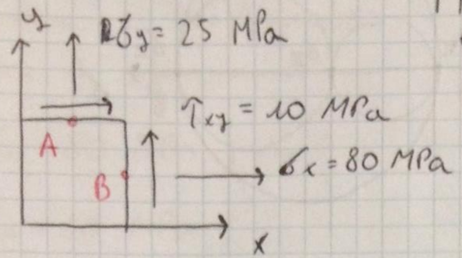
$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = 0 - (-93{,}08)\text{ MPa} = 93{,}08\text{ MPa}$$

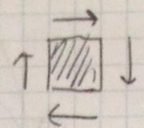
$$\eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = 3{,}71$$

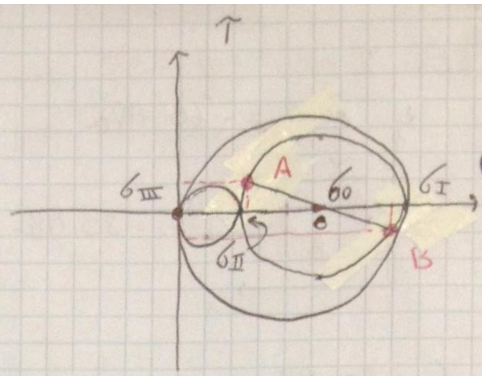
$$\sigma^*_{VM} = \sqrt{\sigma_{II}^2 + \sigma_{III}^2 - \sigma_{II}\sigma_{III}} = 85{,}88\text{ MPa}$$

$$\eta_{VM} = \frac{R_s}{\sigma^*_{VM}} = 4{,}02$$

Es. 4







$$\sigma_0 = \frac{\sigma_A + \sigma_B}{2} = \frac{(25+80)\,MPa}{2} = 52,5\ MPa$$

$$\overline{OB} = \sqrt{(\sigma_B - \sigma_0)^2 + \tau_B^2} = 29,26\ MPa$$

$$\sigma_I = \sigma_0 + \overline{OB} = 81,76\ MPa$$

$$\sigma_{II} = \sigma_0 - \overline{OB} = 23,24\ MPa$$

$$\sigma_{III} = 0.$$

$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = 81,76\ MPa - 0\ MPa = 81,76\ MPa$$

$$\eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = 4,22$$

$$\sigma^*_{VM} = \sqrt{\sigma_I^2 + \sigma_{II}^2 - \sigma_I \sigma_{II}} = 72,97\ MPa$$

$$\eta^*_{VM} = \frac{R_s}{\sigma^*_{VM}} = 4,73$$

→ Materiale fragile: Criterio di Galileo, Rankine, Navier

Es. 1: $\sigma_I = 80\ MPa$, $\sigma_{III} = 0\ MPa$

$$\sigma^*_{GRN,t} \leq \sigma_{lim,trazi} = \frac{R_{m,t}}{\eta_{GRN,t}} \qquad \eta_{GRN,t} = \frac{R_{m,t}}{\sigma^*_{GRN,t}} = 2,5$$

$2,5 < 3,0$! Non verificato (il 2° $\eta \to \infty$)

Es. 2: $\sigma_I = 80\ MPa$, $\sigma_{II} = -60\ MPa$

$$\eta_{GRN} = \frac{R_{m,t}}{\sigma^*_{GRN,t}} = 2,5 < 3,0$$ non verificato!

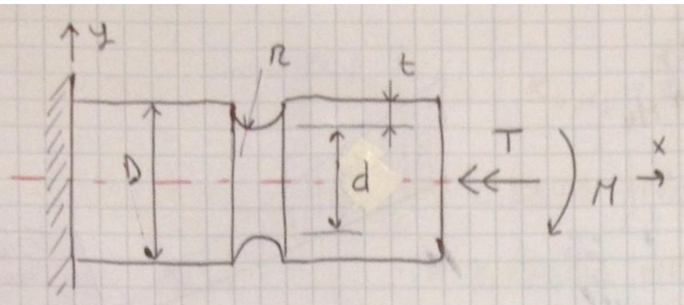
Es. 3: $\sigma_I = 0\ MPa$, $\sigma_{III} = -93\ MPa$

$$\eta_{GRN} = \frac{|R_{m,c}|}{|\sigma^*_{GRN,c}|} = 7,42$$ (il 1° $\eta \to \infty$)

Es. 4: $\sigma_I = 81,26\ MPa$, $\sigma_{III} = 0\ MPa$

$$\eta_{GRN} = \frac{R_{m,t}}{\sigma^*_{GRN,t}} = 2,46 < 3$$ Non verificato

(il 2° $\eta \to \infty$)



$t = 10,5$ mm

$R = 7$ mm

$D = 70$ mm

$M = 1$ kNm

$T = 2,5$ kNm

• Trovare stato di sforzo nella gola dell'intaglio

$$\sigma_{x,nom} = \frac{M \cdot d/2}{J} = \frac{M \cdot d/2}{\frac{\pi d^4}{64}} = 86,58 \text{ MPa}$$

$d = D - 2t = 49$ mm

$$\tau_{nom} = \frac{T \cdot d/2}{J_p} = \frac{T \cdot d/2}{\frac{\pi d^4}{32}} = 108,22 \text{ MPa}$$

Per la flessione:

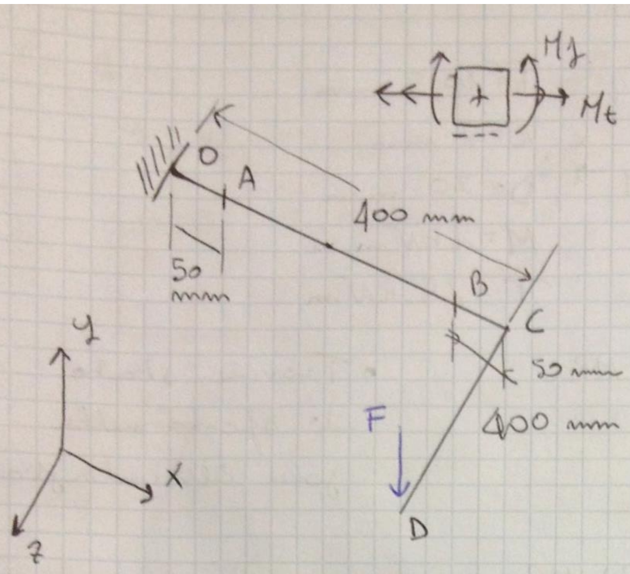
$$\frac{R}{d} = \frac{7 \text{ mm}}{49 \text{ mm}} = 0,143 \quad ; \quad \frac{D}{d} = 1,43 \quad \rightarrow \quad K_{t(M)} = 1,85$$

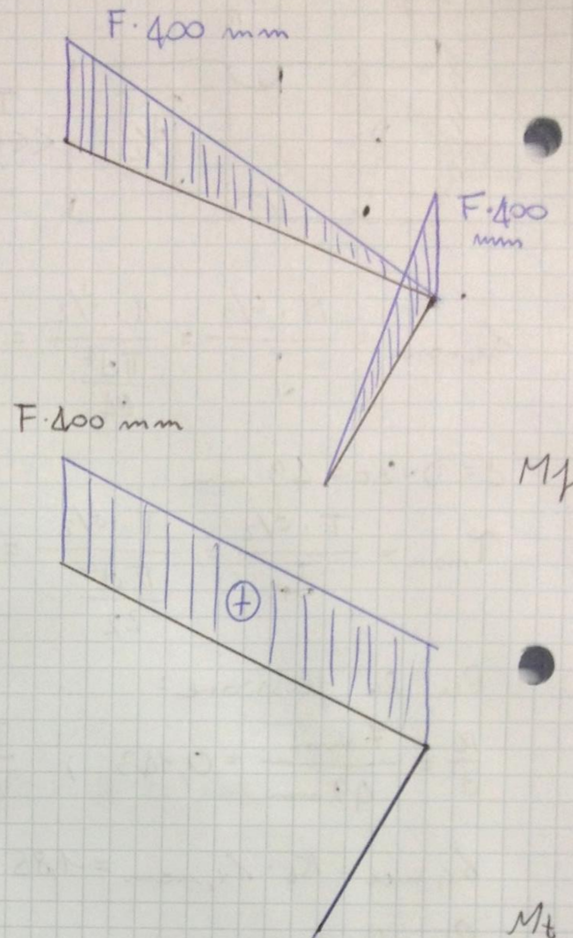
$$\sigma_{x,max} = K_t \cdot \sigma_{x,nom} = 1,85 \cdot 86,58 \text{ MPa} = 160 \text{ MPa}$$

Per la torsione:

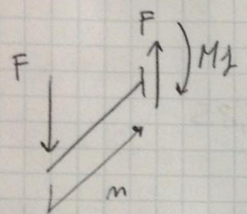
$$K_{t(T)} = 1,43$$

$$\tau_{max} = K_{t(T)} \cdot \tau_{nom} = 1,43 \cdot 108,22 \text{ MPa} = 155 \text{ MPa}$$



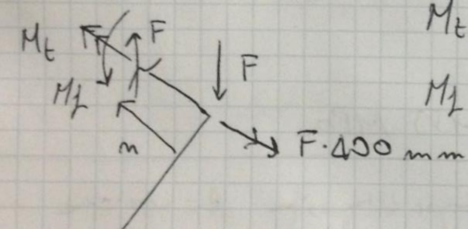


Tratto DC:



$M_f = F n$

Tratto $\overline{OC}$:



$M_t = F \cdot 400$ mm

$M_f = F n$

Nel punto A, dove c'è il cambio di diametro:

$M_t = F \cdot 400$ mm

$M_f = F \cdot 350$ mm

Sforzi nominali (si calcolano sul diametro minore):

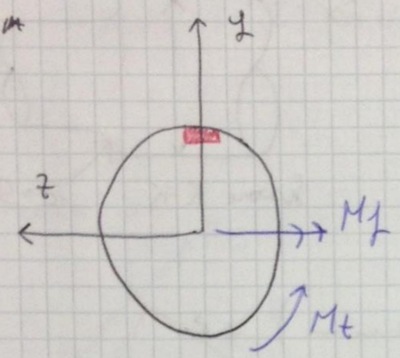
$$\sigma_{x,nom} = \frac{M_f \cdot d/2}{\frac{\pi d^4}{64}} = F \cdot 0{,}22816 \text{ MPa}$$

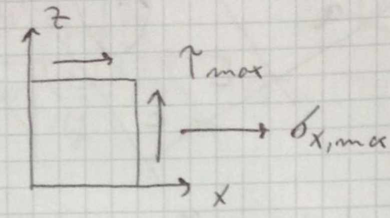
$$\tau_{nom} = \frac{M_t \cdot d/2}{J_p} = \frac{M_t \cdot d/2}{\frac{\pi d^4}{32}} = F \cdot 0{,}1304 \text{ MPa}$$

$\frac{R}{d} = 0{,}12$; $\frac{D}{d} = 1{,}6$; $K_{t,Mf} = 1{,}7$; $K_{t,Mt} = 1{,}35$

$\sigma_{x,max} = \sigma_{nom} \cdot K_t = F \cdot 0{,}3879$ MPa

$\tau_{max} = K_{t,Mt} \cdot \tau_{nom} = F \cdot 0{,}17604$ MPa





Ho usato $\sigma_{x,max}$ e τ_{max}

$\sigma^*_{VM} = \sqrt{\sigma^2 + 3\tau^2} = F \cdot 0{,}4934$ MPa $= R_s = 460$ MPa

Significa che siamo a inizio plasticizzazione locale

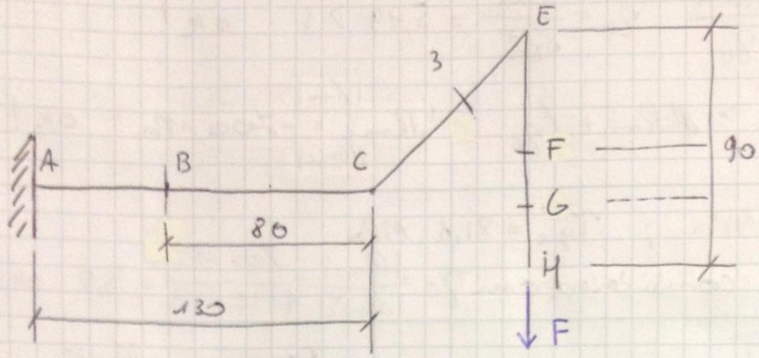
$\Rightarrow F = 932$ N (Von Mises)

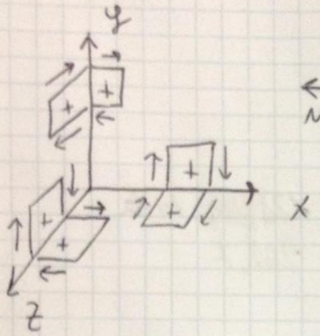
$\sigma^*_{GT} = \sqrt{\sigma^2 + 4\tau^2} = F \cdot 0{,}5239$ MPa $= R_s = 460$ MPa

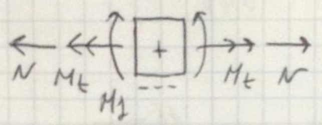
$\Rightarrow F = 878$ N (Guest-Tresca)

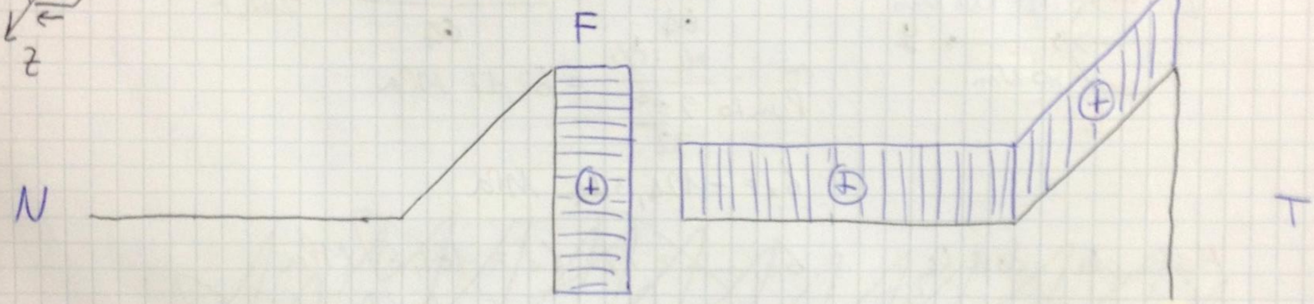
Esercizio leva

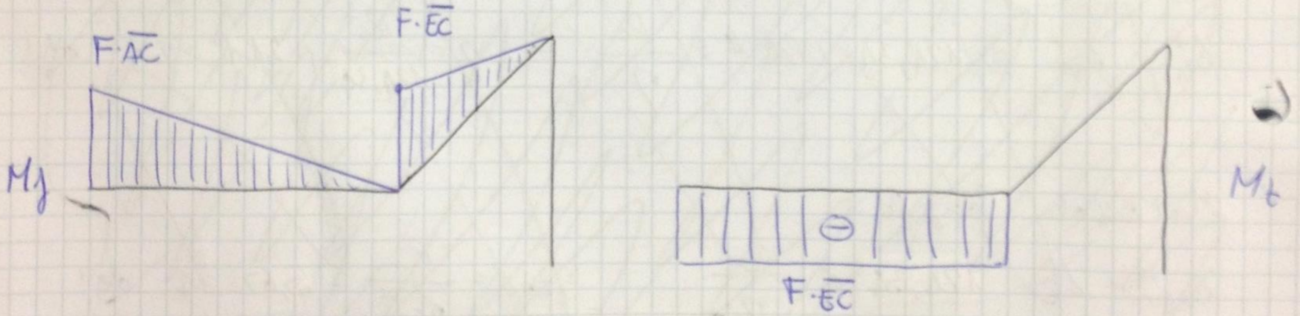
- Azioni interne
- Dati 2 materiali (Fe410 e GG25) Calcolare F_{max} per il tratto rettangolare
- Calcolare $\sigma_{nom,max}$



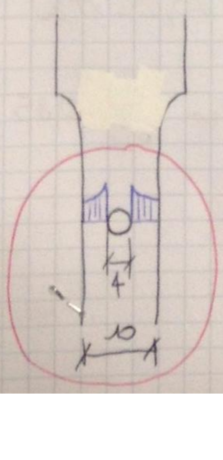








Tratto $\overline{EH}$: FORO



$$\sigma_{nom} = \frac{F}{A_{nom}} = \frac{F}{(10-4)\,6\ mm^2} = \frac{F}{36\ mm^2}$$

$$K_t \rightarrow \frac{d}{H} = \frac{4\ mm}{10\ mm} = 0{,}4 \rightarrow K_t = 2{,}25$$

Prima plasticizzazione (Materiale duttile Fe410):

$$\sigma_{max} = R_s = K_t \cdot \sigma_{nom} \rightarrow \sigma_{nom} = \frac{R_s}{K_t} = \frac{230\ MPa}{2{,}25} = 102\ MPa$$

$\sigma_{nom} = \frac{F_{lim,pp}}{36\ mm^2} \rightarrow F_{lim,pp} = \sigma_{nom} \cdot 36\ mm^2 = 3680\ N$

Forza di prima plasticizzazione sul foro con materiale duttile: $F = 3680\ N$

Forza di plasticizzazione totale: tutta la sezione nominale del foro ha sforzo $= R_s$

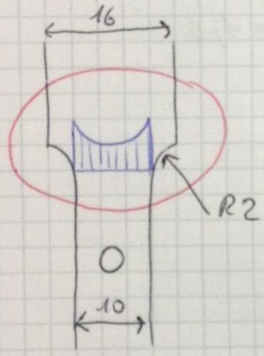
$\sigma_{nom} = R_s \rightarrow \sigma_{nom} = \frac{F_{lim,pt}}{36\ mm^2} = R_s \rightarrow F_{lim,pt} = R_s \cdot 36\ mm^2 = 8280\ N$

Se utilizziamo materiale fragile:

$R_m = 250\ MPa$

$\sigma_{max} = R_m = K_t \cdot \sigma_{nom} = K_t \cdot \frac{F_{lim}}{36\ mm^2} \Rightarrow F_{lim} = \frac{R_m}{K_t} \cdot 36\ mm^2 = 4000\ N$

Tratto $\overline{EH}$: INTAGLIO



$\sigma_{nom} = \frac{F}{A} = \frac{F}{10\ mm \cdot 6\ mm} = \frac{F}{60\ mm^2} = \frac{F}{A}$

$F = \sigma_{nom} \cdot A$

Materiale duttile (Fe410):

Forza di 1ª plasticizzazione: Condizione $\sigma_{max} = R_s$

$\sigma_{max} = K_t \cdot \sigma_{nom} \qquad K_t = 1,75$

$\sigma_{max} = 1,75 \cdot \sigma_{nom} = R_s \qquad r/h = 0,2 \qquad H/h = 1,6$

$K_t \cdot \frac{F_{lim,pp}}{A} = R_s \qquad F_{lim,pp} = \frac{A \cdot R_s}{K_t} = \frac{60\ mm^2 \cdot 230\ MPa}{1,75} = 7885\ N$

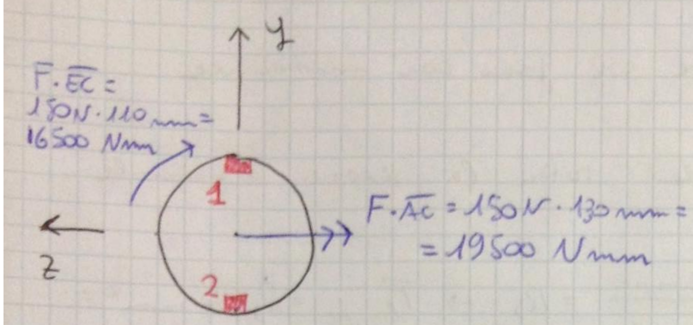
Forza di plasticizzazione totale: Condizione: tutta la sezione R_s

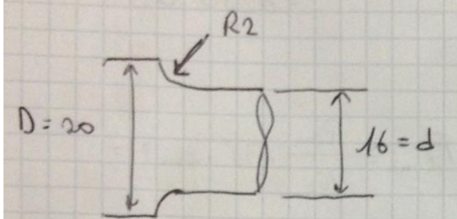
$F_{lim,pt} = R_s \cdot A = 230\ MPa \cdot 60\ mm^2 = 13800\ N$

Materiale fragile (GG25):

$\sigma_{max} = K_t \cdot \sigma_{nom} = R_m \qquad K_t \cdot \frac{F_{lim}}{A} = R_m \qquad F_{lim} = \frac{A \cdot R_m}{K_t} = 8571\ N$

Verifica solo nel punto A:





Punto 1:

$$\sigma_x = \frac{M_f \cdot d/2}{J} = \frac{M_f\, d/2}{\frac{\pi d^4}{64}} = 48{,}5 \text{ MPa}$$

$$\tau_{xz} = \frac{M_t \cdot d/2}{\frac{\pi d^4}{32}} = -20{,}52 \text{ MPa}$$

Punto 2:

$\sigma_x = -48{,}5$ MPa

$\tau_{xz} = 20{,}52$ MPa

M_f: $r/d = \frac{2}{16} = 0{,}125$; $\frac{D}{d} = \frac{20}{16} = 1{,}25$ $K_{t(M_f)} = 1{,}6$

M_t: $r/d = 0{,}125$; $d/D = 0{,}8$ $K_t = 1{,}28$

Punto 1: $\sigma_{x,max} = K_{t(M_f)} \cdot \sigma_x = 77{,}6$ MPa

$\tau_{xz} = K_{t(M_t)} \cdot \tau_{xz} = -26{,}27$ MPa

τ ... σ

$$\sigma_I = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = 85{,}66 \text{ MPa}$$

$\sigma_{II} = 0$

[Materiale Duttile:

$$\sigma_{III} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = -8 \text{ MPa}$$

$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = 85{,}66 \text{ MPa} - (-8) \text{ MPa} = 93{,}72 \text{ MPa}$$

$$\sigma^*_{GT} \leq \sigma_{amm} = \frac{R_s}{\eta_{GT}} \Rightarrow \eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = \frac{230 \text{ MPa}}{93{,}72 \text{ MPa}} = 2{,}45$$ (Prima plasticizzazione)

Sulla plasticizzazione totale:

$\sigma_I = 56$ MPa ; $\sigma_{II} = 0$; $\sigma_{III} = -7{,}52$ MPa (Calcolati con gli sforzi nominali)

$\sigma^*_{GT} = 63{,}51$ MPa

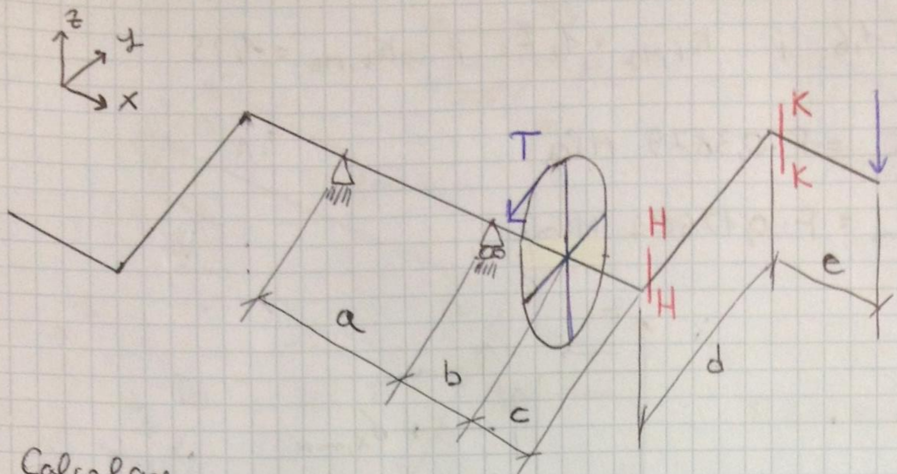
$$\eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = 3{,}62$$ (Plasticizzazione totale)

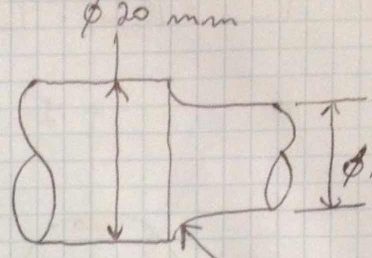
(Si potevano usare anche le formule semplificate)

$$\sigma^*_{GT} = \sqrt{\sigma^2 + 4\tau^2}$$

Materiale fragile:

$$\sigma^*_{GRV} = \sigma_{P,max} = \sigma_I \leq R_m / \eta_{GRV} \qquad \eta_{GRV} = \frac{R_m}{\sigma_I} = \frac{250\ MPa}{85{,}66\ MPa} = 2{,}93$$

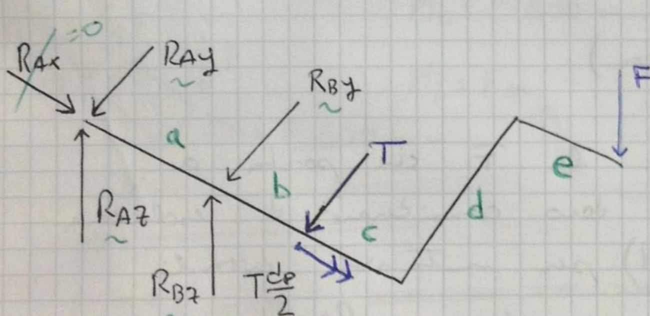




Sezione K-K

Calcolare
- Forza T esercitata sulla catena
- Diagramma delle azioni interne
- Calcolo sforzi principali in H-H (ϕ 20 mm) ed effettuare verifica di resistenza statica con materiale A: $R_s = 300$ MPa ; $R_m = 500$ MPa , B: $R_m = 200$ MPa

$a = 50$ mm $\quad e = 100$ mm
$b = 20$ mm $\quad$ diametro puleggia $= 300$ mm (d_p)
$c = 30$ mm $\quad F = 500$ N
$d = 200$ mm



$R_{Ax} = 0 \qquad \Sigma F_x = 0$

$\Sigma M_x = 0$

$T \frac{d_p}{2} - F d = 0$

$T = F d \frac{2}{d_p} = 500N \cdot 200\,mm \frac{2}{300\,mm}$

$= 666,7$ N

$\Sigma M_{y(A)} = 0$

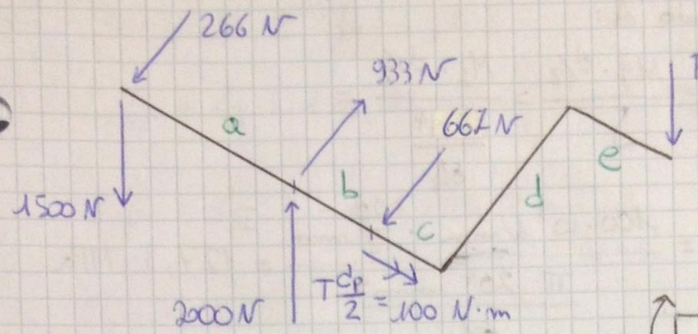
$R_{Bz} \cdot a - F(a+b+c+e) = 0 \qquad R_{Bz} = F \frac{a+b+c+e}{a} = 2000$ N

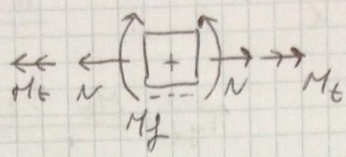
$\Sigma F_y = 0 \qquad R_{Az} + R_{Bz} - F = 0 \qquad R_{Az} = F - R_{Bz} = -1500$ N

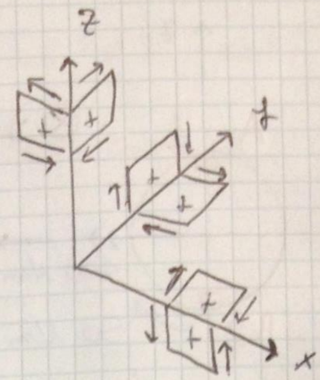
$\Sigma M_{z(A)} = 0$

$R_{By} \cdot a + T(a+b) = 0 \qquad R_{By} = -T \frac{a+b}{a} = -933,38$ N

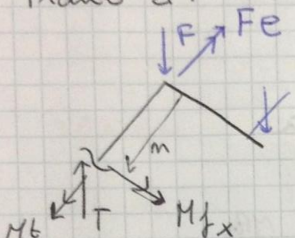
$R_{Ay} + R_{By} + T = 0 \qquad R_{Ay} = -R_{By} - T = 266,68$ N





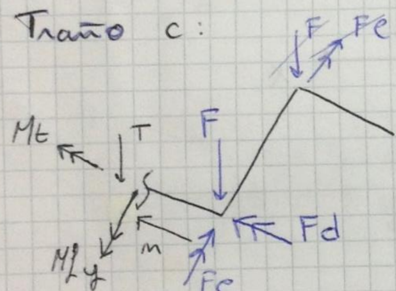


Tramo d:



$T = F \quad M_t = Fe \quad Mf_x = Fm$

Tramo c:

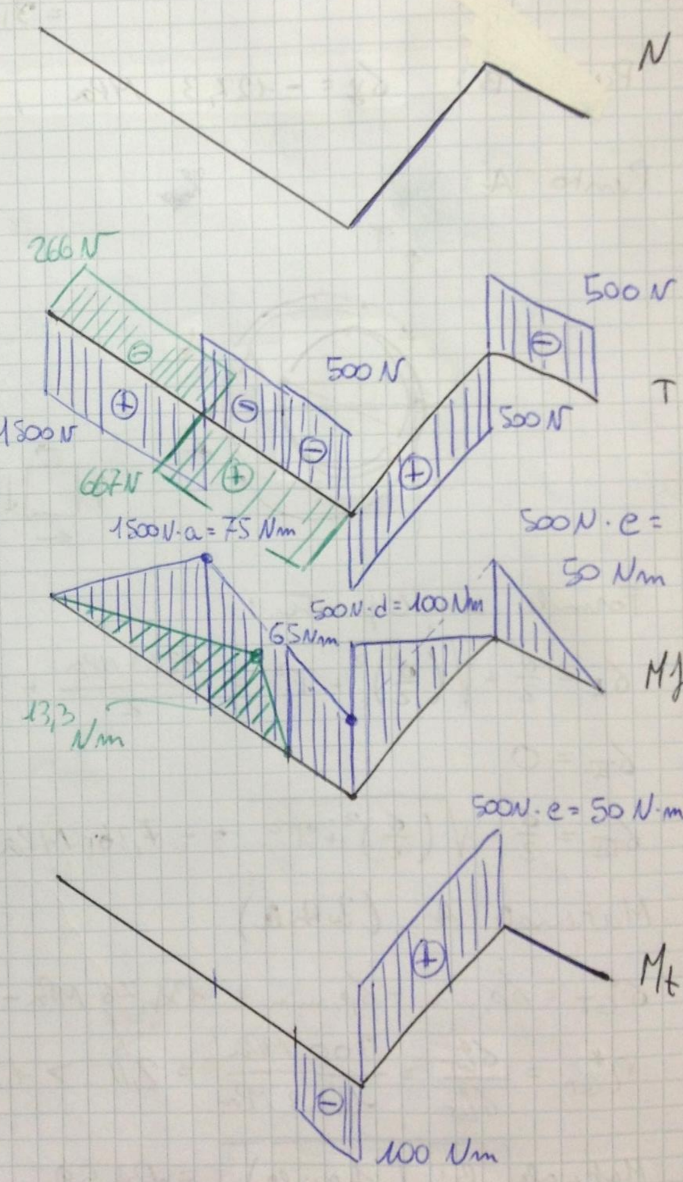


$T = -F \; ; \; M_t = -Fd$

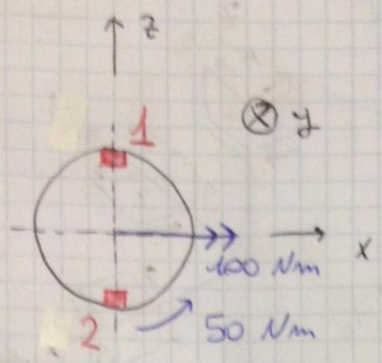
$Mf_y - Fe - Fm = 0 \quad Mf_y = +Fe + Fm$

$Mf_y(m=c) = 65\ Nm$

Tramo a: Si tracciano i grafici a mano!



Sezione H-H:



Punto A:

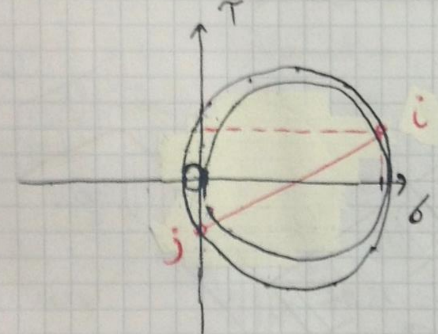
$$\sigma_y = \frac{M_f \cdot d/2}{J} = \frac{M_f \cdot d/2}{\frac{\pi d^4}{64}} =$$

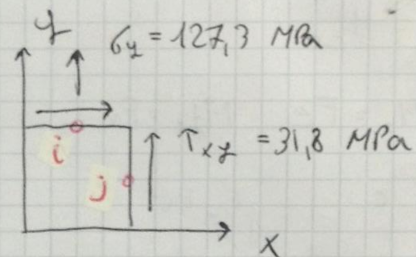
$$= \frac{100 \cdot 10^3 \, Nmm \cdot \frac{20}{2} mm}{\frac{\pi \; 20^4 \, mm^4}{64}} = 127{,}3 \; MPa$$

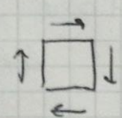
$$\tau_{yx} = \frac{M_t \cdot d/2}{J_p} = \frac{M_t \cdot d/2}{\frac{\pi d^4}{32}} = \frac{50 \cdot 10^3 \, Nmm \cdot \frac{20}{2} mm}{\frac{\pi \; 20^4 \, mm^4}{32}} =$$

$$= 31{,}8 \; MPa$$

Punto 1:







Formule semplificate:

$$\sigma_I = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = \frac{127{,}3 \; MPa}{2} + \sqrt{\left(\frac{127{,}3}{2}\right)^2 + 31{,}8^2} = 134{,}76 \; MPa$$

$$\sigma_{II} = 0$$

$$\sigma_{III} = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = -7{,}36 \; MPa$$

Materiale A: (duttile)

$$\sigma^*_{GT} = \sigma_{p,max} - \sigma_{p,min} = 134{,}76 \; MPa - (-7{,}36 \; MPa) = 142{,}13 \; MPa$$

$$\eta_{GT} = \frac{R_s}{\sigma^*_{GT}} = \frac{300 \; MPa}{142{,}3 \; MPa} = 2{,}11 > 1{,}5 \quad \text{ok!}$$

$$\sigma^*_{VM} = \sqrt{\sigma_I^2 + \sigma_{II}^2 - \sigma_I \sigma_{II}} = 138{,}59 \qquad \eta_{VM} = \frac{R_s}{\sigma^*_{VM}} = 2{,}16 \quad \text{ok!}$$

Materiale 2 (fragile)

$\sigma^*_{GRV} = \sigma_I = 134,76 \leq \dfrac{R_{m,t}}{\eta}$ $\quad \eta = \dfrac{R_{m,t}}{\sigma^*_{GRV}} = 5,2 > 3$ ok!

$\sigma^*_{GRV} = \sigma_{III} = -7,36 \text{ MPa} \geq \dfrac{R_{m,c}}{\eta}$ $\quad \eta = \dfrac{R_{m,c}}{\sigma^*_{GRV}} = 95 > 3$ ok!

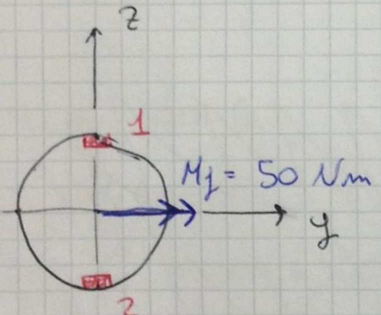
Punto 2:

$\sigma_x = -127,3 \text{ MPa}$; $\tau_{yx} = 31,8 \text{ MPa}$

$\sigma_I = 7,5 \text{ MPa}$; $\sigma_{II} = 0$; $\sigma_{III} = -134,8 \text{ MPa}$ $\quad \eta_c = \dfrac{R_{m,c}}{\sigma^*_{GRV}} = \dfrac{700 \text{ MPa}}{134,8 \text{ MPa}} = 5,2$

Sezione K-K

Tabella : $\left.\begin{array}{l} D/d = 1,25 \\ r/d = 0,31 \end{array}\right] \rightarrow K_t(M_f) = 1,3$



Punto 1:

$$\sigma_x = \frac{M_f \cdot d/2}{\frac{\pi d^4}{64}} = \frac{M_f \cdot \frac{16 \text{ mm}}{2}}{\frac{\pi\, 16^4 \text{ mm}^4}{64}} = 124,34 \text{ MPa}$$

Materiale duttile:

$\sigma_{x,max} = \sigma_x \cdot K_t = 161,6 \text{ MPa}$

$\sigma^*_{GT} = \sigma^*_{VM} = 161,6 \text{ MPa} \leq \dfrac{R_s}{\eta}$ $\quad \eta = \dfrac{R_s}{\sigma^*} = 1,86 > 1,5$ ok!

Materiale fragile:

$\sigma^*_{GRV} = \sigma_I = 161,6 \leq \dfrac{R_m}{\eta}$ $\quad \eta = \dfrac{R_m}{\sigma^*_{GRV}} = 4,33 > 3$ ok!