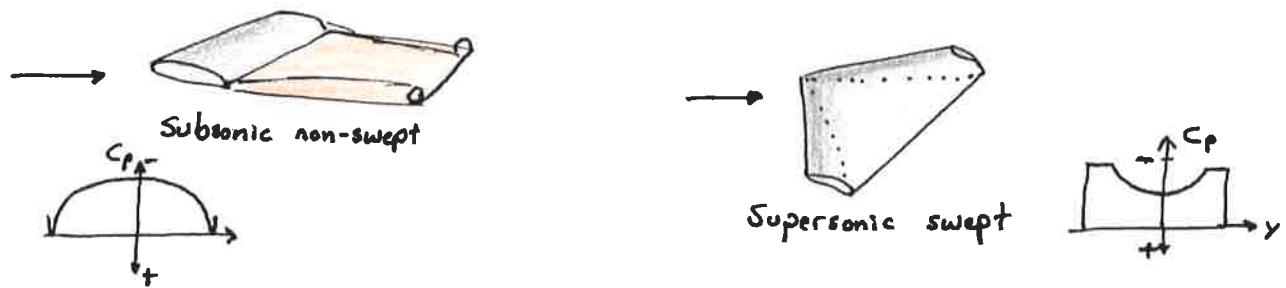


Lesson 18
Delta Wings

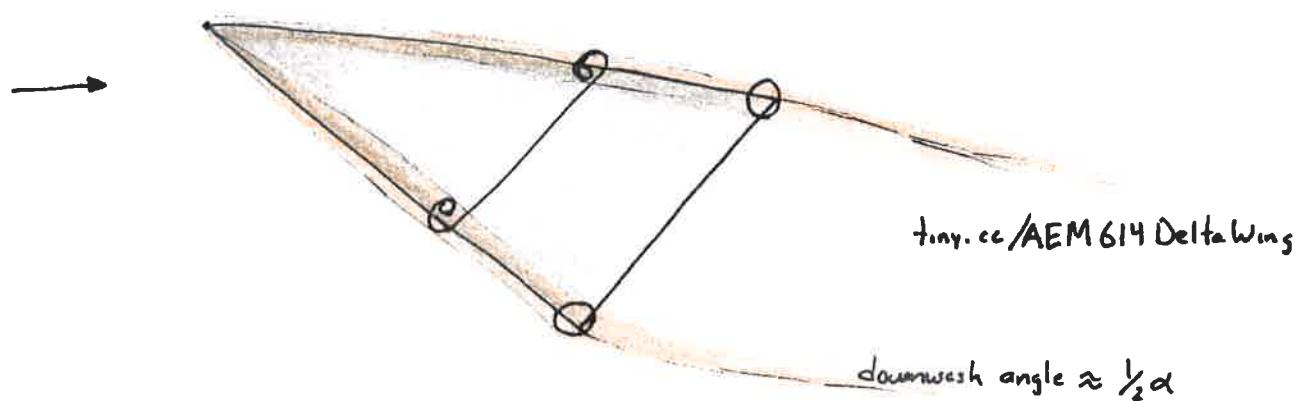
Slender Delta Wings in subsonic flow

Behavior is different from higher AR or rectangular non-swept platforms.

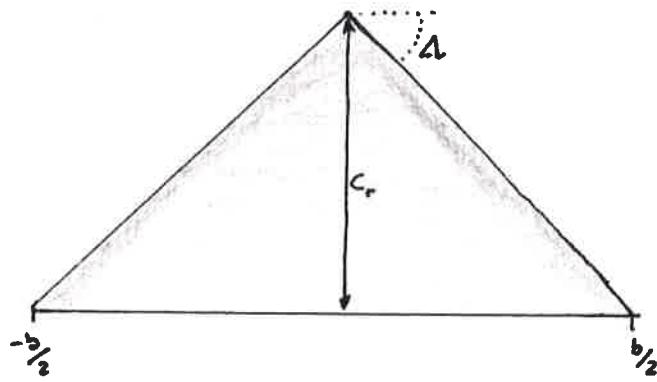


As the LE sweep angle increases in a subsonic flow, a change in the flow occurs.

Leading edge vortices form along the leading edge.



Geometry



$$\lambda = 0$$

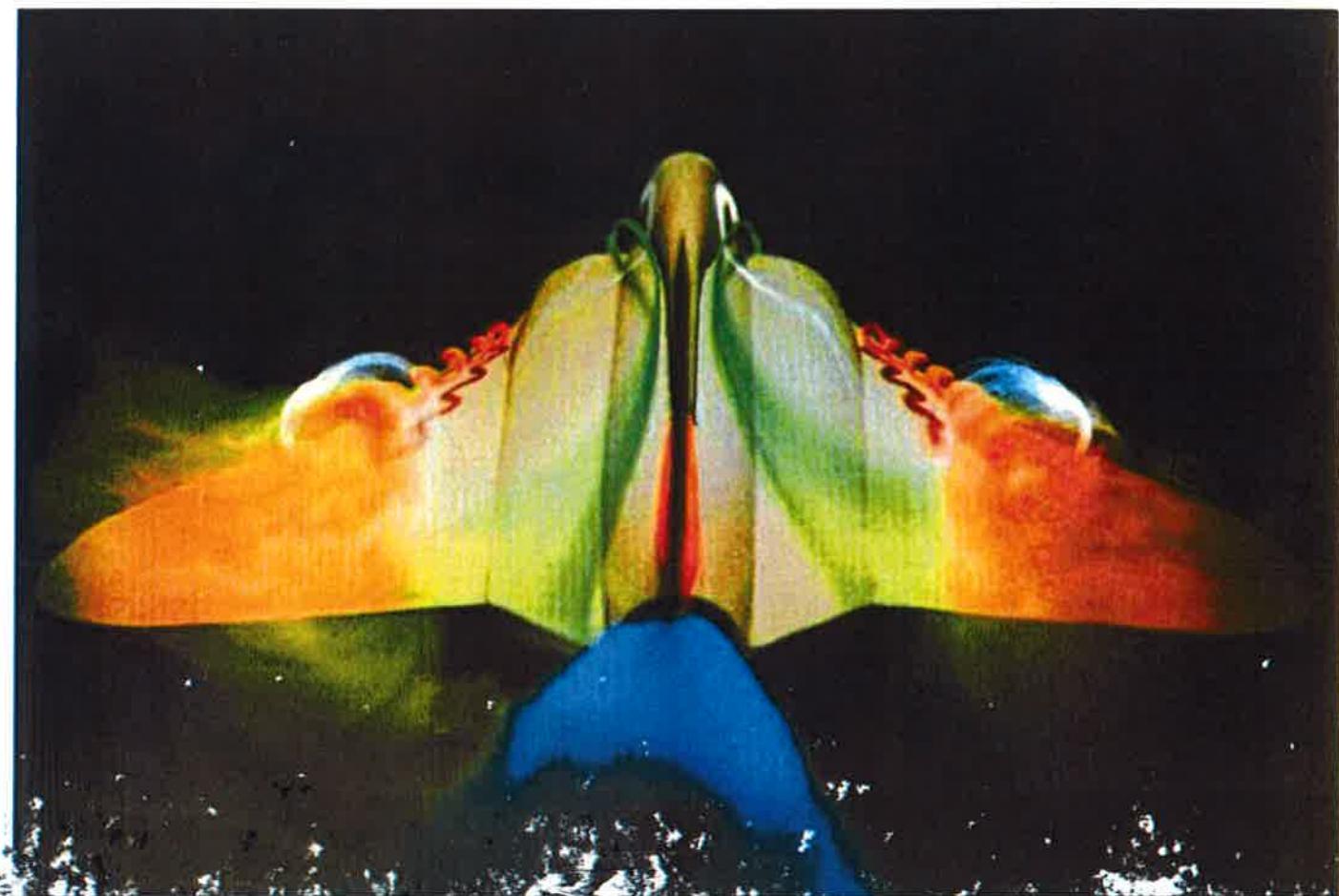
$$\tan \lambda = \frac{c_r}{b/2} \quad \text{and} \quad S = \frac{b \cdot c_r}{2}$$

$$AR = \frac{b^2}{S} = \frac{b^2}{b c_r / 2} = \frac{b^2}{b b/2 \tan \lambda / 2}$$

$$AR = \frac{4}{\tan \lambda}$$

Leading Edge Vortices used to increase effective AOA range of aircraft.





Actual Delta Wings create vortices along the LE.

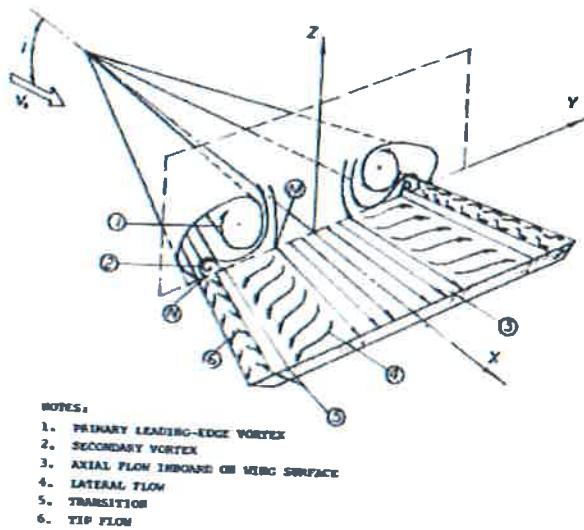
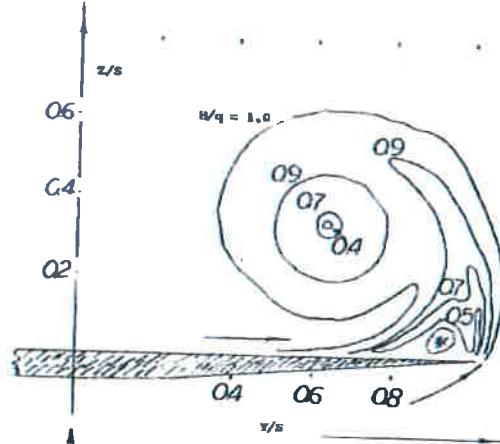


Figure 3. Flow distribution of a sharp-edge delta wing showing primary and secondary leading-edge vortices.



The vortices are regions of low pressure occurring only on the upper surface.

In 2D, the flow pattern is

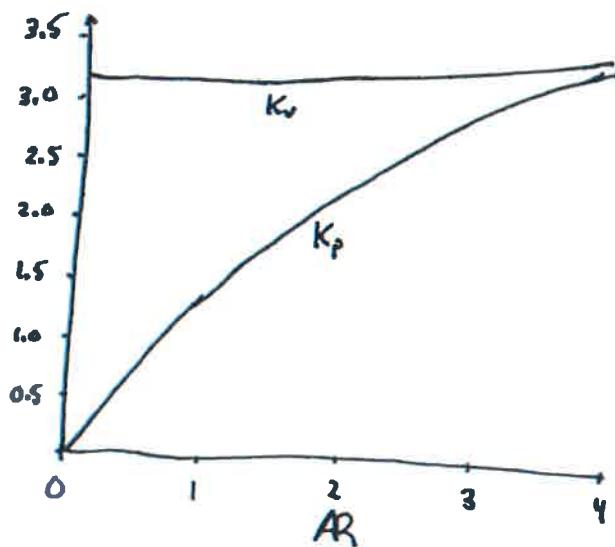


Vortex lift is produced from the leading edge suction

Polhamus (NASA TN D-3767) provides

$$C_L = K_p \underbrace{\sin \alpha \cos^2 \alpha}_{\text{potential flow lift per. page}} + K_v \underbrace{\cos \alpha \sin^2 \alpha}_{\text{separated vortex lift}}$$

$$CD = CD_0 + K_p \cdot \sin(\alpha)^2 \cdot \cos(\alpha) + K_v \cdot \sin(\alpha)^3$$



$$K_p = C_{L_d} \text{ lift, Surface Theory}$$

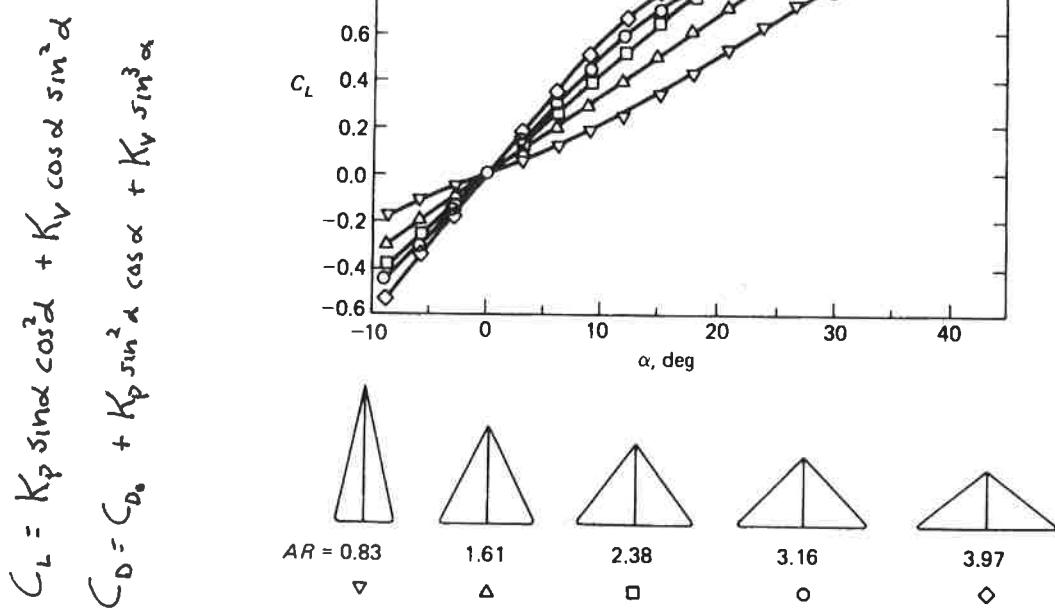
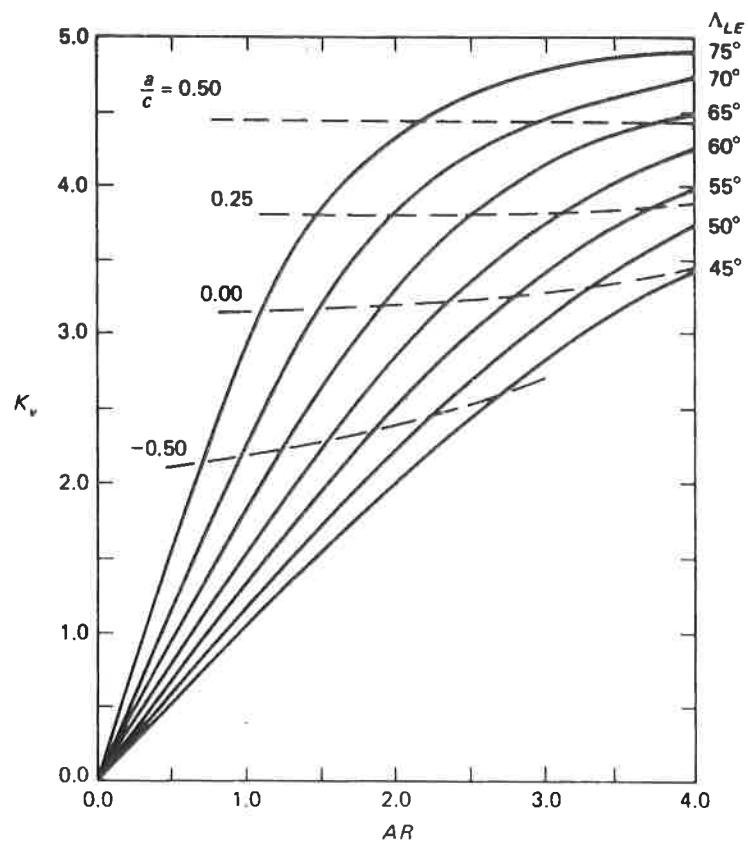
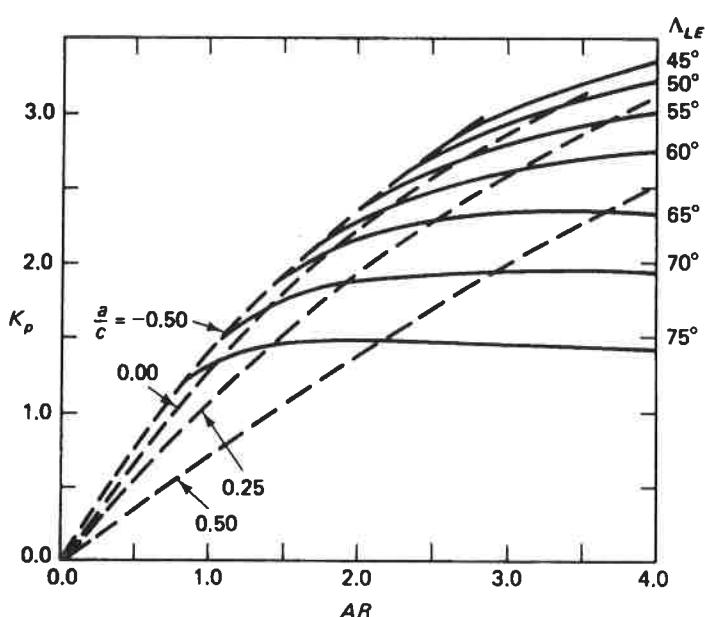
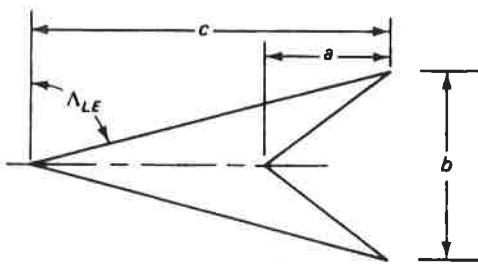
$$K_v = \frac{K_p - K_p^2 K_i}{\cos \Lambda}$$

$$K_i = \frac{1}{\pi A}$$

Only good for small aoa and small AR

Only good for small aoa and AR

Source: Aerodynamics for Engineers
Berlin + Smith



Aerodynamic Force Analysis

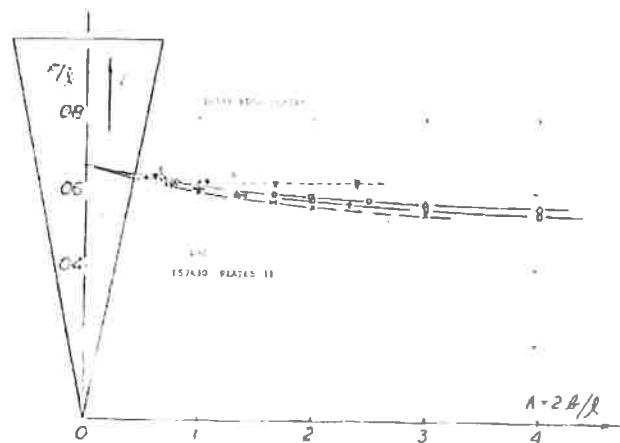
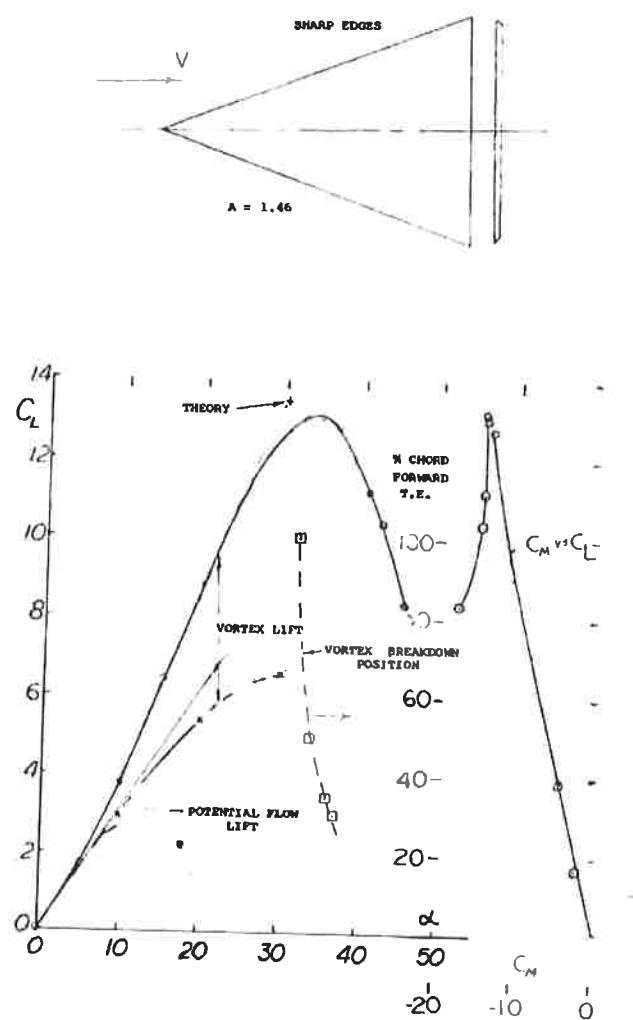
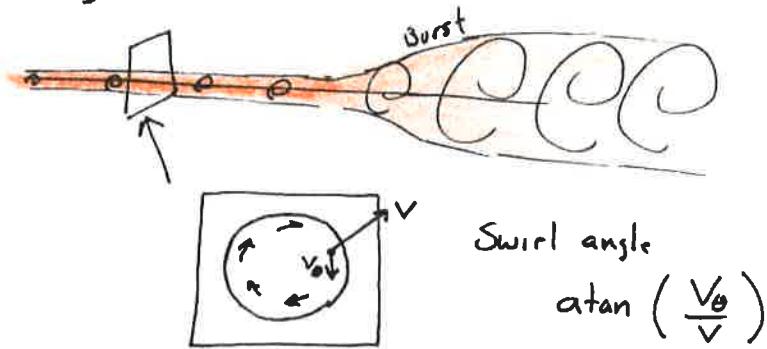


Figure 12. Aerodynamic center of delta wings derived from experimental results.

The a.c. is theoretically at $\frac{2}{3} C$ for $AR \approx 0$.

Vortex lift provides the majority of C_L as α increases beyond 20° (depending on configuration)

Vortex Bursting



When the swirl angle is large, an instability forms with the result of a significantly larger size and a lower swirl velocity. This is the vortex equivalent of hydraulic jump  in an open channel or a shock in supersonic fluid.

Vortex bursting is troublesome for designers. The burst point is sensitive to design parameters and operational parameters.

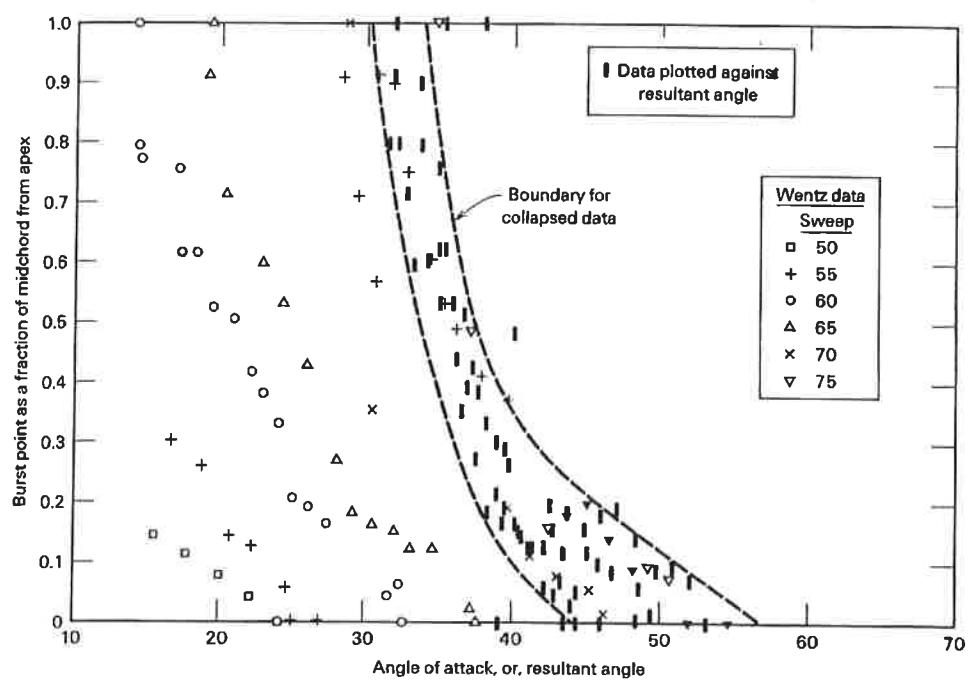
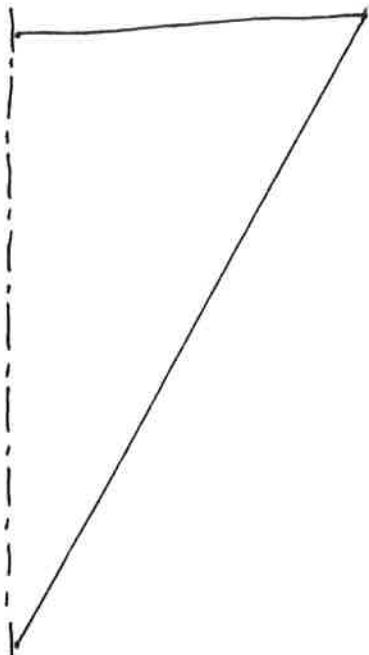


Figure 3.76 Burst point data as a function of angle of attack and resultant angle.

Vortex Bursting



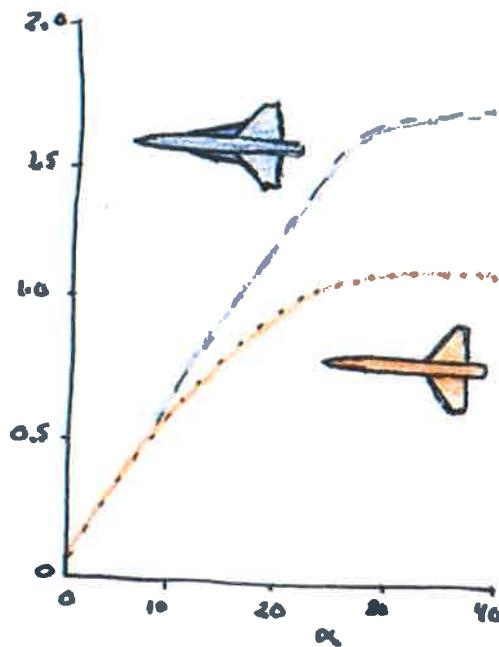
The F-18 had a significant development issue with the LEX stroke vortex bursting and interacting with the canted verticles. The vortex created large stresses and eventually fatigue issues.

tiny.cc/AEM614F18HARV

5:00 - 7:00

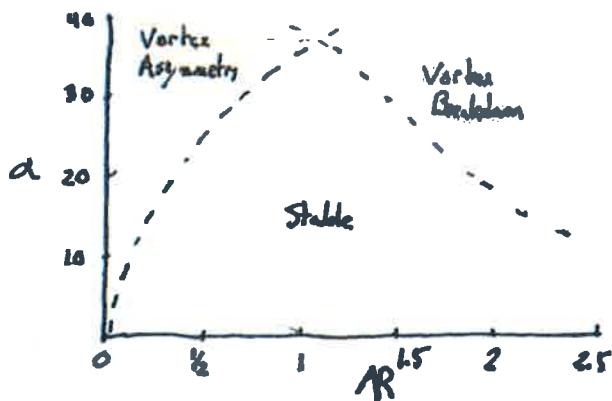
8:00
8:50 -

Comparative Advantage of Stakes



"Forebody/Wing Vortex Interactions and Their Influence on Departure and Spin Resistance"

Skow, Titterton, Moore AGARD/NATO CP 247 1978



Low Speed Aerodynamics, Katz + Plotkin , 2001

High AOA problems.

tiny.cc/AEM614_HighAOA

- Wing rock: The delta wing exhibits a nonlinear roll moment behavior leading to a limit cycle oscillation. tiny.cc/AEM614_WingRockFS



- Vortex interaction + Bursting,
F18 vertical tail

- Spins

- Non-linear Aerodynamics, coupled with Inertial coupling.

- High Drag

Roughly
Compare a B-47 swept wing jet with the British Avro Vulcan.

$$b = 116 \text{ ft}$$

$$S = 1428 \text{ ft}^2$$

$$W_0 = 79000 \text{ lbf}$$

$$W_g = 133000 \text{ lbf}$$

$$T = 6 \cdot 7200 \text{ lbf}$$

$$C_{d_0} = 0.0148$$

$$b = 100 \text{ ft}$$

$$S = 3554 \text{ ft}^2$$

$$W_0 = 83573 \text{ lbf}$$

$$W_g = 170000 \text{ lbf}$$

$$T = 44000 \text{ lbf}$$

$$C_{d_0} \approx 0.0090$$

Calculations:

$$AR = \frac{b^2}{S} = 9.4$$

$$AR = 2.8$$

$$\Delta_{LE} = \tan\left(\frac{4}{AR}\right) \approx 55^\circ$$

Delta Wing

$$C_L = K_p \sin \alpha \cos^2 \alpha + K_v \sin^2 \alpha \cos \alpha$$

$$C_D = C_{D_0} + K_p \sin^2 \alpha \cos \alpha + K_v \sin^3 \alpha$$

\uparrow
2.75 \uparrow
 \downarrow \downarrow
 Δ_{LE} Δ_{LE}

Swept Wing

$$C_{L_\infty} \approx \frac{C_{d_0}}{1 + \frac{C_{d_0}}{\pi AR}} \approx \frac{2\pi}{1 + \frac{2}{AR}} = 5.1 \approx$$

$$C_{D_\infty} = C_{D_0} + C_{D_i} = C_{D_0} + \frac{C_L^2}{\pi AR_e}$$

$$e \approx 4.61 \left(1 - 0.045 \cdot AR^{0.68}\right) \left(\cos \Delta_{LE}\right)^{0.15} - 3.1$$

$\Delta_{LE} \approx 35^\circ$

$$\approx 0.45$$

What C_L ?

$$35000 \text{ ft} \approx 570 \text{ kft} \Rightarrow g \approx 2 \text{ psi}$$

B47

$$C_L \approx \frac{130000}{2 \text{ psi}} \cdot \frac{1 \text{ ft}^2}{1428 \text{ ft}^2} \cdot \frac{1 \text{ in}^2}{144 \text{ in}^2} \approx 0.3$$

Vulcan

$$C_L \approx \frac{150000}{24 \text{ psi}} \cdot \frac{1 \text{ in}^2}{3554 \text{ ft}^2} \cdot \frac{1 \text{ ft}^2}{144 \text{ in}^2} \approx 0.15$$

