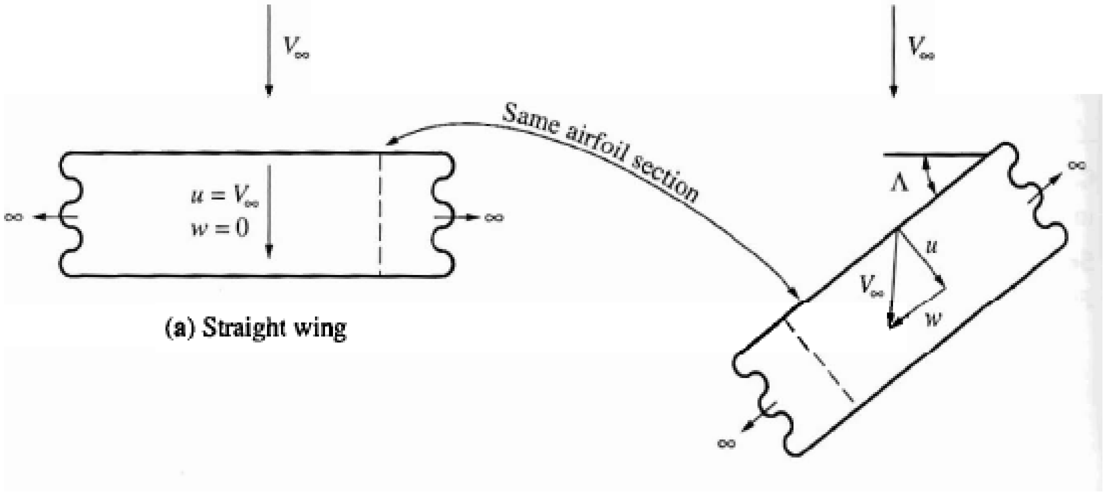
Swept Wings

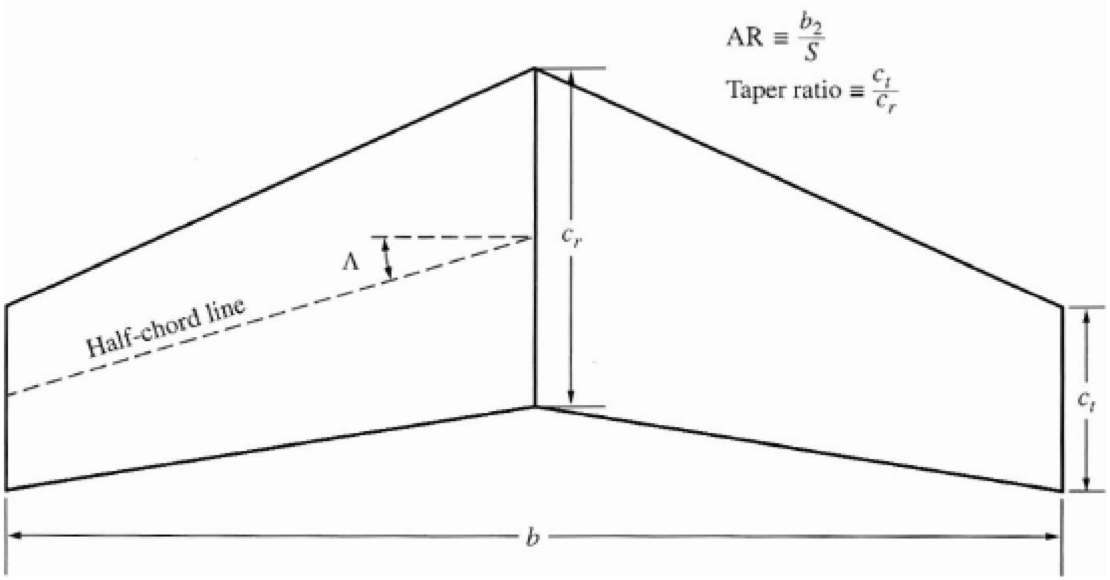
The main function of a swept wing is to reduce wave drag at transonic and supersonic speeds. Consider a straight wing and a swept wing in a flow with a free-stream velocity V. Assume that the aspect ratio is high for both wings, so that we can ignore tip effects. Let ***u*** and ***w*** be the components of V, perpendicular and parallel to the leading edge, respectively. The pressure distribution over the airfoil section oriented perpendicular to the leading edge is mainly governed by the chordwise component of velocity ***u;*** the spanwise component of velocity ***w*** has little effect on the pressure distribution. For the straight wing the chordwise velocity component ***u*** is the full V, for the swept wing the chordwise component of the velocity *u* is smaller than V: $u = V\cos\Lambda$



(a) Straight wing

(b) Swept wing

Since u for the swept wing is smaller than *u* for the straight wing, the difference in pressure between the top and bottom surfaces of the swept wing will be less than the difference in pressure between the top and bottom surfaces of the straight wing. Since lift is generated by these differences in pressure, the lift on the swept wing will **be** less than that on the straight wing.



The wingspan b is the straight-line distance between the wing tips, the wing platform area is *S,* and the aspect ratio and the taper ratio are defined AR = b^2/S and taper ratio ***ct/cr.***

an approximate calculation of the lift slope for a swept finite wing, Kuchemann suggests the following approach. The lift slope for an infinite swept wing should be $a_0 \cos\Lambda$

therefore

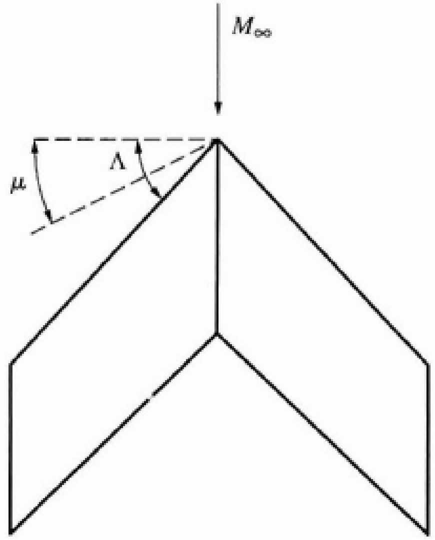
$$\boxed{a = \frac{a_0 \cos\Lambda}{\sqrt{1 + [(a_0 \cos\Lambda)/(\pi \mathrm{AR})]^2} + (a_0 \cos\Lambda)/(\pi \mathrm{AR})}}$$

The subsonic compressibility effect is added by replacing

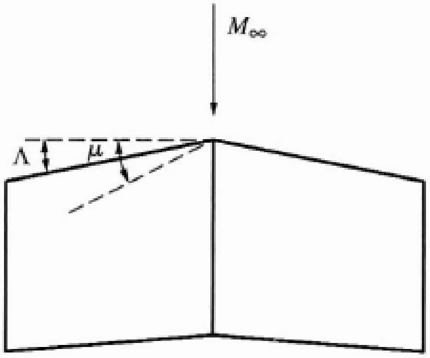
a_0 with $a_0\sqrt{1-Ma}$

$$a_{\text{comp}} = \frac{a_0 \cos \Lambda}{\sqrt{1 - M_\infty^2 \cos^2 \Lambda + [(a_0 \cos \Lambda)/(\pi \text{AR})]^2} + (a_0 \cos \Lambda)/(\pi \text{AR})}$$

Supersonic Delta wings



(a) Subsonic leading edge



(b) Supersonic leading edge

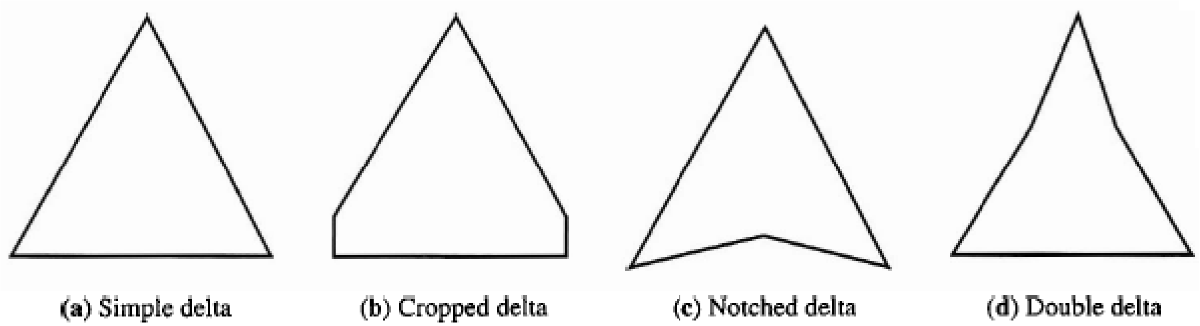
For a swept wing moving at supersonic speeds, the aerodynamic properties depend on the location of the leading edge relative to a Mach wave emanating from the apex of the wing.

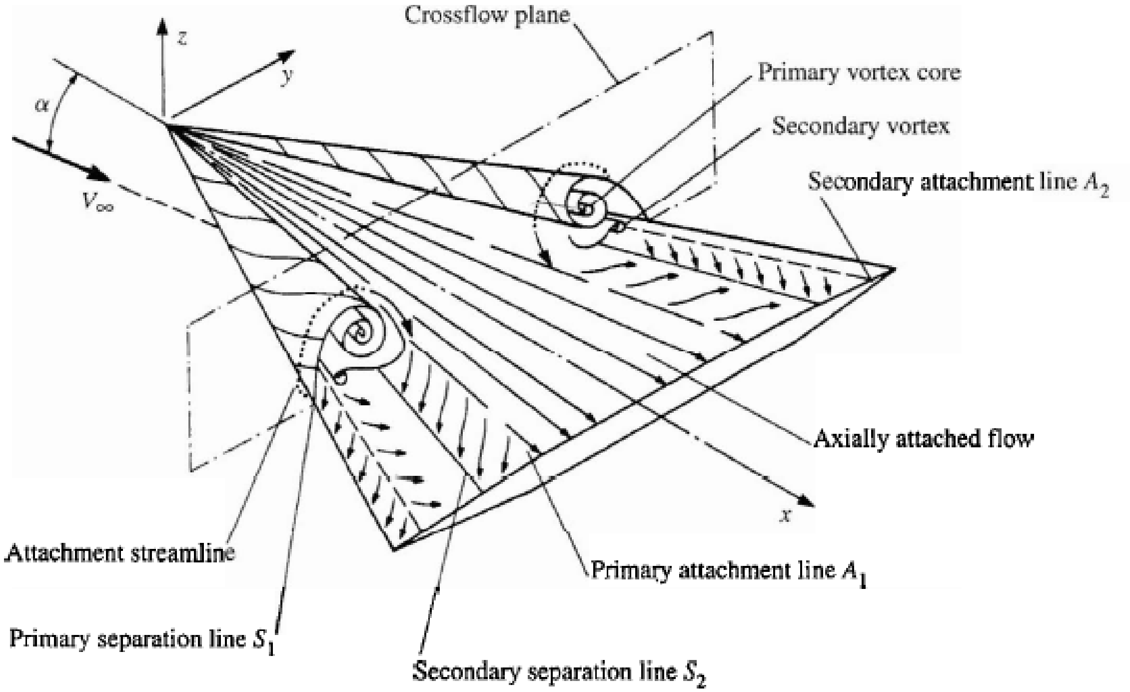
The Mach angle is given by $\mu = \cos^{-1}(1/Ma)$

If the wing leading edge is swept inside the Mach cone the component of *Ma* perpendicular to the leading edge is subsonic; hence, the swept wing is said to have a *subsonic leading edge.* For the wing in supersonic flight, there is a weak shock that emanates from the apex, but there is *no* shock attached elsewhere along the wing leading edge. In contrast, if the wing leading edge is swept outside the Mach cone the component of *Ma,* perpendicular to the leading edge is supersonic; hence the swept wing is said to have a *supersonic leading edge.* For this wing in supersonic flight, there will be a shock wave attached along the entire leading edge. **A** swept wing with a subsonic leading edge behaves somewhat as a wing at subsonic speeds, although the actual free-stream Mach number is supersonic.

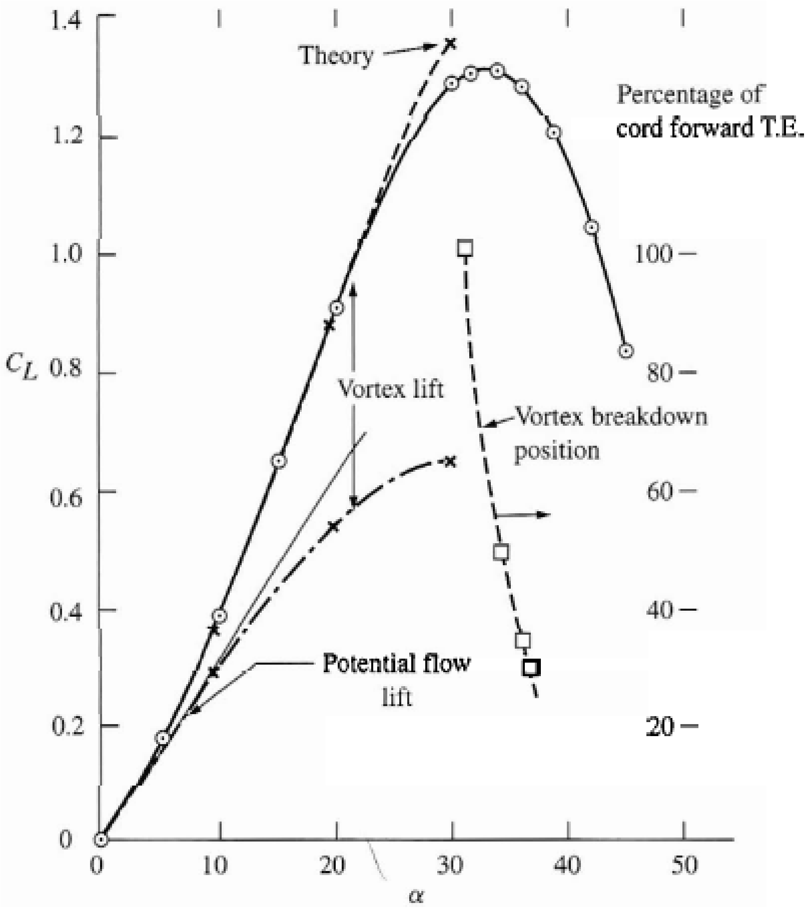
Delta Wings

Swept wings that have platforms such as shown in Fig are called delta wings*.*


(a) Simple delta (b) Cropped delta (c) Notched delta (d) Double delta



dominant aspect of this flow is the two vortices that are formed along the highly swept leading edges, and that trail downstream over the top of the wing. This vortex pattern is created by the following mechanism. The pressure on the bottom surface of the wing is higher than the pressure on the top surface. Thus, the flow on the bottom surface in the vicinity of the leading edge tries to curl around the leading edge from the bottom to the top. If the leading edge is relatively sharp, the flow will separate along its entire length. This separated flow curls into a primary vortex above the wing just inboard of each leading edge. The stream surface which has separated at the leading edge loops above the wing and then reattaches along the primary attachment line. The primary vortex is contained within this loop. **A** secondary vortex is formed underneath the primary vortex, with its own separation line, and its own reattachment line. Unlike many separated flows in aerodynamics, the vortex pattern over a delta wing is a friendly flow in regard to the production of lift. The vortices are strong and generally stable. They are a source of high energy, relatively high vorticity flow, and the local static pressure in the vicinity of the vortices is small. Hence, the vortices create a lower pressure on the top surface than would exist if the vortices were not there. This increases the lift compared to what it would be without the vortices.



The difference between the experimental data and the potential flow lift is the ***vortex lift.*** The vortex lift is a major contributor to the overall lift; The lift slope is small, on the order of 0.05 per degree. The lift, however, continues to increase over a large range of angle of attack (the stalling angle of attack is about **35°).**

The net result is a reasonable value of **CLmax=**1.35. The lift curve is ***nonlinear,*** in contrast to the linear variation exhibited by conventional wings for subsonic aircraft. The vortex lift is mainly responsible for this nonlinearity.

The next time you have an opportunity to watch a delta-wing aircraft take off or land, for example, the televised landing of the space shuttle, note the large angle of attack of the vehicle. Also, this is why the Concorde supersonic transport, with its low-aspect-ratio deltalike wing, lands at a high angle of attack. In fact, the angle of attack is so high that the front part of the fuselage must be mechanically drooped upon landing in order for the pilots to see the runway.