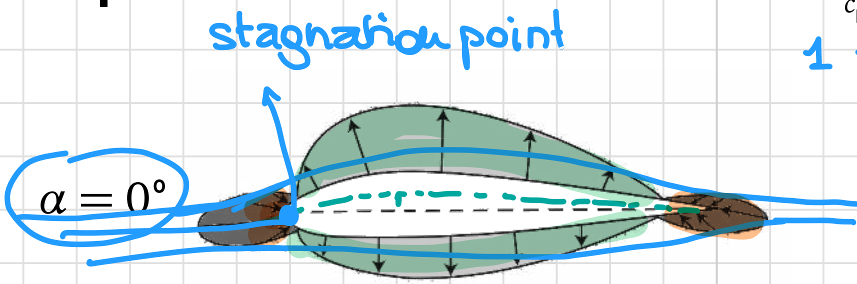
ME-445 AERODYNAMICS

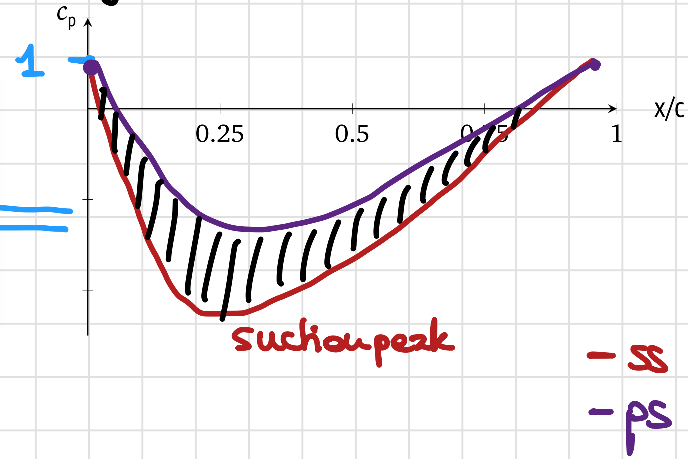
02 - Basic concepts

K. Mulleners

Airfoil pressure distributions

$$C_N = \int_0^1 \left(C_{p_{ps}} - C_{p_{ss}} \right) d\left(\frac{x}{c}\right)$$





$$c_p = \frac{p - p_\infty}{\frac{1}{2}\rho U_\infty^2} \quad < 0 \quad > 0$$

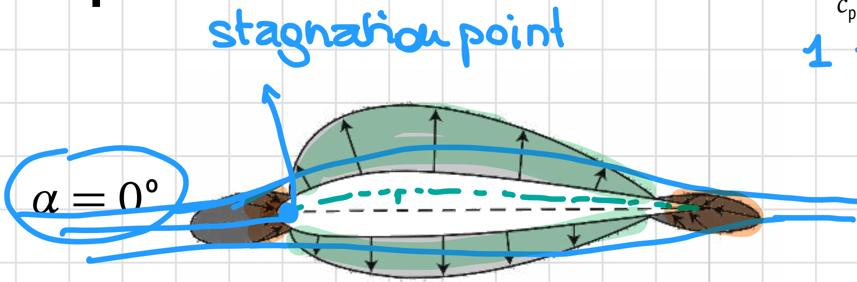
in stagnation point:

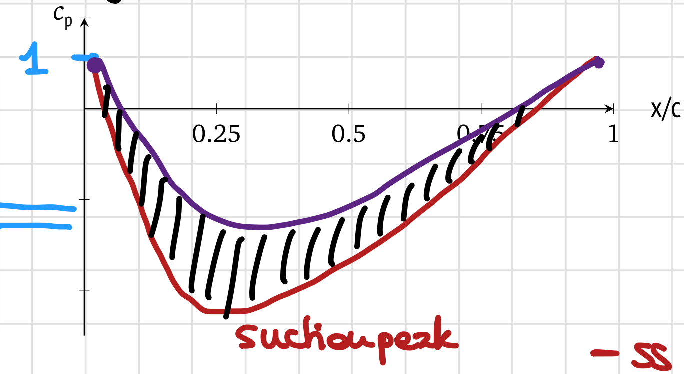
$$p_{sp} + \frac{1}{2}\rho \underbrace{U_{sp}^2}_{=0} = p_\infty + \frac{1}{2}\rho U_\infty^2$$

$$\Rightarrow \quad \frac{p_{sp} - p_\infty}{\frac{1}{2}\rho U_\infty^2} = \boxed{1 = c_p}$$

Airfoil pressure distributions

$$C_N = \int_0^1 \left(c_{p_{ps}} - c_{p_{ss}} \right) d\left(\frac{x}{c}\right)$$

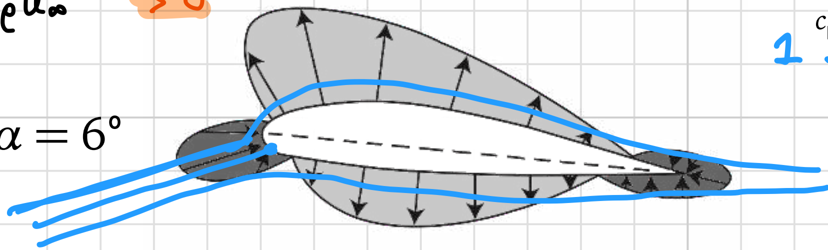


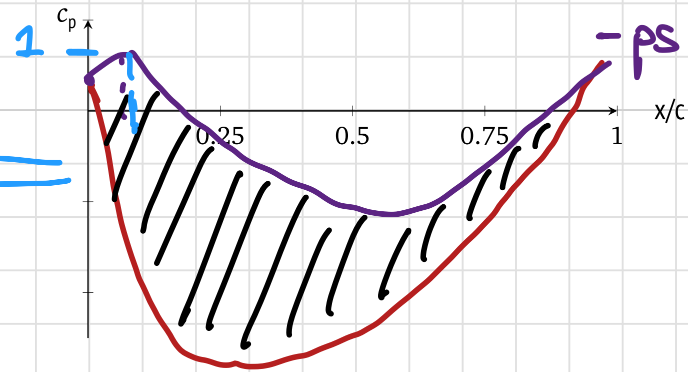


$$c_p = \frac{p - p_\infty}{\frac{1}{2}\rho u_\infty^2}$$

< 0

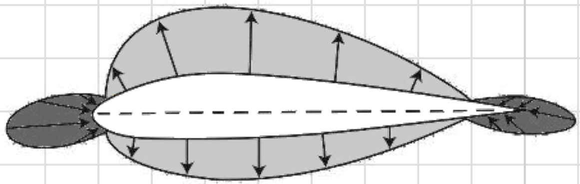
> 0

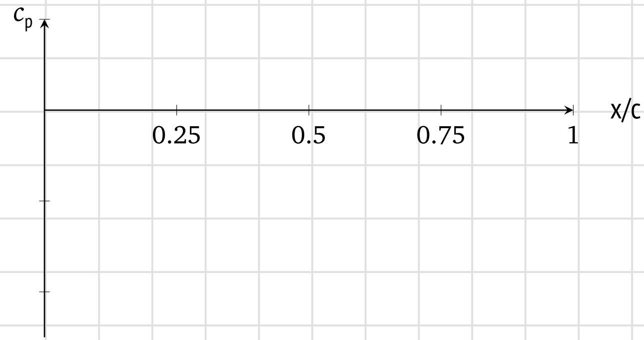




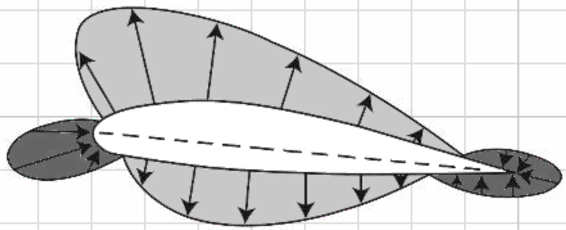
Airfoil pressure distributions

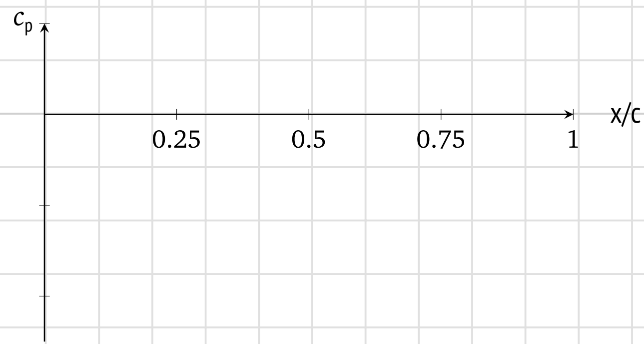
$\alpha = 0°$



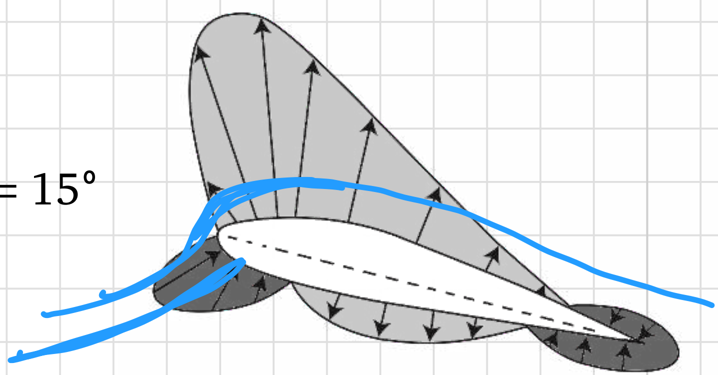


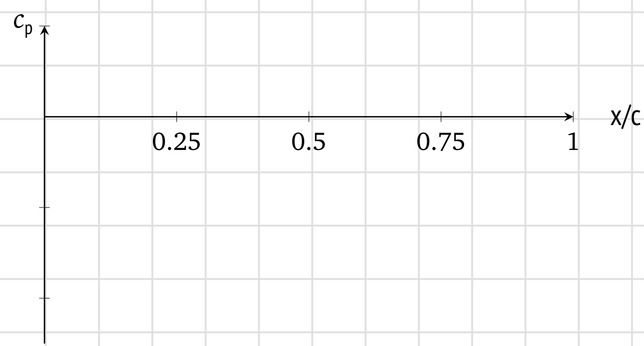
$\alpha = 6°$





$\alpha = 15°$

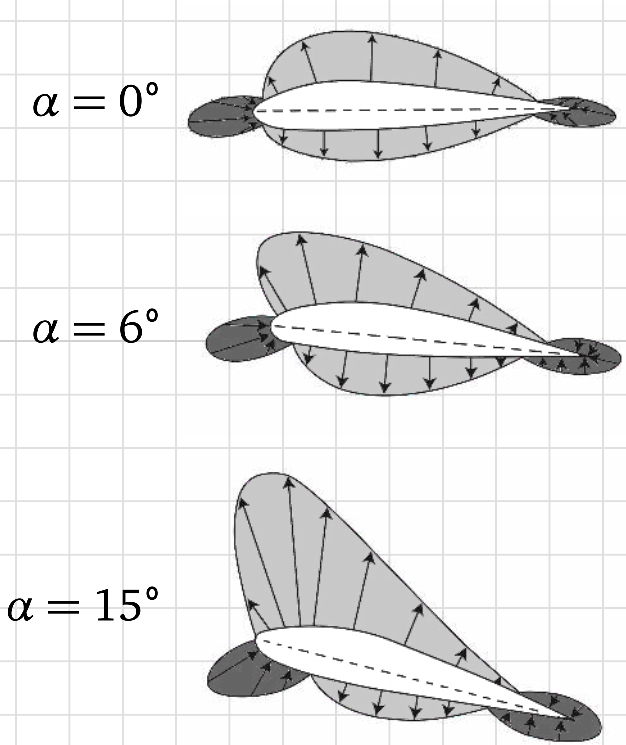


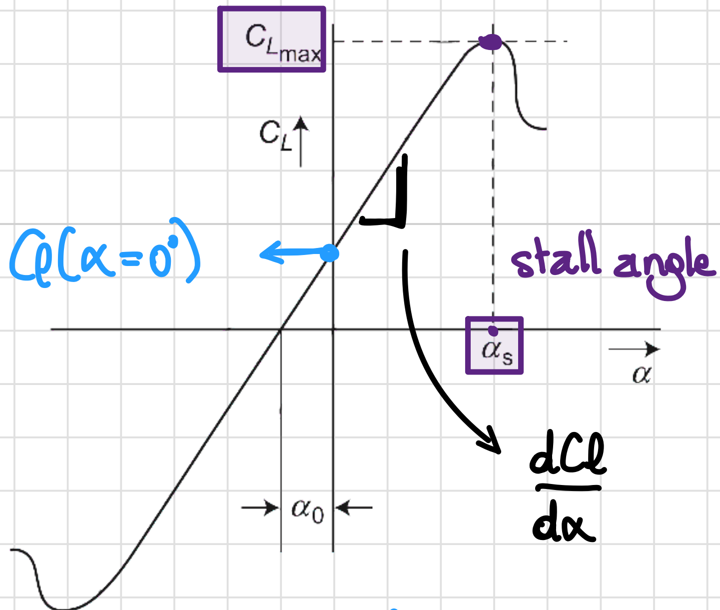


Airfoil lift polar → $c_\ell(\alpha)$

for given airfoil @
given Ma & Re

- $dC_l/d\alpha$ ☐
- α_0 ☐
- α_{stall} ☐
- $C_{l,max}$ ☐





$\alpha_0 = \alpha$ for which we have $c_\ell = 0$

Airfoil lift polar

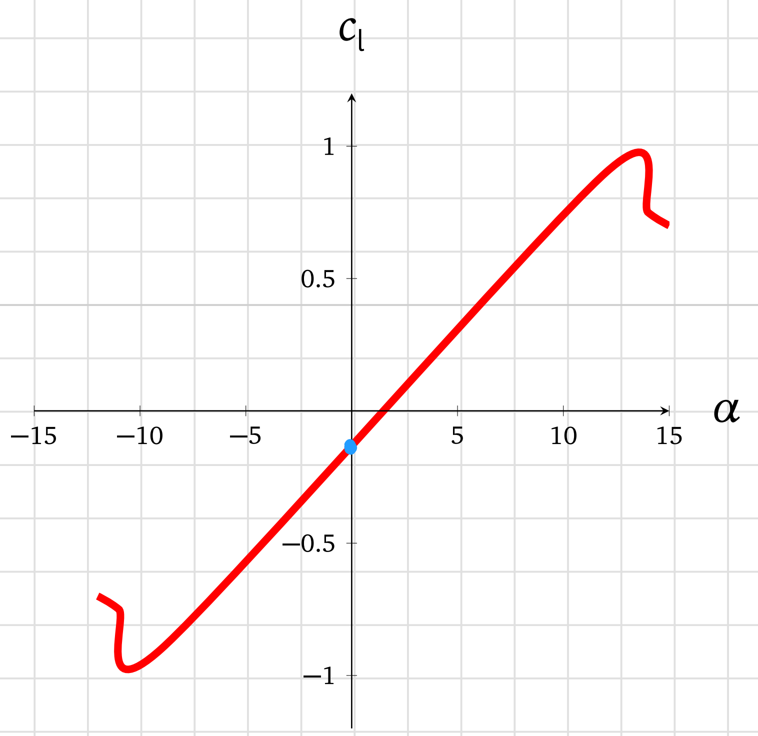
Which airfoil belongs to this curve

(A)

(B)

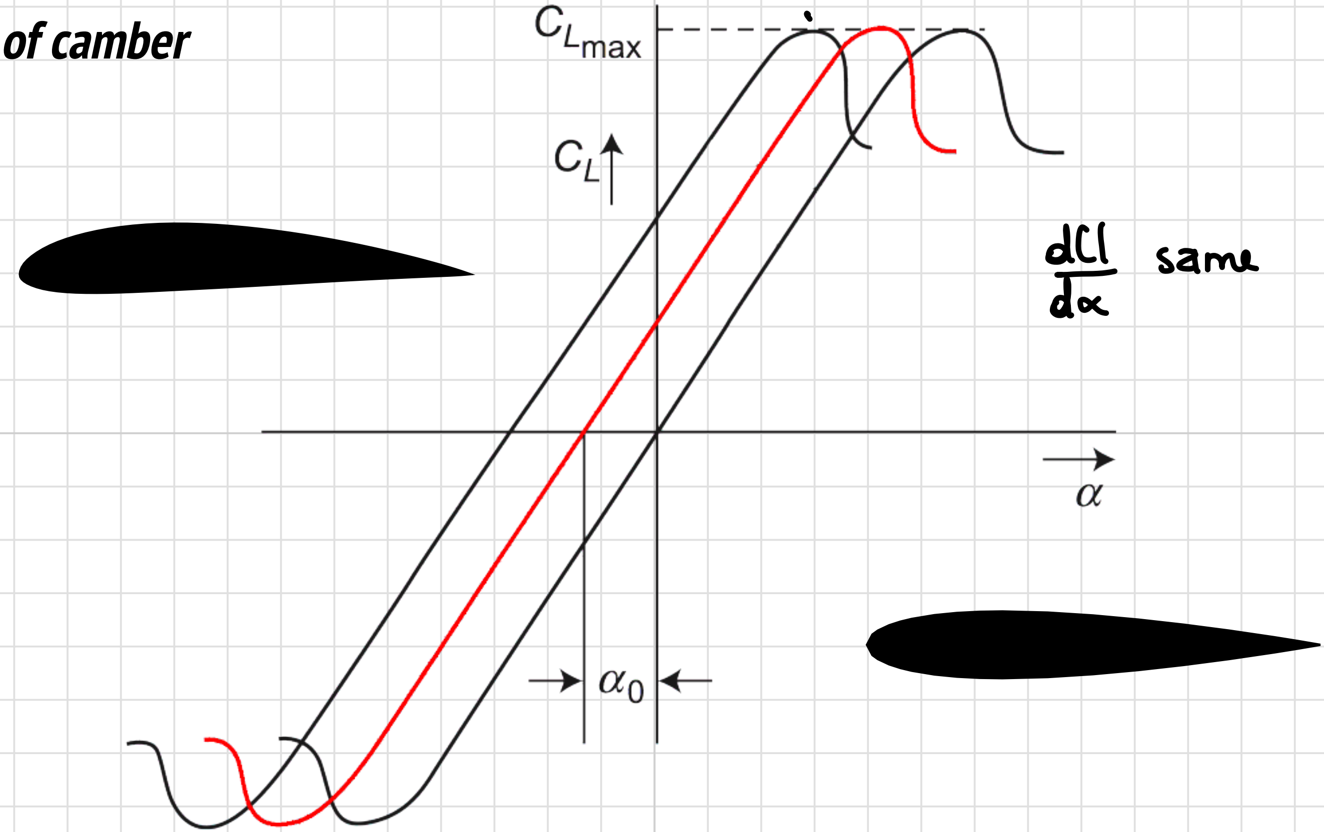
(C)

@ $\alpha = 0 \rightarrow C_l < 0$



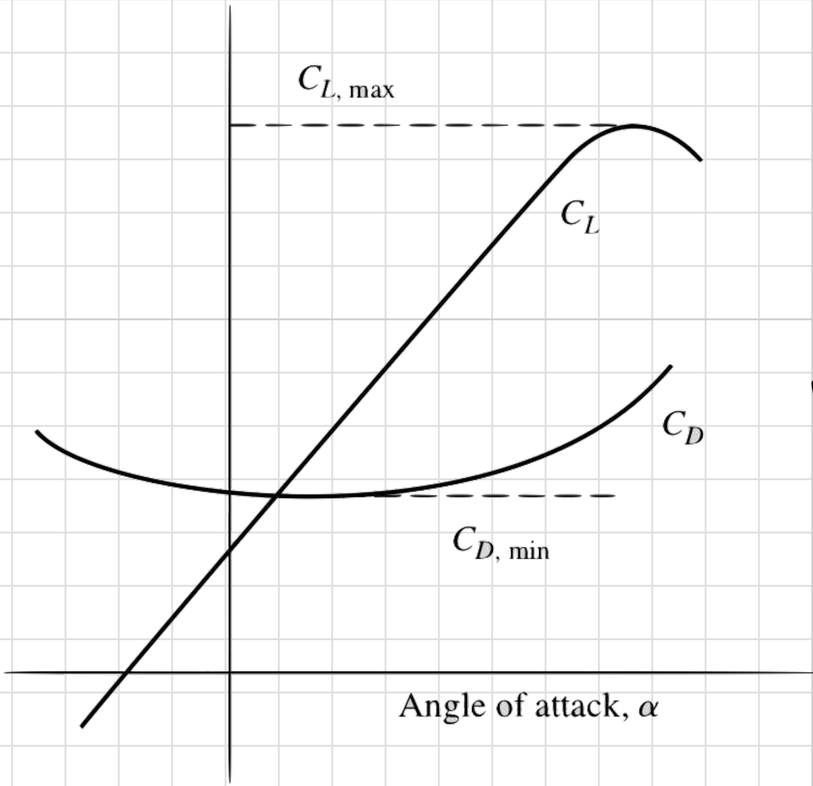
Airfoil lift polar

Effect of camber



$\frac{dCl}{d\alpha}$ same

Lift and drag



to stay aloft / keep altitude
(cruising flight)

$$L \geq W$$

$$c_l \frac{1}{2}\rho u_\infty^2 S \geq W$$

$$\Rightarrow u_\infty \geq \sqrt{\frac{2W}{\rho c_l S}}$$

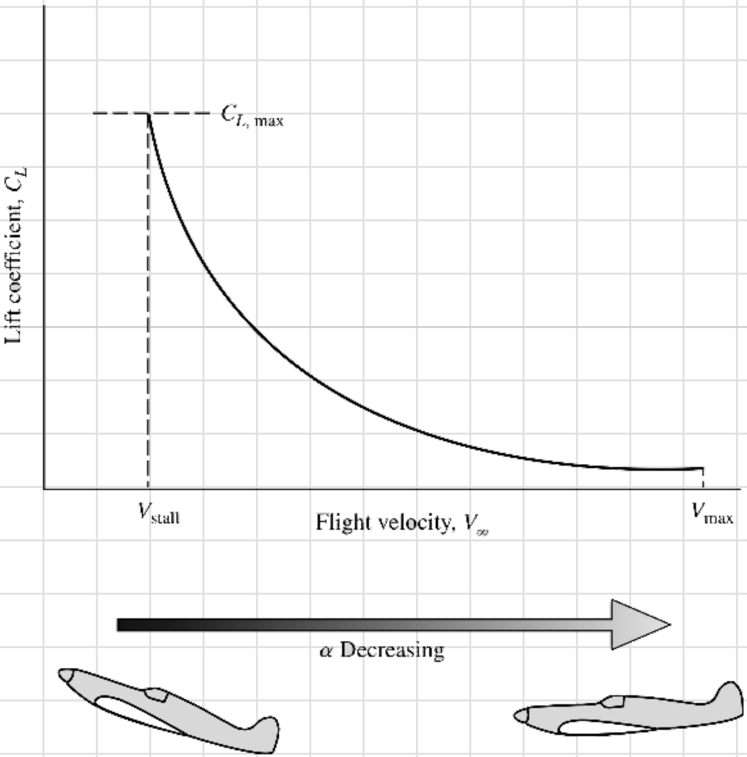
to move forward

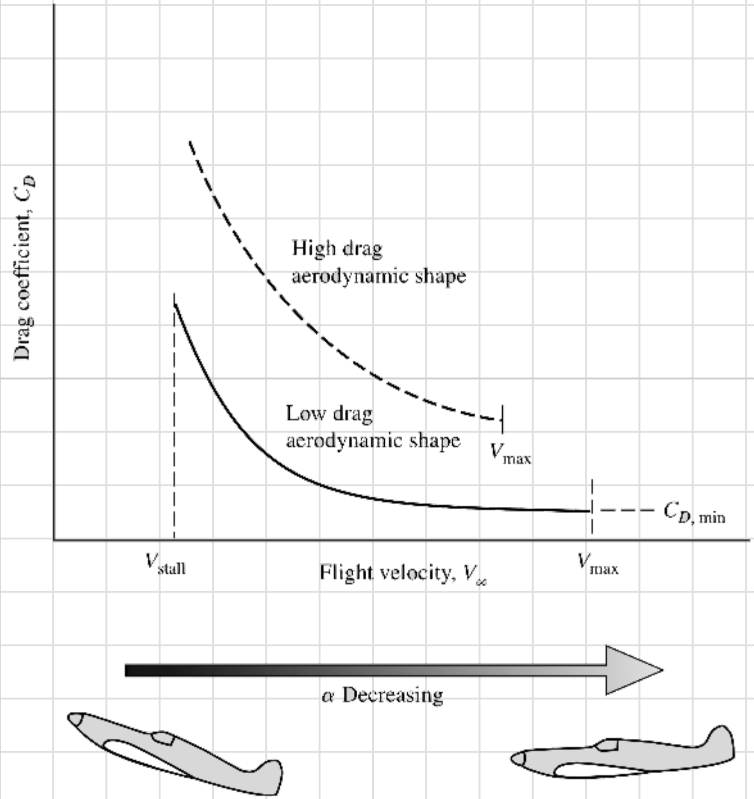
$$D \leq T$$

$$\frac{1}{2}\rho u_\infty^2 S c_D \leq T$$

$$u_\infty \leq \sqrt{\frac{2T}{\rho S c_D}}$$

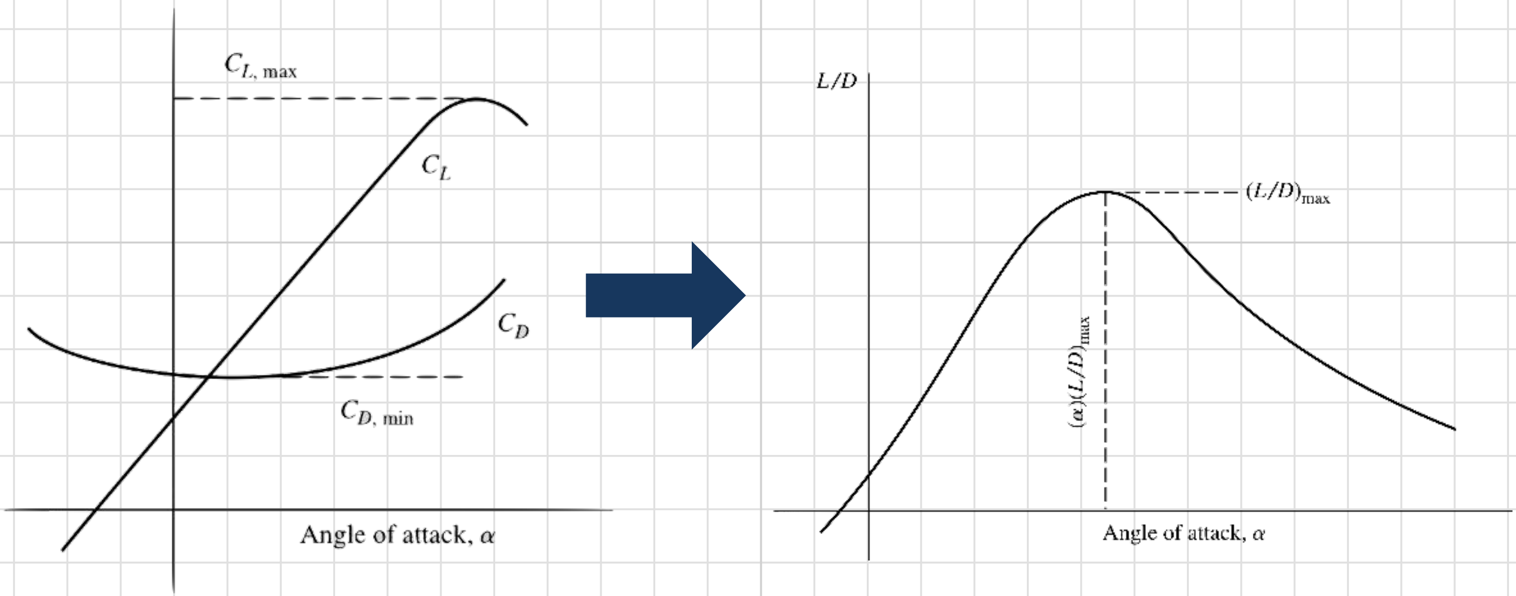
Variation of force coefficients with flight velocity



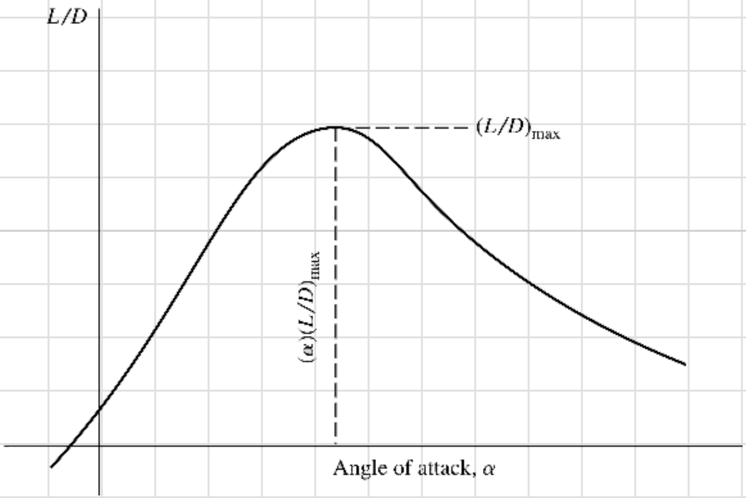


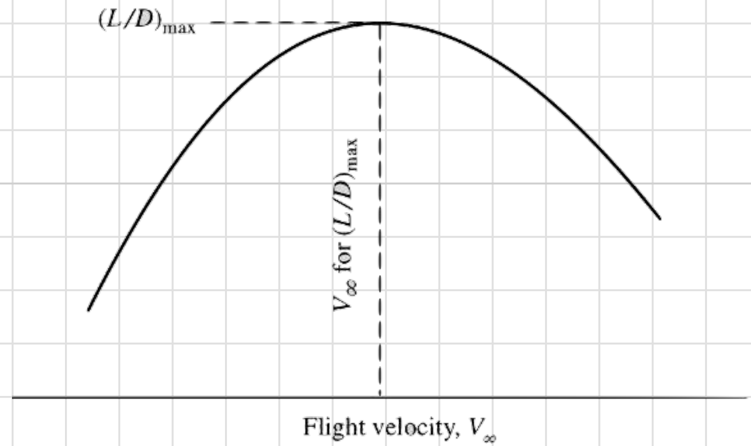
Lift-to-drag ratio

$$\frac{L}{D} = \frac{C_L}{C_D} \, \frac{\cancel{\tfrac{1}{2}\rho U_\infty^2 S}}{\cancel{\tfrac{1}{2}\rho U_\infty^2 S}}$$

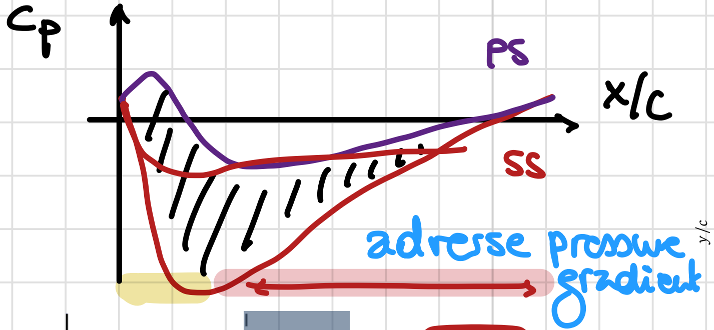


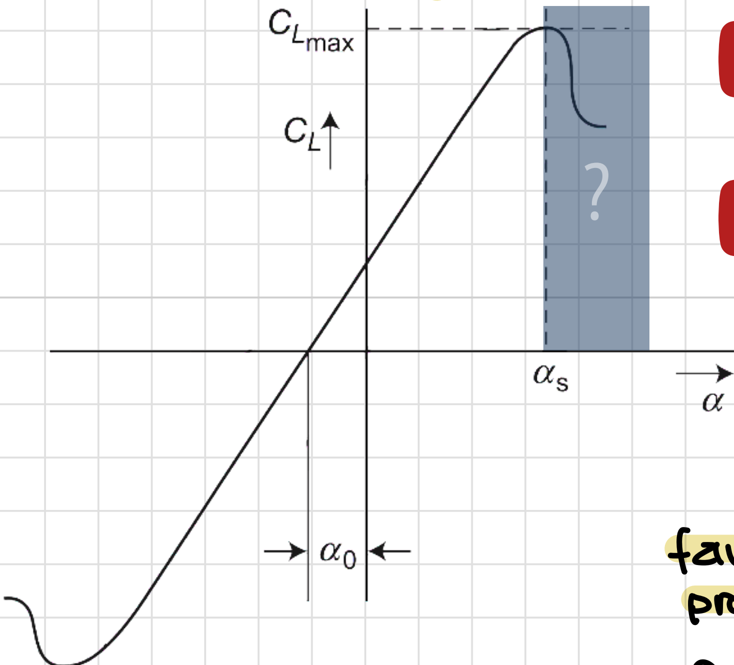
Lift-to-drag ratio

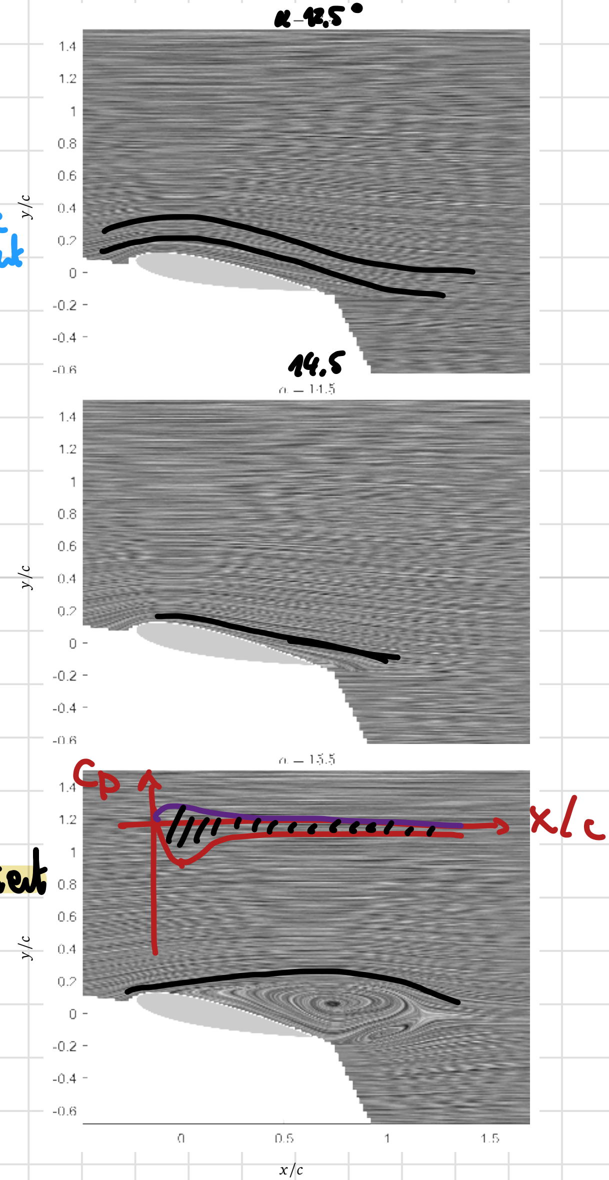




Airfoil stall







favourable pressure-gradient

in chordwise-direction $\frac{\partial c_p}{\partial x} < 0$