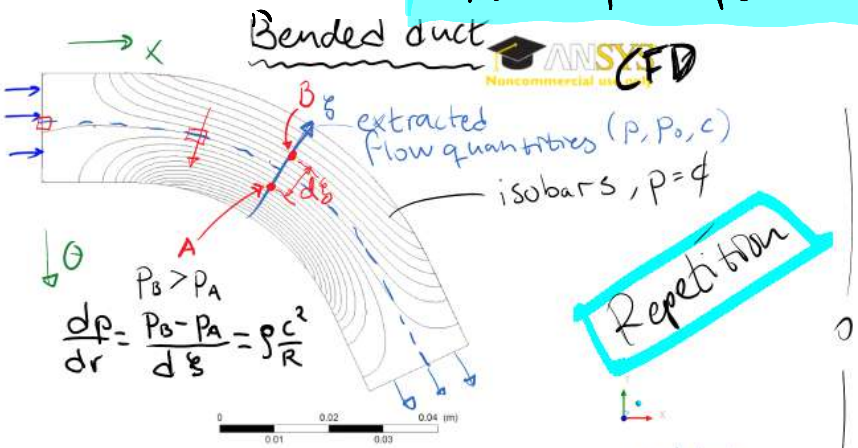
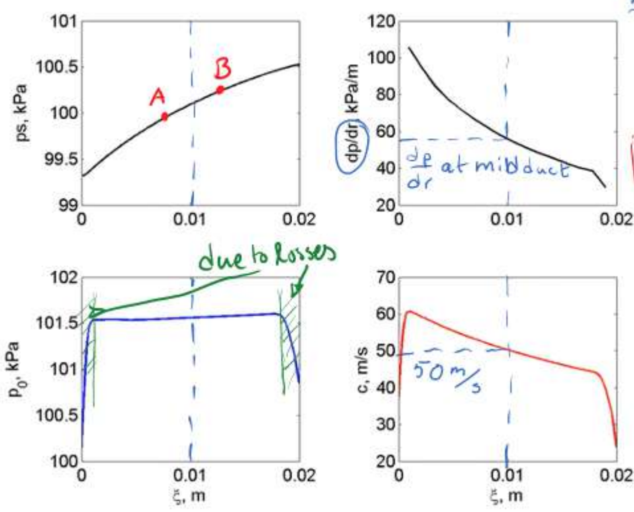
Global flow features (acceleration/deceleration ; bended duct)

Bended duct



$p_B > p_A$

$$\frac{dp}{dr} = \frac{p_B - p_A}{d\xi} = \rho \frac{c^2}{R}$$

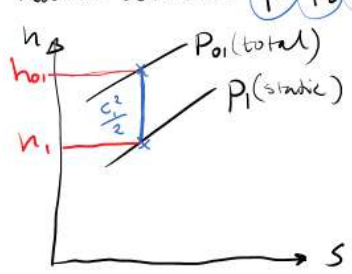


mid duct
$\rho = 1.18$
$R = 50\,mm$
$c = 50\,m/s$

$$\boxed{\frac{dp}{dr} = \rho \cdot \frac{c^2}{R}}$$

$$1.18 \cdot \frac{50^2}{0.05} = 58\,\frac{kPa}{m}$$

relation between p p_0 c (c determined by p_0 & p)



P_{01} — total condition, position index

$$h_{01} = h_1 + \frac{c_1^2}{2} \Rightarrow h_{01} - h_1 = \frac{c_1^2}{2}$$

(kinetic energy)

$$\left.\begin{aligned} h_{01} &= c_p T_{01} \\ h_1 &= c_p T_1 \end{aligned}\right\} \Rightarrow \frac{c_1^2}{2} = c_p (T_{01} - T_1)$$

isentropic relation $\frac{P_{01}}{P_1} = \left(\frac{T_{01}}{T_1}\right)^{\frac{\gamma}{\gamma - 1}}$

$$\left[\text{or } \frac{T_{01}}{T_1} = \left(\frac{P_{01}}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \right]$$

Local flow features of 2D aerodynamics

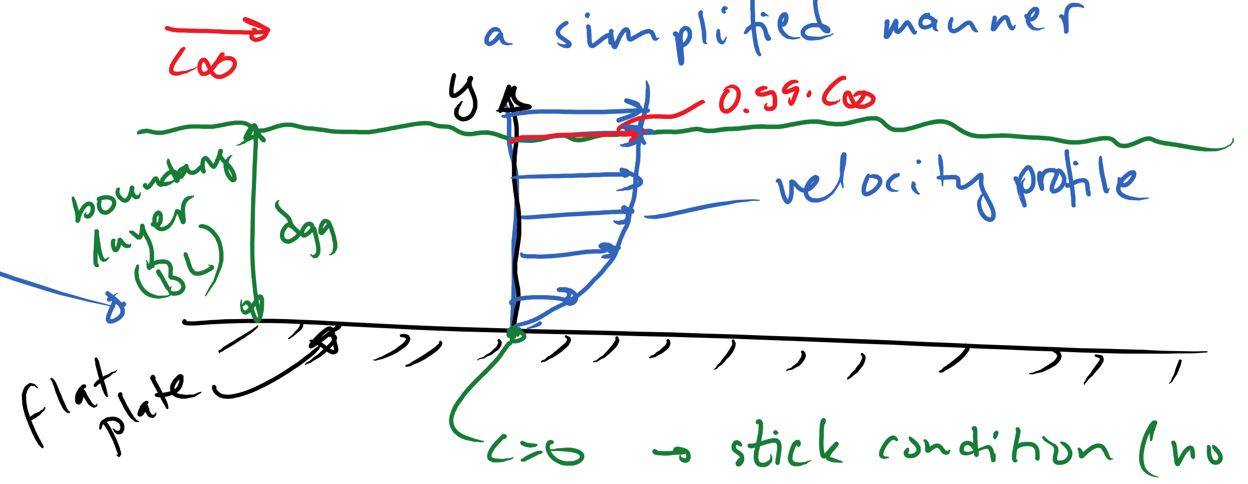
- Primarily due to losses
- Very limited in spatial extent (usually)

why losses?

because there is friction
→ reason fluid viscosity

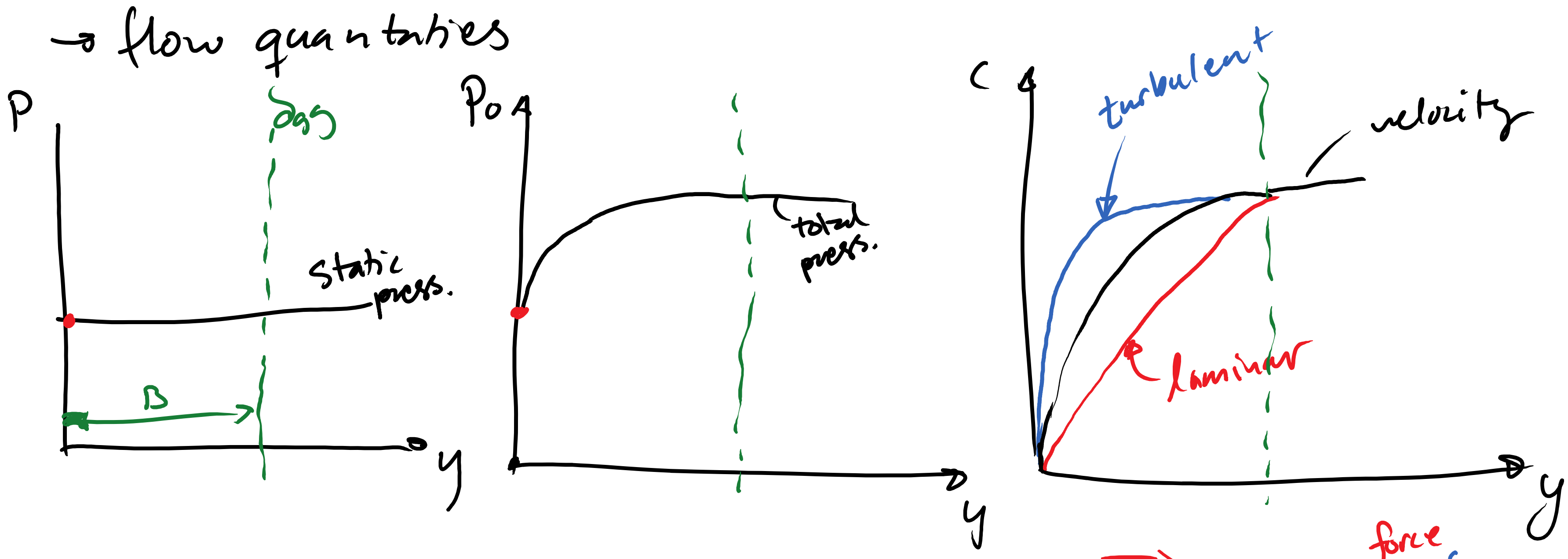
viscous fluid: all fluids are viscous
e.g. (oil → high viscosity, air → low viscosity)

inviscid fluid: fluid with zero viscosity
are used to treat the flow (modelling) a simplified manner

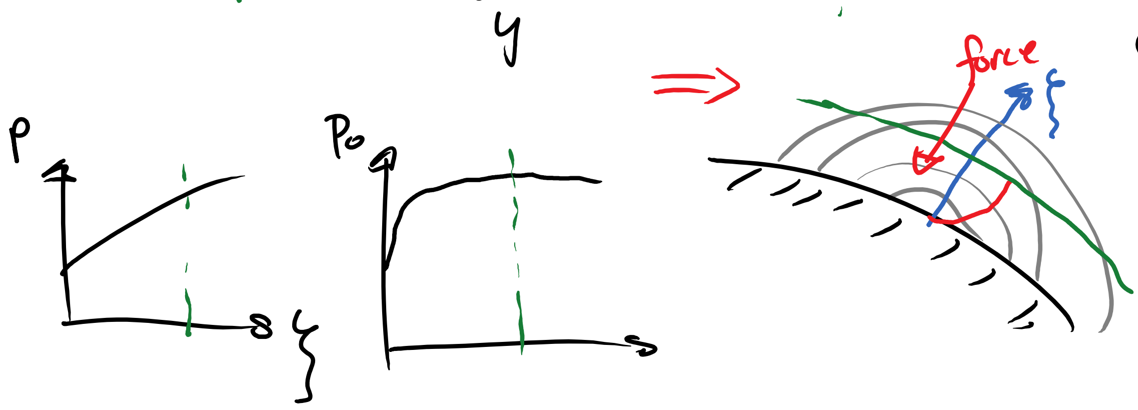


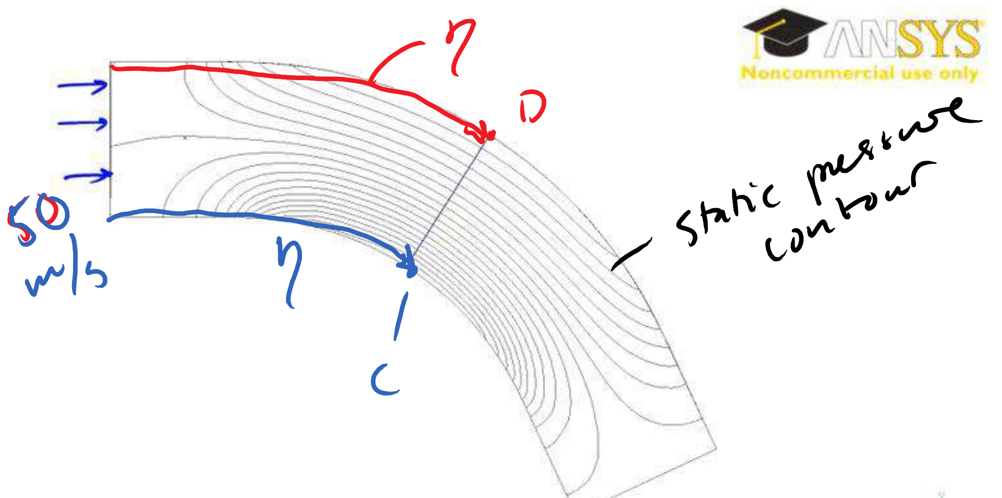
viscosity ↓ → δ_{99} ↓

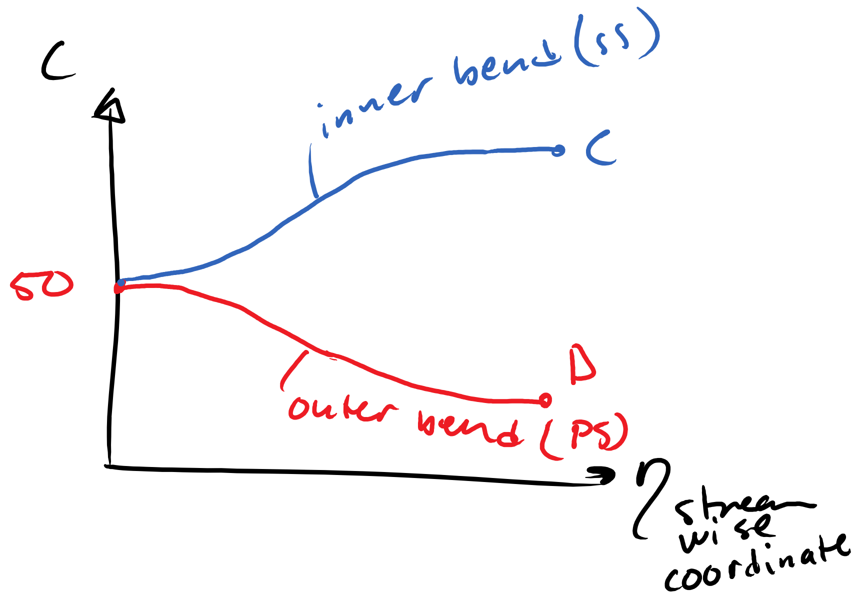
→ flow quantities

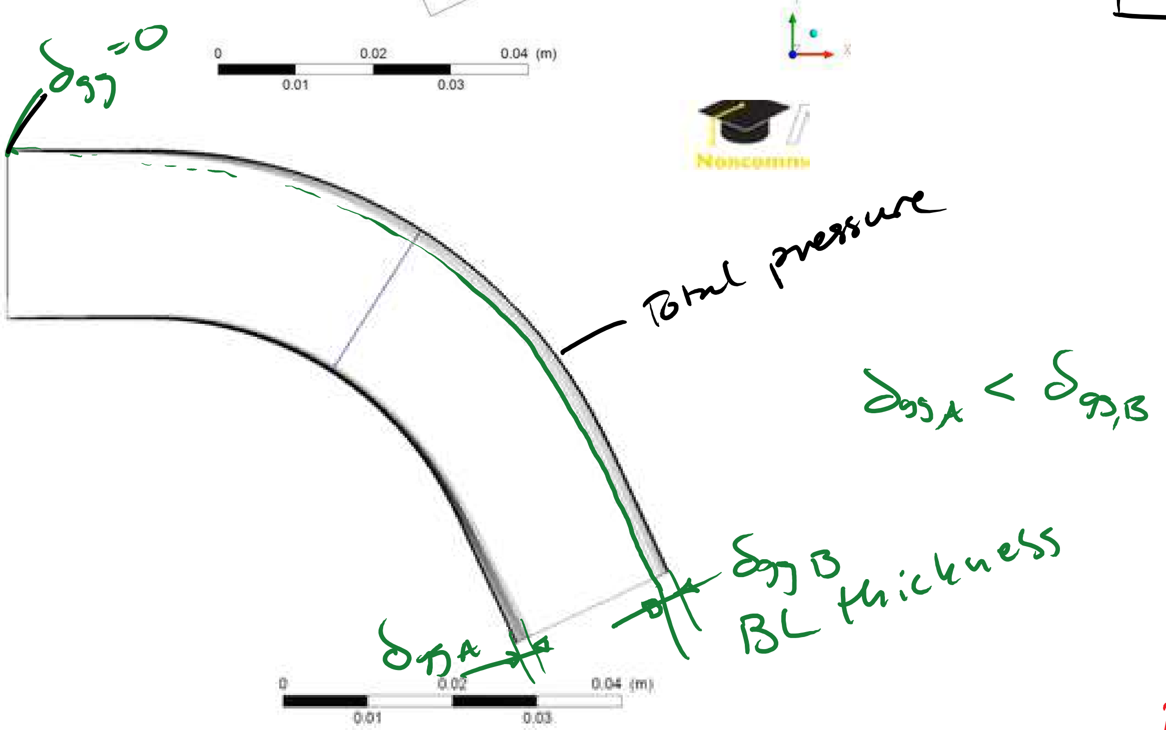


→ curved walls

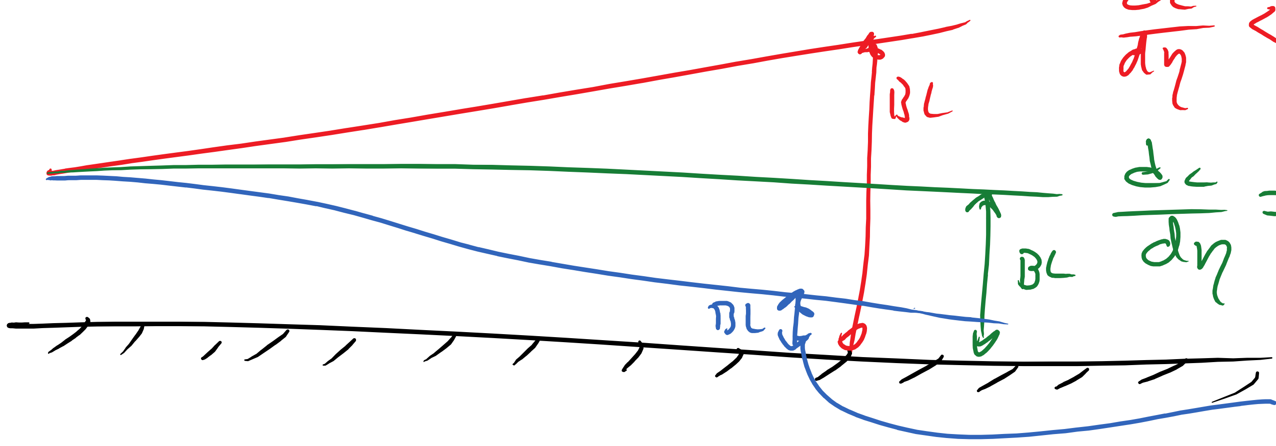








$\delta_{99,A} < \delta_{99,B}$

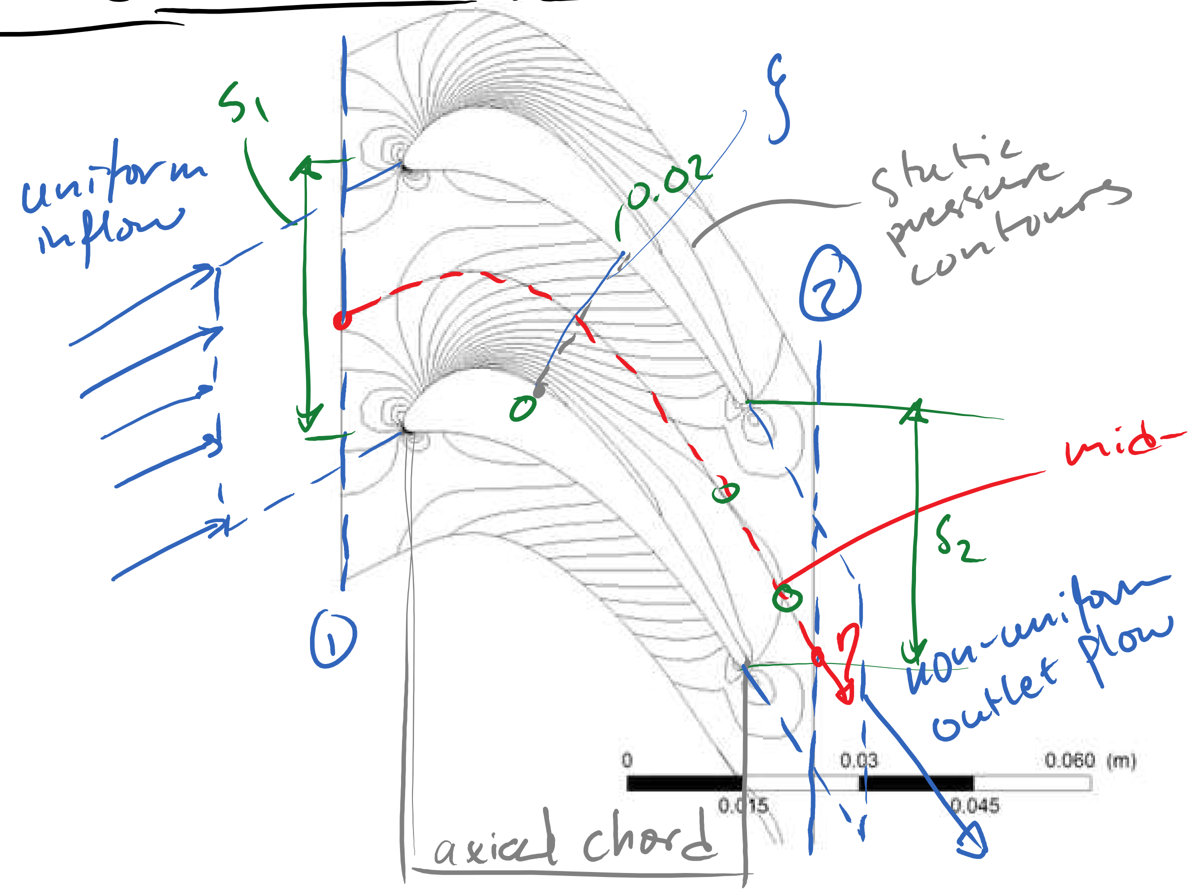


$\frac{dc}{d\eta} < 0$ decelerating

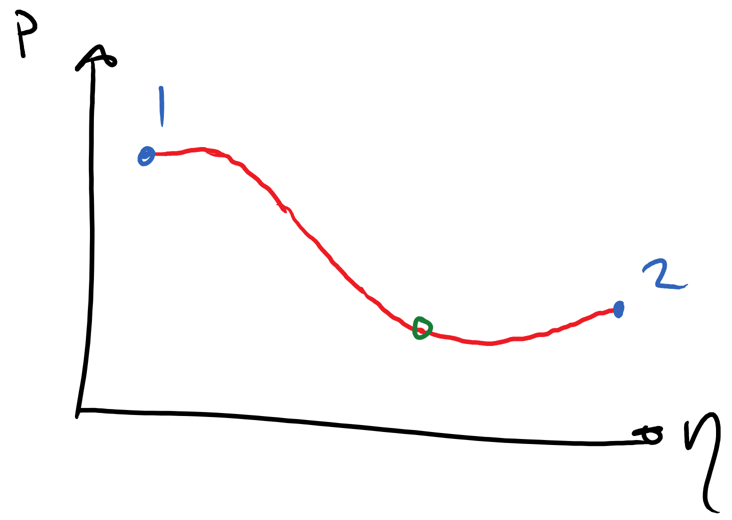
$\frac{dc}{d\eta} = 0$

$\frac{dc}{d\eta} > 0$ accelerating flow if $\left|\frac{dc}{dy}\right|$ is to great (and $\frac{dp}{dy}$ ↑↑) => risk of seperation

turbine blade passage



plot the static pressure on the mid-passage in streamwise direction (η)



→ decrease in pressure from 1 to 2

→ to the acceleration

→ the 2D static pressure field is a combination of flow deviation and (here) acceleration

turbine blade

→ the reason for having the channel cross-section decreasing (or) increasing $s_1 = s_2$ if $r_m = ¢$

$$s_1 = \frac{2\pi \cdot r_m}{N} \quad \Rightarrow \quad s = \text{const.}$$

N # blades

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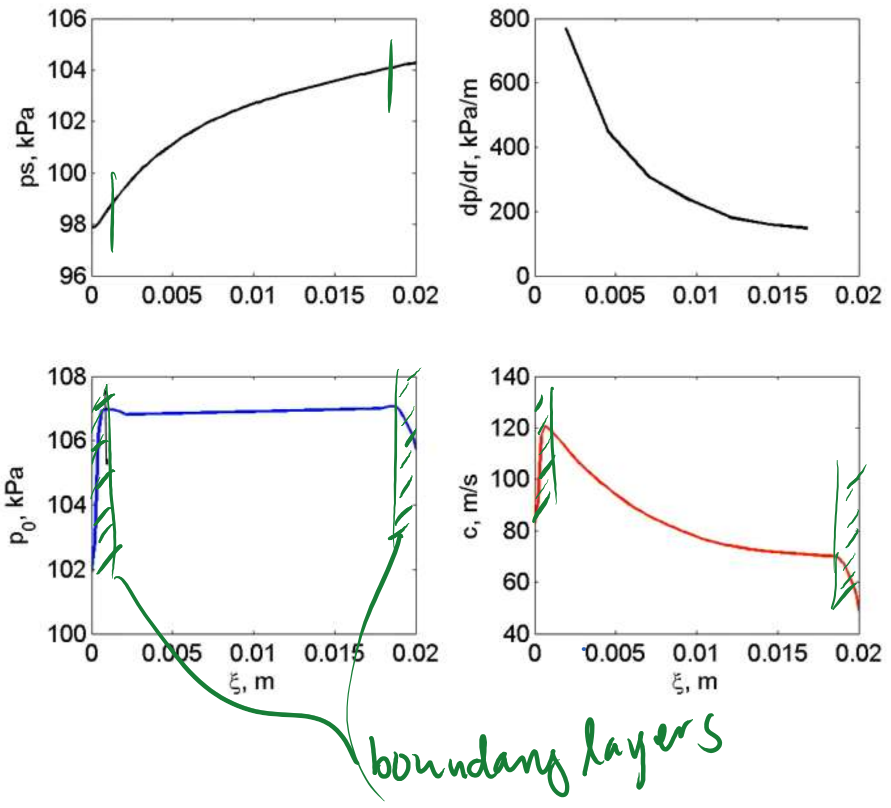
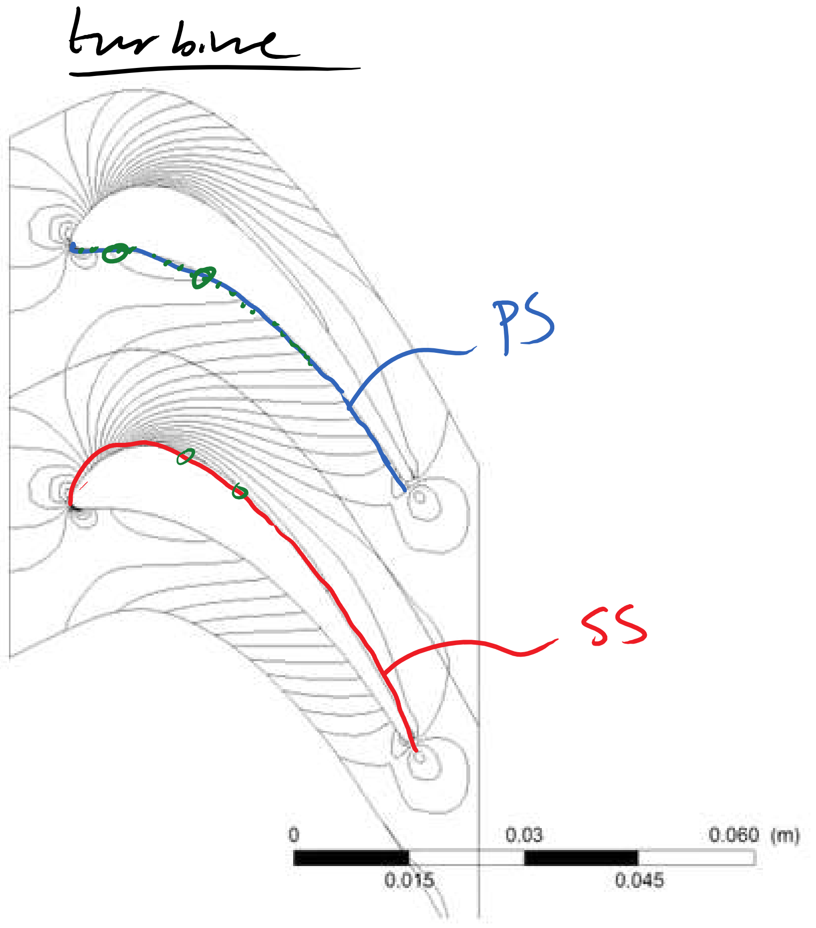
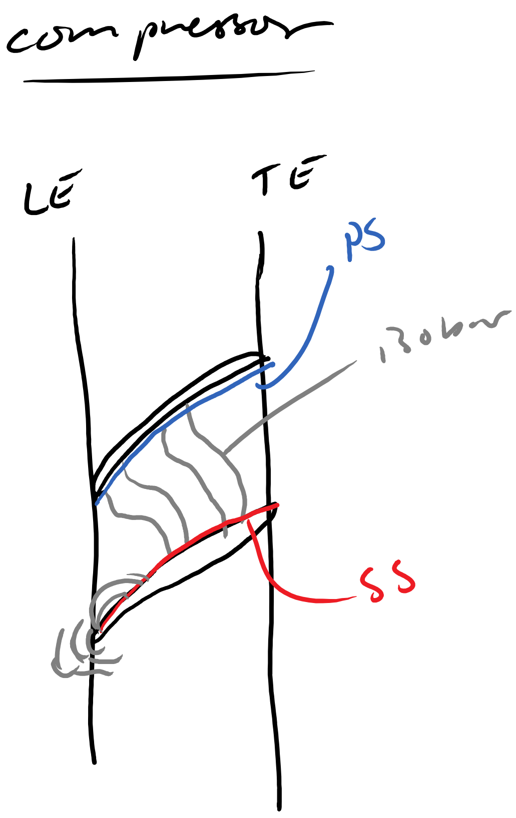
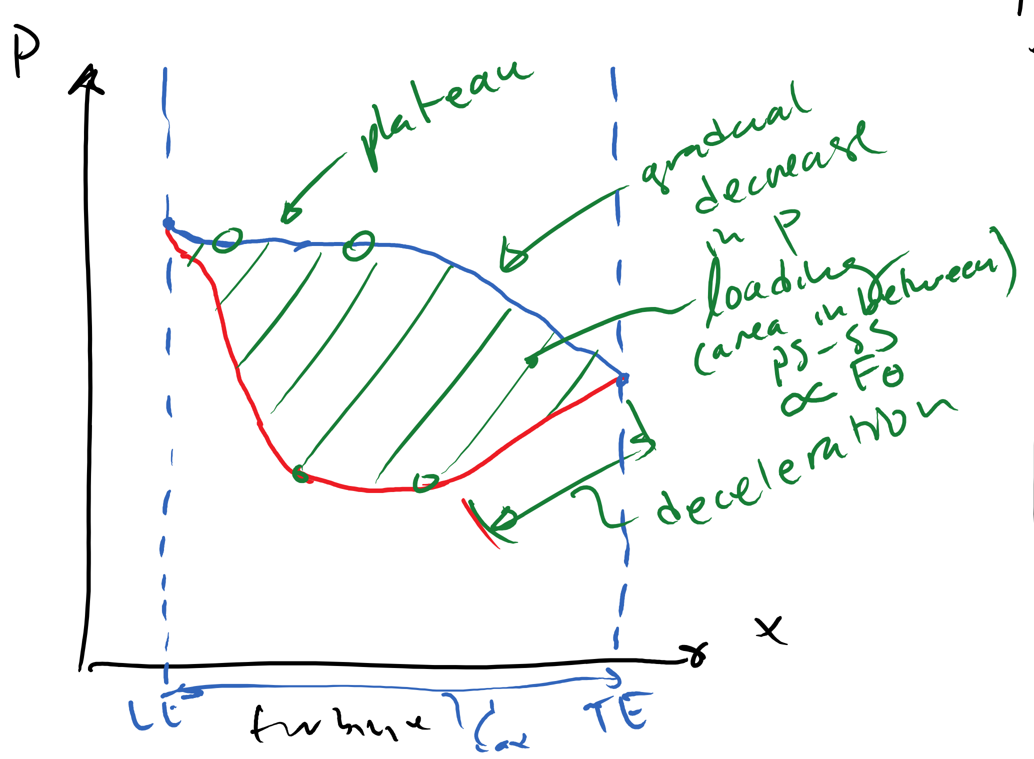
flow quantities on a line normal to the mean flow direction at about mid-chord

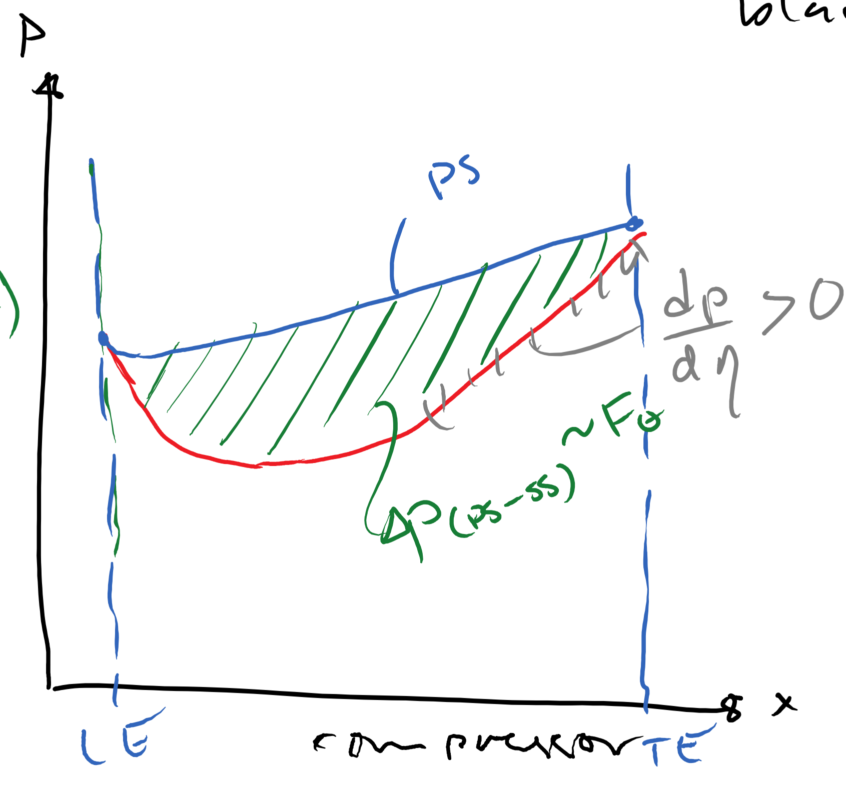




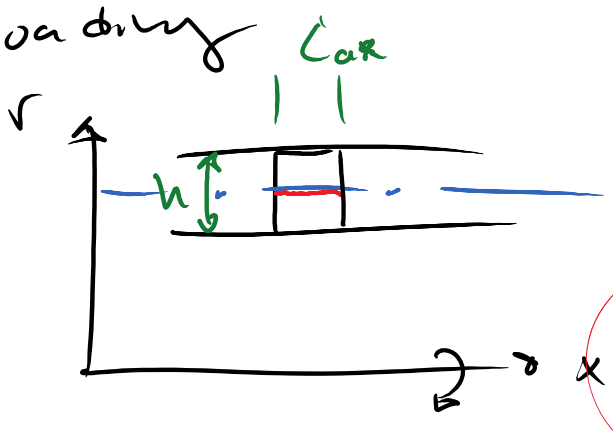


distribution of static pressure around turbomachinery blades





... loading



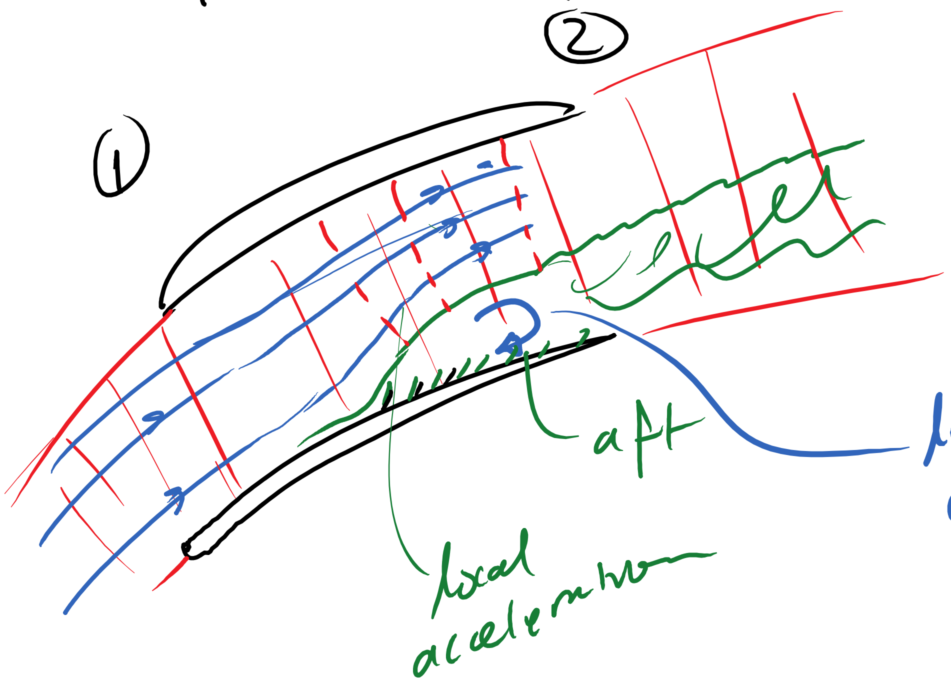
x loading $\sim F_\theta \sim \Delta c_\theta , U \sim \Delta h_0 \sim P$

if known

(Π) pressure ratio

$\boxed{\dot m \cdot \Delta c_\theta = F_\theta}$

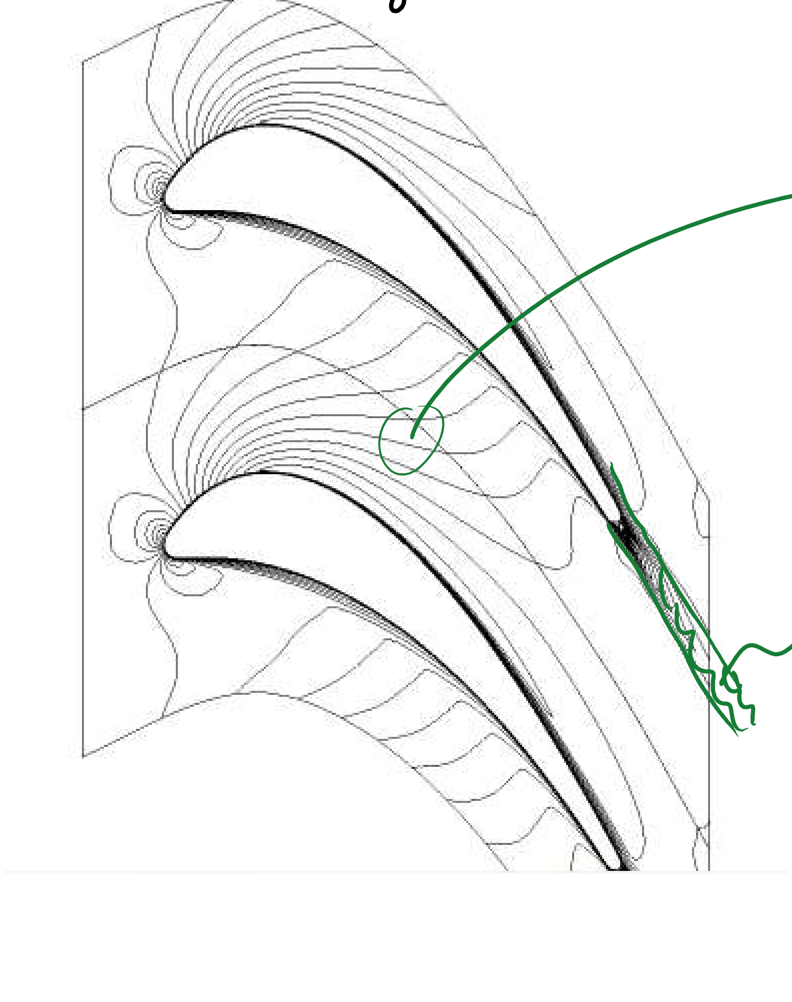
compressor flow on aft suction side



local area of separation if $\left|\frac{dp}{dn}\right| > 0$ too high!

eventually if $p_2 \downarrow < p_1 \Rightarrow$ surge!

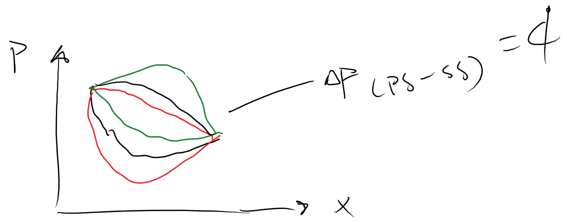
velocity contours



change in velocity due to deviation and acceleration (global flow features)

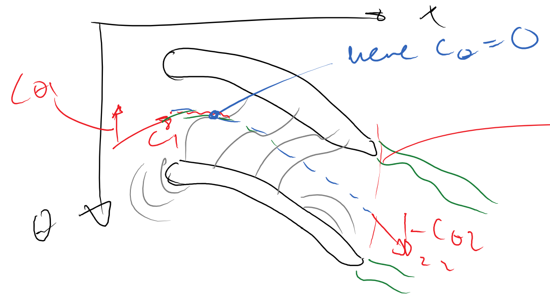
wake (where you have the main losses) local flow features

change of velocity in the BL region

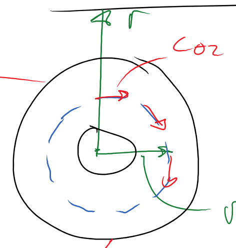


→ shape of the blade affects the loading

→ shape of the loading affects how the BL develops → associated with losses



machine axis view



swirling character

$$\boxed{\frac{dp}{dr} = \rho \cdot \frac{c_\theta^2}{R}}$$

radial equilibrium eq.

$r_{hub} \leq R \leq r_{casing}$