9/29/2024

Airplane Control Surfaces

Rudder vs fin

Elevator vs horizontal stab.

Aero

Lift $\perp$ to V_∞

Drag $=$ to V_∞

happy aerodynamic center.

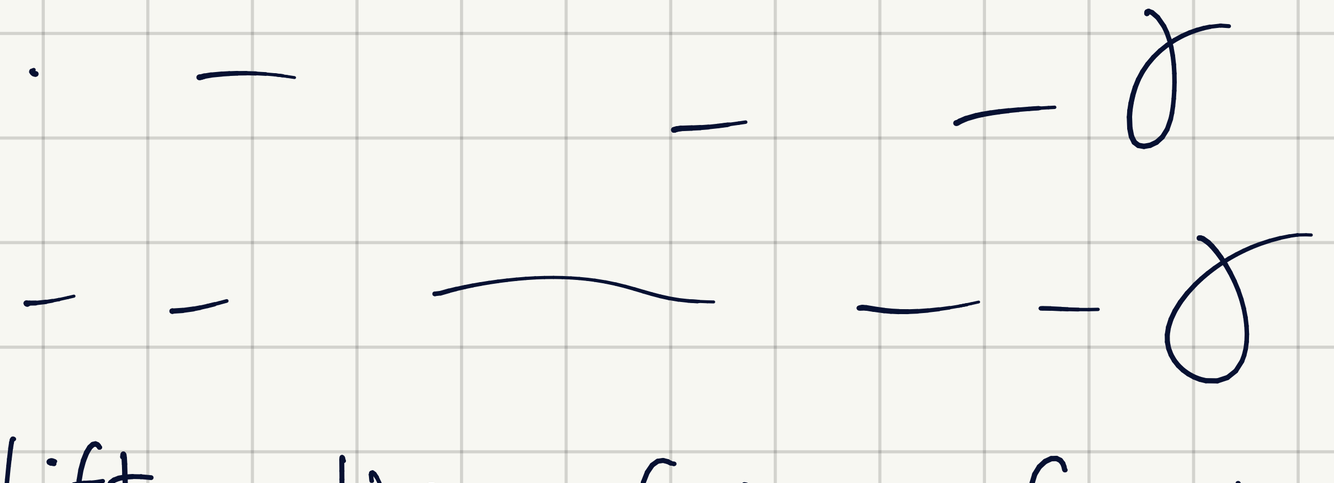
Resultant force

$\alpha =$ relative wind vs chordline

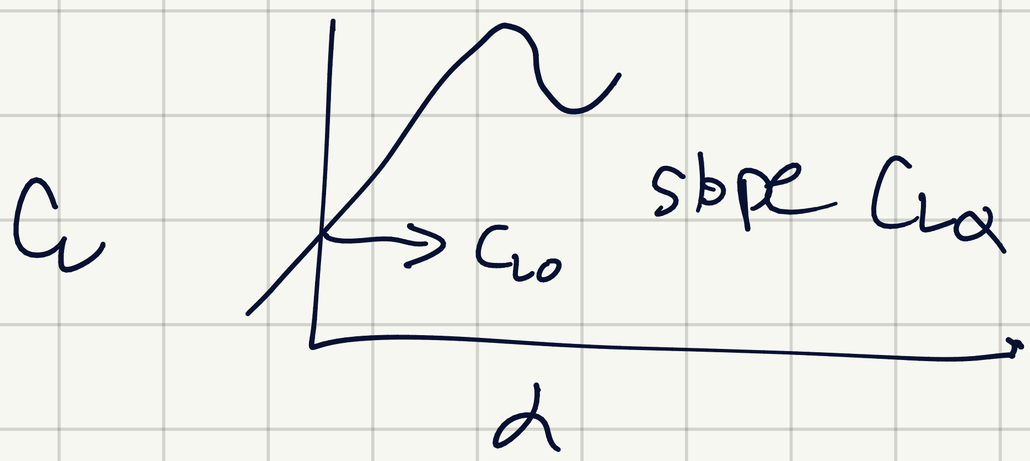
$L = \frac{1}{2}\rho V^2 S C_L$

$D = \frac{1}{2}\rho V^2 S C_D$

Steady:



Lift linear function of α.

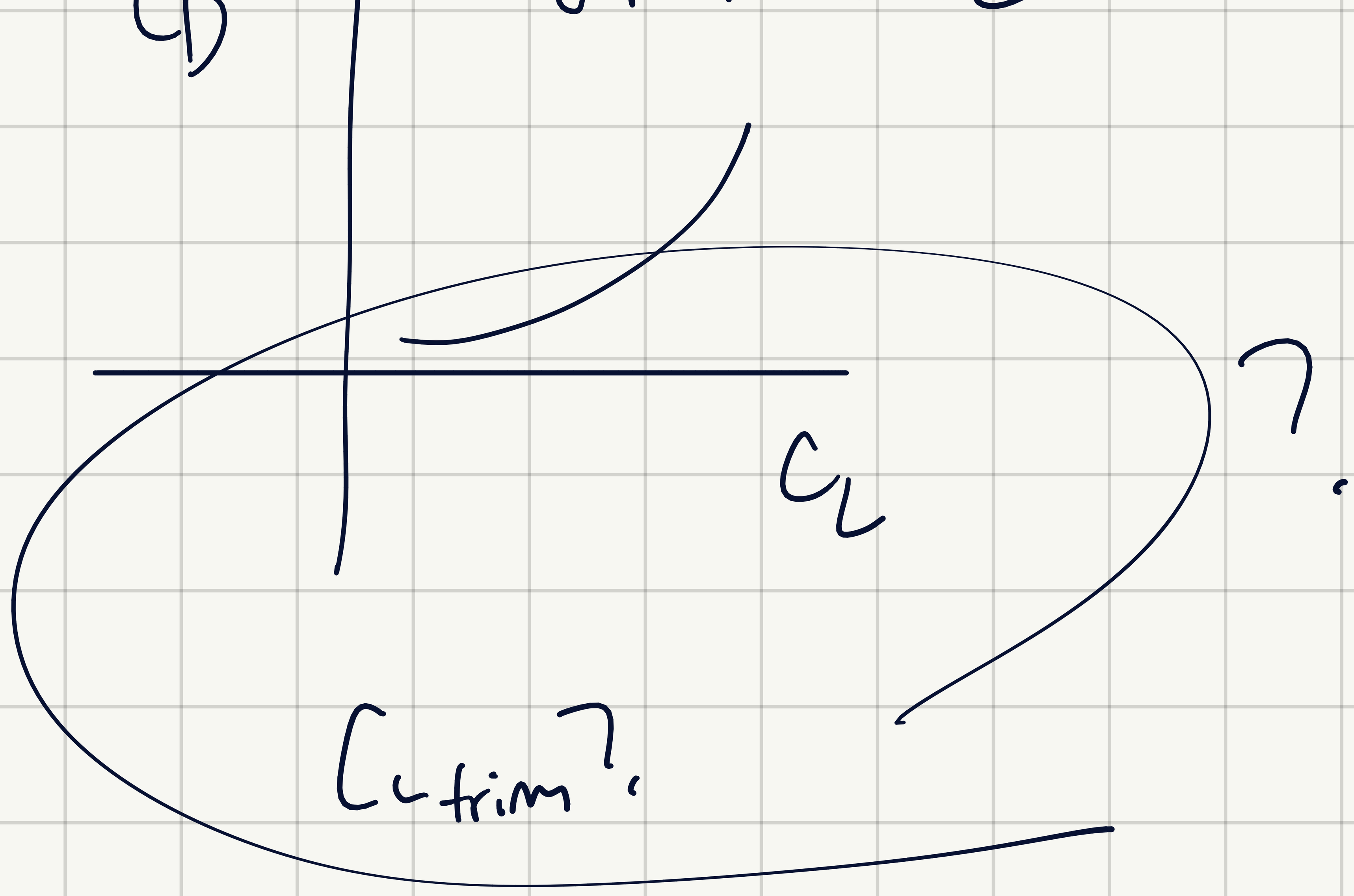


Drag = prof. + ind.

$C_{D_{trim}} = C_{D_0} + C_L^2/(\pi e AR)$

↑ Drag polar

Drag Polar Curve



Anhedral   Dihedral

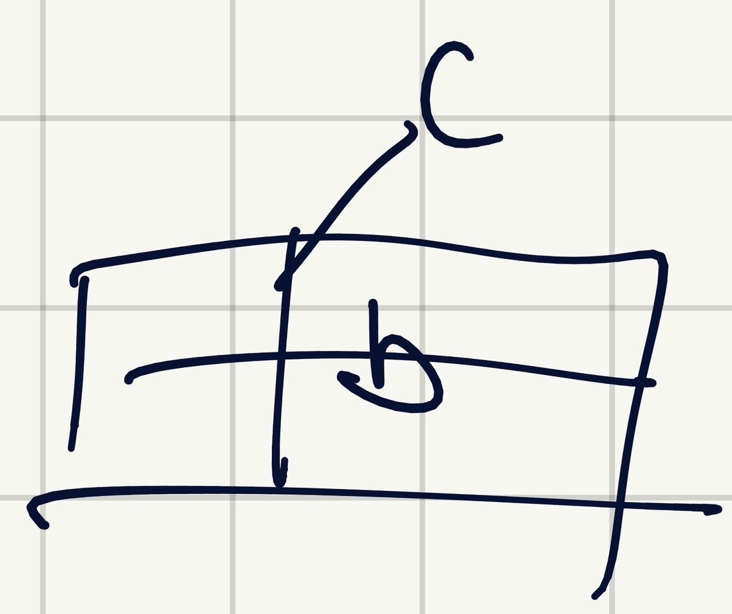
anhedral takes away roll stiffness
wing sweep gives roll stiffness

l_t = CG to ac of tail

Aspect ratio

$AR = \frac{b}{c}$ rect.

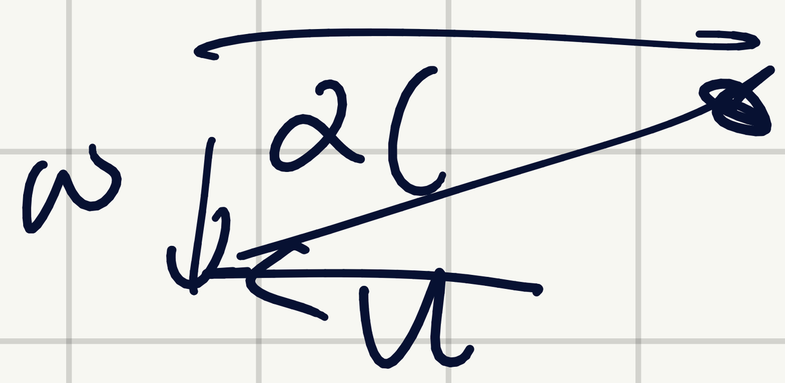
$= \frac{b^2}{S}$ for any wing



a.c. is quarter chord line

elliptical wing
tip to root wind flow is smooth
good for bending moment.

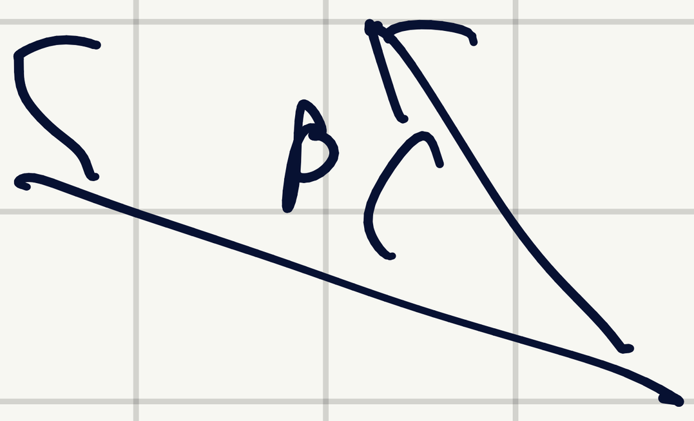
x y z
L M N moment
u v w velocity
p q r



Force X Y Z

α = velocity vs reference line = $\tan^{-1}\frac{w}{u}$

β = $\sin^{-1}\frac{u}{V}$



Pitch stability

C_r

i_t relates angle of attack of tail.

Lift summary

$$C_L = C_{L0} + C_{L\alpha}\alpha + C_{Li} i_t + C_{L\delta_e}\delta_e$$

$$C_{L0} = C_{L0w} + C_{L\alpha_w} i_w + \frac{\bar{q}_t S_t}{\bar{q} S}(C_{L0t} - C_{L\alpha_t}\epsilon_{0t})$$

$$C_{L\alpha} = C_{L\alpha w} + \frac{\bar{q}_t S_t}{\bar{q} S} C_{L\alpha_t}(1 - \epsilon_{\alpha t})$$

$$C_{Li_t} = \frac{\bar{q}_t S_t}{\bar{q} S} C_{L\alpha_t}$$

$$C_{m_r} = C_{m_{0r}} + C_{m_{\alpha_r}}\alpha + C_{m_{i_{tr}}} i_t + C_{m_{\delta_{er}}}\delta_e$$

$$C_{m_{0r}} = C_{m_{acw}} + \frac{\bar{q}_t S_t \bar{c}_t}{\bar{q} S \bar{c}} C_{m_{act}} + C_{m_{0p}} + C_{m_{0f}}$$

$$+ (\bar{x}_r - \bar{x}_{acw})(C_{L0w} + \ldots$$

aerodynamic center.

$$C_{m_{\alpha_{ac}}} = 0$$ Moment constant as α changes

determine ac

Pitch stiffness

CG is the point where the airplane rotates about

Static margin

$C_{L_\alpha} < 0$

$\bar{x}_{cg} C_{L_\alpha} - \bar{x}_{ac} C_{L_\alpha} = C_{m_\alpha}$

$C_{m_\alpha} = -SM\, C_{L_\alpha}$

$SM = (\bar{x}_{ac} - \bar{x}_{cg})$

↑

ac behind cg.

a.c. = neutral point

Trim = everything in equilibrium

$M = 0$

$\parallel \perp F = 0$

- Moving CG forward helps pitch stability
- What limits CG moving forward: we will run out of elevator control if cg is too far.

  ↓

  moment arm doesn't increase as much.

most commercial
Variable horiz. stabilizer
trim tab too.

Yaw stiffness

$C_{n_\beta} > 0$

roll stiffness

$C_{l_\beta} < 0$

$C_{n_F} = \ldots$

$\frac{V_F}{V} \approx 1$

$\frac{V_F}{V}$ -- ...

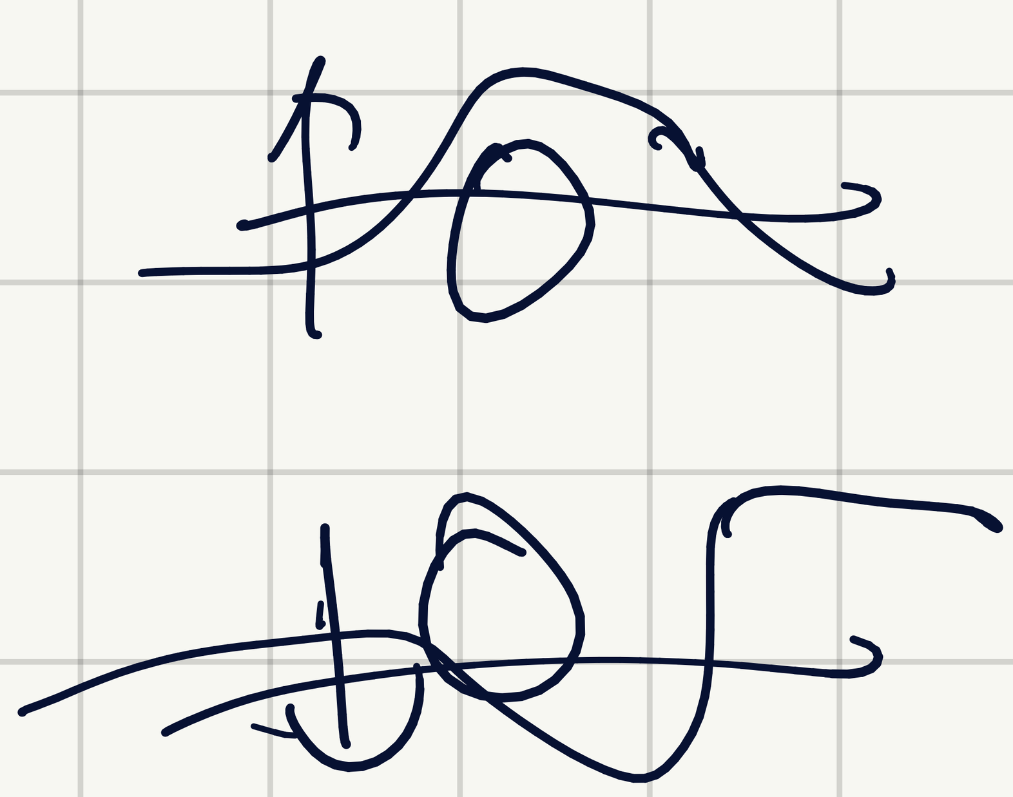
$C_{n_{\delta r}} = \ldots$

↑ rudder power

$C_{n_\beta}\beta + C_{n_{\delta r}}\delta_r$

Roll stiffness

$C_{l_\beta} < 0$



$$C_l = -\frac{y\,a_{cw}}{b} C_{L\alpha w}\,\Gamma\,\beta$$

Sweep

AC = Center of pressure is same for airfoil.

Roll control

aileron involves yaw too.

Straight / level flight

Jet = thrust constant = True airspeed

Power ↑

Prop = Power const with true speed

Thrust ↓

Performance Parameters

Thrust required => level flight.

Breguet Range eq.

$\frac{dr}{dm}$