Wing Design I

Lecture 8

ME EN 415
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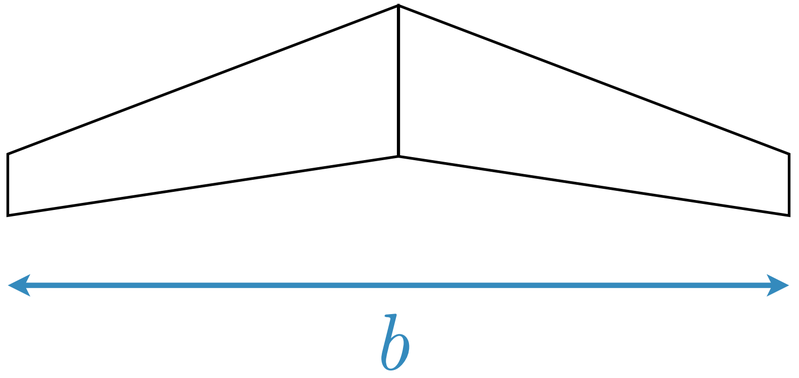
Span

- increasing span
  - + decrease induced drag $\sim \frac{1}{b^2}$
  - − structural weight
  - − for a fixed wing area
    - − decrease Re ⇒ increase parasitic drag
      decrease max lift.
    - − less internal volume.

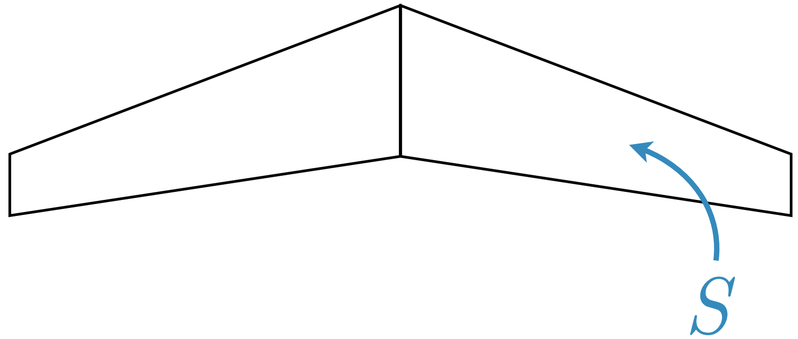
+/− for a swept wing − move a.c. back



Area (increasing)

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

$$V_{min} = \sqrt{\frac{L}{\frac{1}{2}\rho S_{ref} C_{L_{max}}}}$$



+ decrease stall speed (field length shorter)

– skin friction drag increases.

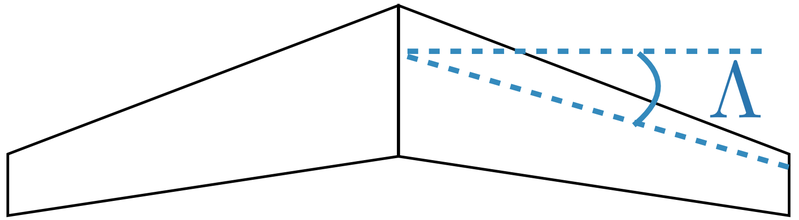
– increases weight

+/– affect cruise C_L

Sweep (+)

+ decrease transonic drag

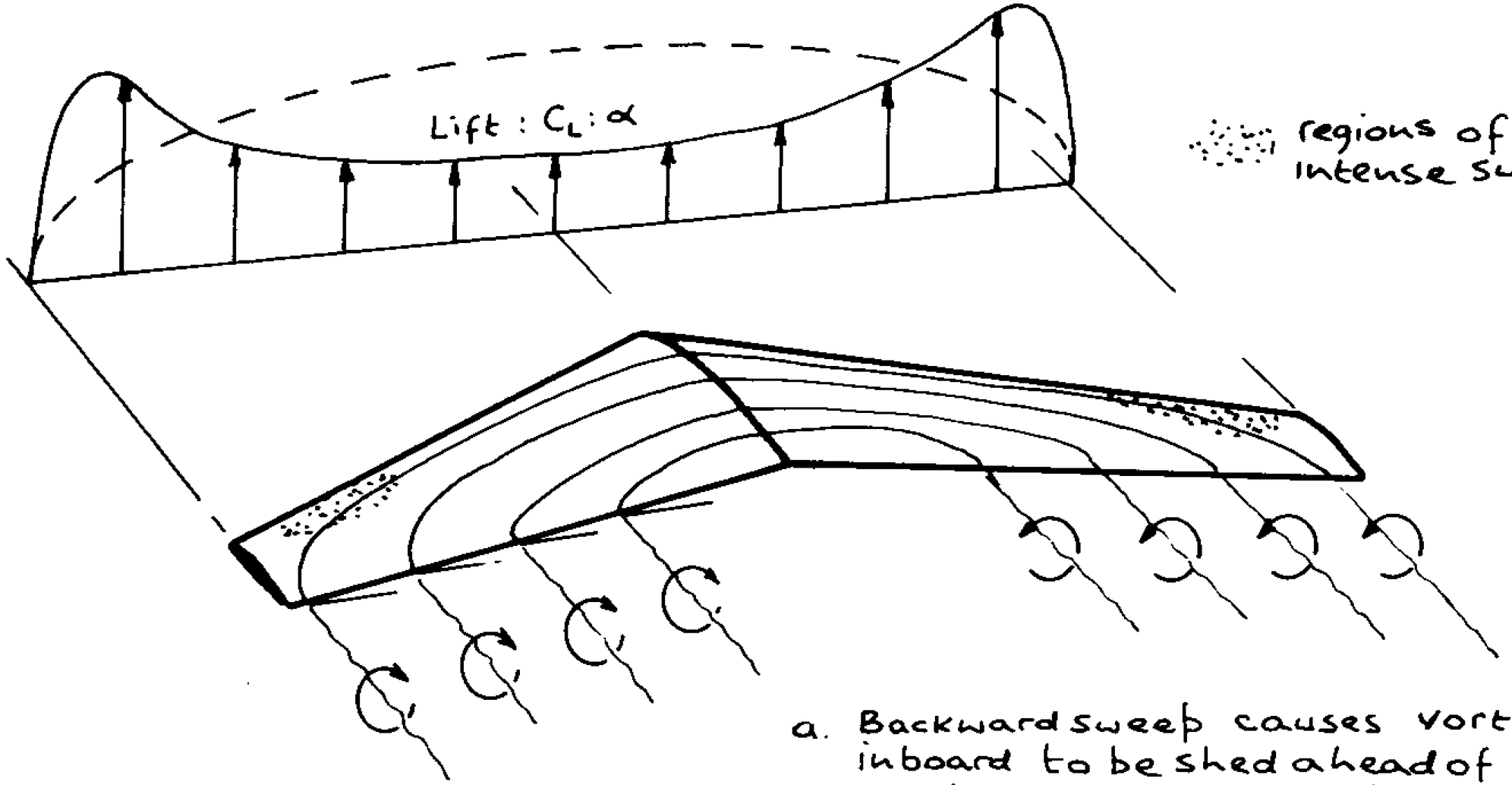
+ moves a.c. back (particularly important for flying wing)



– reduces C_{Lmax}

– increases structural span (and weight)

– increase tip loads (and weight, tip stall)



a. Backward sweep causes vortices inboard to be shed ahead of those outboard, so inducing upwash towards the tips. Angle of attack and lift coefficient of outboard sections are increased, causing tips to stall first.

Thickness distribution (+)

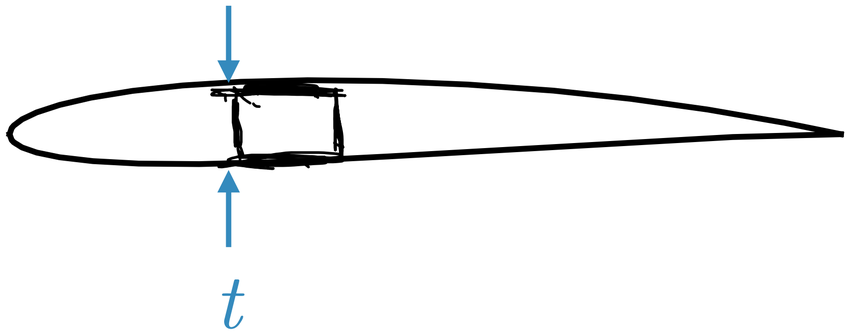
+ reduce wing weight if bending constrained

− increases parasite drag

+ increases $C_{L_{max}}$ (up to a point)

− increases wave drag

+ increases fuel volume



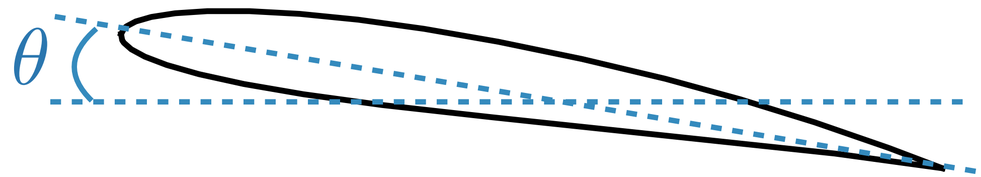
Chord distribution

+ smaller tip chords ⇒ less weight

− smaller tip chord ⇒ stall

- strong affect on lift/cl distribution

Twist distribution



Definitions

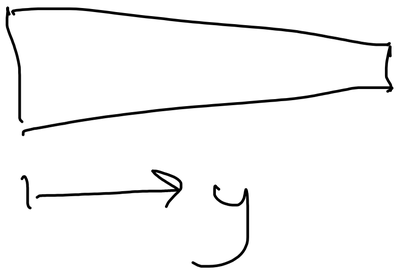
Aspect ratio

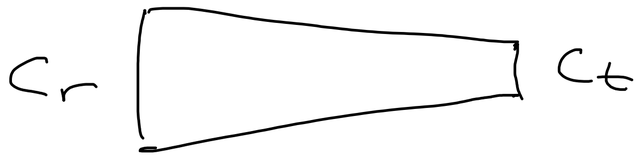
$$AR = \frac{b^2}{S_{ref}}$$

Mean aerodynamic chord

$$c_{avg} = \frac{S_{ref}}{b} \quad \text{(geometric average)}$$

$$c_{mac} = \frac{2}{S_{ref}} \int_0^{b/2} c^2 \, dy$$





$$c_{mac} = \frac{2}{3}\left(c_r + c_t - \frac{c_r c_t}{c_r + c_t}\right)$$