Parasitic Drag

Lecture 4

ME EN 415
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Drag Breakdown

Drag Breakdown

Parasitic Drag + Induced Drag + Compressibility Drag

Drag Breakdown

Parasitic Drag + Induced Drag + Compressibility Drag

zero-lift drag

vortex drag

lift-dependent drag

wave drag

Drag Breakdown

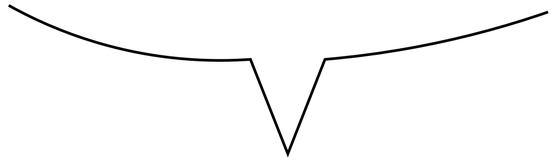
Parasitic Drag + Induced Drag + Compressibility Drag

alternative:

Zero-Lift Drag + Lift-Dependent Drag

Drag Breakdown

Parasitic Drag + Induced Drag + Compressibility Drag



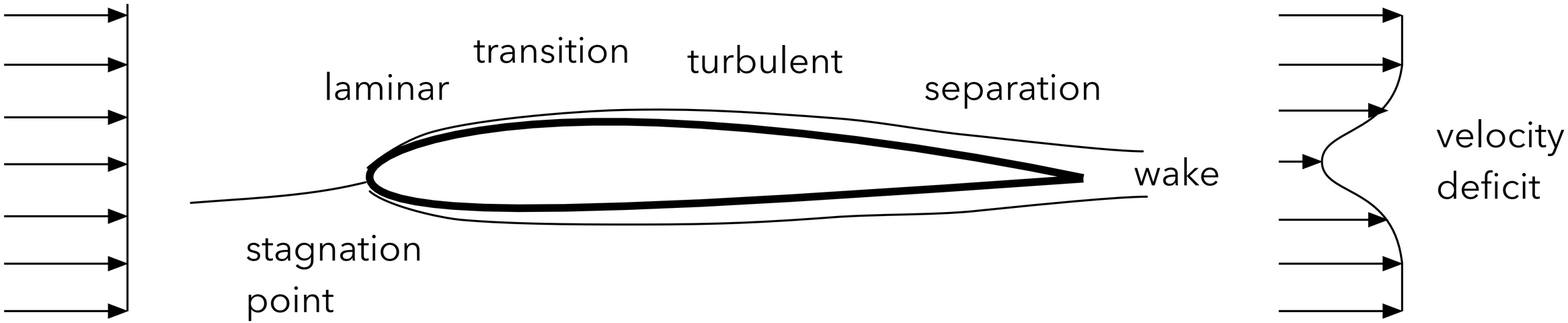
Parasitic drag = skin friction drag + viscous pressure drag

(a.k.a. form drag)

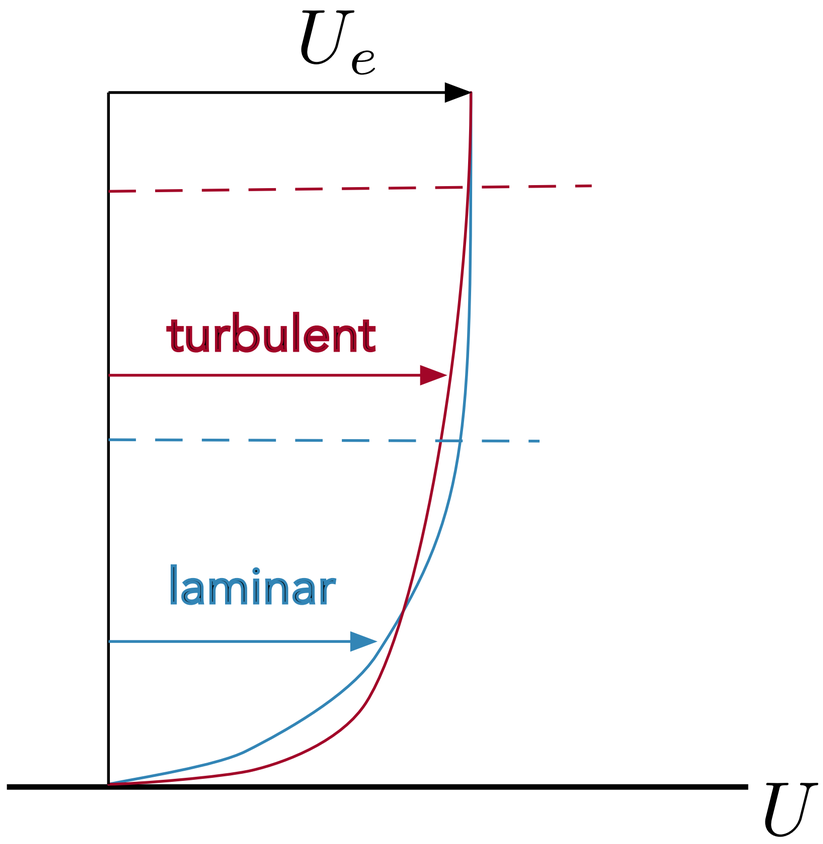
Skin Friction Drag

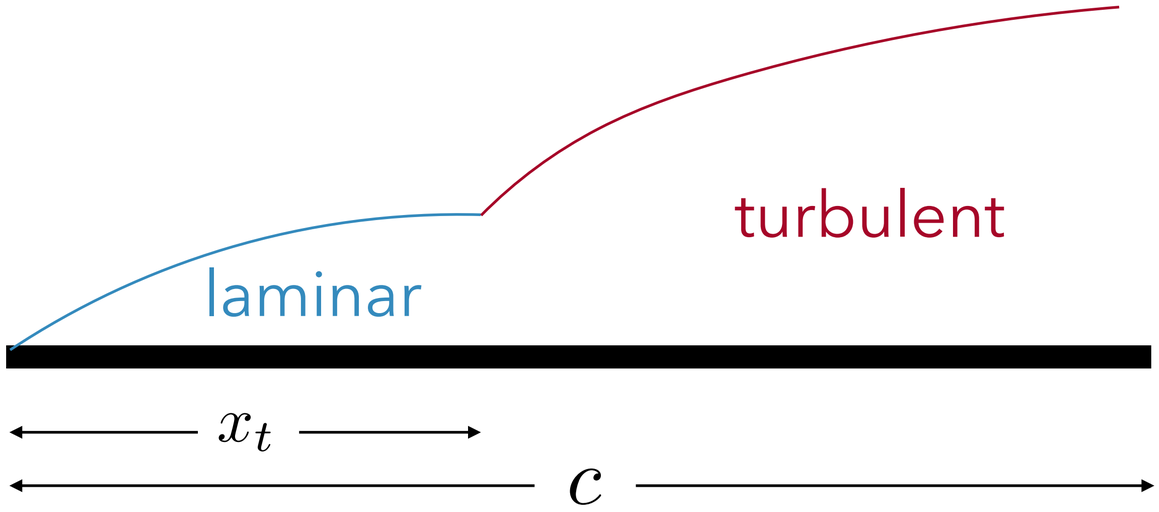
Boundary Layers

$$Re_x = \frac{\rho V x}{\mu}$$

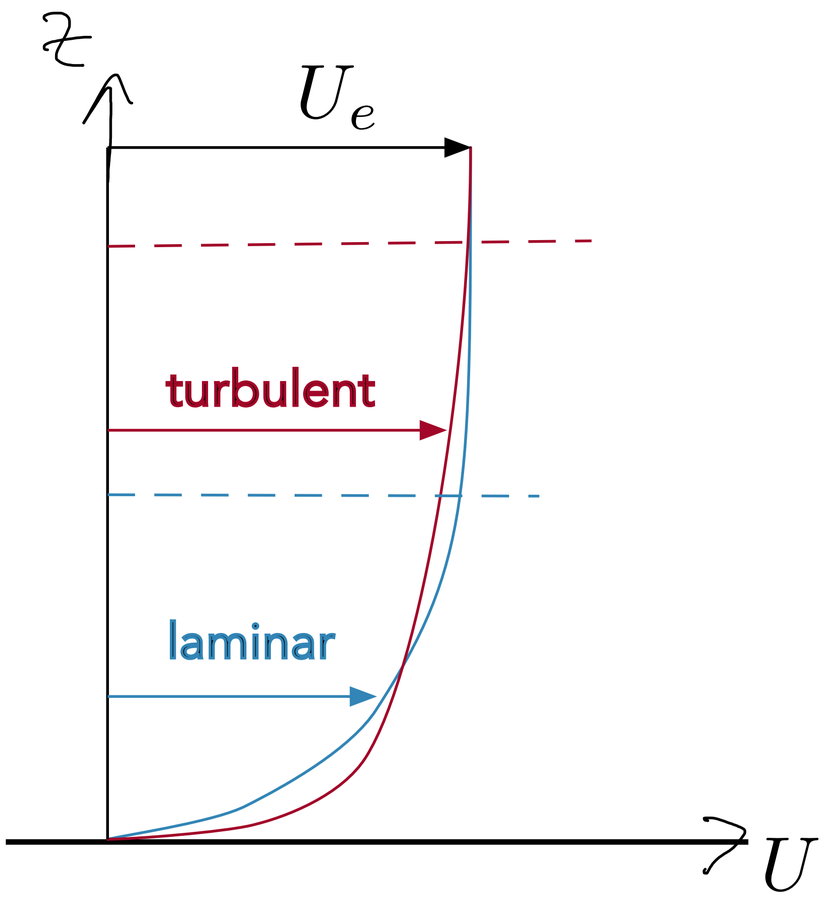


transition ~ $Re = 1e5 - 1e6$


U_e
turbulent
laminar
U


turbulent
laminar
x_t
c

Skin Friction Drag



$$\tau_w = \mu \left.\frac{du}{dz}\right|_{z=0}$$

(wall shear stress)

$$C_f = \frac{\tau_w}{q_\infty} = \frac{\tau_w}{\frac{1}{2}\rho_\infty V_\infty^2}$$

(skin friction coefficient)

Skin Friction - Flat Plate

(Blasius)

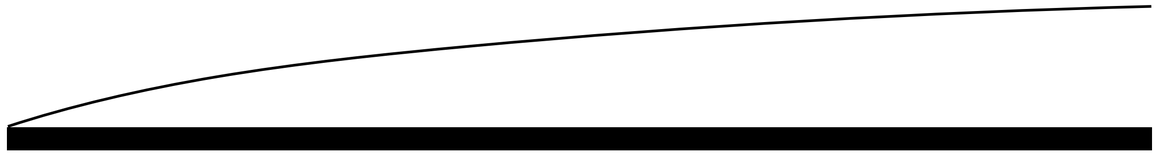
$$C_f = \frac{1.328}{\sqrt{Re}}$$

laminar

(Prandtl) (Schlichting)

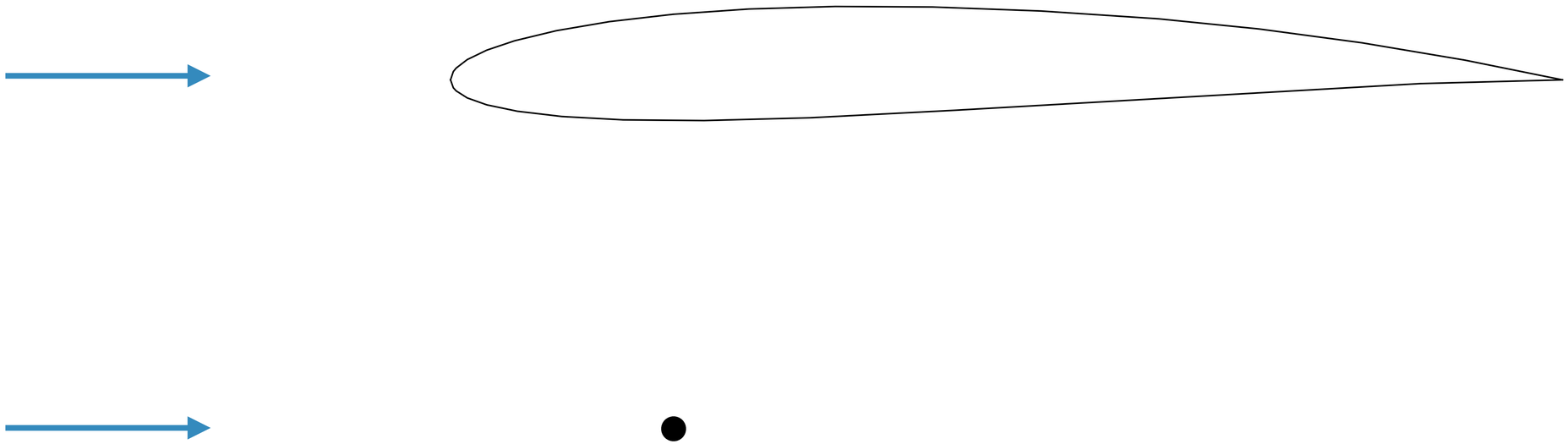
$$C_f = \frac{0.074}{Re^{0.2}} \text{ or } = \frac{0.455}{(\log_{10} Re)^{2.58}}$$

turbulent



Viscous Pressure Drag

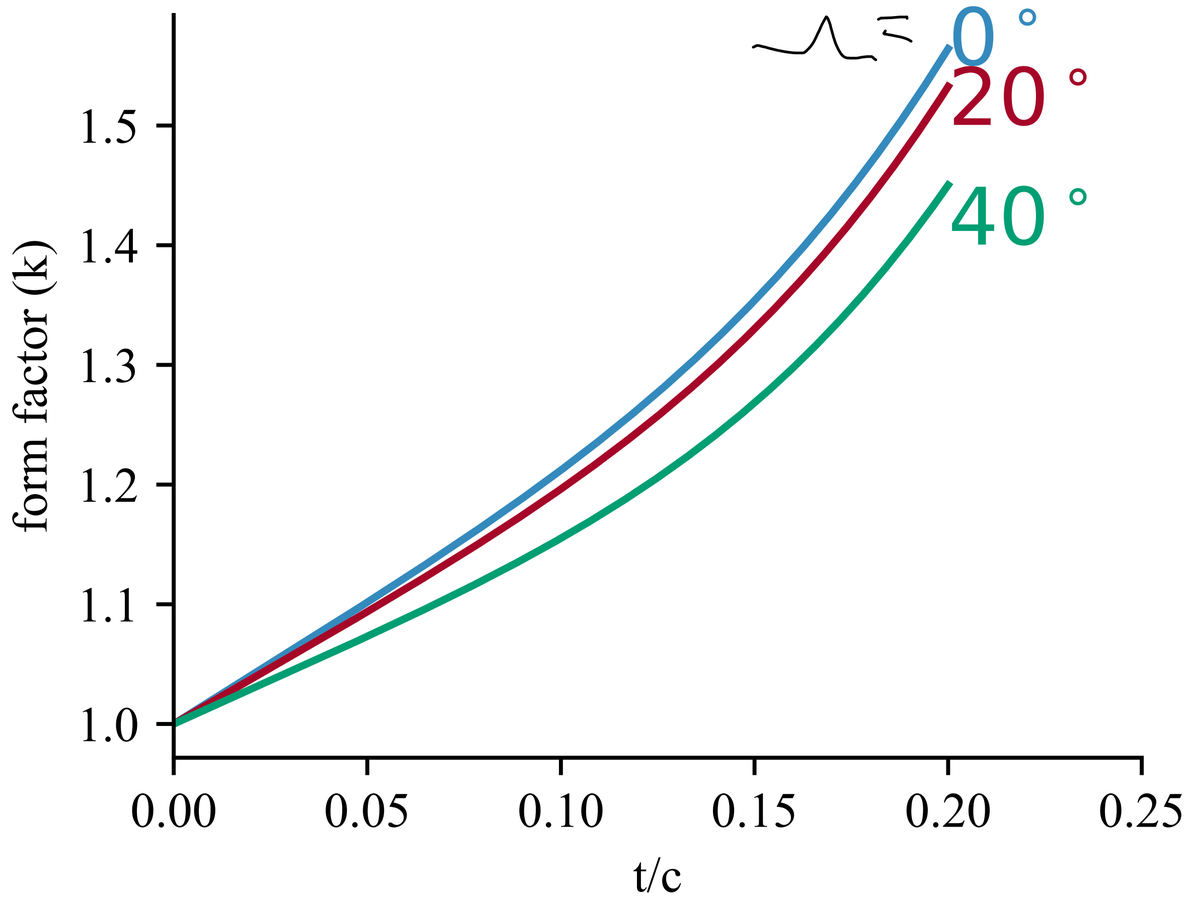
Drag Comparison



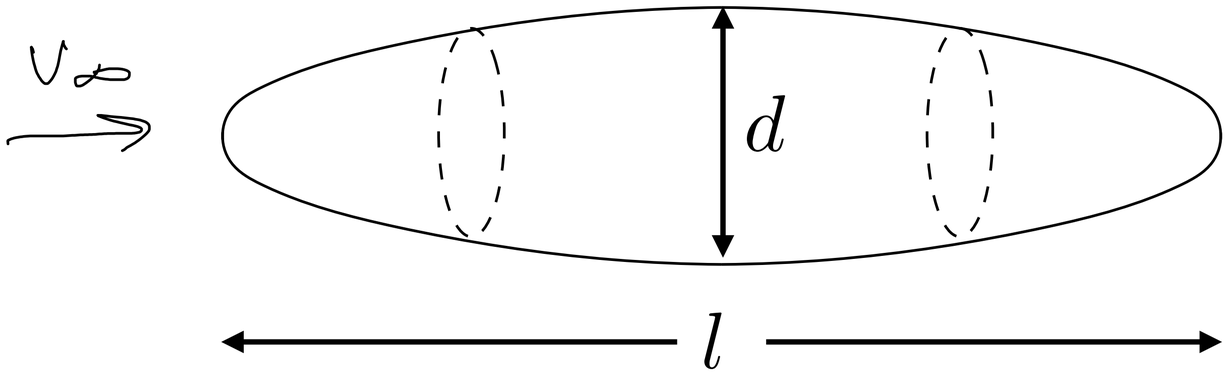
Form Factor - Lifting Surface

$$k = 1 + 2\cos\Lambda\frac{t}{c} + 100\left(\frac{t}{c}\right)^4$$

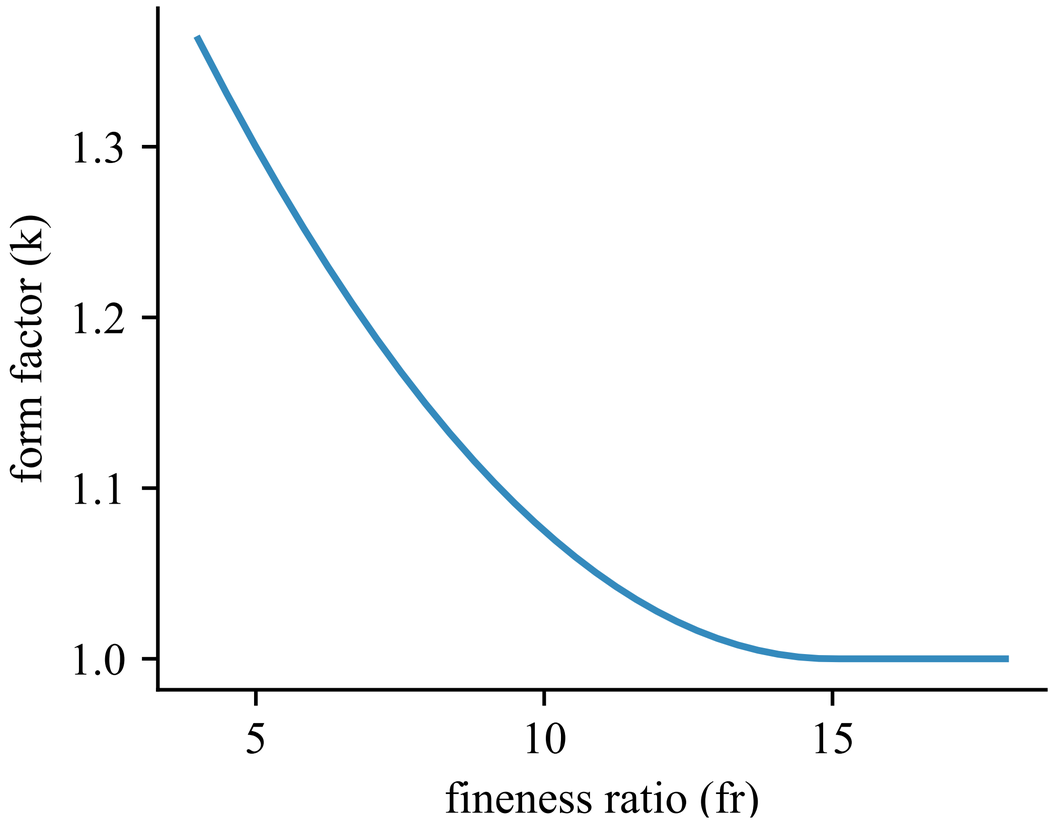
conceptual design



Form Factor - Body of Revolution



$$fr = \frac{l}{d} \quad \text{(fineness ratio)}$$



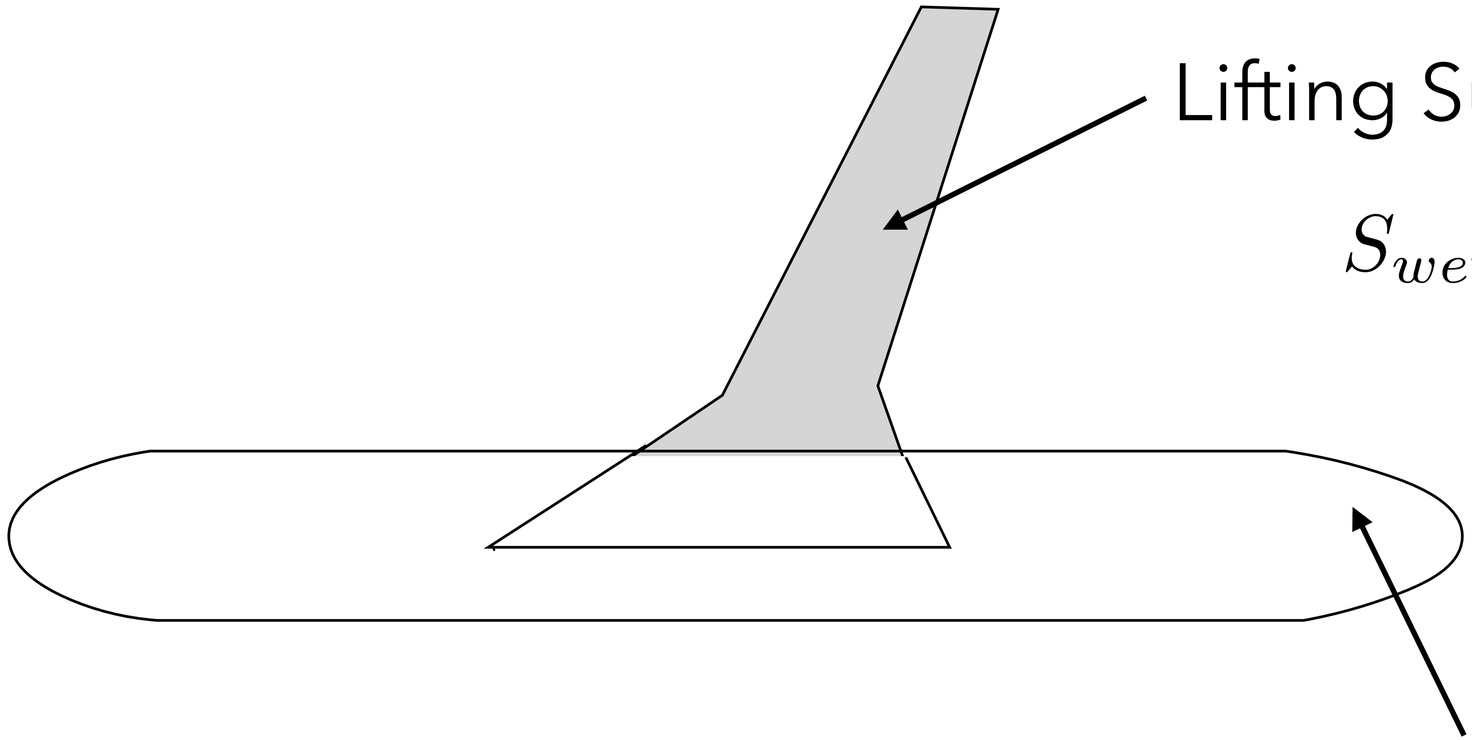
$$k = \begin{cases} 1.675 - 0.09fr + 0.003fr^2 & fr < 15 \\ 1 & fr \geq 15 \end{cases}$$

non-circular cross-section: $$d_{eff} = \sqrt{\frac{4S}{\pi}}$$

S: max cross-sectional area.

Parasitic Drag

Wetted Area



Lifting Surfaces:

$$S_{wet} \approx 2\left(1 + 0.2\frac{t}{c}\right) S_{exposed}$$

Nose/Tail Cone:

$$S_{wet} \approx 0.75\pi dl$$

Parasitic Drag

$$C_D = \frac{D}{qS}$$

$$C_{Dp} = kC_f \frac{S_{wet}}{S_{ref}}$$

$$D = kC_f q_\infty S_{wet}$$

$$C_D = \frac{D}{q_\infty S_{ref}} = \frac{kC_f q_\infty S_{wet}}{q_\infty S_{ref}} = kC_f \frac{S_{wet}}{S_{ref}}$$

Other Sources of Parasitic Drag

- Interference Drag
- Control Surface Gap Drag
- Nacelle Base Drag
- Fuselage Upsweep Drag
- Hinges/Protuberances