PROGETTO POMPA CENTRIFUGA - MACCHINE 1

$Q_v = 44\ L/s = 0.044\ m^3/s$

$h = 40\ m$

$$n = \frac{60f}{m}(1 - s)$$

- s → scorrimento → 3%
- f → frequenza (50 Hz)
- m → n° di coppie polari

I^ soluzione ⟶ $m = 1$

$$n = \frac{60 \cdot 50}{1}(1 - 0.03) = 2910\ \frac{giri}{min}$$

$$\omega = \frac{2\pi n}{60} = \frac{2\pi}{60} \cdot 2910 = 304,73\ rad/s$$

$$K = \omega \frac{Q_v^{0.5}}{(gh)^{0.75}} = 304.73 \cdot \frac{0.044^{0.5}}{(9.81 \cdot 40)^{0.75}}$$

$$= 0.7250$$ ⟶ diagrammi statici

$K = 0.7250$ ⟶

$\psi = 0.4522$
$\phi = 0.1247$
$\eta_{idr} = 0.9198$
$\eta_v = 0.9637$
$\eta_{mv} = 0.9152$

} dal foglio Excel

$$\psi = \frac{gh}{u_2^2} \longrightarrow u_2 = \sqrt{\frac{gh}{\psi}} = 29.46 \ \frac{m}{s}$$

I° step verifica (strutturale) $\longrightarrow u_2 \leq u_{cr}$

↳ ghise: $40 \ \frac{m}{s}$

acciai: $60 \ \frac{m}{s}$

$u_2 \leq 40$ ok ✓

$$u_2 = \omega \frac{D_2}{2} \longrightarrow D_2 = \frac{2u_2}{\omega} = \frac{2 \cdot 29.46}{304.73}$$

$$= 0.1933 \ m$$

$$= 193.3 \ mm$$

$$\phi = \frac{Q_v}{\pi D_2 b_2 u_2} = \frac{c_{u_2}}{u_2}$$

$$b_2 = \frac{Q_v}{\pi D_2 \phi u_2}$$

$$= \frac{0.044}{\pi \cdot 0.1933 \cdot 0.1247 \cdot 29.46} = 19.7 \ mm$$

II° step verifica (fluidodinamico) $\longrightarrow 0.02 \leq \frac{b_2}{D_2} \leq 0.3$

b_2 → $\frac{19.7}{193.3} = 0.102$ ok ✓ ← D_2

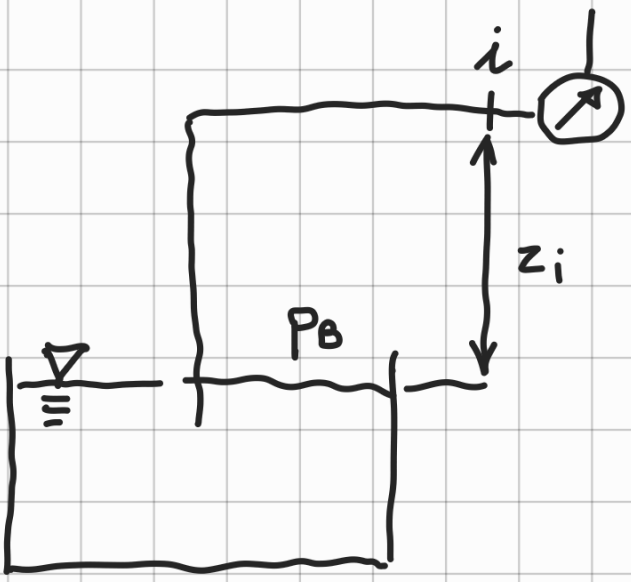
$$D_{IN,NPSH} = 4.79 \left(\frac{Q_v}{n}\right)^{1/3} = 4.79 \cdot \left(\frac{0.044}{2910}\right)^{1/3}$$

$$= 0.1184\ m = 118.4\ mm$$

$$NPSH_R = 1.107 \cdot 10^{-3}\, Q_v^{2/3}\, n^{4/3}$$

$$= 1.107 \cdot 10^{-3} \cdot 0.044^{2/3}\, 2910^{4/3}$$

$$= 5.732\ m$$



$$NPSH_R = \frac{P_B - P_v}{\rho g} - z_i - h_L - x$$

$$\rho = 1000\ kg/m^3$$

$$P_B = P_{atm} = 101325\ Pa$$

$$P_v = 2400\ Pa$$

$$x = 1\ m$$

$$h_L = 1\ m$$

$$z_i = \frac{P_B - P_v}{\rho g} - NPSH_R - h_L - x =$$

$$= \frac{101325 - 2400}{1000 \cdot 9.81} - 5.732 - 1 - 1$$

$$= 2.738 \text{ m} \quad (\text{macchina veloce})$$

II° caso $\longrightarrow$ $m = 2$ (4 poli)

$n = 1455$ giri/min $\longrightarrow$ $\omega = 152.37 \frac{\text{rad}}{\text{s}}$

$k = 0.363 \longrightarrow$

$\psi = 0.5211$
$\phi = 0.0950$
$\eta_{idr} = 0.8248$
$\eta_v = 0.9395$
$\eta_{mv} = 0.9639$
$\eta_{TOT} = 0.7469$

} EXCEL

$u_2 = 27.44 \text{ m/s} \overset{?}{\leq} 40 \text{ m/s}$ OK ✓

(I° step)

$D_2 = 360.2 \text{ mm}$

$\phi \longrightarrow b_2 = 14.9 \text{ mm}$

II° step $\longrightarrow$ $\frac{b_2}{D_2} = \frac{14.9}{360.2} = 0.0414$

OK ✓

$$0.02 \leq \frac{b_2}{D_2} \leq 0.3$$

$D_{IN,NPSH} = 149.2 \text{ mm}$

$NPSH_R = 2.275 \text{ m} \longrightarrow z_i = 5.836 \text{ m}$

III° CASO $\longrightarrow$ $m = 3$ (6 poli)

$n = 970 \frac{\text{giri}}{\text{min}} \longrightarrow \omega = 101.58 \frac{\text{rad}}{\text{s}}$

$K = 0.242 \longrightarrow$

$\psi = 0.5441$

$\phi = 0.0810$

$\eta_{idr} = 0.8039$ ($\eta_{idr} < 0.82$)

$\eta_v = 0.9253$

$\eta_{mv} = 0.9130$

$\eta_{TOT} = 0.6791$

imposizione $\longrightarrow$ $\eta_{idr} = 0.82 \longrightarrow$ ricalcolo η_{mv}

se $\eta_{idr} < 0.82$

$$\eta_{mv} = \frac{\eta_{TOT}}{\eta_{idr} \cdot \eta_v} = 0.8950$$

$$\eta_{TOT} = \eta_v \, \eta_{idr} \, \eta_{mv}$$ ($\eta_{idr} = 0.82$)

$$\eta_{mv} = \frac{\eta_{TOT}}{\eta_{idr} \, \eta_v} = \frac{0.6791}{0.82 \cdot 0.9253}$$

$K = 0.242 \longrightarrow$

$\psi = 0.5441$

$\phi = 0.0810$

$\eta_{TOT} = 0.6791$

$\eta_{idr} = 0.82$

$\eta_v = 0.9253$

$\eta_{mv} = 0.8950$

$\psi \longrightarrow u_2 = 26.86 \text{ m/s} < 40 \text{ m/s}$

$\hookrightarrow D_2 = 528.8 \text{ mm}$ OK ✓

$\phi \longrightarrow b_2 = 12.2 \text{ mm}$

II° step $\quad \frac{b_2}{D_2} = \frac{12.2}{528.8} = 0.023$

OK ✓

$D_{IN,\,NPSH} = 170.8 \text{ mm}$

$NPSH_R = 1.325 \text{ m}$

$z_i = 6.786 \text{ m}$

m	1	2	3
n	2910 rpm	1455 rpm	970 rpm
K	0.725	0.363	0.242
η_{TOT}	81.13 %	74.69 %	67.91 %
D_2	193.3 mm	360.2 mm	528.8 mm
z_i	2.378 m	5.836 m	6.786 m

SCELTA ⟶ m = 2

DIMENSIONAMENTO

$m = 2$
$s = 0.03$
$f = 50\ Hz$

$Q_v = 44\ L/s$
$h = 40\ m$
$n = 1455\ rpm$

$K = 0.363 \longrightarrow \psi = 0.5211$

$\phi = 0.095$

$\eta_{TOT} = 74.69\ \%$

$\eta_{idr} = 82.48\ \%$

$\eta_v = 93.95\ \%$

$\eta_{mv} = 96.39\ \%$

$$\psi = \frac{gh}{u_2^2} \longrightarrow u_2 = \sqrt{\frac{gh}{\psi}} \longrightarrow D_2$$

$D_2 = 360.3\ mm \longrightarrow$ **$D_2 = 360\ mm$**

$D_2 = 183\ mm \longrightarrow D_2 = 180\ mm$

$D_2 = 185\ mm$

$$u_2 = \omega \frac{D_2}{2} = 27.43 \text{ m/s}$$

$$\phi = \frac{Q_v}{\pi D_2 b_2 \xi_2 \eta_v u_2}$$

ξ_2 η_v → trascurati in fase di studio di fattibilità → da considerare nel dimensionamento preliminare!

ξ_e = ostruzione = 0.95

$$b_2 = \frac{Q_v}{\pi D_2 \phi \xi_2 \eta_v u_2}$$

$$= 16.7 \text{ mm} \rightarrow 17 \text{ mm}$$

$D_2 = 360 \text{ mm}$

$b_2 = 17 \text{ mm}$

$$D_{IN} = 4.79 \left(\frac{Q_v}{n} \right)^{1/3}$$

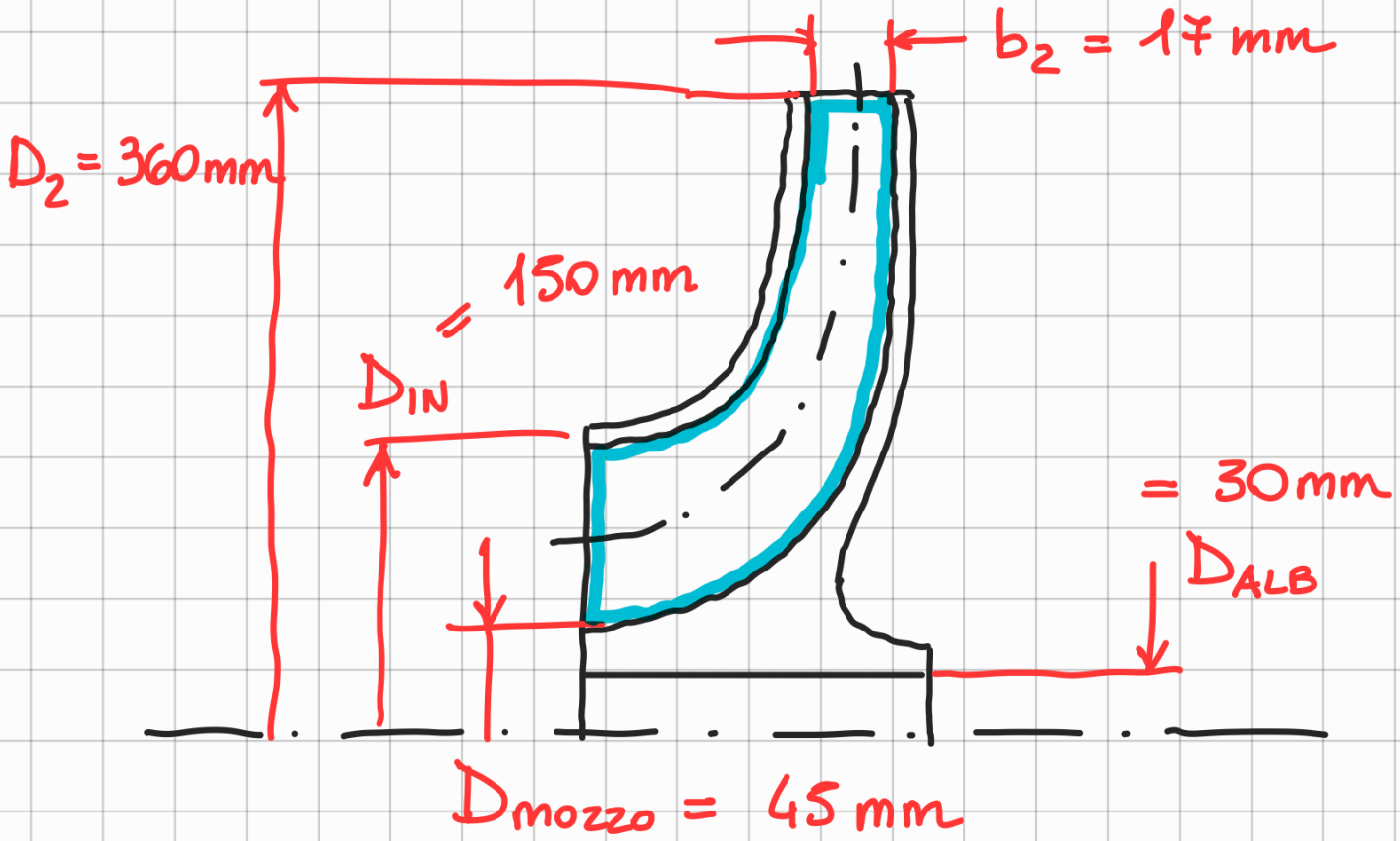
$= 149.2 \text{ mm}$

$D_{IN} = 150 \text{ mm}$

diametri unificati delle condotte

$D = 150 \text{ mm}$

CONDOTTO MERIDIANO



$$D_{ALB,min} = \sqrt[3]{\frac{16\,M_t}{\pi\,\tau_{adm}}}$$

(MPa)

$$\tau_{adm} = 30\ \frac{N}{mm^2}$$

$$P_{alb} = \frac{P_{idr}}{\eta_{TOT}} = \frac{\rho g q_v h}{\eta_{TOT}} =$$

$$= \frac{1000 \cdot 9.81 \cdot 0.044 \cdot 40}{0.7463}$$

$$= 23.1\ kW$$

$$P_{alb} = M_t \cdot \omega \longrightarrow M_t = 151.4\ Nm$$

$$= 151400\ Nmm$$

$$D_{alb,\,min} = \sqrt[3]{\frac{16 \cdot 151400}{\pi \cdot 30}} = 29.51 \text{ mm}$$

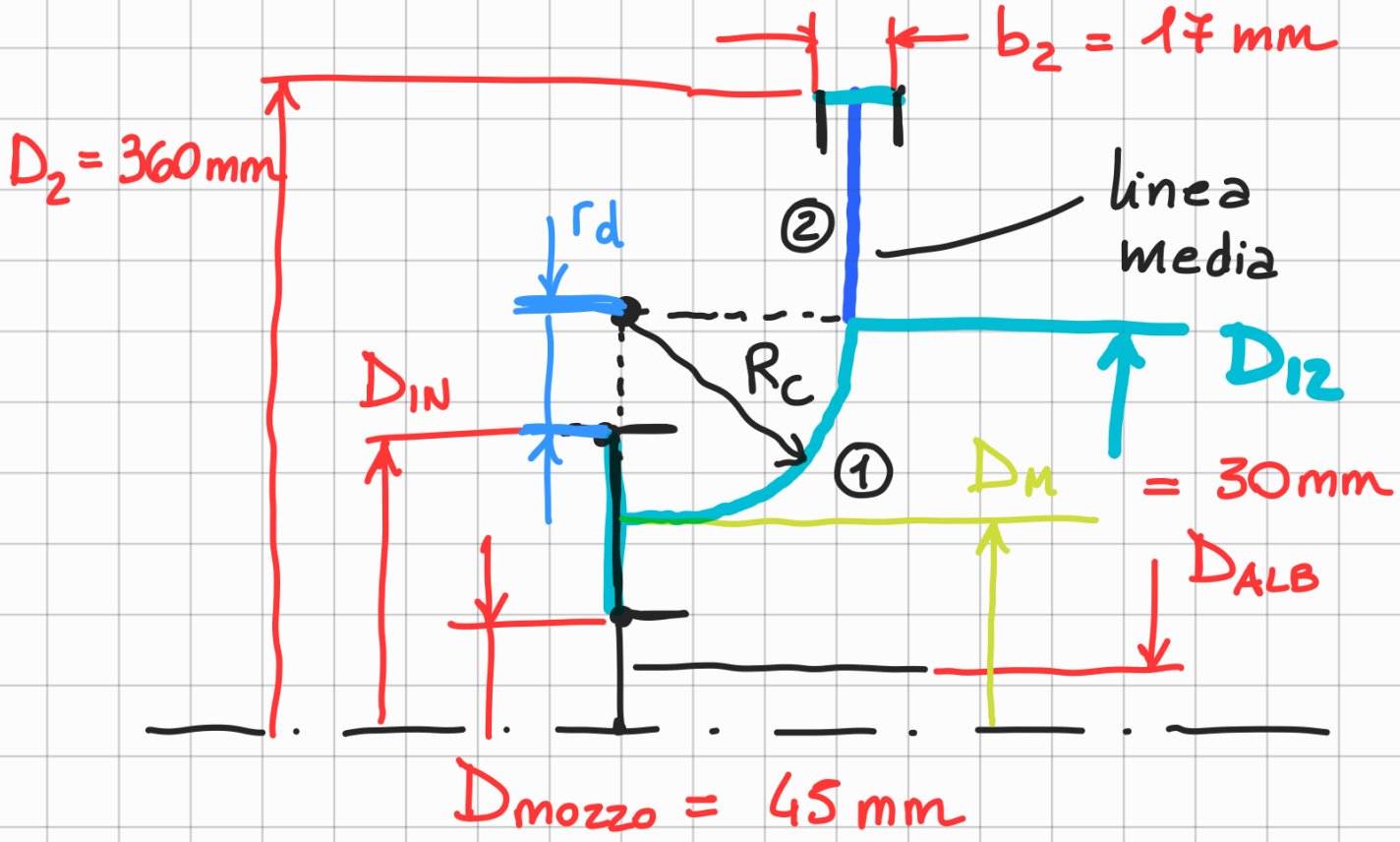
$$D_{alb} \geq D_{alb,\,min} \qquad D_{alb} = 30 \text{ mm}$$

(guardare tabelle profilati in acciaio')

$$D_{mozzo} = (1.4 \div 1.5)\, D_{alb}$$

scelta $\longrightarrow$ $D_{mozzo} = 1.5\, D_{alb}$

$= 45$ mm



① → arco di circonferenza di 90°

② → tratto rettilineo verticale

→ linea media

$$R_C = r_d + \frac{D_{IN} - D_M}{2}$$

$$r_d = (0.05 \div 0.06)\, D_2$$

$$r_d = 0.05\, D_2 = 0.05 \cdot 360 = 18 \text{ mm}$$

$$D_M = \frac{D_{IN} + D_{MOZZO}}{2} = \frac{150 + 45}{2}$$

$$= 97.5 \text{ mm}$$

$$R_c = 18 + \frac{150 - 97.5}{2} = 44.25 \text{ mm}$$

$$D_{12} = D_{IN} + 2 r_d = 150 + 2 \cdot 18$$

$$= 186 \text{ mm}$$

$$L_{TOT} = L_{①} + L_{②}$$

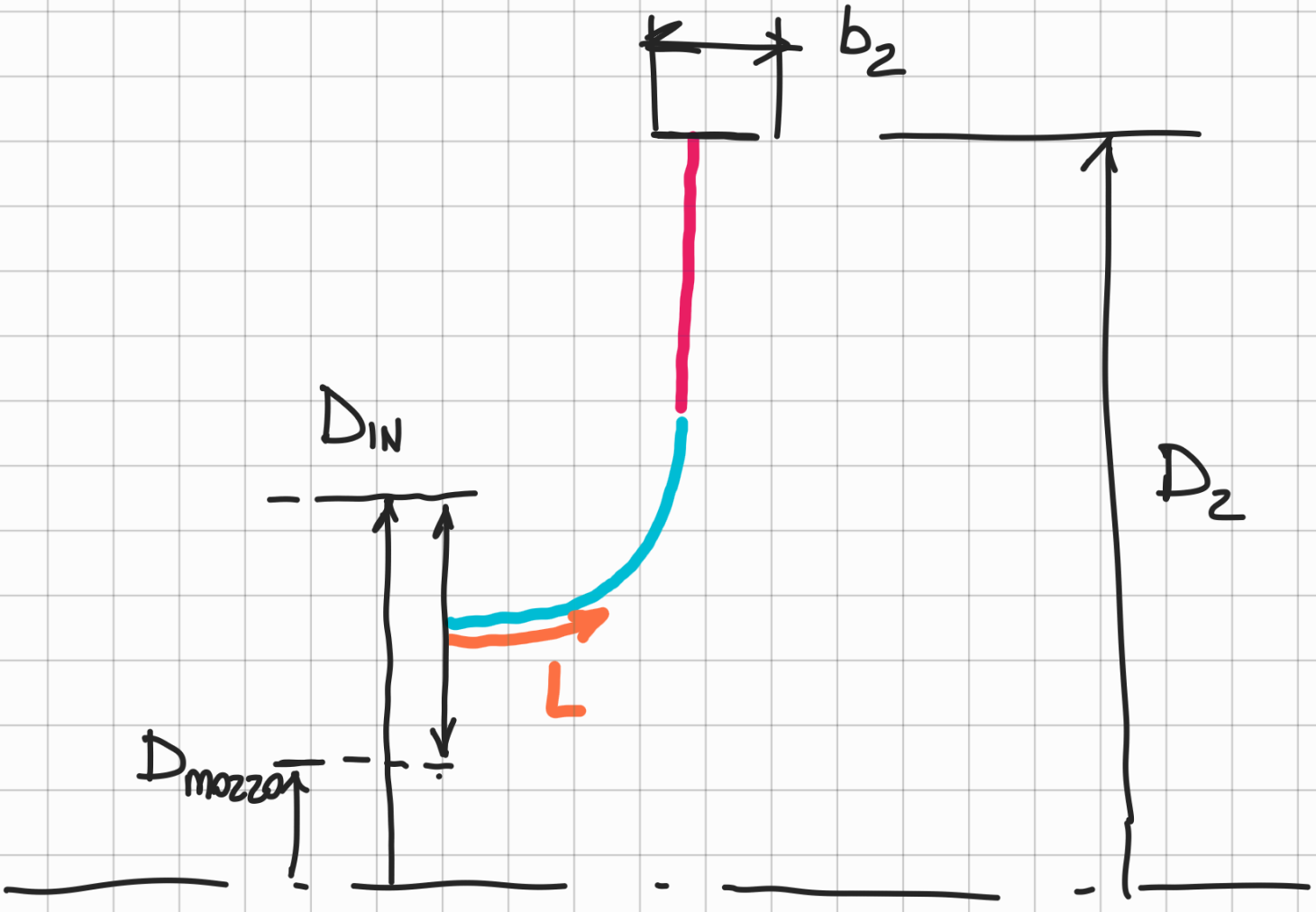
$$L_{①} = \frac{1}{\cancel{4}\,2} \cdot \cancel{2}\pi R_c = \frac{\pi R_c}{2}$$

$$= \frac{\pi}{2} \cdot 44.25 = 69.51 \text{ mm}$$

$$L_{②} = \frac{D_2 - D_{12}}{2} = \frac{360 - 186}{2}$$

$$= 87 \text{ mm}$$

$$L_{TOT} = 69.51 + 87 = 156.51 \text{ mm}$$



$L = 0$

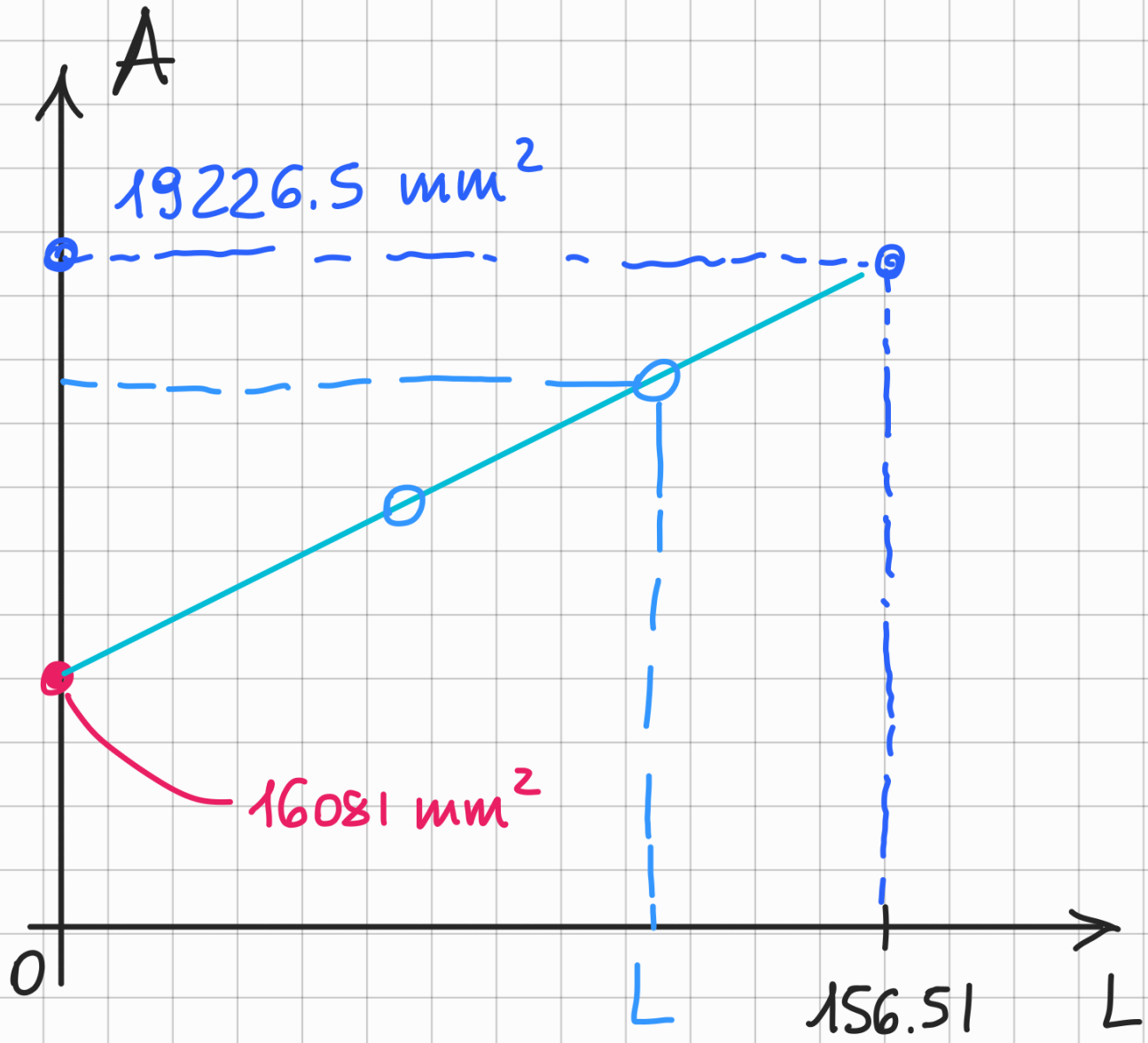
$$A = A_{IN} = \frac{\pi}{4}\left(D_{IN}^2 - D_{mozzo}^2\right)$$

$$= \frac{\pi}{4}\left(150^2 - 45^2\right)$$

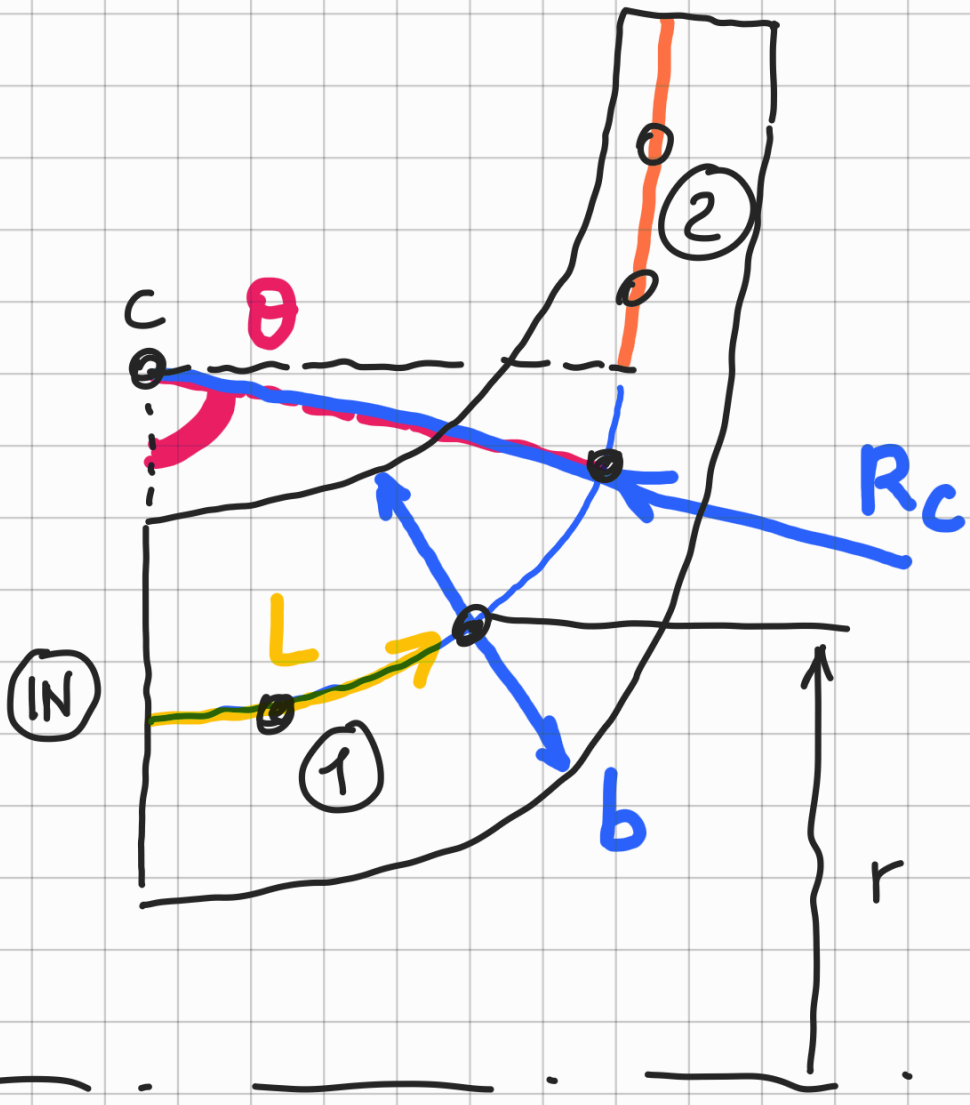
$$= 16081 \text{ mm}^2$$

$L = L_{TOT}$

$$A = \pi D_2 b_2$$
$$= \pi \cdot 360 \cdot 17$$
$$= 19226.5 \text{ mm}^2$$



$$A(L) = A_{IN} + \frac{A_2 - A_{IN}}{L_{TOT}} \cdot L$$



$$A(L) = 2\pi\, r(L) \cdot b(L)$$

nel tratto ①

$$\theta\,[^\circ] \longrightarrow \vartheta\,(\text{rad})$$

$$L = R_c\,\vartheta$$

$$r(L) = \frac{D_{12}}{2} - R_c \cos\vartheta$$

nel tratto ②

$L_{②}$

$$0 \leq \Delta L \leq \boxed{\frac{D_2 - D_{12}}{2}}$$

$$L = \frac{\pi}{2} R_c + \Delta L$$

$$r(L) = \frac{D_{12}}{2} + \Delta L$$

tratto (1)

$$\vartheta = 30° \left(\frac{\pi}{6} \text{ rad}\right)$$

$$L = R_c \vartheta = 44.25 \cdot \frac{\pi}{6}$$

$$= 23.17 \text{ mm}$$

$$r(L) = \frac{D_{12}}{2} - R_c \cos\vartheta$$

$$= \frac{186}{2} - 44.25 \cdot \cos\frac{\pi}{6}$$

$$= 54.68 \text{ mm}$$

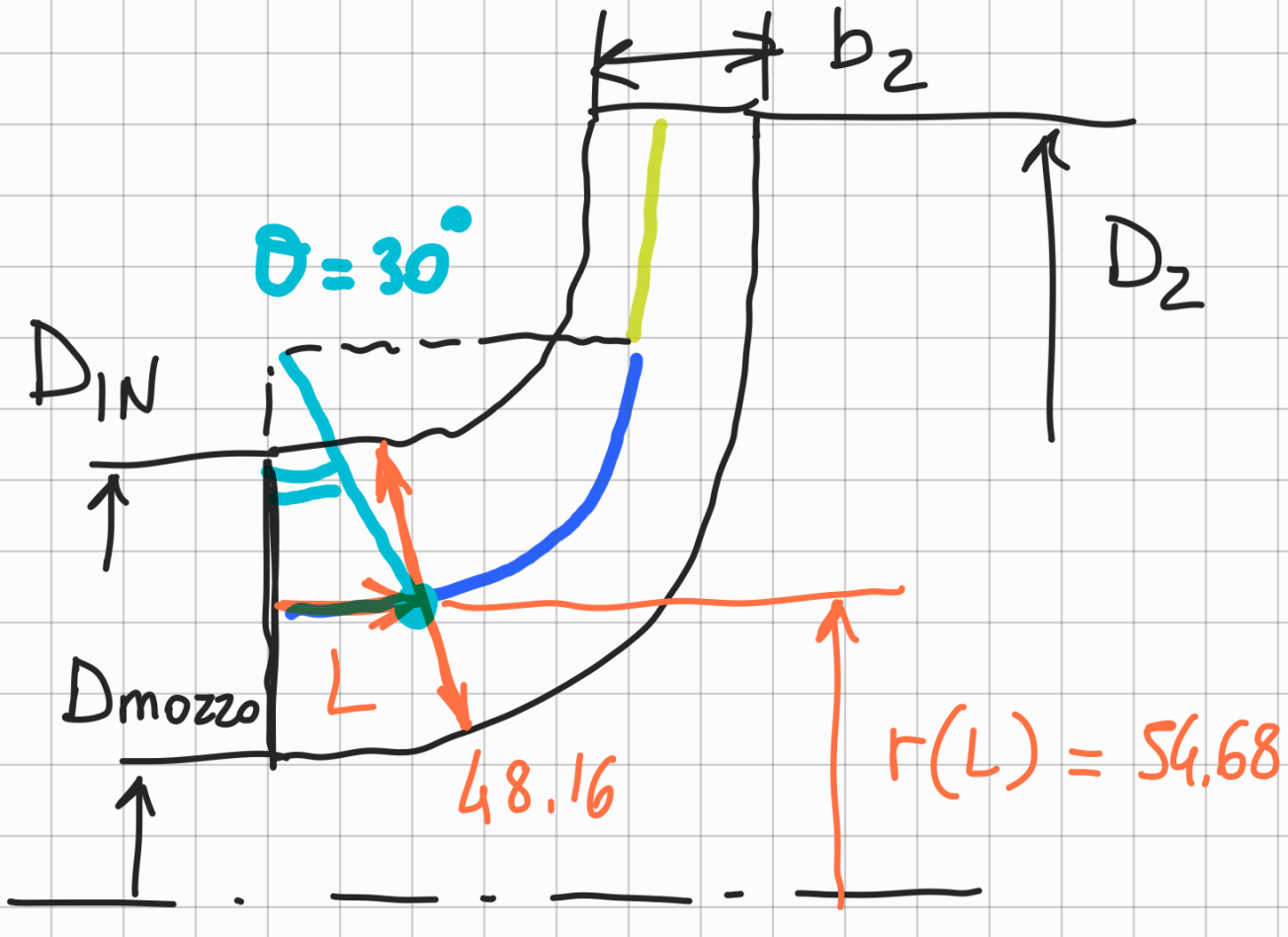
$$A(L) = A_{IN} + \frac{A_2 - A_{IN}}{L_{TOT}} \cdot L$$

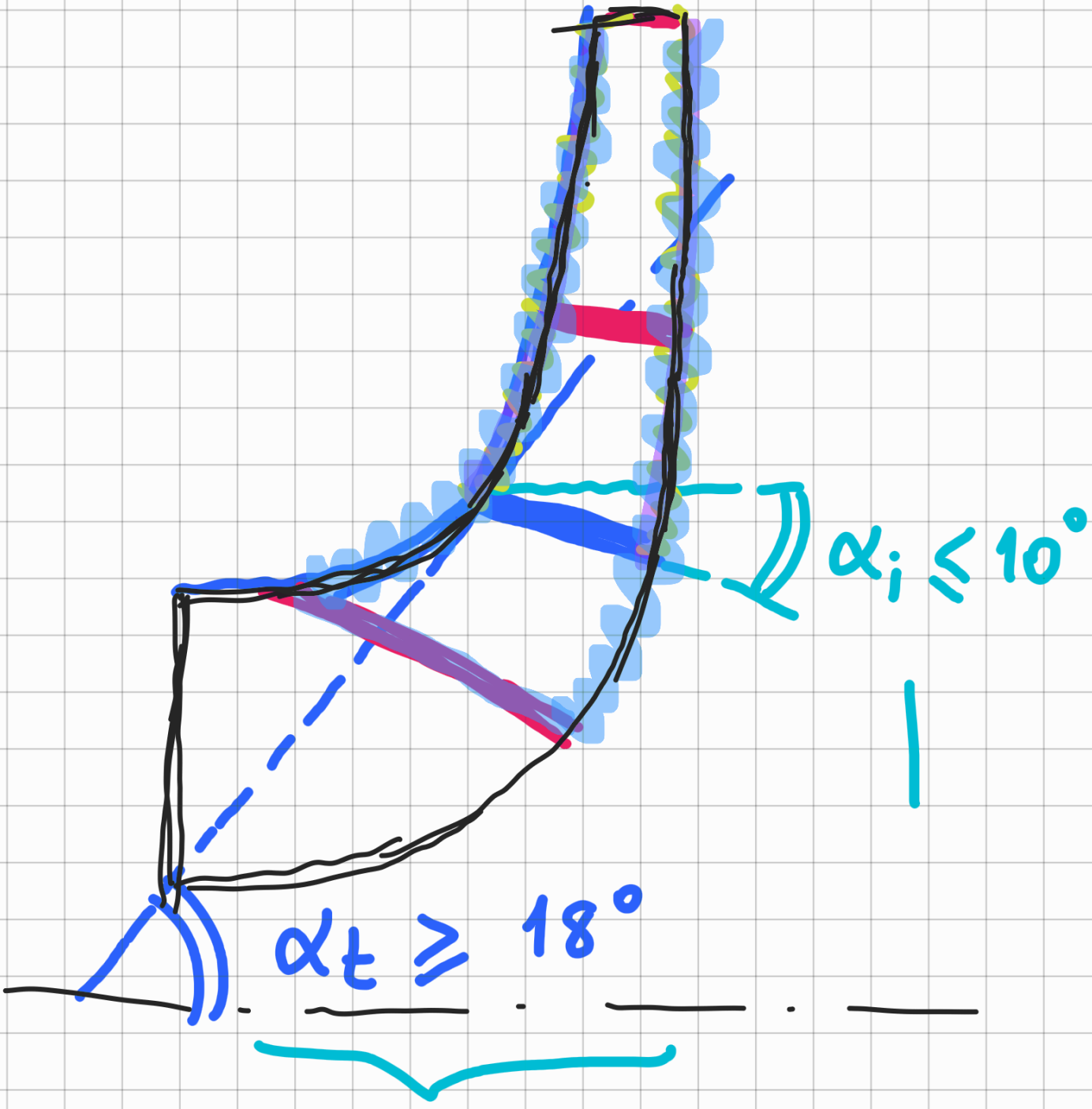
$$= 16081 + \frac{19226.5 - 16081}{156.51} \cdot 23.17$$

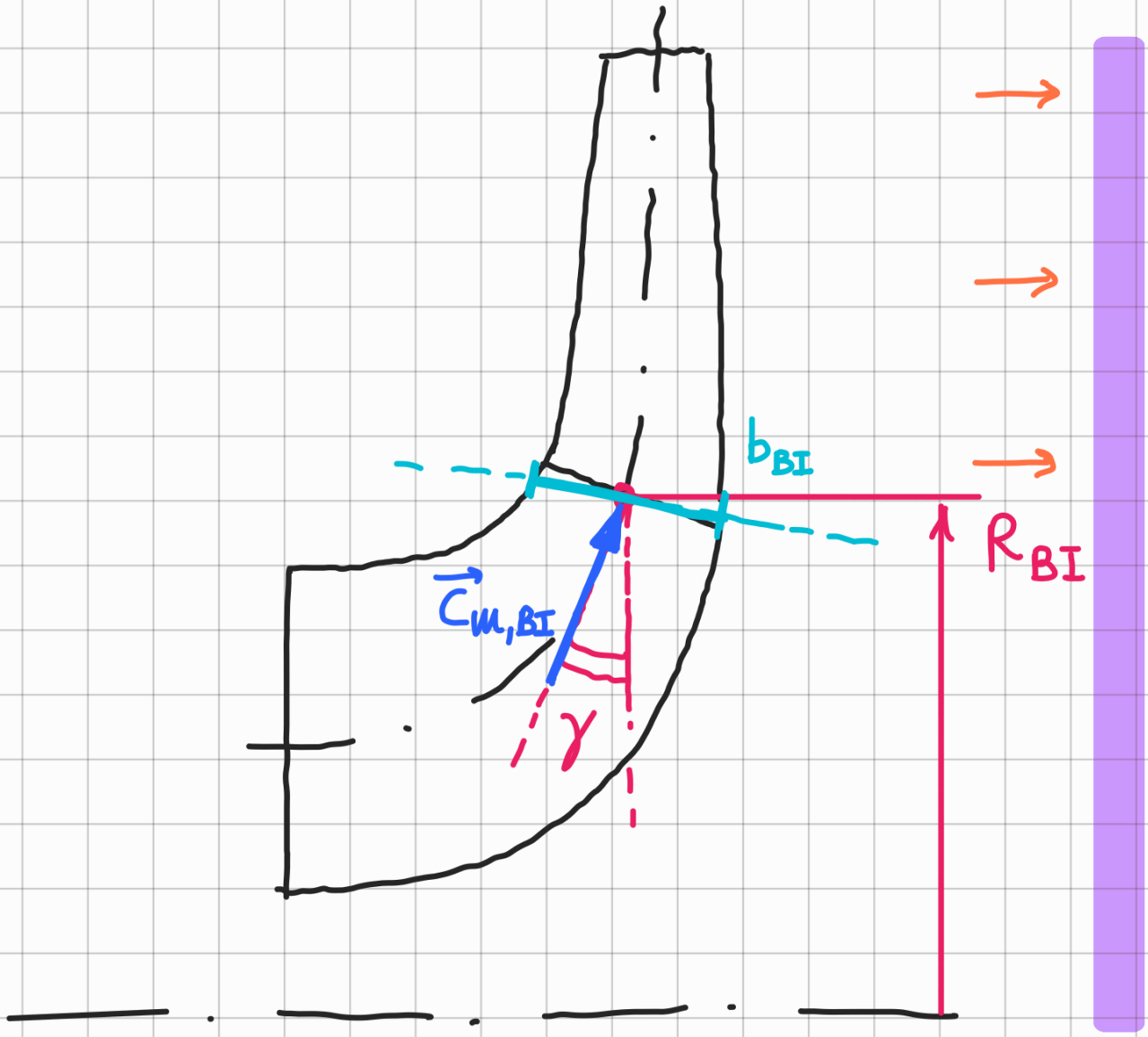
$$= 16546.7 \ mm^2$$

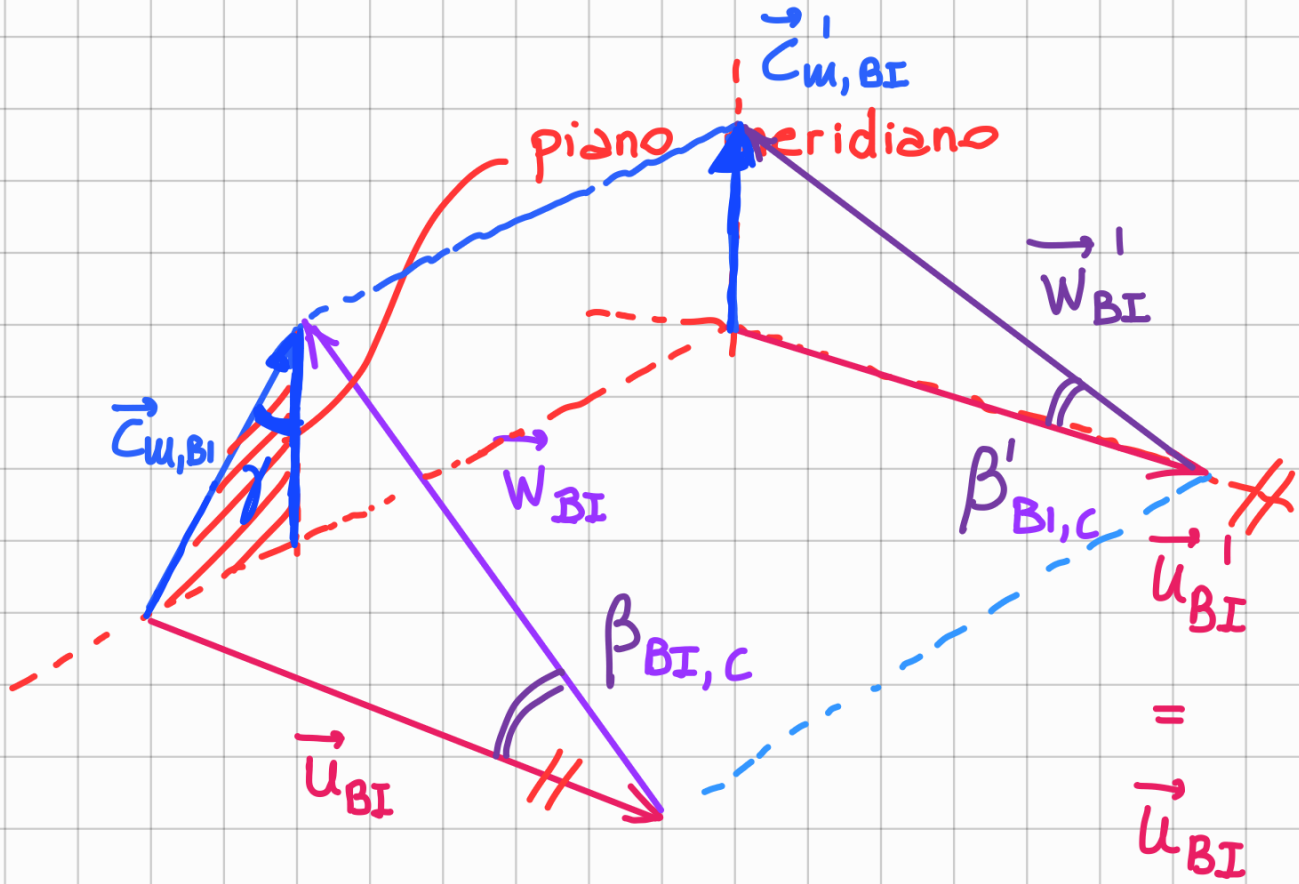
$$A(L) = 2\pi r(L) \cdot b(L)$$

$$b(L) = \frac{A(L)}{2\pi r(L)} = 48.16 \ mm$$




$\alpha_i \leq 10°$
$\alpha_t \geq 18°$


b_{BI}
R_{BI}
$\vec{c}_{m,BI}$
γ


$\vec{c}'_{m,BI}$
piano meridiano
$\vec{w}'_{BI}$
$\vec{c}_{m,BI}$
γ
$\vec{w}_{BI}$
$\beta'_{BI,c}$
$\vec{u}_{BI}$
$\beta_{BI,c}$
$\vec{u}_{BI}$
=
$\vec{u}_{BI}$

$\gamma = 16.09°$ $\qquad R_{BI} = 80.74$ mm

$b_{BI} = 32.23$ mm

$$u_{BI} = R_{BI}\,\omega$$

$$tg\,\beta_{BI,C} = \frac{C_{u,BI}}{u_{BI}}$$

$$tg\,\beta'_{BI,C} = \frac{C'_{u,BI}}{u_{BI}}$$

$$tg\,\beta'_{BI,C} = \frac{C'_{u,BI}}{C_{u\,BI}} \cdot tg\,\beta_{BI,C}$$

$$C'_{u\,BI} = C_{u\,BI}\cos\gamma$$

$$\frac{C'_{u\,BI}}{C_{u\,BI}} = \cos\gamma$$

$$tg\,\beta'_{B1,c} = \cos\gamma\; tg\,\beta_{B1,c}$$

$$tg\,\beta'_{BI,c} = \cos\gamma \cdot \frac{c_{u,BI}}{u_{BI}}$$

$$= \frac{\cos\gamma}{R_{BI}\,\omega} \cdot \frac{Q_v}{2\pi R_{BI}\, b_{BI}\, \eta_v\, \xi_{BI}}$$

$$\xi_{BI} = 1 - \frac{z\, s'_n}{\pi D_{BI} \sin \beta'_{B1,c}}$$

z = n° pale

s'_n = spessore palare

1) $\xi_{BI} = 1$ $\qquad u_{BI} = \omega R_{BI}$

$= 152.37 \cdot 0.08074$

$= 12.3 \text{ m/s}$

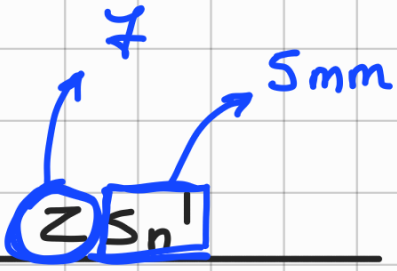
$$tg\,\beta'_{B1,c} = \frac{q_v \cos\gamma}{\eta_v \pi D_{BI} b_{BI} \xi_{\beta I} u_{BI}}$$

$\xi_{\beta I} \to 1$

$$= \frac{0.044 \cos 16.09°}{0.9395 \pi \cdot 0.1615 \cdot 0.03223 \cdot 1 \cdot 12.3}$$

$= 0.2237 \longrightarrow \beta'_{B1,c} = tg^{-1} 0.2237$

$= 12.6°$



$$\xi_{BI} = 1 - \frac{z s_n'}{\pi D_{BI} \sin \beta'_{B1,c}} =$$

$$= 1 - \frac{7 \cdot 0.005}{\pi \cdot 0.1615 \cdot \sin 12.6°} = 0.684$$

2) $\xi_{BI} = 0.684$

$$tg\,\beta'_{B1,C} = \frac{Q_V \cos\gamma}{\eta_V \pi D_{BI} b_{B1} \xi_{B1} u_{B1}}$$

$$= \frac{0.044 \cos 16.09°}{0.9395 \cdot \pi \cdot 0.1615 \cdot 0.03223 \cdot 0.684 \cdot 12.3}$$

$$= 0.327 \rightarrow \boxed{\beta'_{B1,C} = 18.1°}$$

$\xi_{BI} = 0.778$

3) $\xi_{BI} = 0.778$

$tg\,\beta'_{B1,C} = 0.2875$

$\hookrightarrow \beta'_{BI,C} = 16.0°$

$\xi_{BI} = 0.750$

4) $\xi_{BI} = 0.750$

$\hookrightarrow tg\,\beta'_{B1,C} = 0.2981$

$\hookrightarrow \beta'_{B1,C} = 16.6°$

$\xi_{BI} = 0.759$

5) $\xi_{BI} = 0.759$

$\hookrightarrow tg\,\beta'_{B1,C} = 0.2949$

$\hookrightarrow \beta'_{B1,C} = 16.4°$

$\xi_{B1} = 0.756$

6) $\xi_{BI} = 0.756$

$tg\,\beta'_{B1,C} = 0.2959 \rightarrow \beta'_{B1,C} = 16.5°$

$\xi_{BI} = 0.757$

$$0.7 \leq \xi_{BI} \leq 0.8$$

$z = 5 \div 8$

$s_n' \geq 3\ mm$

→ linea guida!

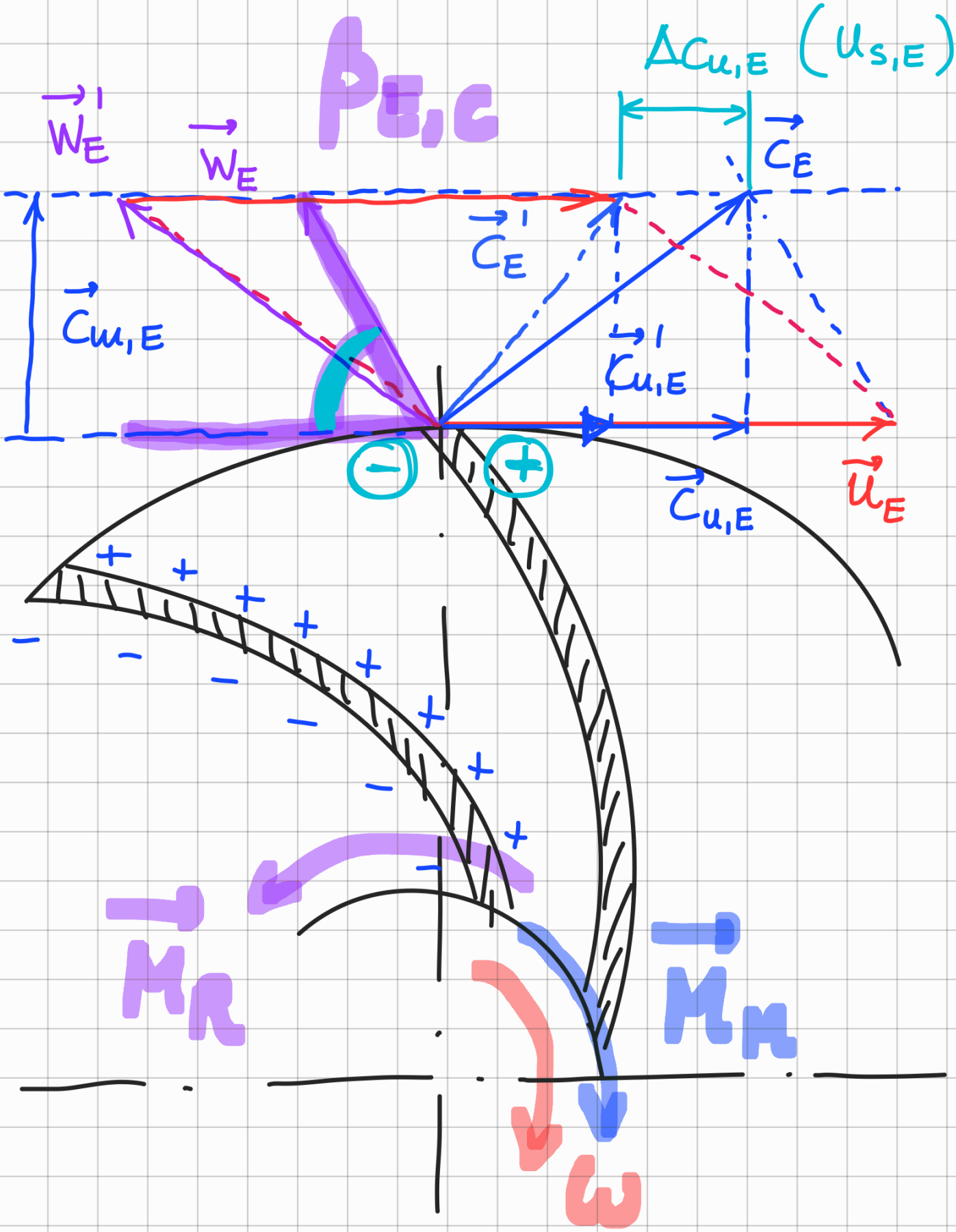
$\beta'_{B1,C} = 16.5°$ | INGRESSO

$\xi_{BI} = 0.757$ $\quad \gamma = 16.09°$

$R_{B1} = 80.74\ mm$

$b_{BI} = 32.23\ mm$

USCITA GIRANTE - ANGOLO COSTRUTTIVO



$$g h_t = u_E c_{u,E} - \cancel{u_I c_{u_I}}$$

$= 0 \ m/s$

$$g h_t = u_E c_{u,E}$$

$$c_{u,E} = u_E - \frac{c_{u,E}}{tg\,\beta_{E,C}} - u_E \left(\frac{\Delta c_{u,E}}{u_E} \right)$$

$$c_{u,E} = u_E - \frac{q_V}{\eta_V \pi D_E b_E \zeta_E tg\,\beta_{E,C}} - u_E \left(\frac{\Delta c_{u,E}}{u_E} \right)$$

$$g h_t = u_E c_{u_E}$$

$$\frac{gh_t}{u_E^2} = u_E^2 - \frac{u_E Q_v}{\eta_v \pi D_E b_E \xi_E \operatorname{tg}\beta_{E,c}} - \frac{u_E^2 \left(\frac{\Delta c_{u,E}}{u_E}\right)}{u_E^2}$$

$$\frac{gh_t}{u_E^2} = 1 - \frac{Q_v}{\eta_v \pi D_E b_E \xi_E \operatorname{tg}\beta_{E,c} u_E} c_{u,E} - \frac{\Delta c_{u,E}}{u_E}$$

$$\psi_t$$

$$\psi = \frac{gh}{u_E^2}$$

$$\frac{c_{u,E}}{u_E} = \phi$$

$$\psi_t = \frac{gh_t}{u_E^2}$$

$$\eta_{idr} = \frac{gh}{gh_t}$$ (macchina operatrice)

$$\frac{gh_t}{u_E^2} = \psi_t = \frac{gh}{\eta_{idr}} \cdot \frac{1}{u_E^2}$$

$$\psi_t = \frac{\psi}{\eta_{idr}}$$

note

$$\frac{\psi}{\eta_{idr}} = 1 - \frac{Q_v}{\eta_v \pi D_E b_E \xi_E u_E \underbrace{tg\beta_{E,C}}} - \frac{\Delta c_{u,E}}{u_E}$$

$$\xi_E = 1 - \frac{z\, s_n'}{\pi D_E \sin\beta_{E,C}}$$

$$\frac{\Delta c_{u,E}}{u_E} = \frac{\sqrt{\sin\beta_{E,C}}}{z^{0.7}}$$

1) $\xi_E = 1$; $\frac{\Delta c_{u,E}}{u_E} = 0$

$$\frac{gh}{\eta_{idr} u_E^2} = 1 - \frac{q_V}{\eta_V \pi D_E b_E \xi_E u_E \operatorname{tg}\beta_{E,C}} - \frac{\Delta c_{u,E}}{u_E}$$

$$\operatorname{tg}\beta_{E,C} = \frac{q_V}{\eta_V \pi D_E b_E \xi_E u_E \left(1 - \frac{gh}{\eta_{idr} u_E^2} - \frac{\Delta c_{u,E}}{u_E}\right)}$$

$\xi_E = 1$

$D_E = 360\ mm$ $\qquad h = 40\ m$

$b_E = 17\ mm$ $\qquad \eta_{idr} = 0.8248$

$u_E = 27.43\ m/s$ $\qquad \eta_v = 0.9395$

$$tg\,\beta_{E,C} = 0.2417 \rightarrow \beta_{E,C} = \boxed{13.6°}$$

$$\xi_E = 1 - \frac{z\, s_n}{\pi D_E \sin\beta_{E,C}} =$$

($z = 7$, $s_n = 5\ mm$, $\beta_{E,C} = 13.6°$)

$$= 0.8683$$

$$\frac{\Delta c_{u,E}}{u_E} = \frac{\sqrt{\sin\beta_{E,C}}}{z^{0.7}}$$

$$= \frac{\sqrt{\sin 13.6°}}{7^{0.7}} = 0.1241$$

2) $\xi_E = 0.8683 \qquad \frac{\Delta c_{u_E}}{u_E} = 0.1241$

$tg\,\beta_{E,C} = 0.4203 \rightarrow \beta_{E,C} = \boxed{22.8^\circ}$

$\xi_E = 0.9201$

$\frac{\Delta c_{u,E}}{u_E} = 0.1594$

3) $\xi_E = 0.9201$

$\frac{\Delta c_{u,E}}{u_E} = 0.1594$

$tg\,\beta_{E,C} = 0.4639 \rightarrow \beta_{E,C} = \boxed{24.9^\circ}$

$\xi_E = 0.9265$

$\frac{\Delta c_{u,E}}{u_E} = 0.1661$

4) $\xi_E = 0.9265$

$$\frac{\Delta c_{u1E}}{u_E} = 0.1661$$

$$tg\,\beta_{E,C} = 0.4761 \longrightarrow \boxed{\beta_{E,C} = 25.5^\circ}$$

$$\xi_E = 0.9280$$

$$\frac{\Delta c_{u1E}}{u_E} = 0.1679$$

5) $\xi_E = 0.9280$

$$\frac{\Delta c_{u1E}}{u_E} = 0.1679$$

$$tg\,\beta_{E,C} = 0.4761$$

$$\boxed{\beta_{E,C} = 25.6^\circ}$$

$$\xi_E = 0.9284$$

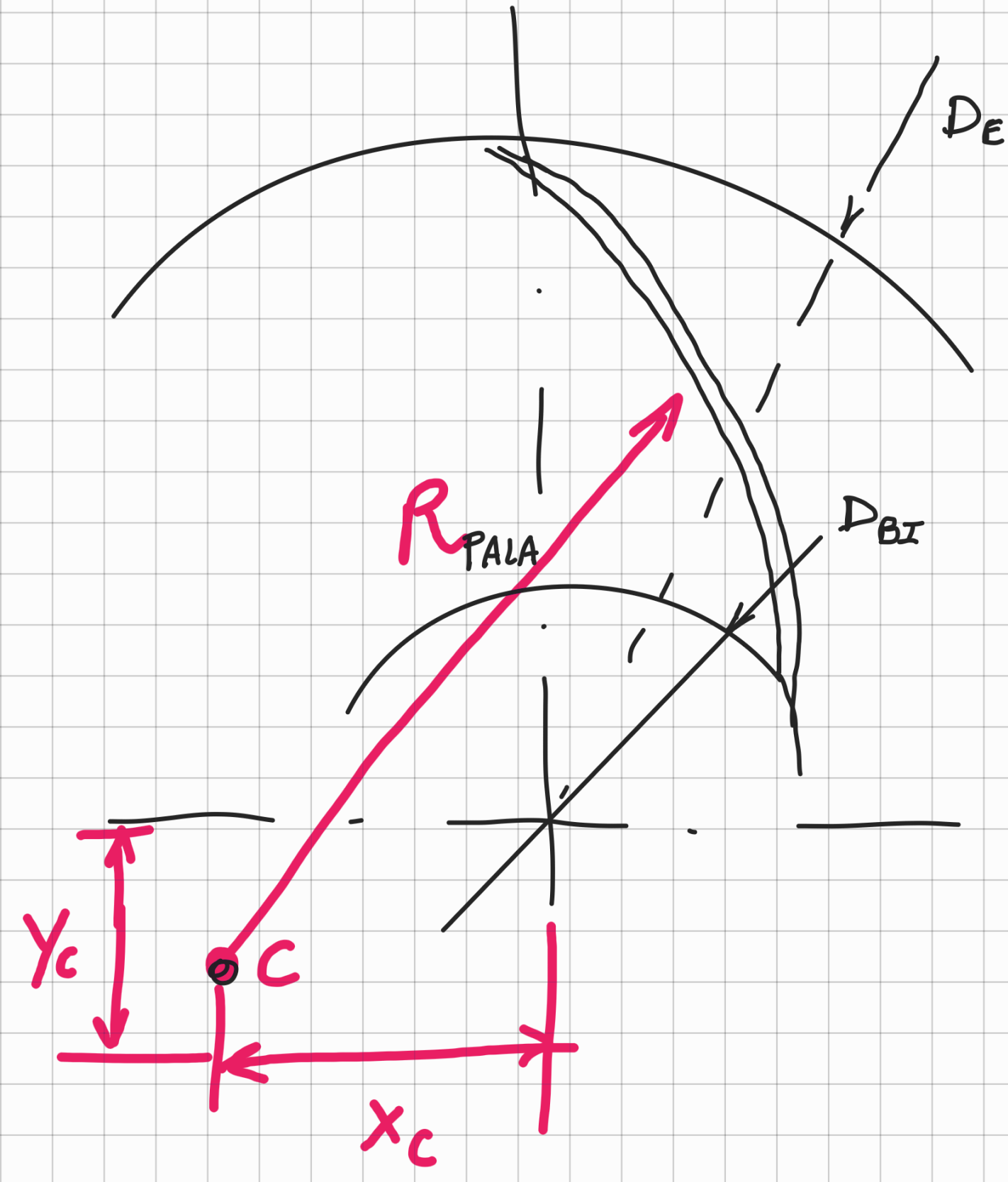
$$\frac{\Delta c_{u,E}}{u_E} = 0.1684$$

$$\left[0.9 \leq \xi_E \leq 0.95 \right]$$ 2 step verifica

$$\left[\beta_{E,C} - \beta'_{B1,C} \leq 10^\circ \right]$$

$$25.7^\circ - 16.5^\circ = 9.2^\circ$$

ok!


D_E
R_{PALA}
D_{BI}
Y_C
C
X_C

$$R_{PALA} = \frac{R_{BI,C}\,(\varepsilon^2 - 1)}{2(\varepsilon \cos\beta_{E,C} - \cos\beta'_{BI,C})}$$

$$\varepsilon = \frac{D_E}{D_{BI}}$$

$$x_{C,PALA} = - R_{PALA} \cdot \operatorname{sen}\beta_{E,C}$$

$$y_{C,PALA} = \frac{D_E}{2} - R_{PALA} \cos\beta_{E,C}$$

$$\varepsilon = \frac{360}{161.5} = 2.23$$

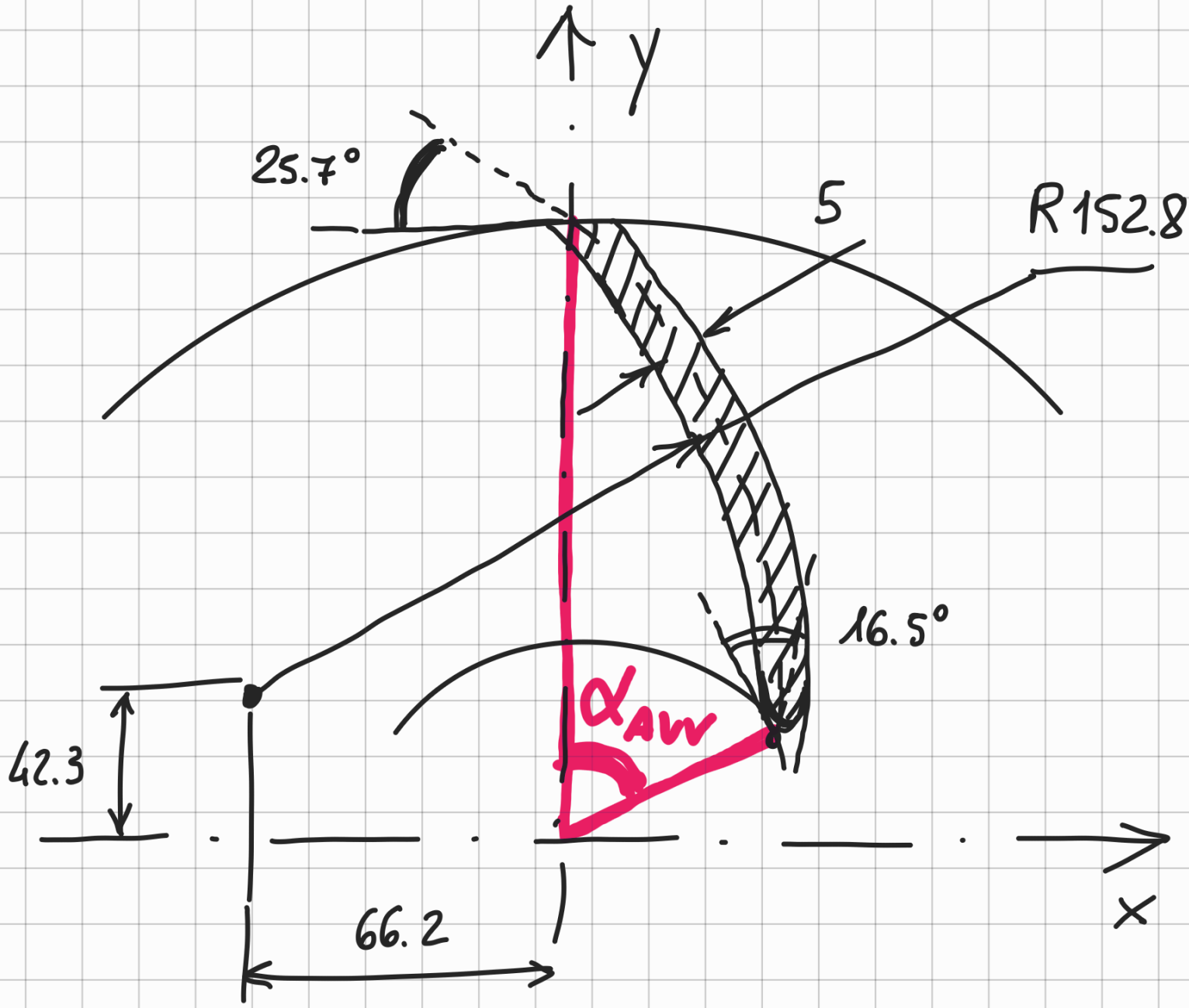
$$R_{PALA} = \frac{R_{BI,C}\,(\varepsilon^2 - 1)}{2(\varepsilon \cos\beta_{E,C} - \cos\beta'_{BI,C})}$$

$$= \frac{80.74\,(2.23^2 - 1)}{2(2.23 \cos 25.7° - \cos 16.5°)}$$

$$= 152.8 \text{ mm}$$

$X_{C,PALA} = -66.2$ mm

$Y_{C,PALA} = 42.3$ mm



$90° \leq \alpha_{AVV} \leq 120°$

$Z = 8$ ← $Z = 5$

$$\alpha_{AW} \approx 90^\circ$$

VOLUTA

criterio del vortice libero

→ corrente in uscita dalla girante effonda liberamente senza operare ulteriori scambi di energia

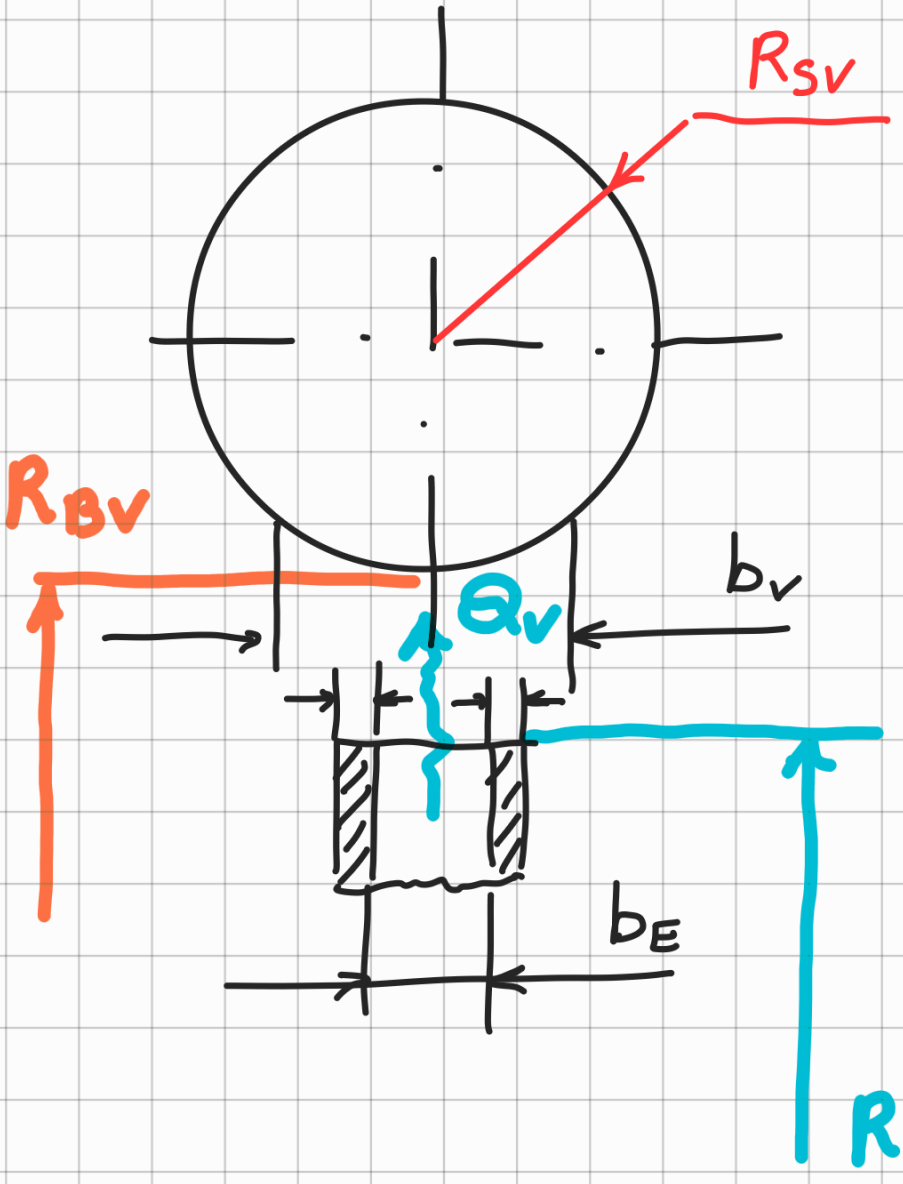
↓

conservazione del momento della quantità di moto

↓

$$r_i \, c_{u_i} = \text{cost}$$

scelta progetto → voluta a sezione circolare



R_{SV} : raggio sezione voluta

b_V : larghezza di base voluta

R_{BV} : raggio base voluta

— . — . — asse macchina

$$R_{BV} = (1.04 \div 1.12)\, R_E$$

$$b_V = (1.5 \div 2)\, b_E$$

$b_V = 30\ mm \rightarrow \frac{b_V}{b_E} = \frac{30}{17}$

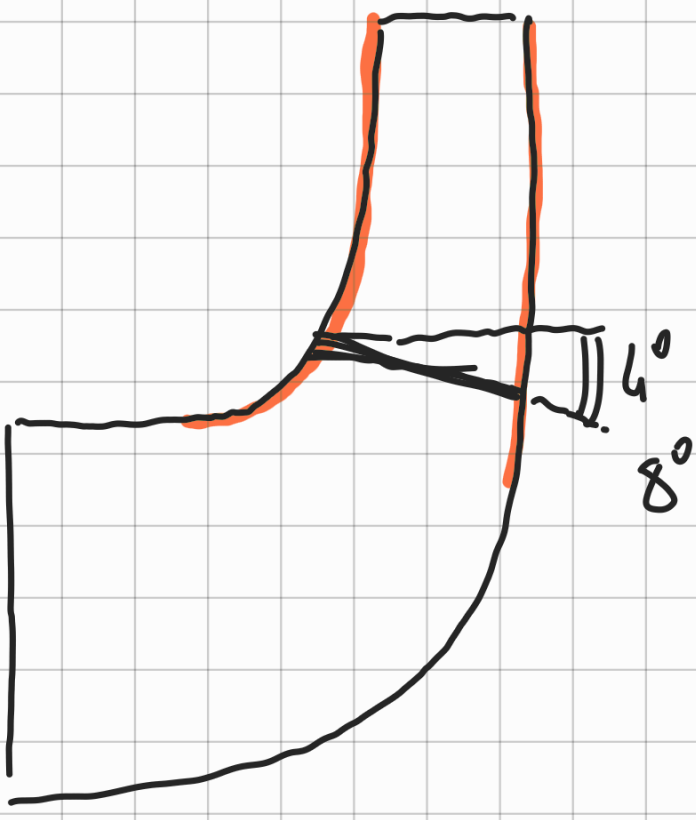
$= 1.765$

ok!

$R_{BV} = 190\ mm \rightarrow \frac{R_{BV}}{R_E} = \frac{190}{180}$

$= 1.056$

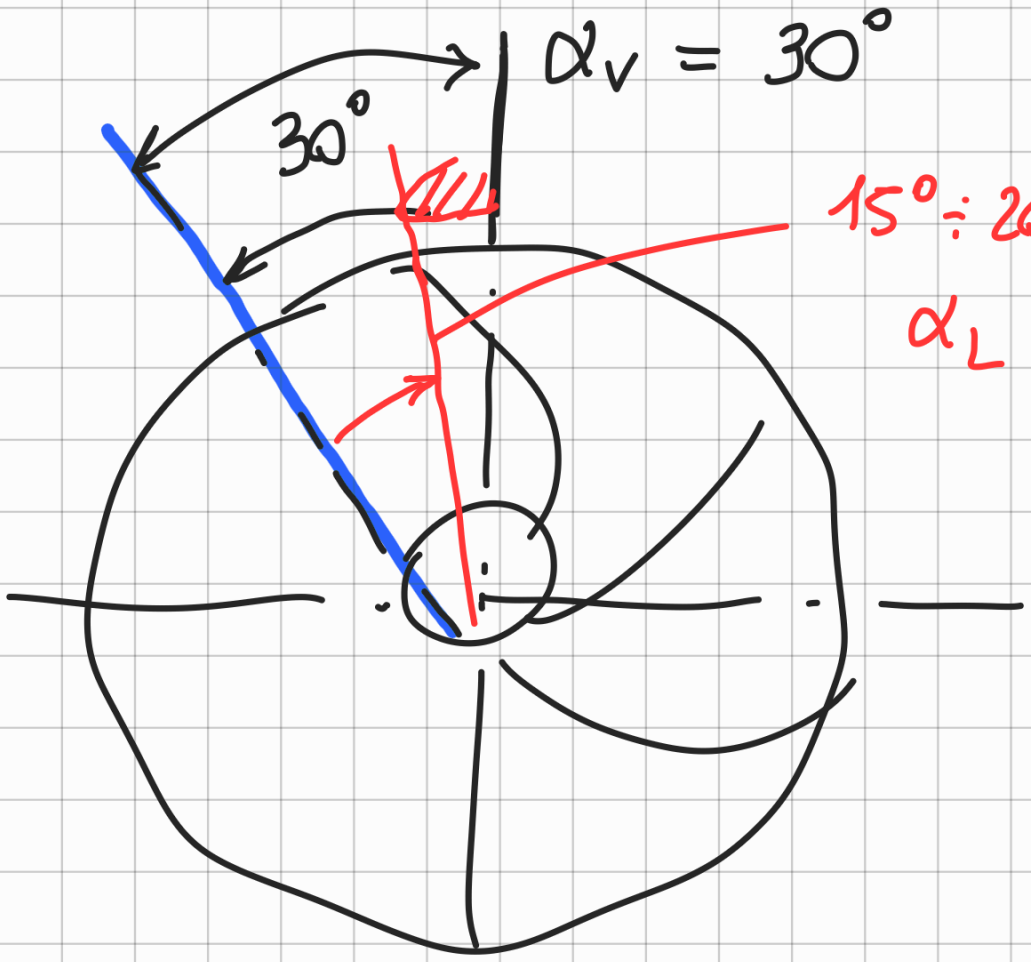
ok!



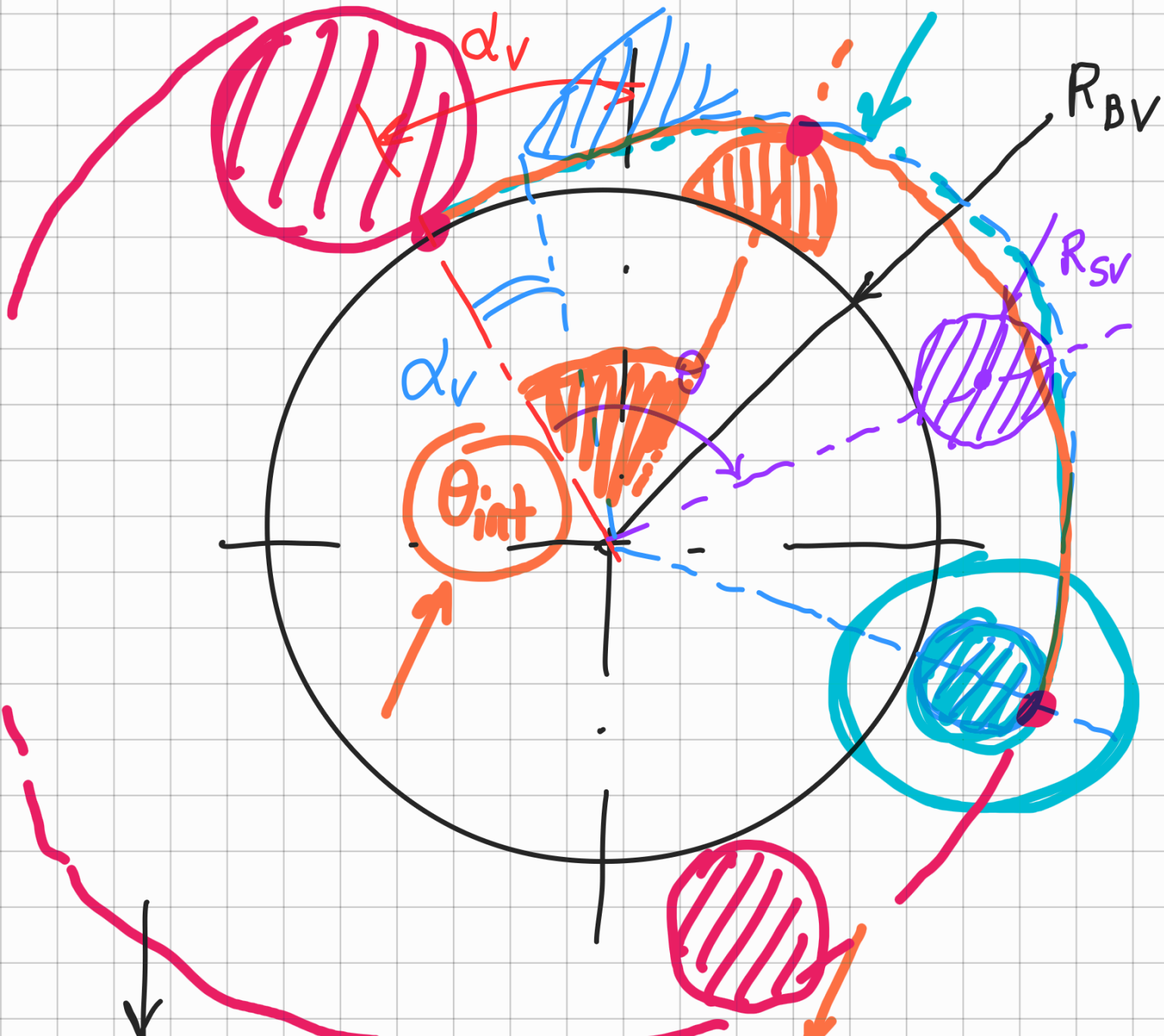
$\frac{\Delta p}{L}$

1) attenzione all'accoppiamento girante - voluta

2)

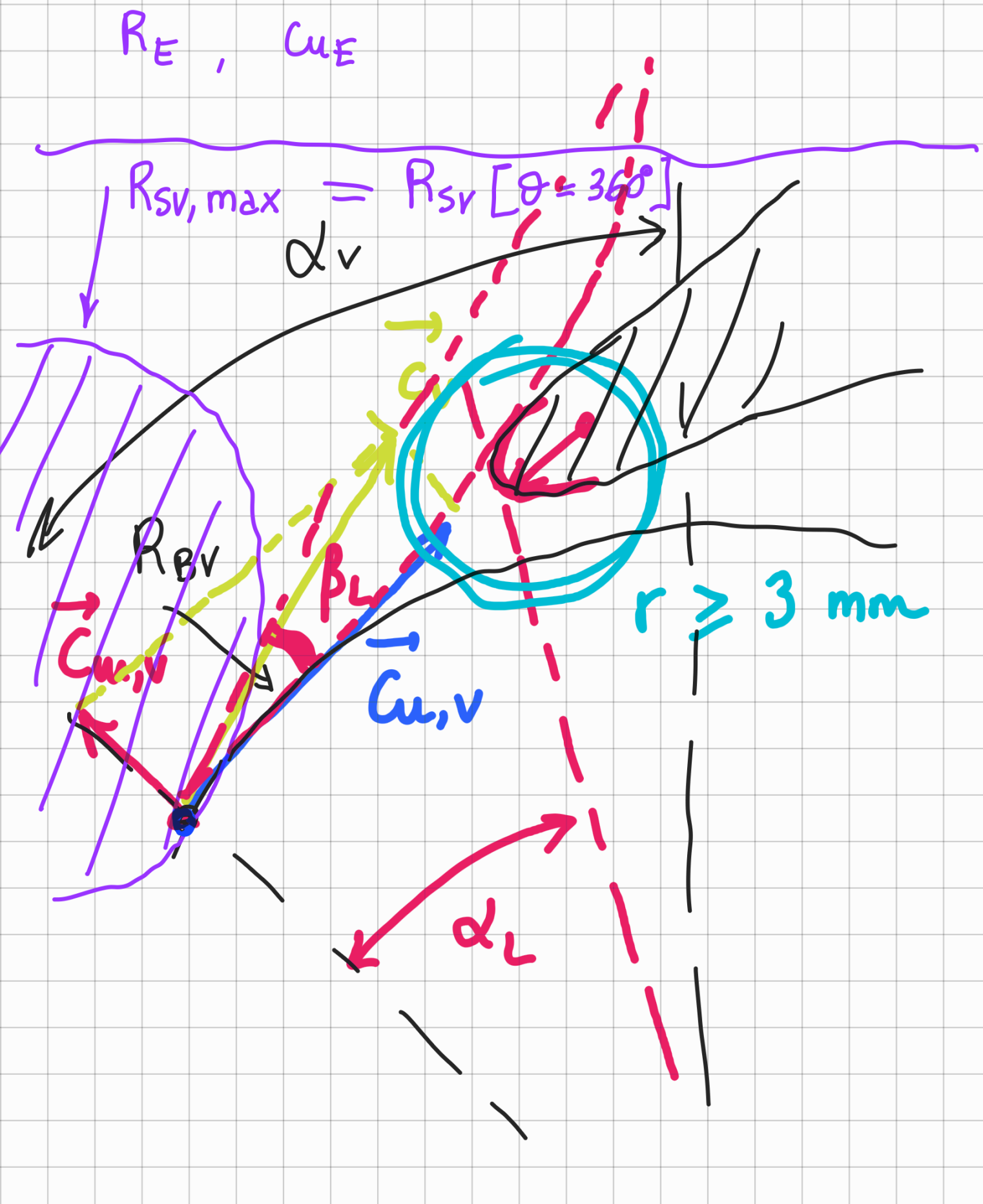


3) Spessori voluta + raggi di raccordo $\geq$ 3 mm (limitazioni fonderia)



$$R_{SV}(\theta) = \frac{Q_V}{720\,\pi\,R_E\,c_{u,E}} \cdot \theta[°] +$$

$$+\sqrt{\frac{2 R_{BV}\, \vartheta_V}{720\,\pi\, R_E\, \omega_E}}\;\vartheta[°]$$



crit. vort. libero: $r\,c_u = \text{cost}$

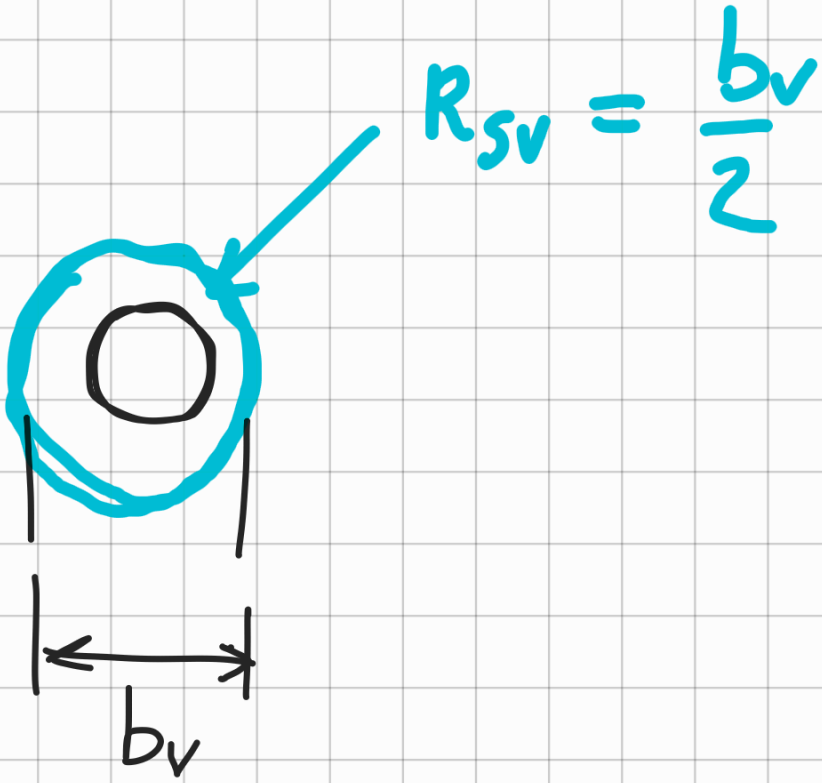
$$r_E\, c_{u_E} = r_{BV}\, c_{u,V}$$

$$c_{u,V} = \frac{r_e}{r_{BV}} \cdot c_{u_E}$$

$$c_{u,V} = \frac{Q_V}{2\pi R_{BV} \cdot b_V}$$

$$c_V = \sqrt{c_{u,V}^2 + c_{m,V}^2}$$

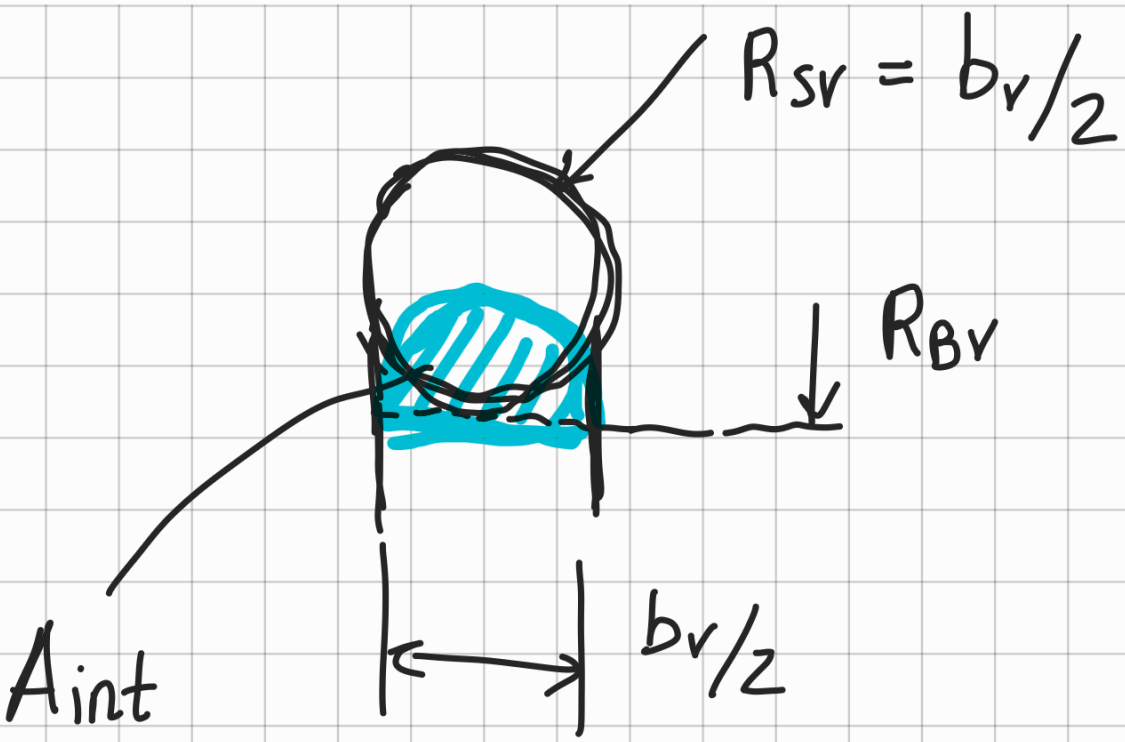
$$\operatorname{tg} \beta_L = \frac{c_{u,V}}{c_{u,V}}$$



$$r_v \leq \frac{b_v}{2}$$

$$\frac{b_v}{2} = 15\ mm$$

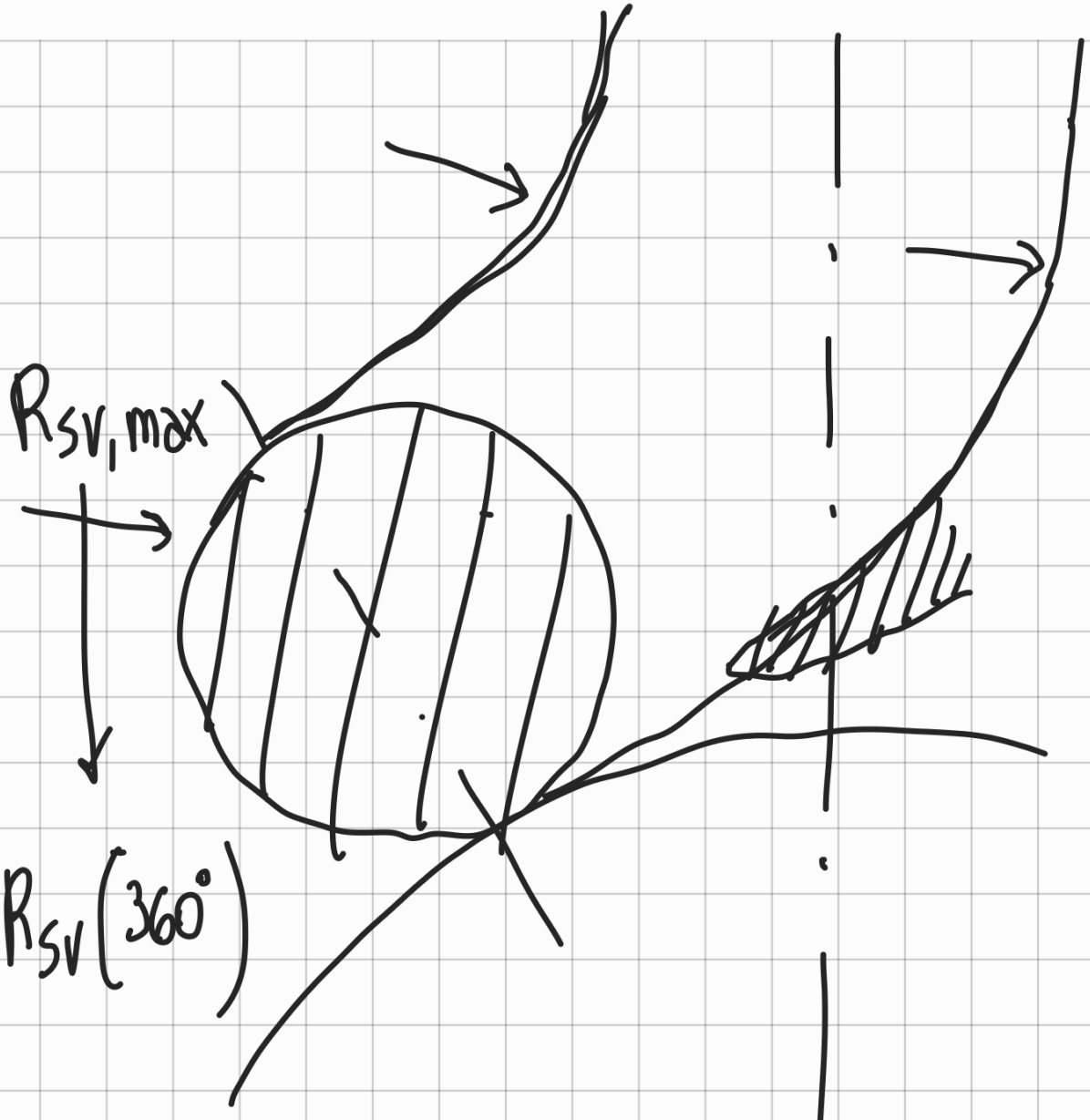
$\theta[°]$	R_{sv}	$b_v/2$
15°	...	
30°	...	13 mm
45°	...	17 mm
...		



$$A_{int} = \frac{1}{2}\left(\frac{\pi}{4} b_v^2\right)$$

$$= \pi R_{sv}^2 (\theta_{int})$$

$$R_{sv}(\theta_{int}) = \frac{b_v}{2\sqrt{2}} \quad (*)$$



Flangia in uscita → DN

PN

$$p = \rho g h = 1000 \cdot 9.81 \cdot 40$$

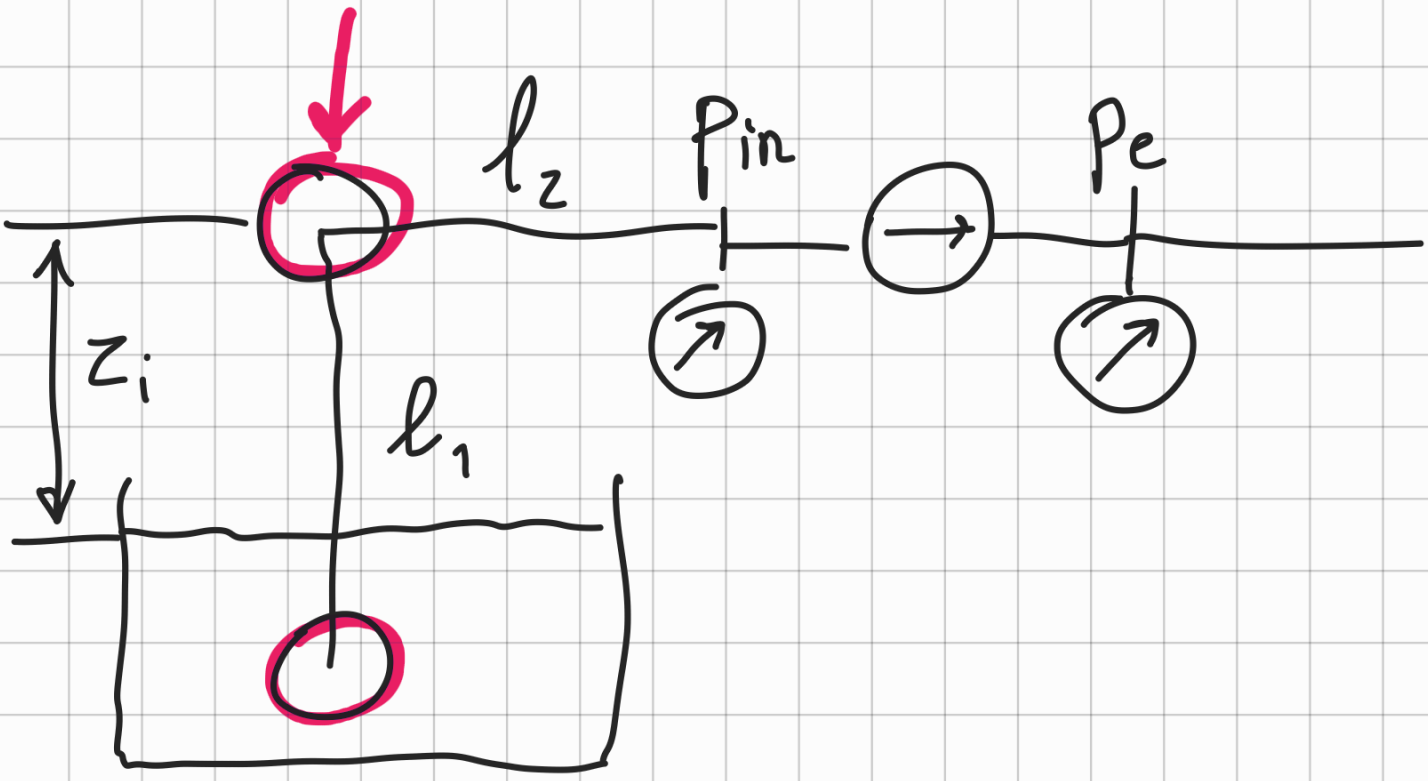
$$\approx 3.91 \text{ bar}$$

PN 10

$$R_a \approx \rho Q_v c_{in} + (p_{in} - p_{amb}) \pi R_{alb}^2$$

$$c_{in} = \frac{Q_v}{\frac{\pi}{4} D_{in}^2} = \frac{0.044}{\frac{\pi}{4} \cdot 0{,}150^2}$$

$$\approx 2.49 \text{ m/s}$$



$z_i = 2\ m \qquad l_1 = 3\ m$

$l_2 = 1\ m$

$\rho = 998\ kg/m^3 \qquad \mu = 8.9 \cdot 10^{-4}\ Pa \cdot s$

$\varepsilon = 0.08\ mm$ (tubi grezzi, saldati)

$\varepsilon = 0.03 \div 0.08\ mm$

$$\frac{p_{in}}{\rho g} + \frac{c_{in}^2}{2g} = \frac{p_{amb}}{\rho g} - z_i - h_{R,D} - h_{R,C}$$

$$(p_{in} - p_{amb}) = -\rho g z_i - \rho g h_{R,D} - \rho g h_{R,C} - \frac{\rho c_{in}^2}{2}$$

$$h_{R,D} = f \frac{c_{in}^2}{2g} \cdot \frac{L}{D_{in}}$$

$$\frac{1}{\sqrt{f}} = -1.8 \log_{10}\left[\left(\frac{\varepsilon/D_{in}}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]$$

$$Re = \frac{\rho c_{in} D_{in}}{\mu} = 418824$$

$$f = 0.0179$$

$$h_{R,D} = 0.151 \text{ m}$$

$$h_{R,C} = K_{L,\text{imbocco}} \frac{c_{in}^2}{2g} + K_{L,\text{curva}} \frac{c_{in}^2}{2g}$$

1

0.3

$$= 1 \cdot \frac{2.49^2}{2 \cdot 9.81} + 0.3 \cdot \frac{2.49^2}{2 \cdot 9.81}$$

$$= 0.41 \text{ m}$$

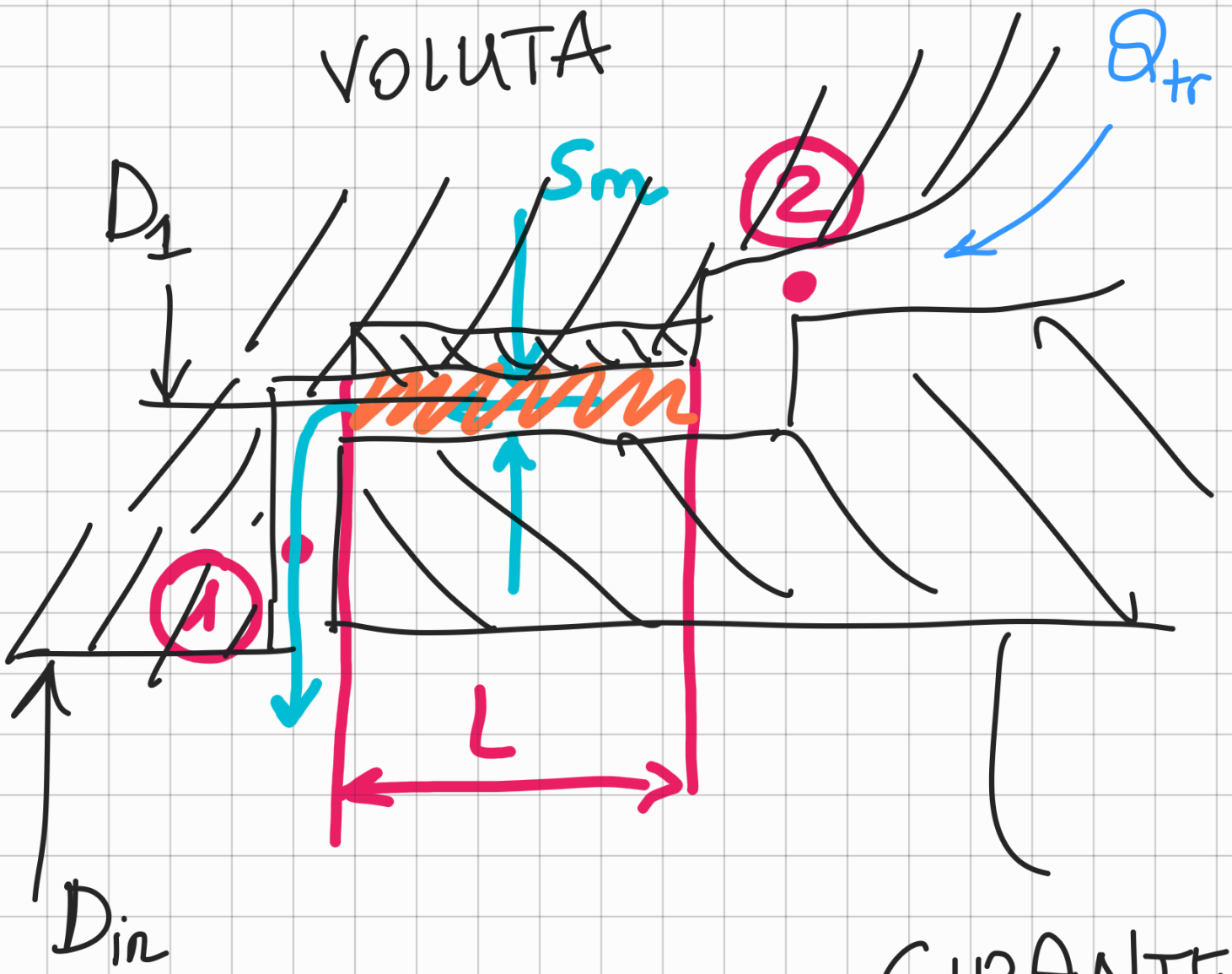
$(p_{in} - p_{amb}) = -28167\ Pa$

$R_a = 89.4\ N$ (con i fori di bilanciatura)

R_a (con i fori)

R_a (senza i fori)

Dimensionamento delle tenute



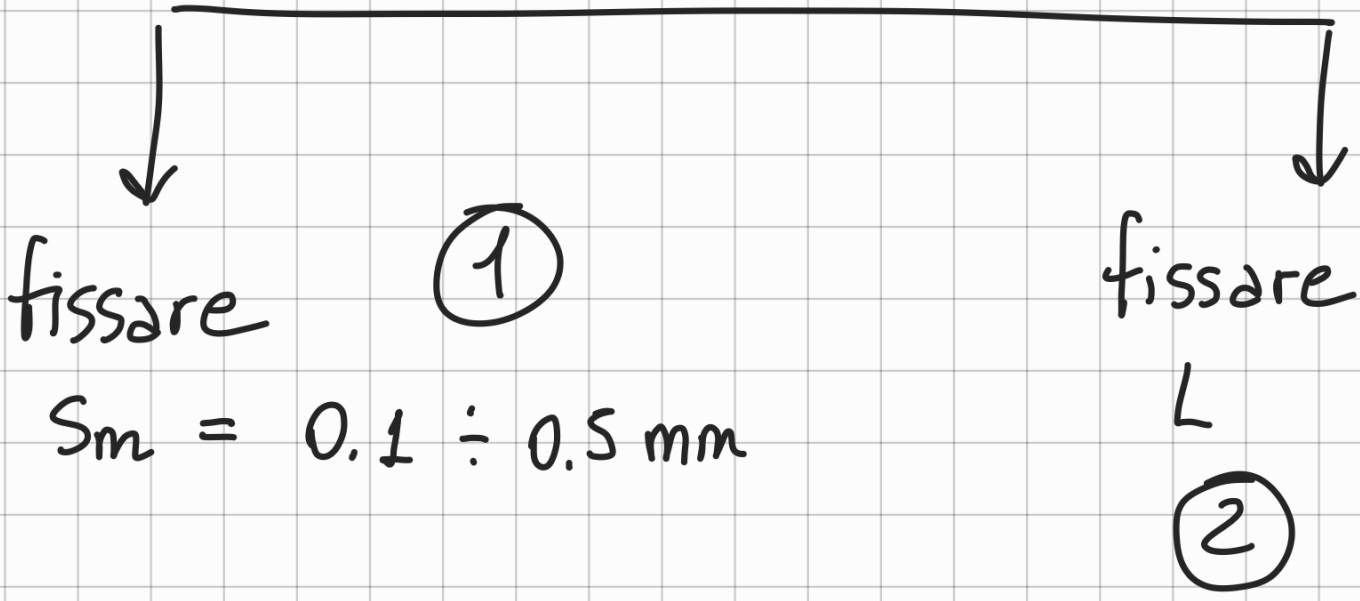
S_m : spessore meato tenuta

$$\frac{p_2}{\rho g} + \frac{c_2^2}{2g} = \frac{p_1}{\rho g} + \frac{c_1^2}{2g} + h_{R,T}$$

$c_2 \ll c_1$

$$h_{R,T} = f \frac{L}{D_h} \cdot \frac{c_1^2}{2g} + 0.5 \frac{c_1^2}{2g}$$

2 possibilità



fissare ①

$s_m = 0.1 \div 0.5$ mm

fissare L ②

1) (a) $s_m = 0.1 \div 0.5$ mm

$s_m = 0.3$ mm

(b) calcolo c_1

$D_1 \approx D_{IN} = 150$ mm

$Q_V = 44$ L/s

$\eta_V = 93.95\%$

$$c_1 = \sqrt{\frac{(1-\eta_V)\,Q_V}{2\pi s_m (D_1 + s_m)}}$$

$$= \sqrt{\frac{(1-0.9395)\cdot 0.044}{2\pi \cdot 0.0003 \cdot (0.150+0.0003)}}$$

$$= 9.40 \text{ m/s}$$

c) $Re = \frac{\rho c_1 D_h}{\mu} =$

$= \frac{\rho c_1 \cdot 2 s_m}{\mu}$

$= 6324.4$

d) calcolo fattore attrito f

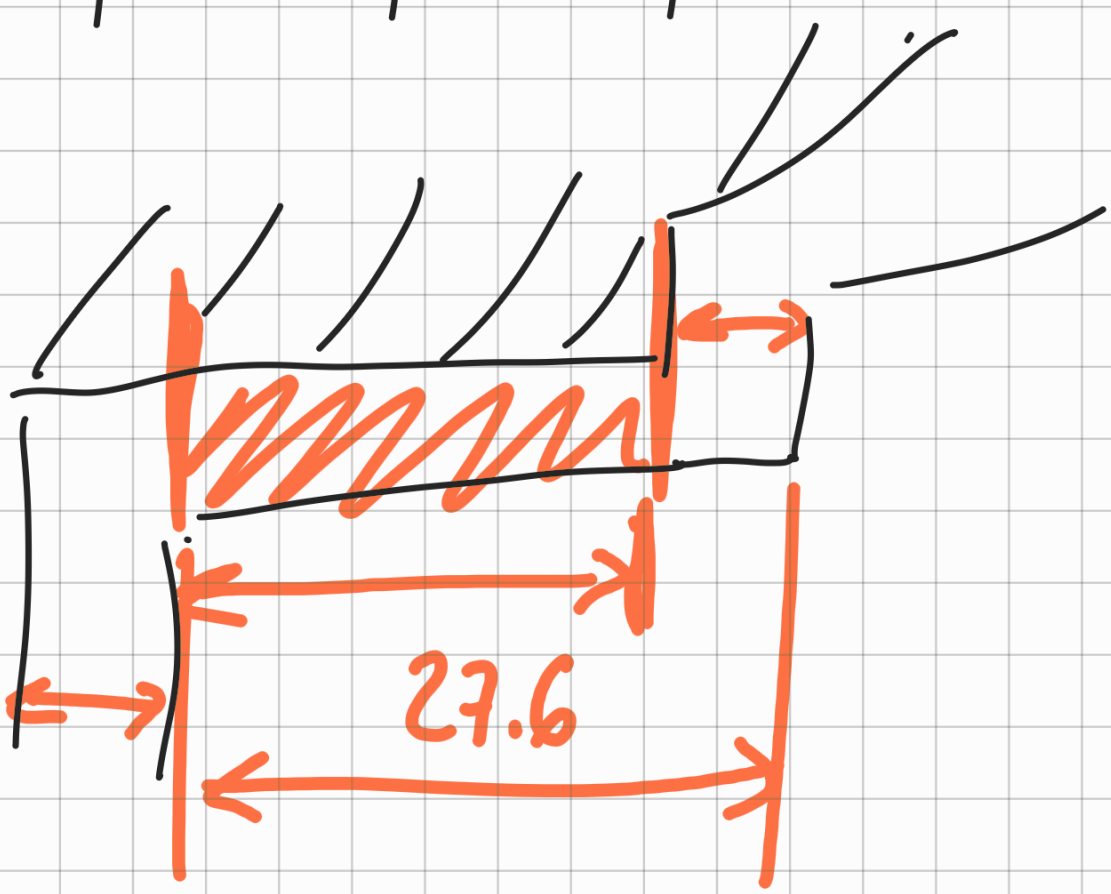
$f = 0.03654$

e) $\frac{3}{4}(u_e^2 - u_{in}^2) =$

$= c_1^2 \left(1.5 + f \frac{L}{2 s_m}\right)$

$L = 59.15 \text{ mm}$

s_m	c_1	Re	f	L
[mm]	[m/s]	[-]	[-]	[mm]
0.3	9.4	6324	0.03654	59.15
↳ 0.2	14.1	/	0.03393	9.05
→ 0.25	11.3	/	0.03683	27.6



(2) a) fissare L

$L = 20\ mm$

b) ipotesi fattore attrito (I° tentativo)

$f = 0.05$

c) determinare s_m di prima iterazione

$$\frac{3}{4}\left(u_e^2 - u_{in}^2\right) =$$

$$= c_{in}^2\left(1.5 + f\frac{L}{2s_m}\right)$$

d) calcola la velocità c_1 attraverso le tenute

$$c_1 = \frac{(1 - \eta_v)\, q_v}{2\pi s_m (\Delta_1 + s_m)}$$

e) calcolo Re

$$Re = \frac{\rho c_1 \cdot 2 s_m}{\mu}$$

f) calcolo f (fattore attrito tenute)

g) reiterare a partire

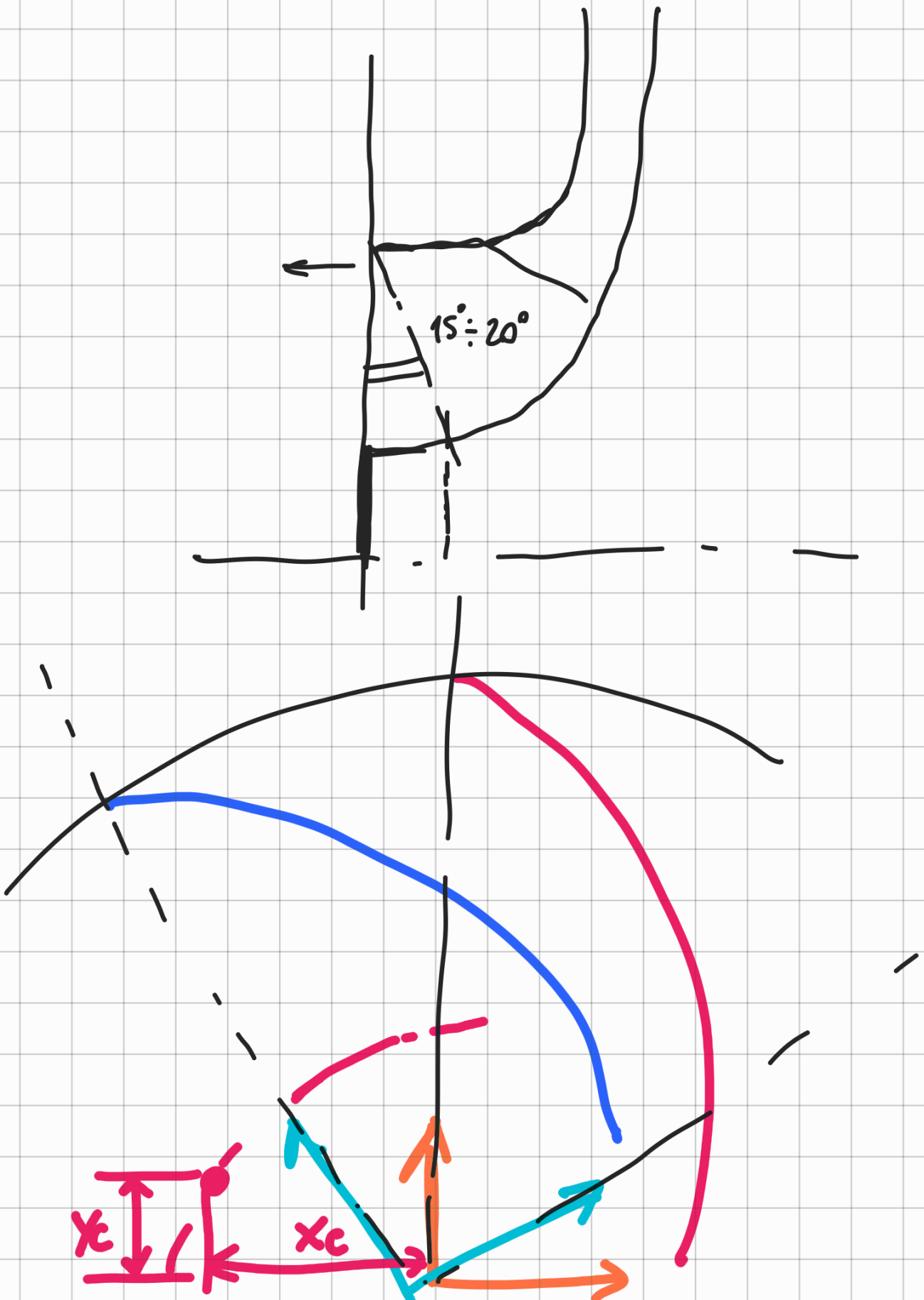
dal punto ©

$L = 20\ mm$

$\hookrightarrow \quad 5m = 0.2485\ mm$

$\approx 0.25\ mm$

$L = 27.6\ mm$


15° ÷ 20°
xc
xc