4.2.4 Design Lift Coefficient

This section may be confusing to some students. It is important to differentiate between airfoil section drag due to lift (C_l), and wing drag due to lift (C_L). You must also differentiate between wing section *L/D* and airplane *L/D*.

In subsonic flow, wing drag due to lift has two components:

- Viscous drag due to lift, which results from additional friction due to acceleration of the airflow over the surface of the wing, and flow separation, especially at higher angles of attack. Viscous drag due to lift occurs on both two-dimensional airfoil sections and wings. Only viscous drag due to lift is discussed in section 4.2.
- Inviscid drag due to lift, which results from the downwash induced onto the flow resulting from vortices which are shed from the wing tips. This downwash has the effect of tipping the lift vector from a direction perpendicular to the free stream to a direction slightly aft. The component of the lift vector parallel to the free stream is the inviscid drag due to lift. Inviscid drag due to lift does not occur on two-dimensional airfoil sections. This is discussed in Section 4.3. There is also more discussion on terminology in the Annotation for Section 12.2.

(In supersonic flow there is an additional component of drag called wave drag due to lift. In both subsonic and supersonic flows there is also trim drag due to lift. These are discussed in Section 12.2.).

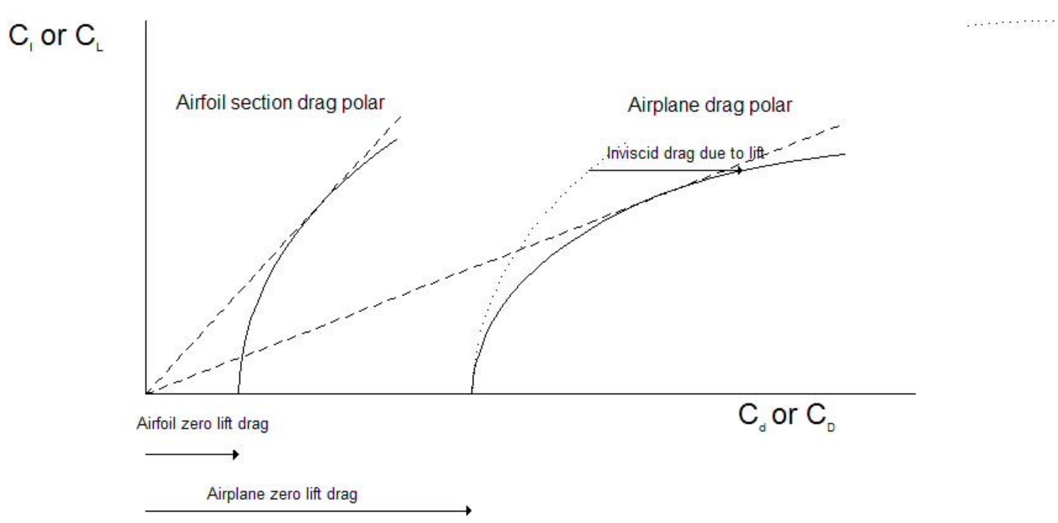

Fig. 4.2.4.1 Comparison between airfoil and airplane drag polars

The left-hand part of Figure 4.2.4.1 shows an airfoil section drag polar, which corresponds to the left-hand part of Raymer's Figure 4.9. Drag is due entirely to skin friction, pressure drag due to boundary layer growth, and separation. To convert the airfoil drag polar to airplane drag polar requires that we add the zero lift drag for the rest of the airplane, which involves a simple translation of the polar to the right (as shown by the dotted line) and then add the effects of a finite wing, which requires adding inviscid drag due to lift (or drag due to tip vortices). We should also add drag due to the change in angle of attack of the fuselage and empennage, but these are relatively small (although not negligible) and will not be considered here. The net result is that the value of airplane $(L/D)_{max}$ is reduced considerably although the wing lift coefficient at which it occurs may, or may not, be about the same as the section lift coefficient for section $(L/D)_{max}$.