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

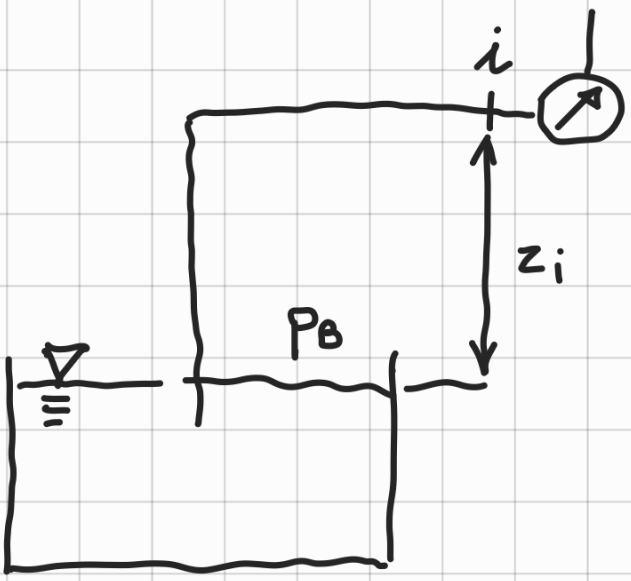
$$D_{IN,NPSH} = 4.79 \left(\frac{Q_v}{n}\right)^{1/3} = 4.79 \cdot \left(\frac{0.044}{2910}\right)^{1/3}$$

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

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

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

$$= 5.732\ m$$



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

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

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

$$P_v = 2400\ Pa$$

$$x = 1\ m$$

$$h_L = 1\ m$$

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

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

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

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 $\eta_{idr} < 0.82$

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

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

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

$K = 0.242 \longrightarrow$

$\psi = 0.5441$

$\phi = 0.0810$

$\eta_{TOT} = 0.6791$

$\eta_{idr} = 0.82$

$\eta_v = 0.9253$

$\eta_{mv} = 0.8950$

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

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

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

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

$K = 0.363 \longrightarrow \psi = 0.5211$

$\phi = 0.095$

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

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

$\eta_v = 93.95\ \%$

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

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

$D_2 = 360.3\ mm \longrightarrow \boxed{D_2 = 360\ mm}$

$D_2 = 183\ mm$ → $D_2 = 180\ mm$

$D_2 = 183\ mm$ → $D_2 = 185\ mm$

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

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

$\xi_2 \eta_v$ → trascurati in fase di studio di fattibilità → da considerare nel dimensionamento preliminare!

ξ_e = ostruzione = 0.95

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

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

$D_2 = 360 \text{ mm}$

$b_2 = 17 \text{ mm}$

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

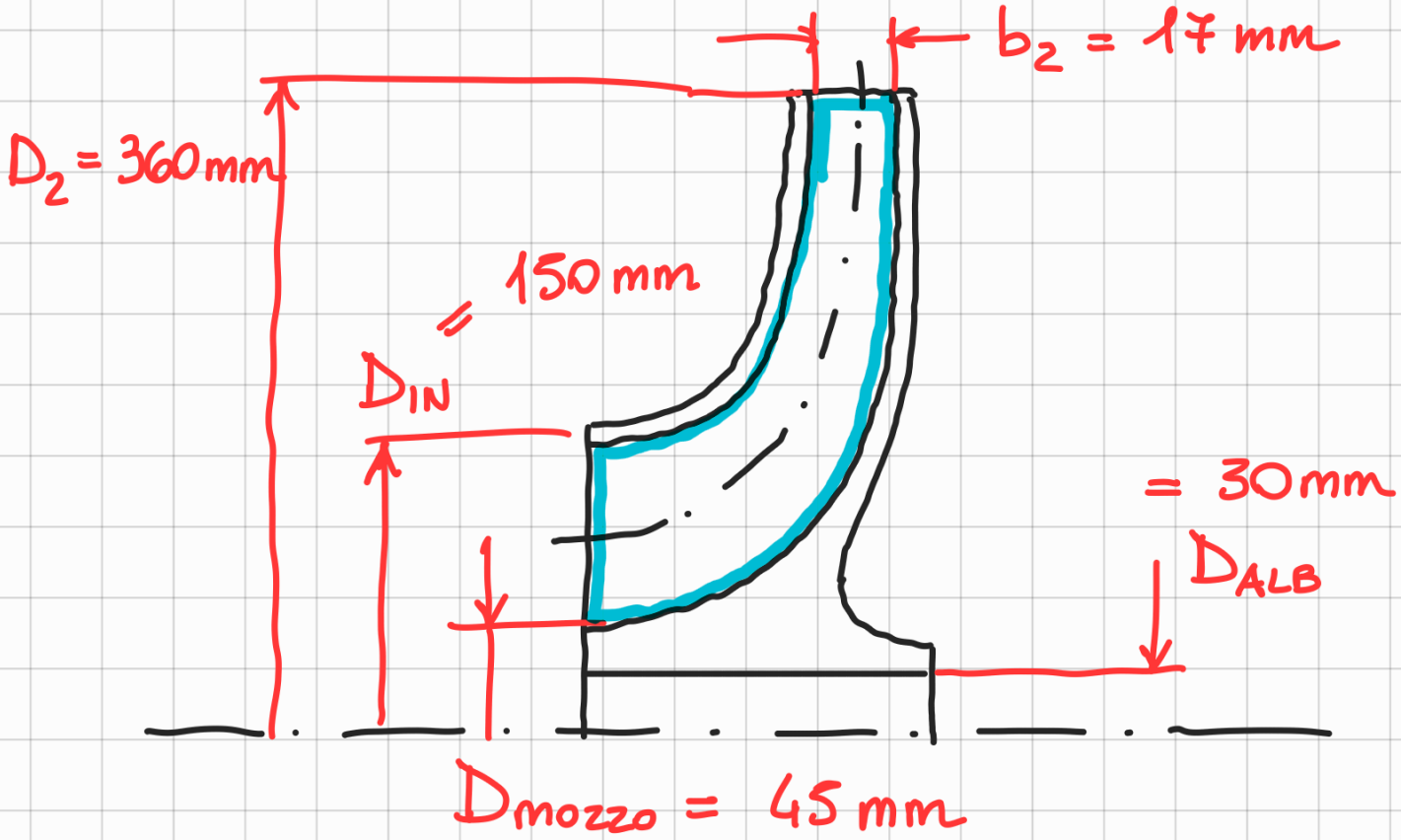
$= 149.2 \text{ mm}$

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

diametri unificati delle condotte

$D = 150 \text{ mm}$

CONDOTTO MERIDIANO



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

(MPa)

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

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

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

$$= 23.1\ kW$$

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

$$= 151400\ Nmm$$

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

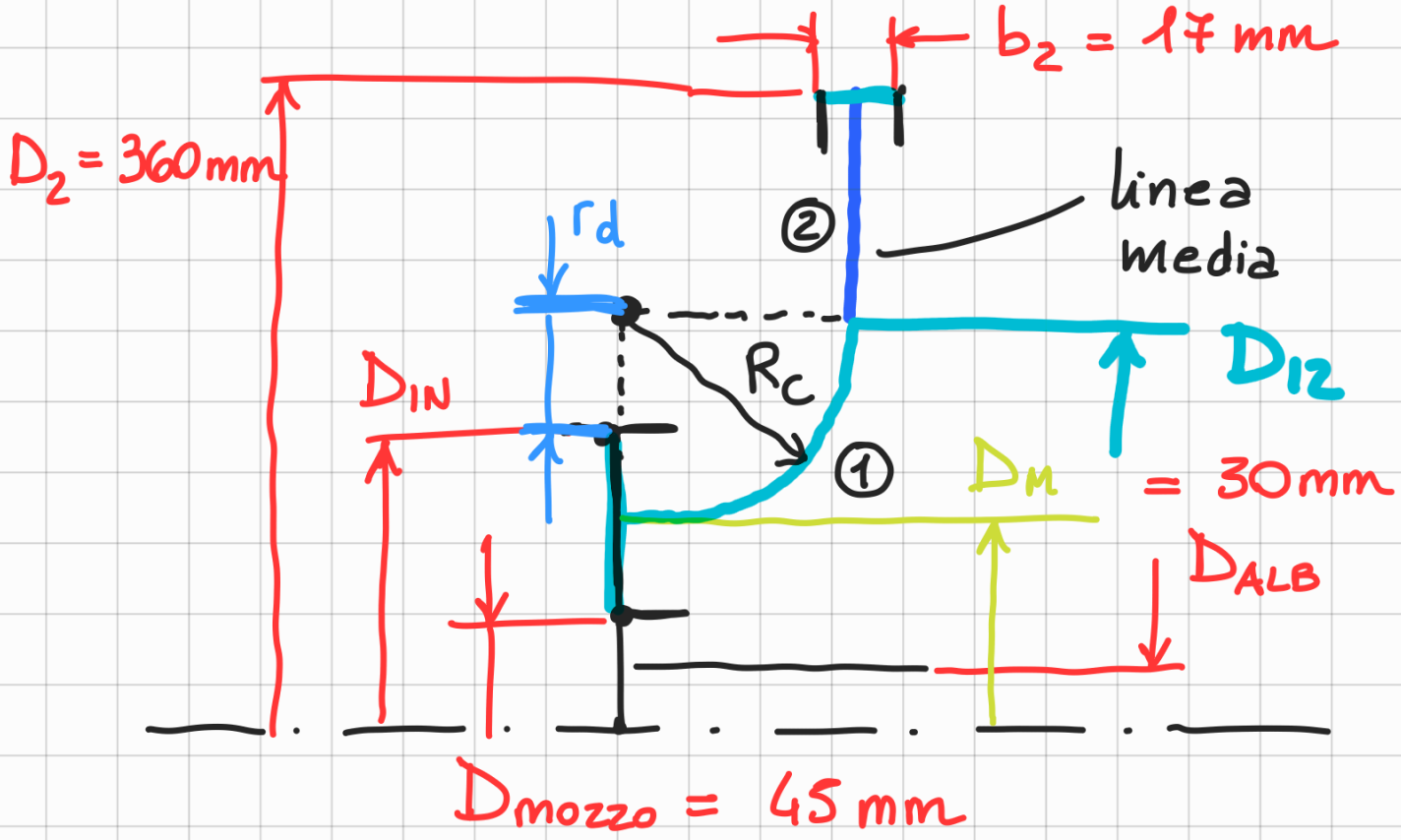
$$D_{alb} \geq D_{alb,\,min} \qquad D_{alb} = 30 \text{ mm}$$

(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

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

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

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

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

$$= 97.5 \text{ mm}$$

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

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

$$= 186 \text{ mm}$$

$$L_{TOT} = L_{①} + L_{②}$$

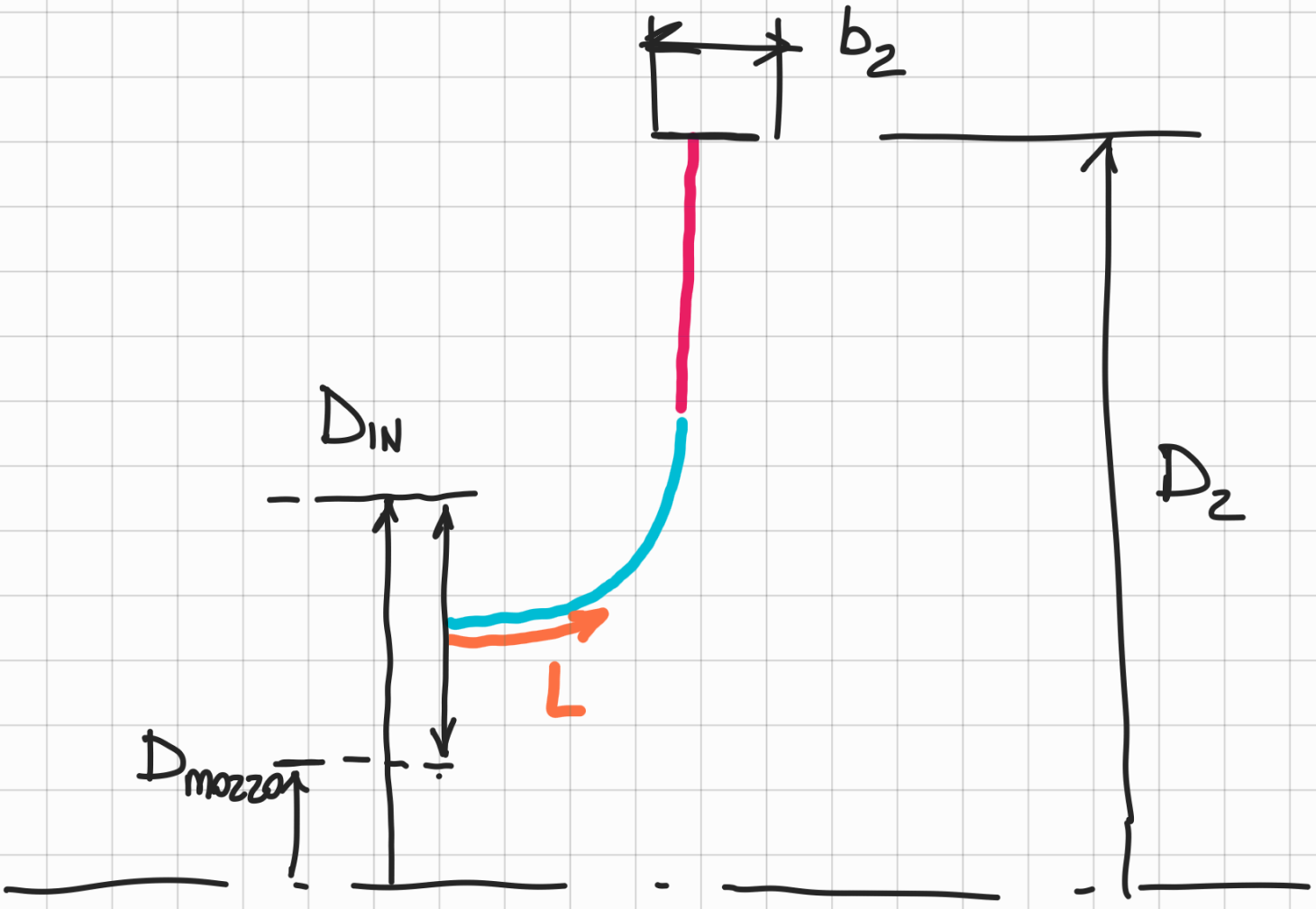
$$L_{①} = \frac{1}{\cancel{4}\,2} \cdot \cancel{2}\pi R_c = \frac{\pi R_c}{2}$$

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

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

$$= 87 \text{ mm}$$

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



$L = 0$

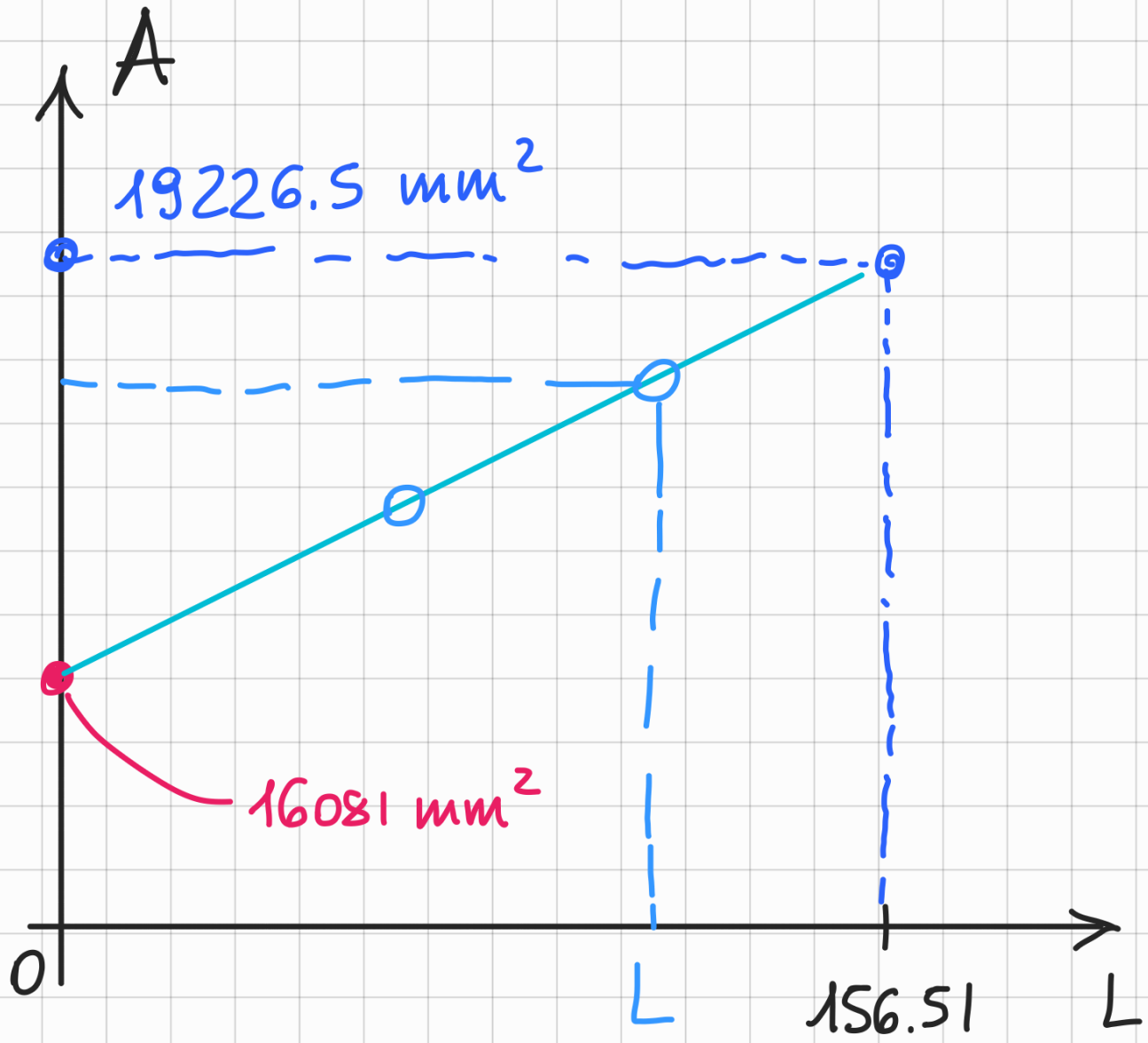
$$A = A_{IN} = \frac{\pi}{4}\left(D_{IN}^2 - D_{mozzo}^2\right)$$

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

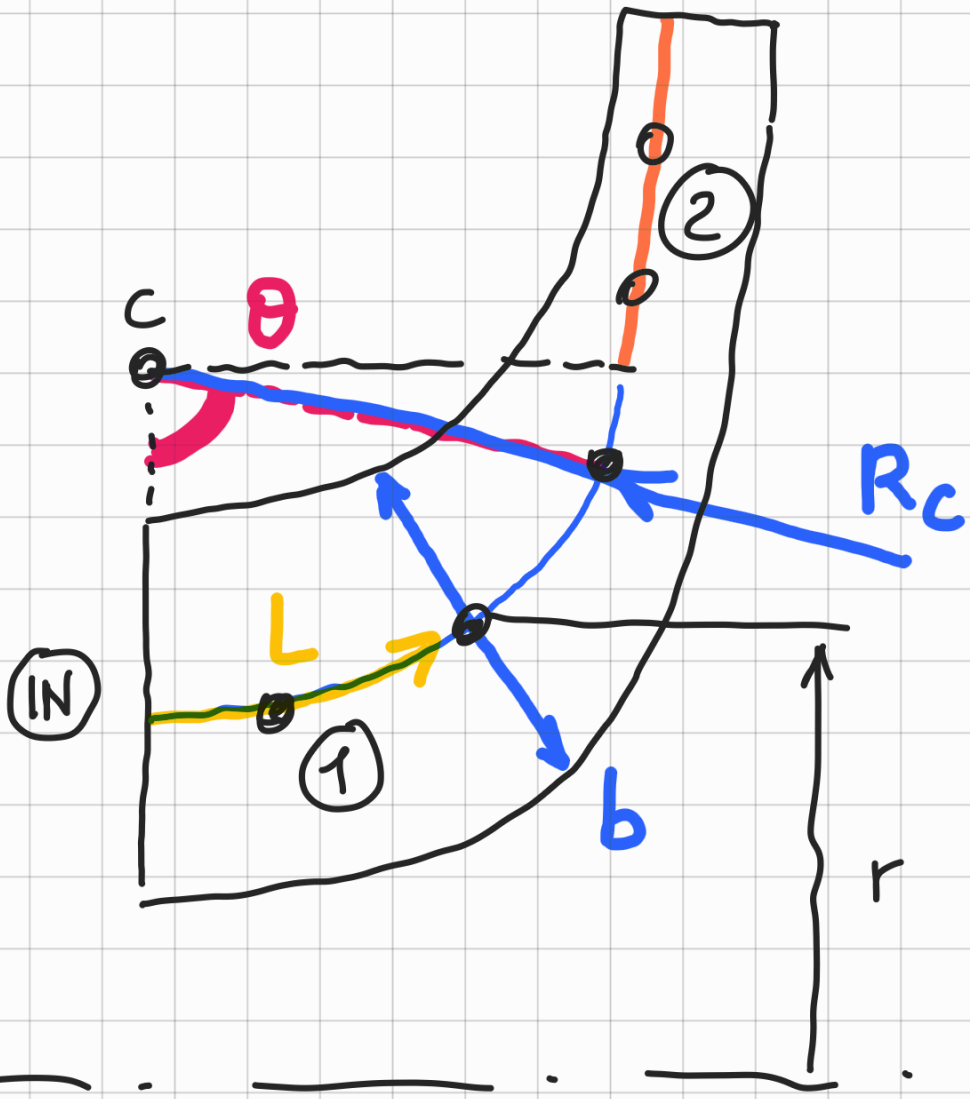
$$= 16081 \text{ mm}^2$$

$L = L_{TOT}$

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



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



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

nel tratto ①

$\vartheta[°] \longrightarrow \vartheta(rad)$

$$L = R_c \vartheta$$

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

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)

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

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

$$= 23.17 \text{ mm}$$

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

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

$$= 54.68 \text{ mm}$$

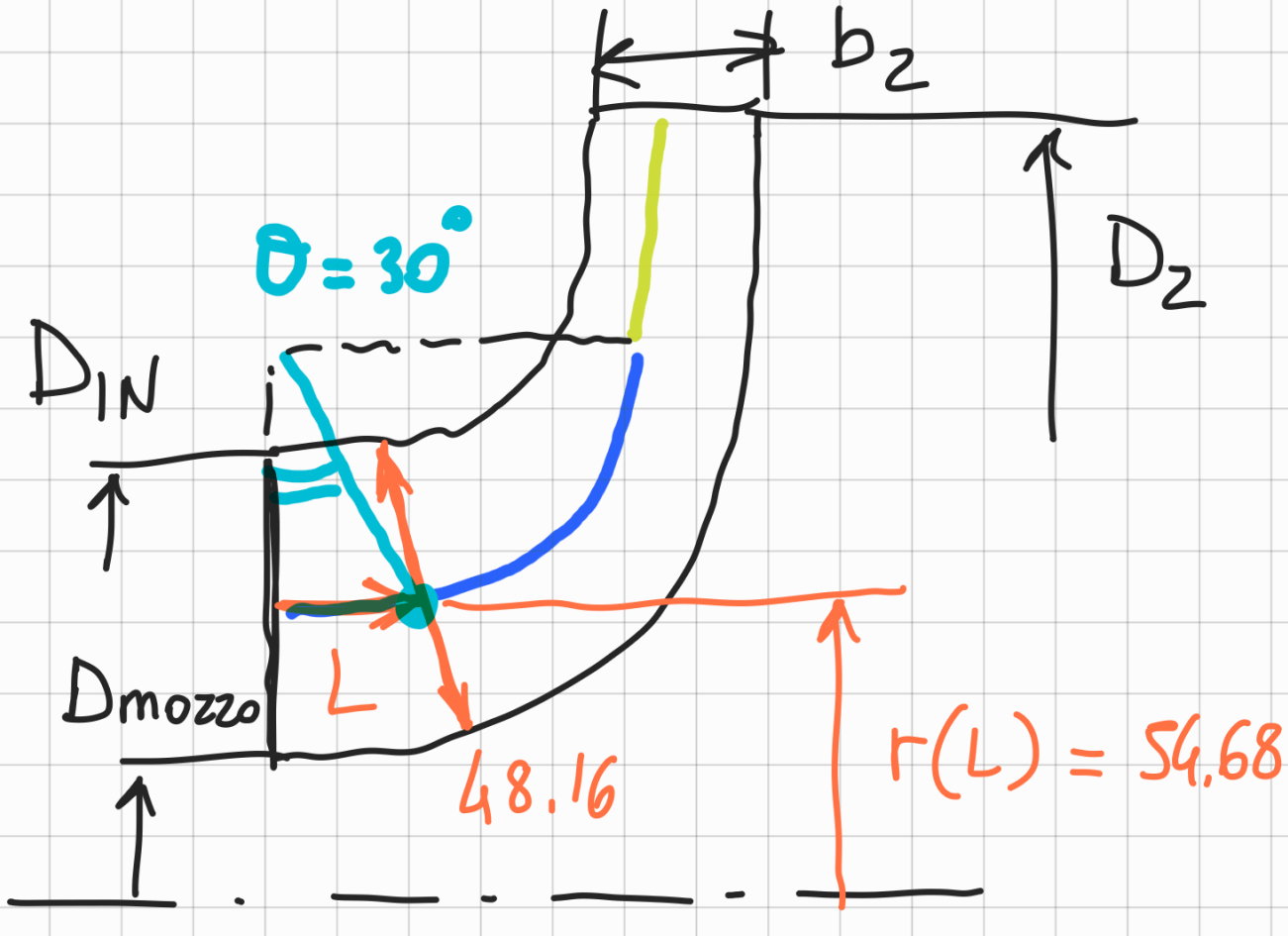
$$A(L) = A_{IN} + \frac{A_2 - A_{IN}}{L_{TOT}} \cdot L$$

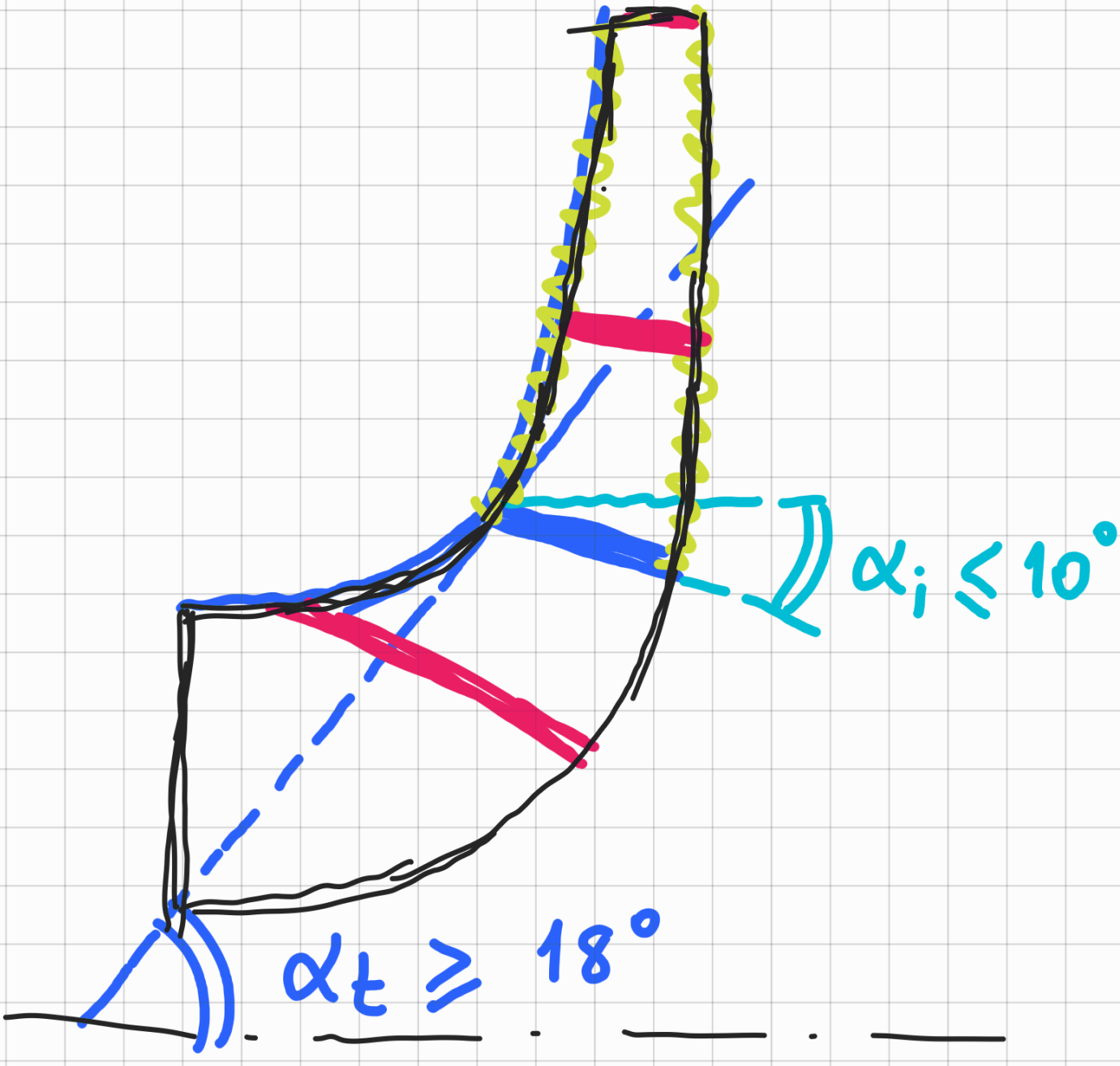
$$= 16081 + \frac{19226.5 - 16081}{156.51} \cdot 23.17$$

$$= 16546.7 \ mm^2$$

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

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




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