Actual Drag Polars

As pointed out in the lecture notes in Chapter 3.2.5, actual drag polars from experimental results will usually differ from the symmetric parabolic form

$$C_D = C_{D0} + \frac{C_L^2}{pAe} \quad . \tag{1}$$

This parabolic form may be used for an uncambered wing. For a cambered wing, on the other hand, a modified asymmetric form should be used

$$C_D = C_{D,\min} + \frac{\left(C_L - C_L(C_{D,\min})\right)^2}{pAe} \quad . \tag{2}$$

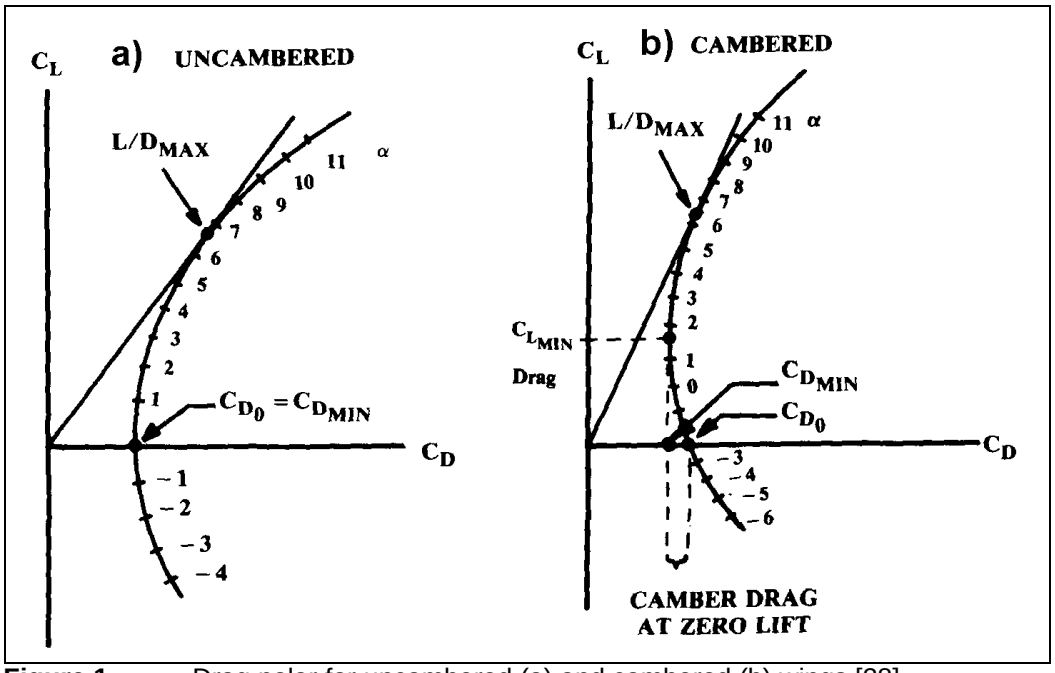

Figure 1 Drag polar for uncambered (a) and cambered (b) wings [28]

At high lift coefficients (near the stall), further discrepancies between the parabolic drag polar and the actual drag polar exist. At these high lift coefficients drag increases faster with angle of attack as predicted by a parabolic drag polar fitted to low lift coefficients. This effect could also been accounted for with a drag polar of the form

$$C_D = C_{D,\min} + k_1\left(C_L - C_L(C_{D,\min})\right)^2 + k_2\left(C_L - C_L(C_{D,\min})\right)^4 \tag{3}$$

If the parameters in the equations are to be obtained from flight test data, each of these equations needs a different number of given data points $C_d\,(C_l)$:

- equation 1 needs 2 data points
- equation 2 needs 3 data points
- equation 3 needs 4 data points
- equation 3 needs only 3 data points, if it is assumed that $C_l\,(C_{D,min}) = 0$.

If more data points are available than required above, a curve shall be fitted to the data points.

The drag polar changes with Mach number and with flap deflection. Example drag polars are given in Figure 2 through 4.

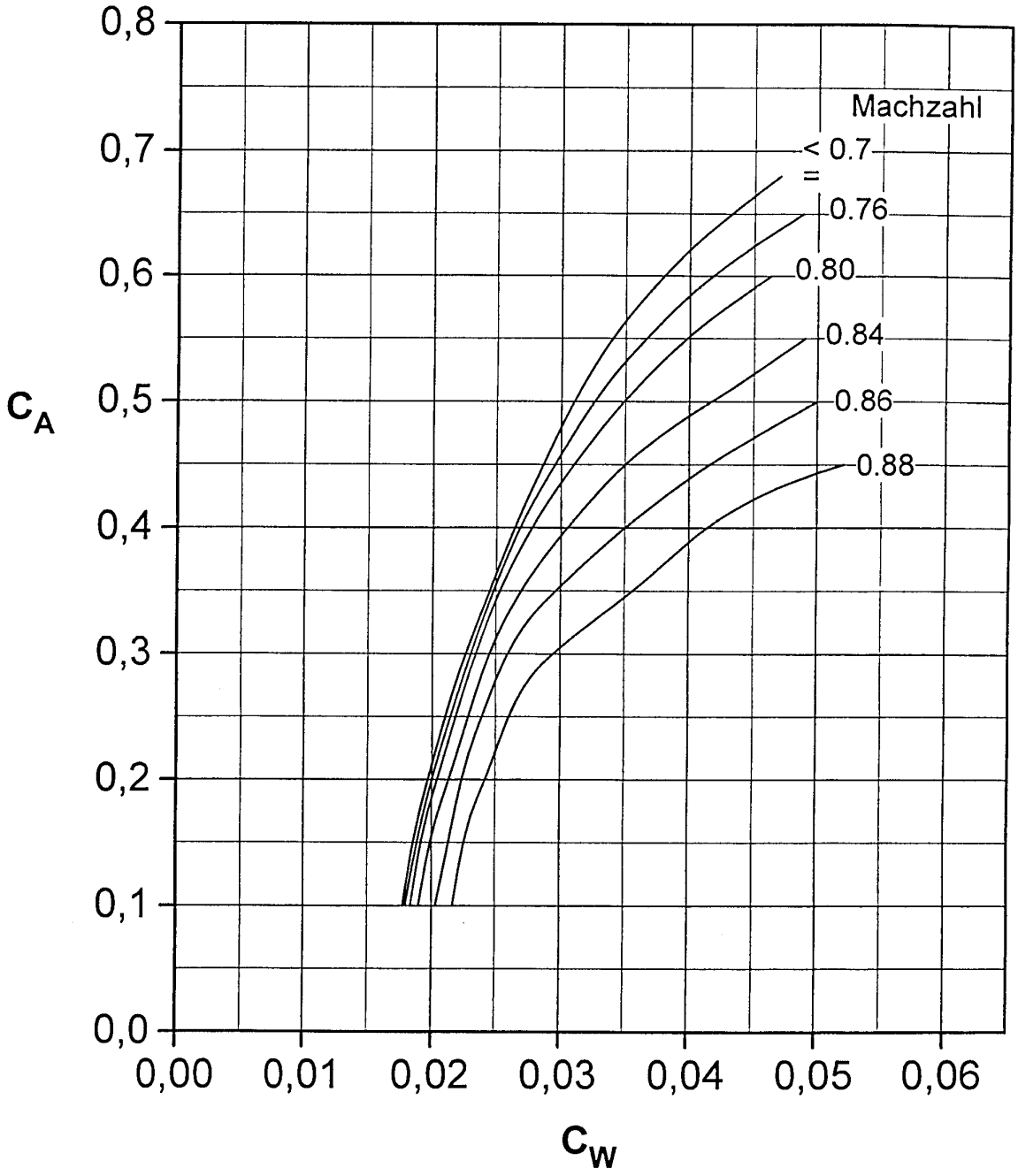

Figure 2 Lift coefficient (Auftriebsbeiwert) C_A plotted as function of drag coefficient (Widerstandsbeiwert) C_W with Machnumber (Machzahl) used as further parameter

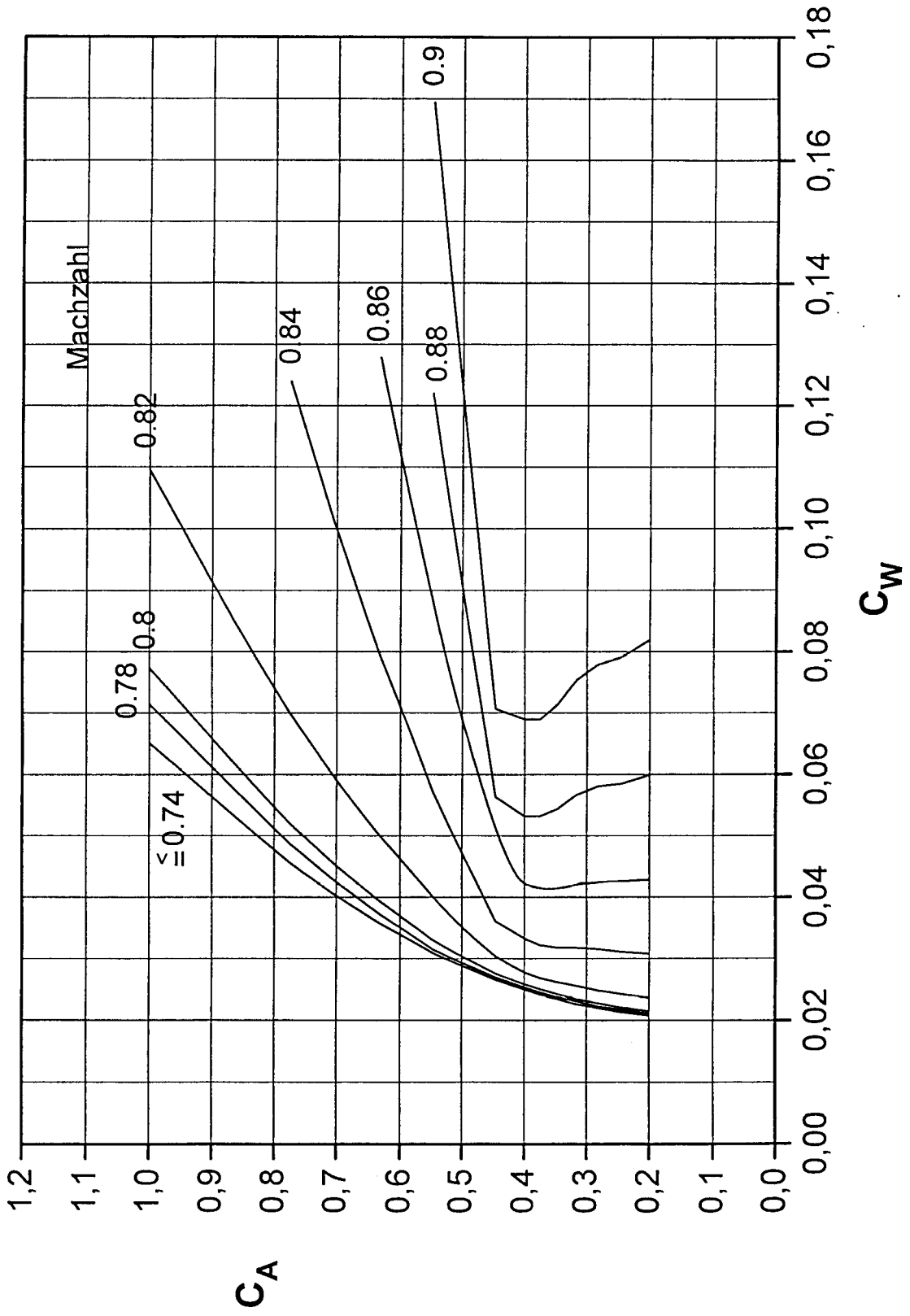

Figure 3 Lift coefficient (Auftriebsbeiwert) C_A plotted as function of drag coefficient (Widerstandsbeiwert) C_W with Machnumber (Machzahl) used as further parameter

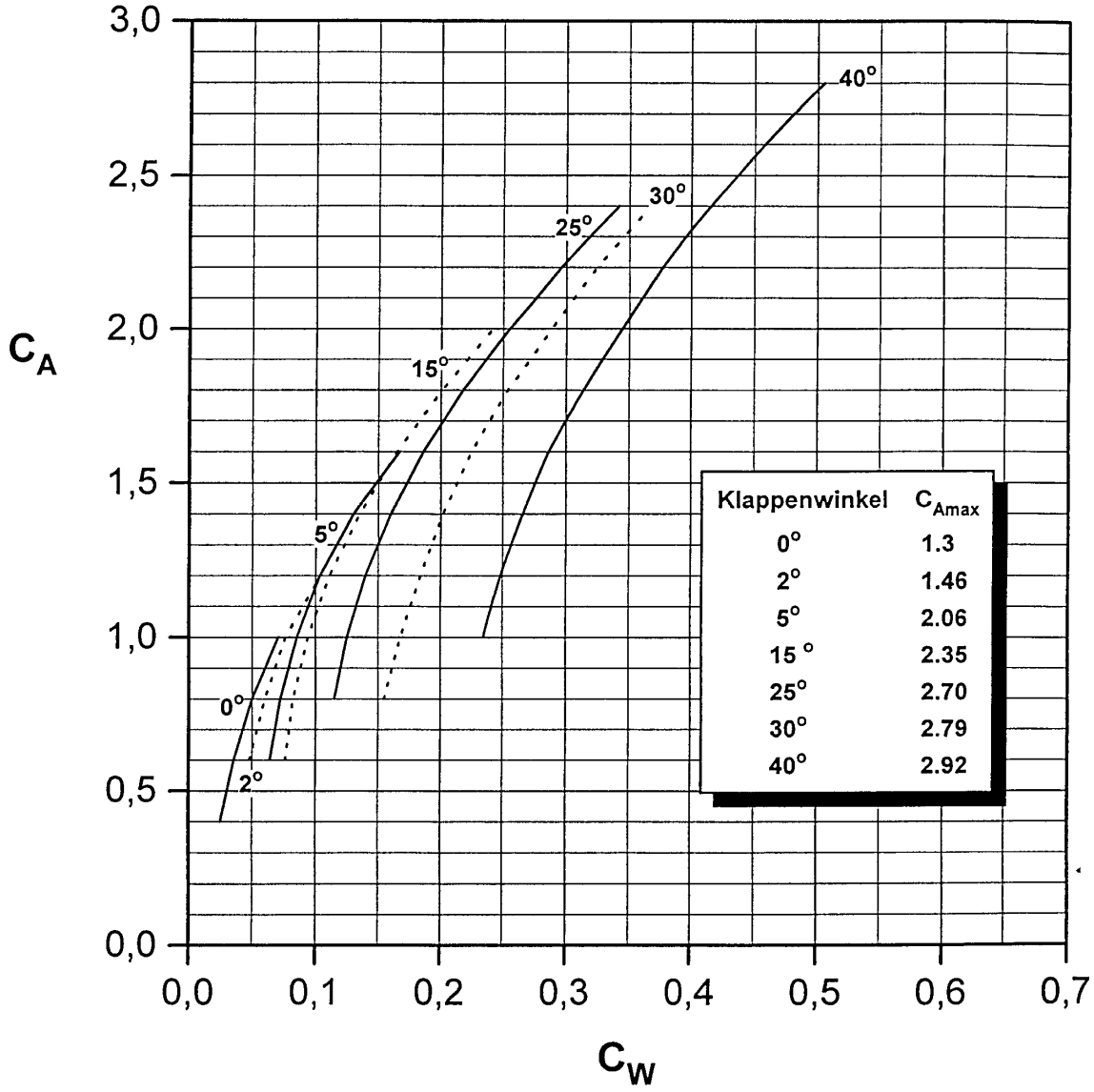

Figure 4 Lift coefficient (Auftriebsbeiwert) C_A plotted as function of drag coefficient (Widerstandsbeiwert) C_W with flap deflection angle (Klappenwinkel) used as further parameter

Source of Figures 2, 3 and 4:

MARCKWARDT, Klaus: *Flugmechanik*. Hamburg, Fachhochschule Hamburg, Fachbereich Fahrzeugtechnik, Vorlesungsskript, 1998