# Schaufele Annotations
# Chapter 1 Review of Basic Concepts

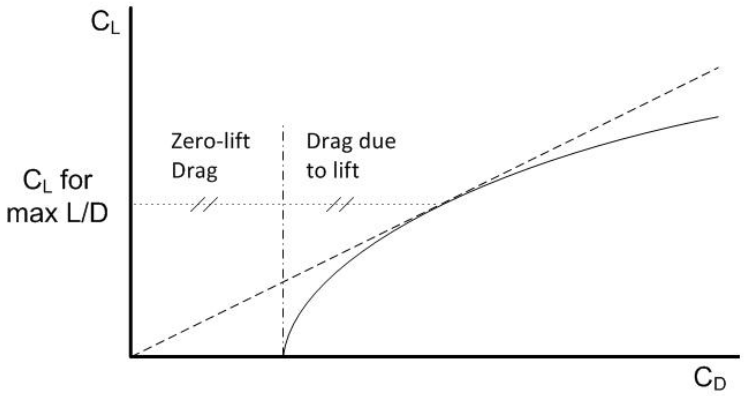



Figure 1.1 Calculating $C_L$ at Maximum Lift/Drag Ratio

Ignoring compressibility effects, an aircraft drag polar may be written as:

$$C_D = C_{D_0} + K C_L^2 \qquad \text{Eq. 1.1}$$

The point on the polar where $C_L/C_D$ is maximized is where the tangent from the origin touches the curve, i.e., where the gradient of the tangent from the origin equals the gradient of the curve. Thus:

$$\frac{C_D}{C_L} = \frac{dC_D}{dC_L} \qquad \text{Eq. 1.2}$$

Differentiating Eq. 1.1: $$\frac{dC_D}{dC_L} = 2KC_L \qquad \text{Eq. 1.3}$$

Thus $$\frac{C_D}{C_L} = 2KC_L \text{ or } C_D = 2KC_L^2 \qquad \text{Eq. 1.4}$$

Inserting this back into Eq. 1.1 we have $C_{D_0} = KC_L^2$, i.e., zero-lift drag is equal to drag due to lift.

For the condition of maximum L/D: $$C_L = \sqrt{\frac{C_{D_0}}{K}} \qquad \text{Eq. 1.5}$$

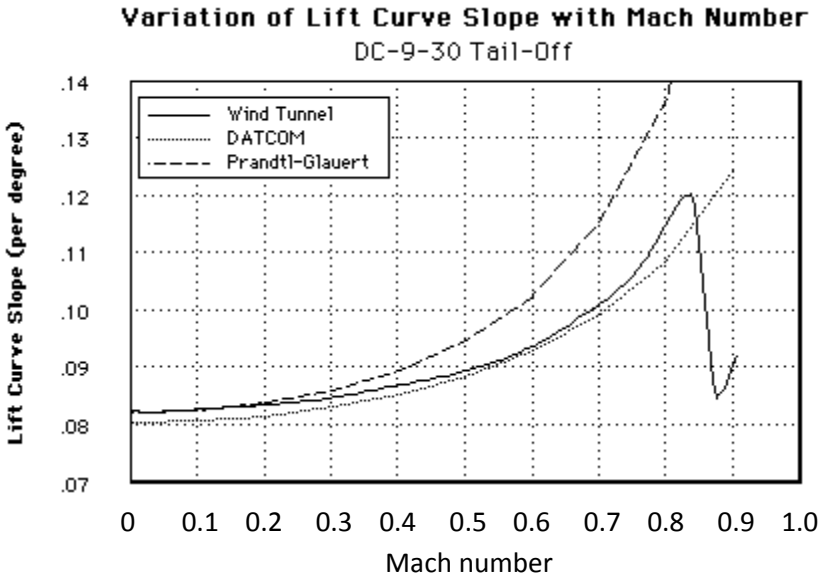
and $$\left(\frac{L}{D}\right)_{max} = \frac{1}{2\sqrt{KC_{D_0}}} \qquad \text{Eq. 1.6}$$

This is the condition for optimum endurance (e.g., when loitering), and related to the condition for maximum range, which is usually at a slightly lower $C_L$ for which $\frac{L}{D} = 0.866\left(\frac{L}{D}\right)_{max}$. This latter condition

arises from the requirement to maximize V(L/D) in the Breguet range equation, which will be discussed in a later chapter.

## Mach Number Effects on Lift and Drag Curves

On page 22 Schaufele states that the gradient of the lift curve increases with Mach number by a factor of $\frac{1}{\sqrt{1-M^2}}$ (the Prandtl-Glauert transformation), where M is the free-stream Mach number. This is true of a wing section, but not for a wing, and then only up to about M = 0.8. For a swept wing, the increase in the gradient of the lift curve is only about 60% of the value predicted by the Prandtl-Glauert transformation, as shown in Fig. 1.2. The DATCOM (Ref. 1.1) value is much closer to the experimental data.




Source: Ilan Kroo

Figure 1.2 Comparison of Calculated and Experimental $C_{L_\alpha}$

References

1.1 Hoak, D.E.,"The USAF Stability and Control DATCOM", Air Force Wright Aeronautical Laboratories, TR-83-3048, Oct 1960