Design Methodology

1) Create a drawing that includes all important components:
   motor, battery, landing gear, payload, receiver, speed control, data recorder, servos

   Show dimensions, and cross-sections of the fuselage to show that everything fits.

2) sizing W_0 = takeoff weight = $\dfrac{W_{payload}}{1 - \dfrac{W_{empty}}{W_{takeoff}}}$ notice recursive definition: requires iteration

→ * all "W" are in kg

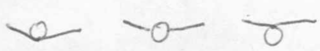
~~[illegible]~~, if you use $\dfrac{W_e}{W_0} = 0.88\,(W_0)^{-0.05}$ for a powered sailplane, this should be a good approx.

3) in cruise, $L = W$ (lift) so $C_L = \dfrac{W_0}{\frac{1}{2}\rho V^2 S}$ (ρ: density of air, V: velocity, S: wing area)

for a given airfoil you can find C_D for a given C_L see chart.

4) select wing & tail geometry – sweep (Λ), incidence, twist, dihedral, aspect ratio (AR), taper ratio (λ)

dihedral guide: low mid high



5 to 7° 2 to 4° 0 to 2°

wing tips:

remember $C_{D,i} = \dfrac{C_L^2}{\pi \cdot AR}(1+\delta)$ see chart for δ based on λ and AR

$\lambda \approx 0.4$ is best for approximating an elliptical lift distribution

5) More advanced, airfoil selection

use $\rho = 1.225 \frac{kg}{m^3}$

choose based on Reynold's number "Re" $Re = \frac{\rho V D}{\mu}$

(density → ρ, velocity → V, length (chord) → D, viscosity → μ (use 3.74×10^{-7}))

and thickness ratio $\frac{t}{c}$

thinner (low $\frac{t}{c}$) may have lower drag, in the end you want to maximize $\frac{L}{D}$

or $\frac{C_L}{C_D}$ when $C_{D,p} = C_{D,i}$, $\frac{L}{D}$ is maximum

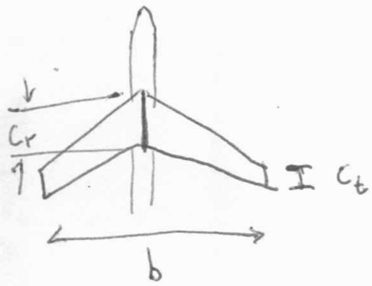
($C_{D,p}$: off airfoil chart)

$C_{D,i} = \frac{C_L^2}{\pi \cdot AR}(1+\delta)$ from previous page

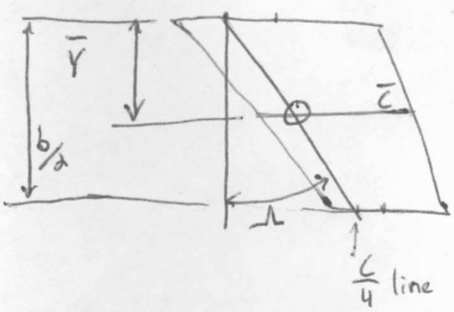
— Geometry Selection

trapezoidal reference wing

$\frac{C_t}{C_r} = \lambda$ taper ratio



note: overlaps fuselage, and this is fine for this stage



Λ = sweep angle of $\frac{c}{4}$ line $\bar{Y} = \frac{b}{6}\left[\frac{1+2\lambda}{1+\lambda}\right]$

$\bar{c}$ = aerodynamic mean chord

the $\frac{\bar{c}}{4}$ point is where you model the lift force location

each 10° of sweep is about the same as 1° of dihedral for stability.

- Things to keep in mind

Stall characteristics

sweep, thickness ratio of airfoil, tail position

landing characteristics

landing gear arrangement (tail dragger, trike, etc.), flaps

handling characteristics / stability

dihedral, tail surfaces, center of gravity

V, T tail, etc.

- $$\text{Score} = (\text{velocity})^{1.3} \left(\frac{\text{meters}}{\text{Joule}}\right) (\text{payload})^{0.6}$$

To make your design better, change one variable and re-evaluate your projected score. This is the process of "trade studies."

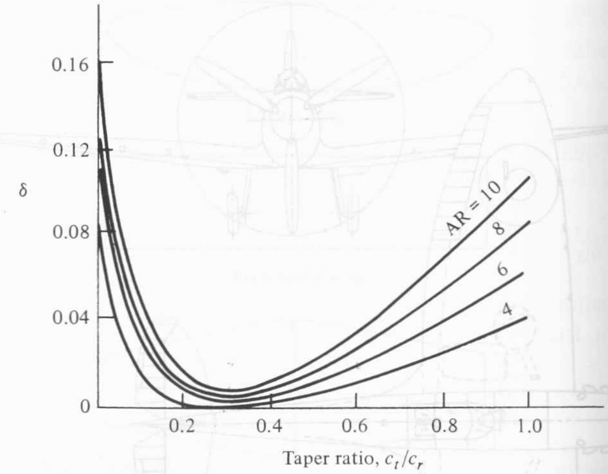


Figure 5.20 Induced drag factor δ as a function of taper ratio. (*Source:* McCormick, B. W., *Aerodynamics, Aeronautics, and Flight Mechanics,* John Wiley & Sons, New York, 1979.)

were measured. The data are given in Figure 5.21. Recall from Equation (5.4) that the total drag of a finite wing is given by

$$C_D = c_d + \frac{C_L^2}{\pi e \mathrm{AR}} \tag{5.63}$$

The parabolic variation of C_D with C_L as expressed in Equation (5.63) is reflected in the data of Figure 5.21. If we consider two wings with different aspect ratios AR_1 and AR_2, Equation (5.63) gives the drag coefficients $C_{D,1}$ and $C_{D,2}$ for the two wings as

$$C_{D,1} = c_d + \frac{C_L^2}{\pi e \mathrm{AR}_1} \tag{5.64a}$$

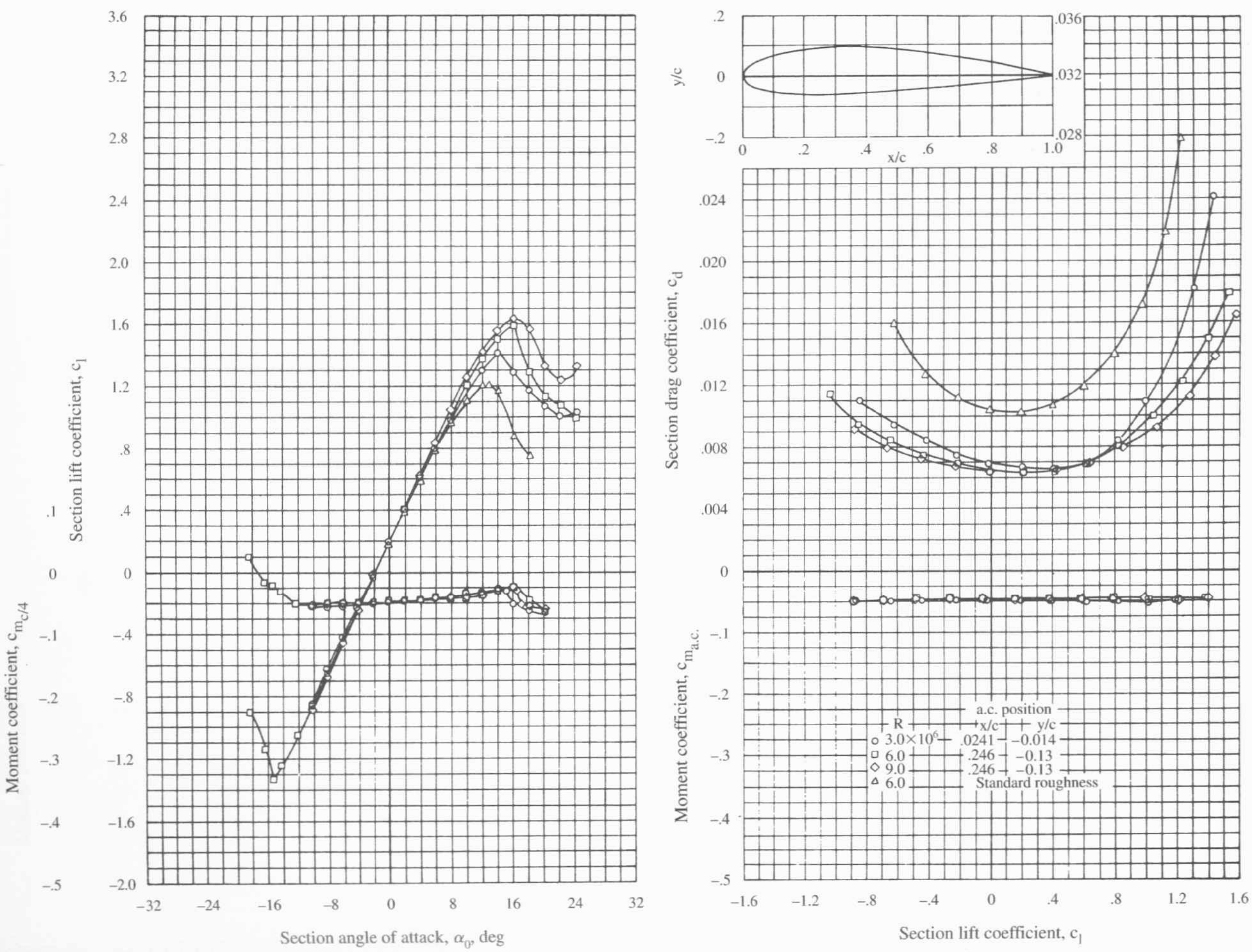
and

$$C_{D,2} = c_d + \frac{C_L^2}{\pi e \mathrm{AR}_2} \tag{5.64b}$$

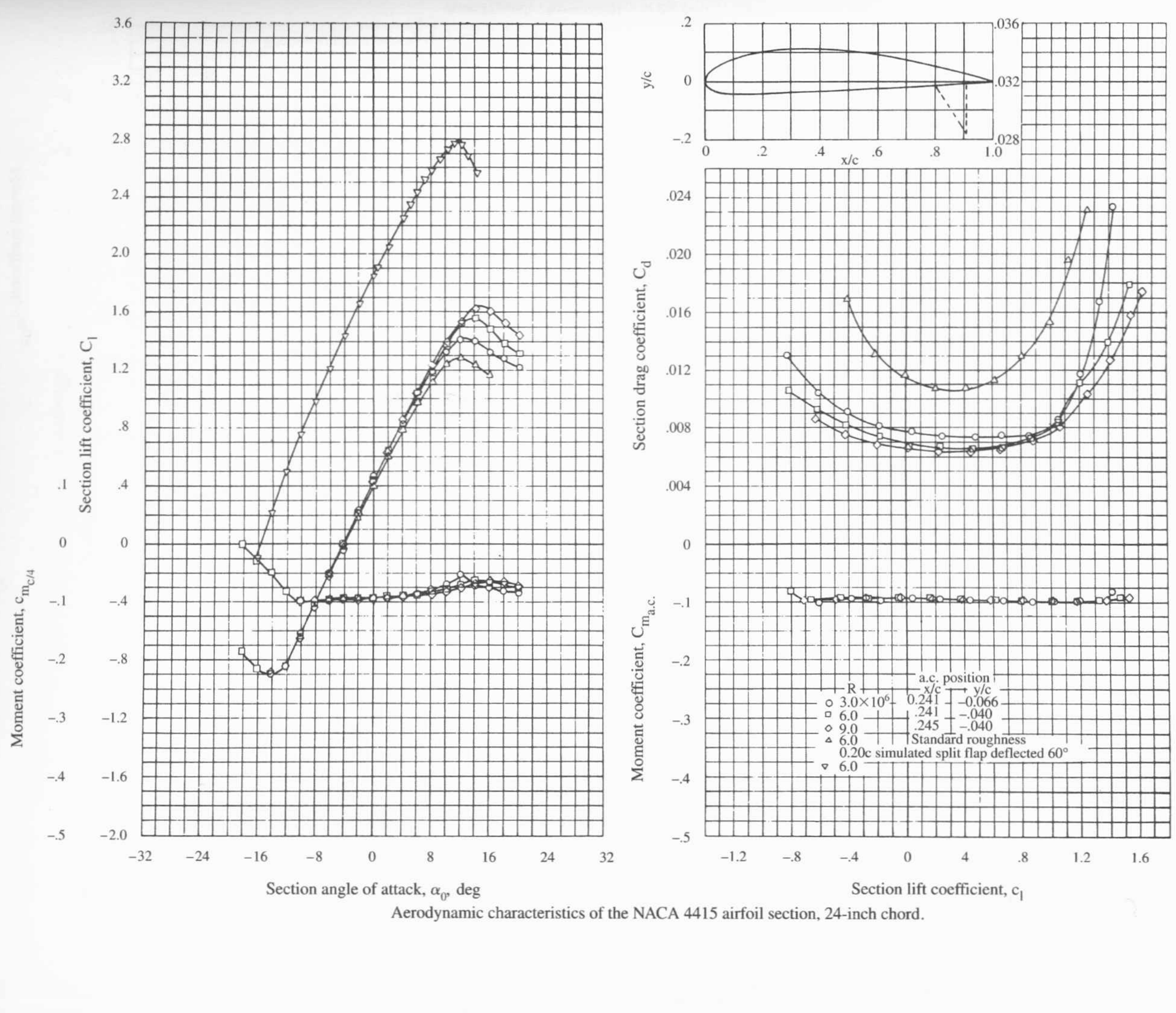
Assume that the wings are at the same C_L. Also, since the airfoil section is the same for both wings, c_d is essentially the same. Moreover, the variation of e between the wings is only a few percent and can be ignored. Hence, subtracting Equation (5.64*b*) from (5.64*a*), we obtain

$$C_{D,1} = C_{D,2} + \frac{C_L^2}{\pi e}\left(\frac{1}{\mathrm{AR}_1} - \frac{1}{\mathrm{AR}_2}\right) \tag{5.65}$$

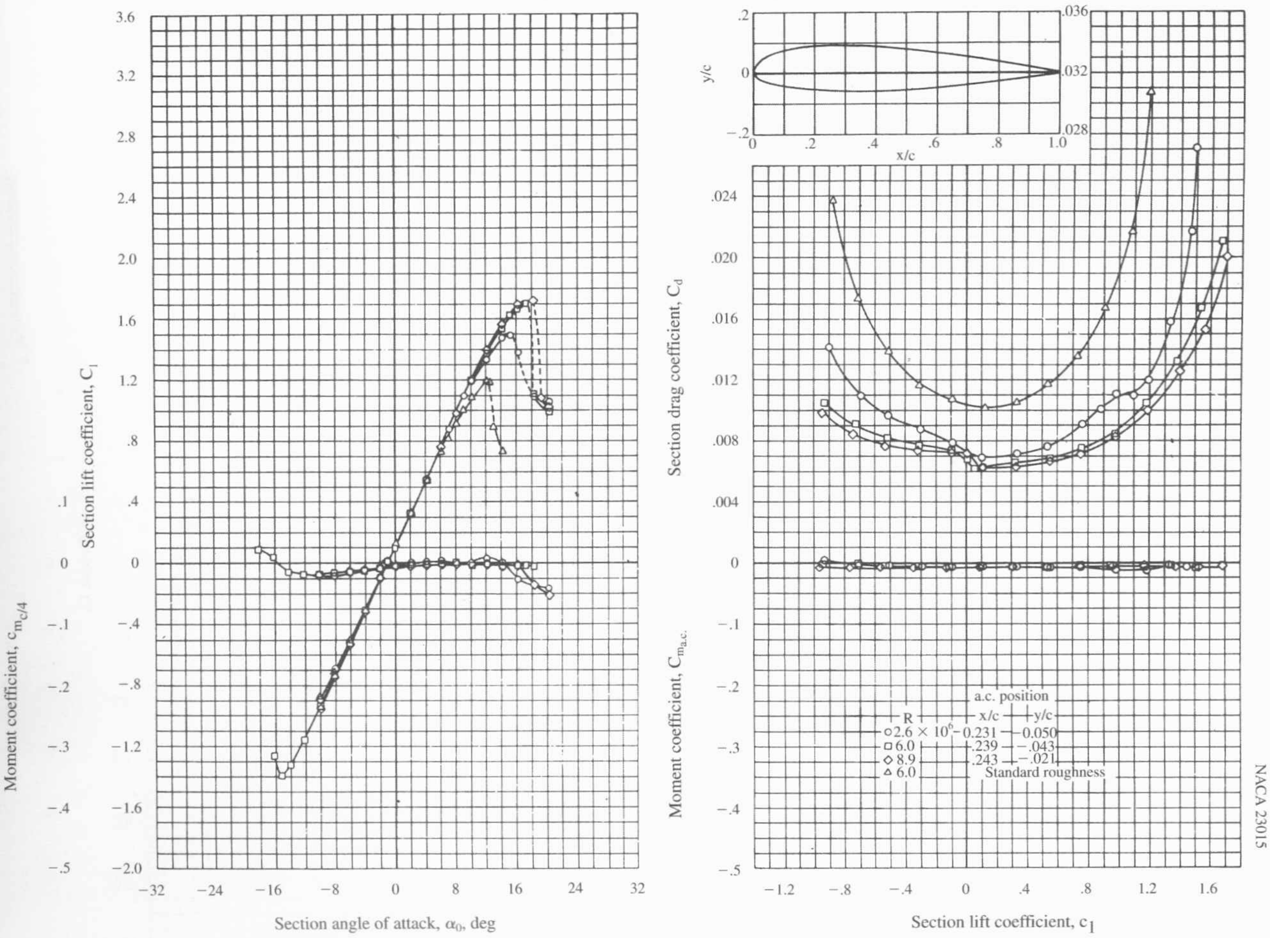
Equation (5.65) can be used to scale the data of a wing with aspect ratio AR_2 to correspond to the case of another aspect ratio AR_1. For example, Prandtl scaled



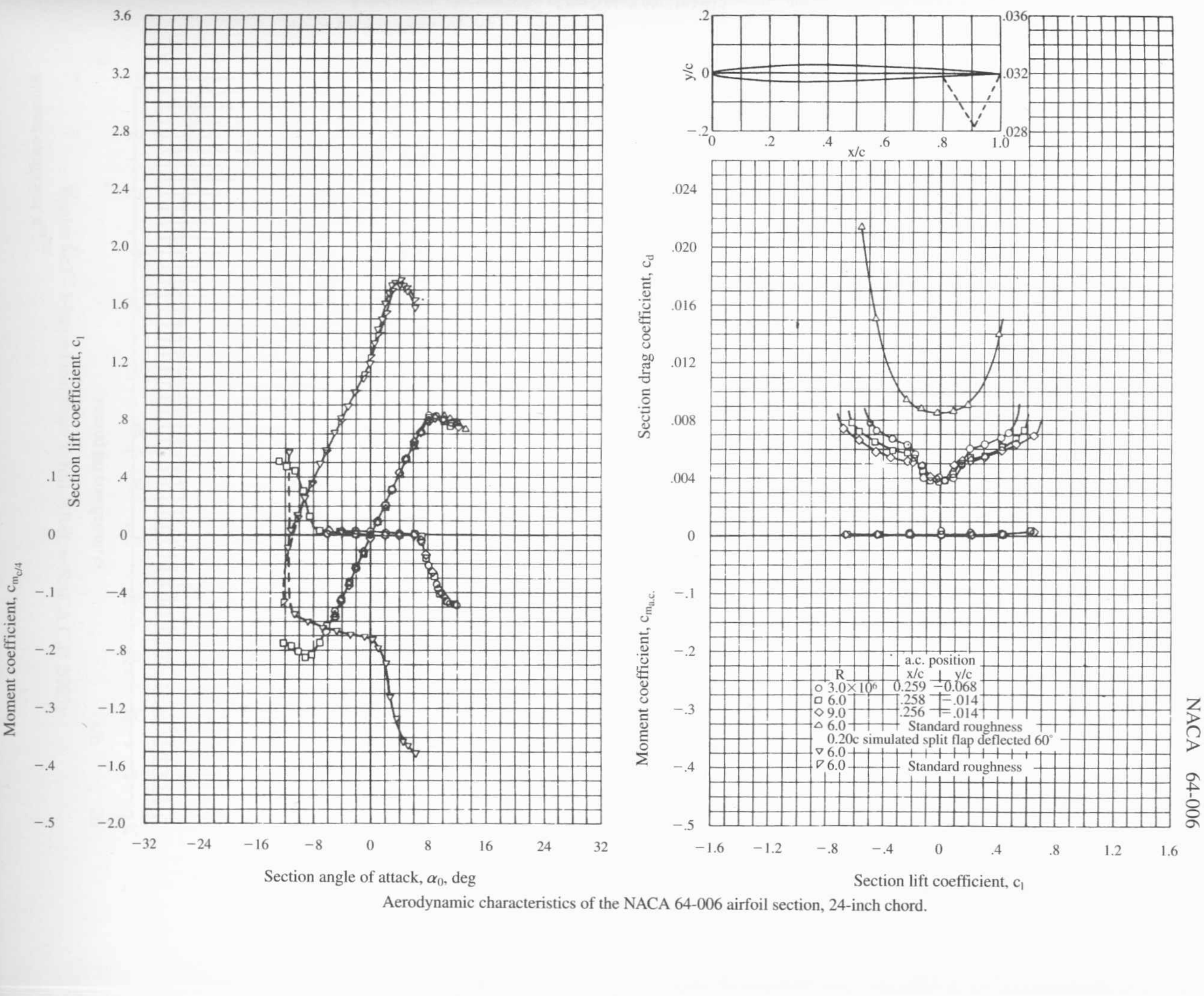
Aerodynamic characteristics of the NACA 2415 airfoil section, 24-inch chord.



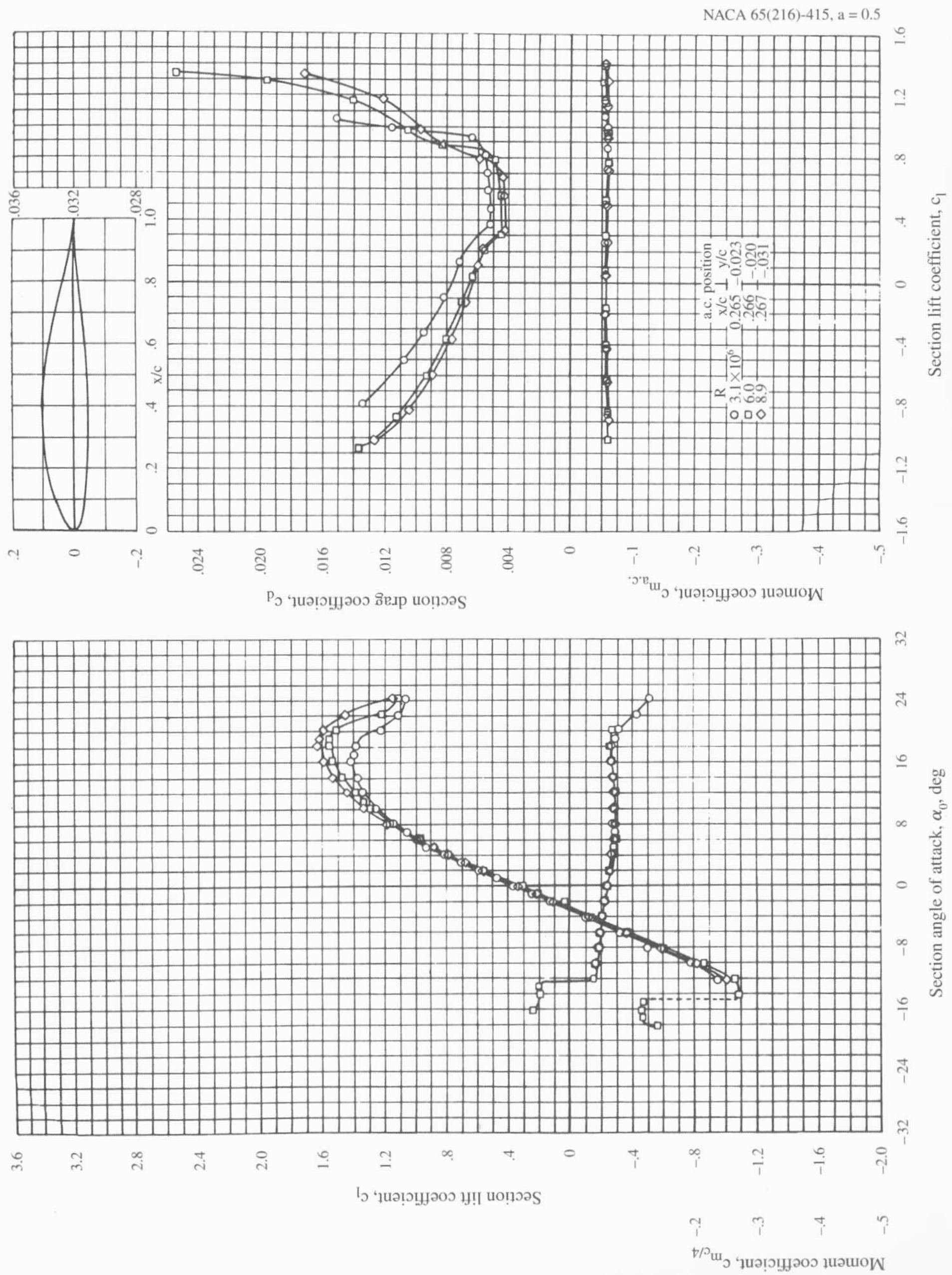
Aerodynamic characteristics of the NACA 4415 airfoil section, 24-inch chord.



Aerodynamic characteristics of the NACA 23015 airfoil section, 24-inch chord.



Aerodynamic characteristics of the NACA 64-006 airfoil section, 24-inch chord.

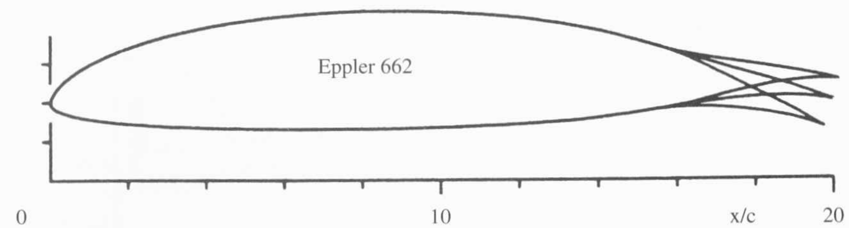


Aerodynamic characteristics of the NACA 65(216)-415, a = 0.5 airfoil section, 24-inch chord.

Airfoil Coordinates
Eppler 662

PROFIL N	662 X	15.02% Y	PROFIL N	662 X	15.02% Y
0	100.000	0.000			
1	99.642	.118	31	.239	.770
2	98.640	.483	32	.003	-.074
3	97.117	1.056	33	.351	-.733
4	95.113	1.745	34	1.336	-1.289
5	92.609	2.516	35	2.879	-1.785
6	89.626	3.395	36	4.966	-2.210
7	86.231	4.390	37	7.571	-2.567
8	82.500	5.493	38	10.668	-2.858
9	78.528	6.682	39	14.221	-3.088
10	74.435	7.890	40	18.189	-3.264
11	70.276	8.968	41	22.522	-3.392
12	65.983	9.824	42	27.165	-3.474
13	61.519	10.489	43	32.061	-3.512
14	56.922	10.988	44	37.148	-3.506
15	52.232	11.331	45	42.363	-3.456
16	47.501	11.525	46	47.642	-3.357
17	42.776	11.570	47	52.919	-3.206
18	38.108	11.470	48	58.130	-2.993
19	33.541	11.225	49	63.214	-2.702
20	29.121	10.841	50	68.116	-2.302
21	24.891	10.324	51	72.841	-1.742
22	20.891	9.681	52	77.449	-1.061
23	17.159	8.923	53	81.940	-.382
24	13.729	8.062	54	86.229	.169
25	10.631	7.113	55	90.177	.509
26	7.892	6.094	56	93.628	.611
27	5.535	5.024	57	96.423	.500
28	3.578	3.926	58	98.431	.276
29	2.037	2.828	59	99.613	.077
30	.921	1.761	60	100.000	-.000

CM= -.1497 β= 5.92°



Eppler 662 – Flapped sailplane airfoil. (Ref. = NACA C.P. 2085)