Chapter 7
Incompressible Flow About Wings of Finite Span

Wing End Effects
Relatively low pressure on the upper surface
Tip vortex
Relatively high pressure on the lower surface

Wing Tip Vortex

Pressure / Lift Distribution

Lifting Line Theory
(Vortex Structure)

Downwash and Induced Drag
Effective lift, acts normal to the effective flow direction
Undisturbed free-stream direction (direction of $C_l$)
The resultant velocity for airfoil section
Elliptic Circulation (lift) Distribution

Effect of AR on $C_L$ and $C_D$
(Experimental)

Spanwise Lift Distribution
(Odd Fourier Terms)

Linear Model

Theory / Experimental Data
(Straight Tapered Wing)

Lift Coefficient Distribution

Note: Peak lift coefficient is not at wing root
Effect of Taper Ratio

Note: For a highly tapered wing, the max. lift coefficient is at the tip.

Effect of Taper Ratio on Wing Stall

Rectangular, $\lambda = 1.0$

Tapered, $\lambda = 0.4$

Pointed, $\lambda = 0.0$

Panel Methods

Modeling Method vs. Experimental

$\Lambda_{c/4} = 45^\circ$

$\Lambda_{c/4} = -45^\circ$

Elemental Panels and Vortices

Single Element per Spanwise Position
(Swept Tapered Wing)
Vortex / CP Location on Panel

Induced Velocity at Point C

Horseshoe Vortex Elements

Sharp Leading Edges

Leading edge flaps can be used to increase leading edge suction.

- Flow separates at leading edge and reattaches further back
- This creates a low leading edge suction wing.
Delta Wings

Flow spills over the leading edge, separates and forms a strong vortex.

Delta Wings – Potential Flow Lift ($K_p$)

Delta Wings – Vortex Lift ($K_v$)

Delta Wings – Lift Coefficient

Note the high $\alpha$ values

Delta Wings – Drag ($\Delta C_D$)

XB-70

At low subsonic speeds delta wings generate a nose-down pitching moment.

The Valkyrie uses canards to generate a nose-up moment.
Concord uses reflexed trailing edge for nose-up moment.

Tupolev uses retractable canards.

Leading Edge Extensions (LEX)

Strake (LEX) Vortex

Strake Implementation

Effect of Strake on Lift