Fluid mechanics (wb1225)

Lecture 11: Flow past immersed bodies

Tacoma Narrows Bridge

[1]

Noren krijgen optie op nieuw snel schaatspak

De Poolse schaatser Pavek Zygmunt demonstreerde dinsdag in een windtunnel in Delft een nieuw schaatspak. Omdat de Nederlanders in Salt Lake City verplicht in kleding van Nike uitkomen, krijgt Noorwegen de optie op het in Delft ontwikkelde nieuwe schaatspak, waarvan een rendement van ongeveer vijf procent wordt verwacht. Het Deltapak 'Flash' is de doorstart van de strips die vier jaar geleden in Nagano mede bijdroegen aan de Nederlandse successen. FOTO ANP

[2]

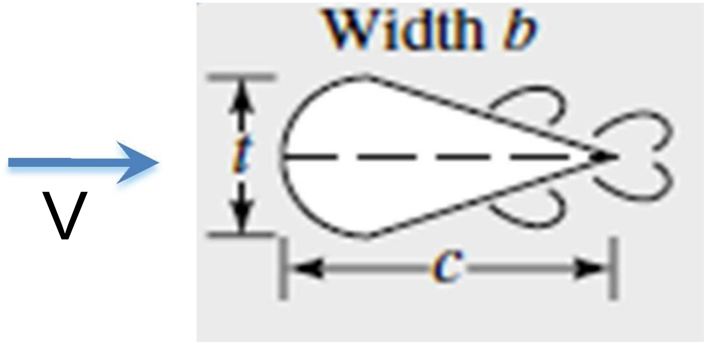
Drag on immersed body

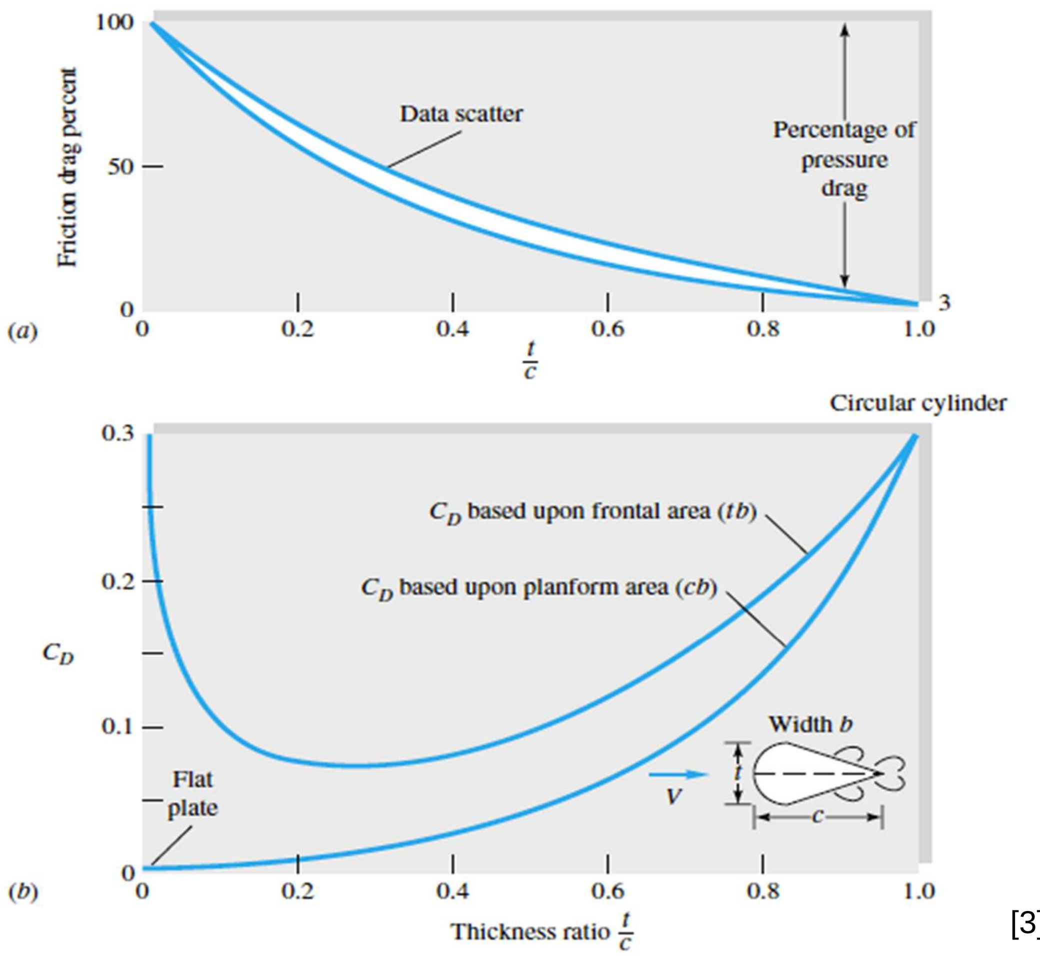
$$C_D = \frac{\text{drag}}{\frac{1}{2}\rho V^2 A}$$

$$C_D = C_{D,\text{pressure}} + C_{D,\text{friction}}$$

$$A = \begin{cases} \text{frontal area} \\ \text{planform area} \end{cases}$$

Streamlined cylinder

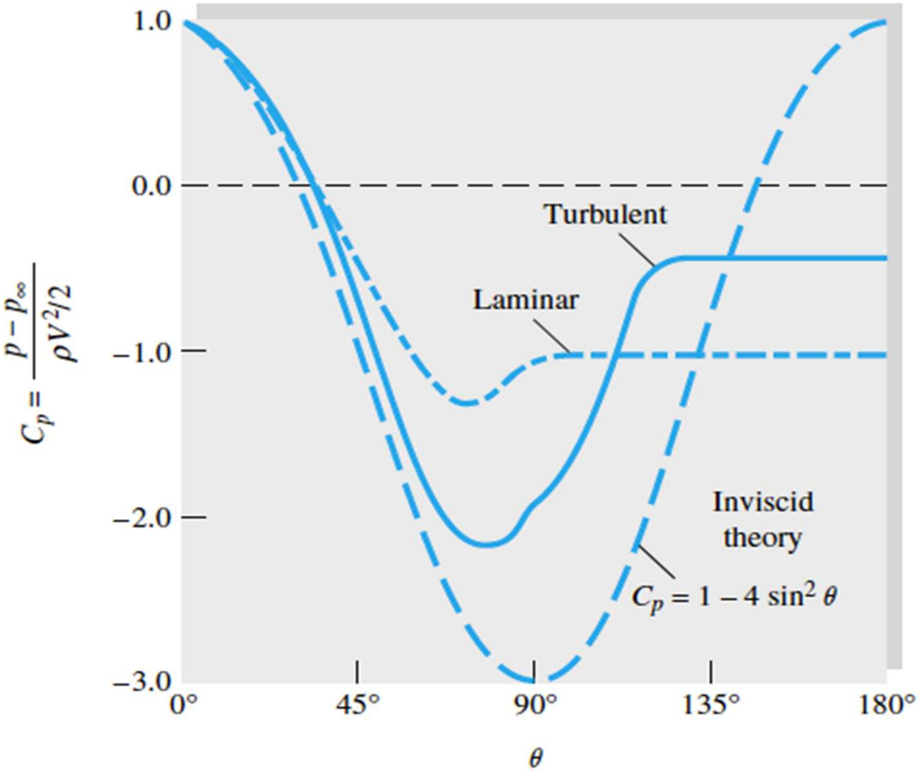


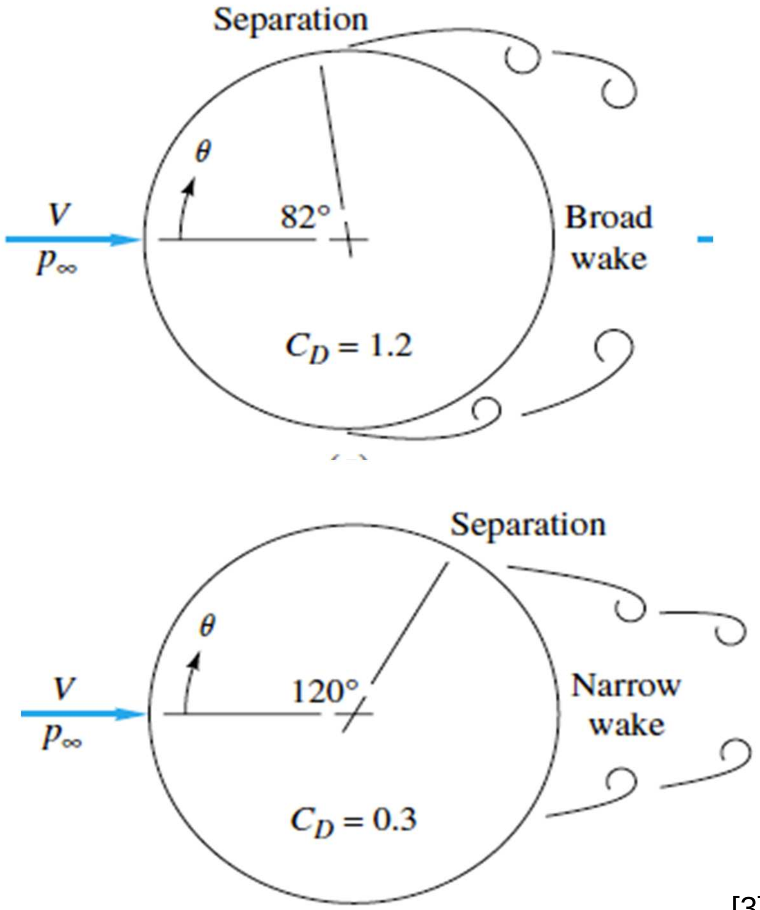


[3]

Pressure distribution

$$C_P = \frac{p - p_\infty}{\frac{1}{2}\rho V^2} = 1 - 4\sin^2\theta$$

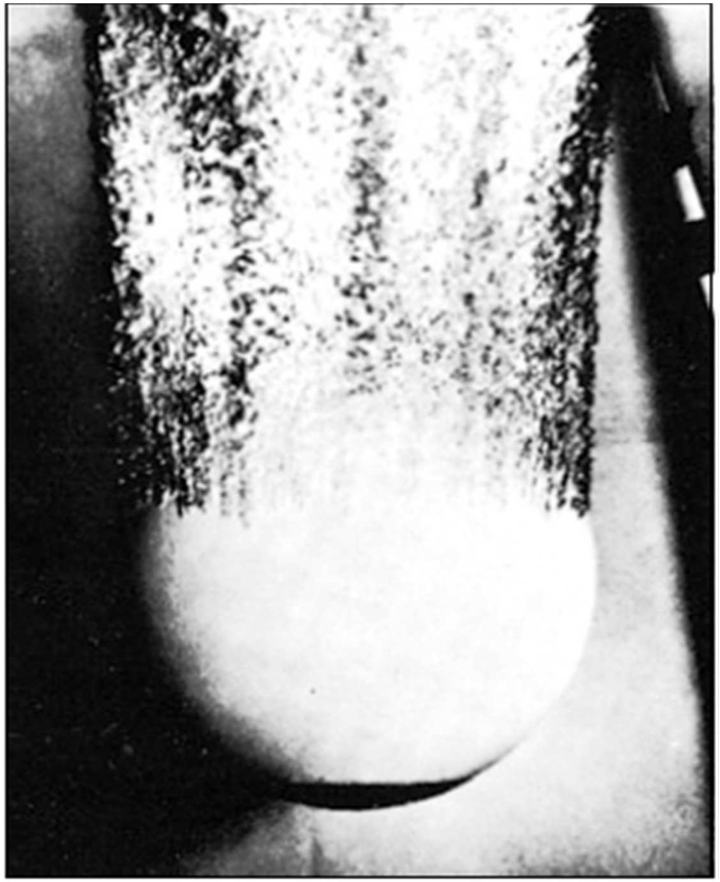




[3]

Laminar vs turbulent flow

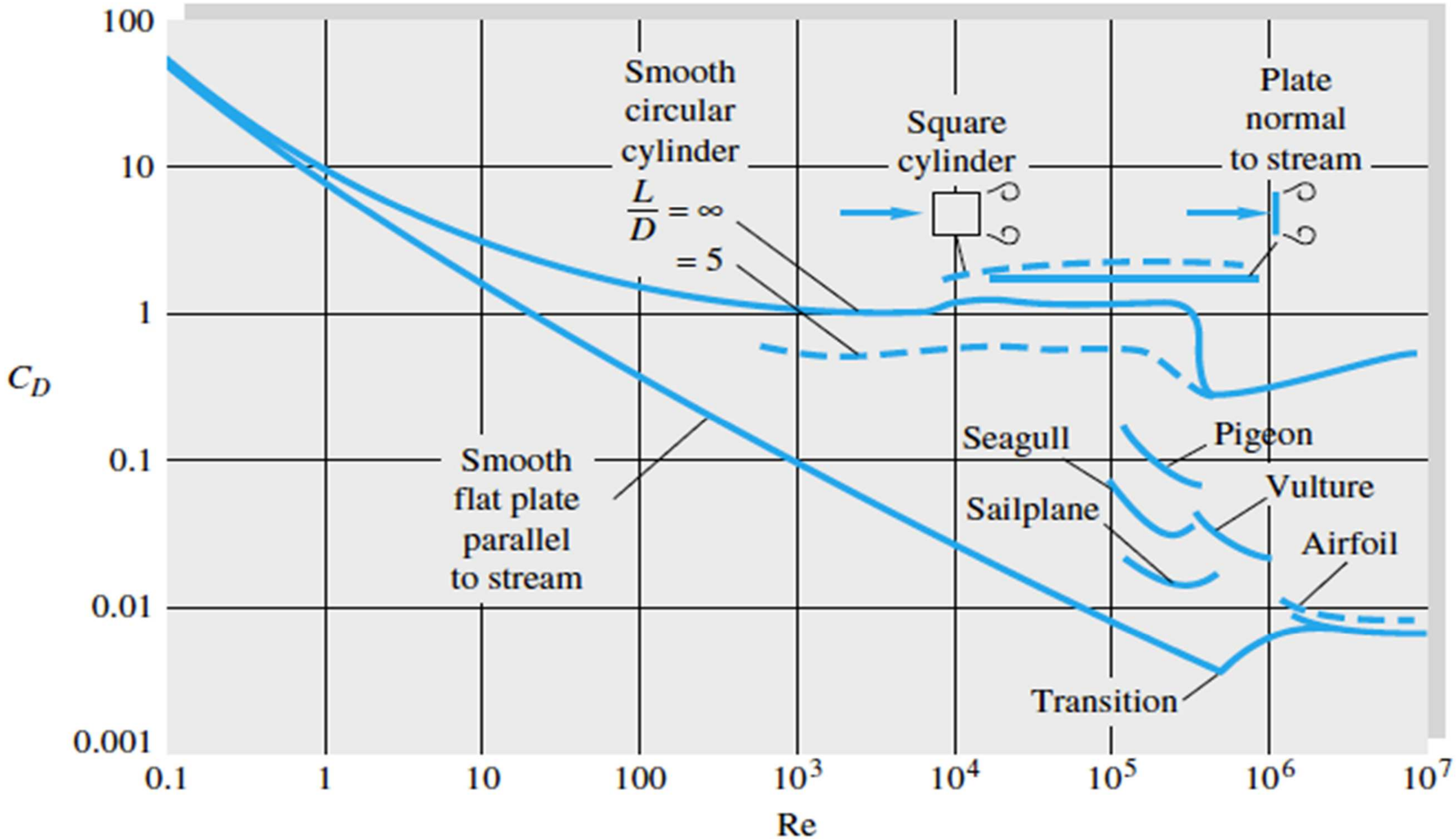
laminar



turbulent

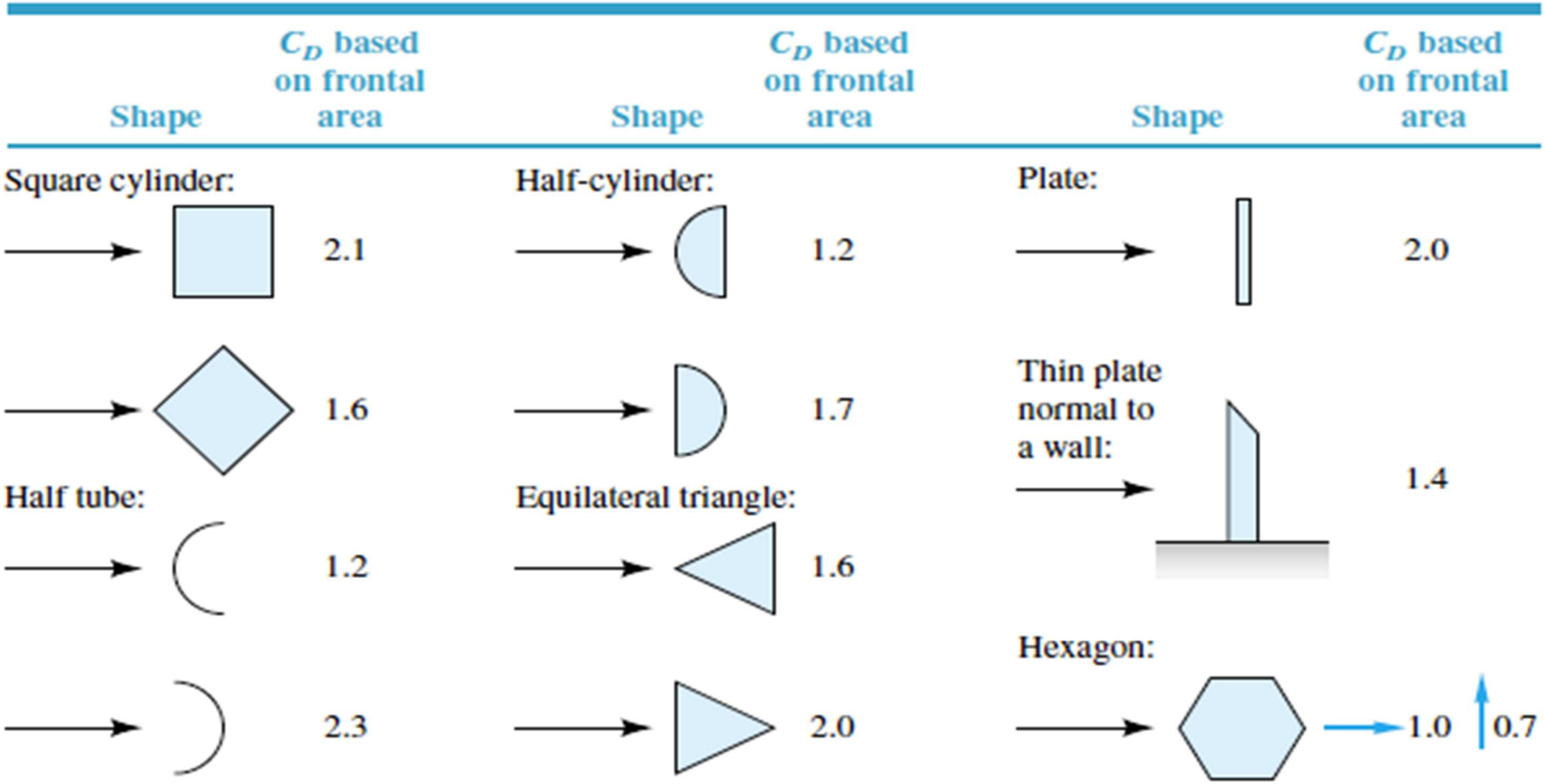
[3]

Arbitrary objects



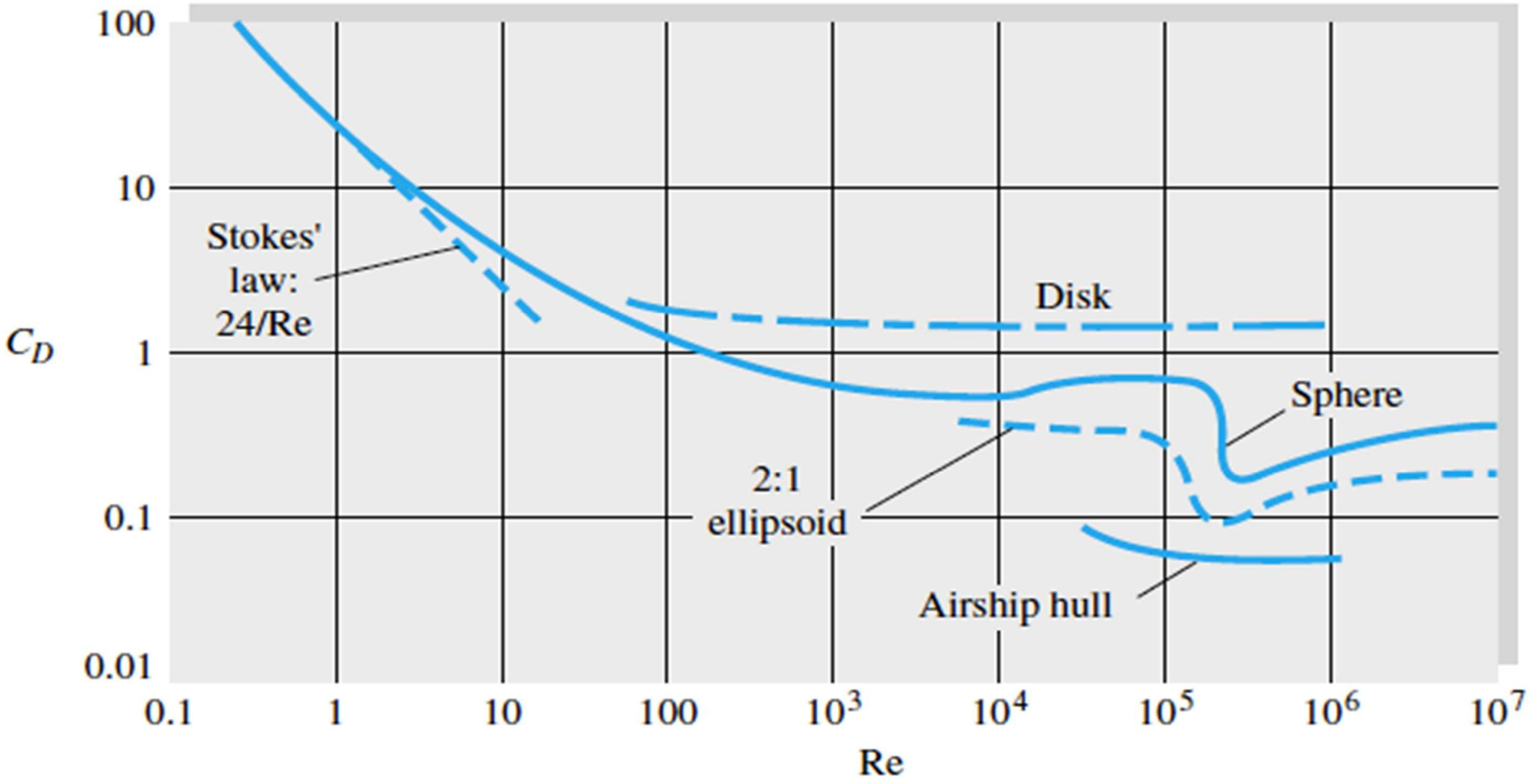
[3]

Two-dimensional objects



[3]

Three-dimensional objects



[3]

Three-dimensional objects

Table 7.3 Drag of Three-Dimensional Bodies at $Re \geq 10^4$

Body	C_D based on frontal area
Cube: (flat face to flow)	1.07
Cube: (edge to flow)	0.81
Cup: (open side facing flow)	1.4
Cup: (rounded side facing flow)	0.4
Disk:	1.17
Parachute (Low porosity):	1.2

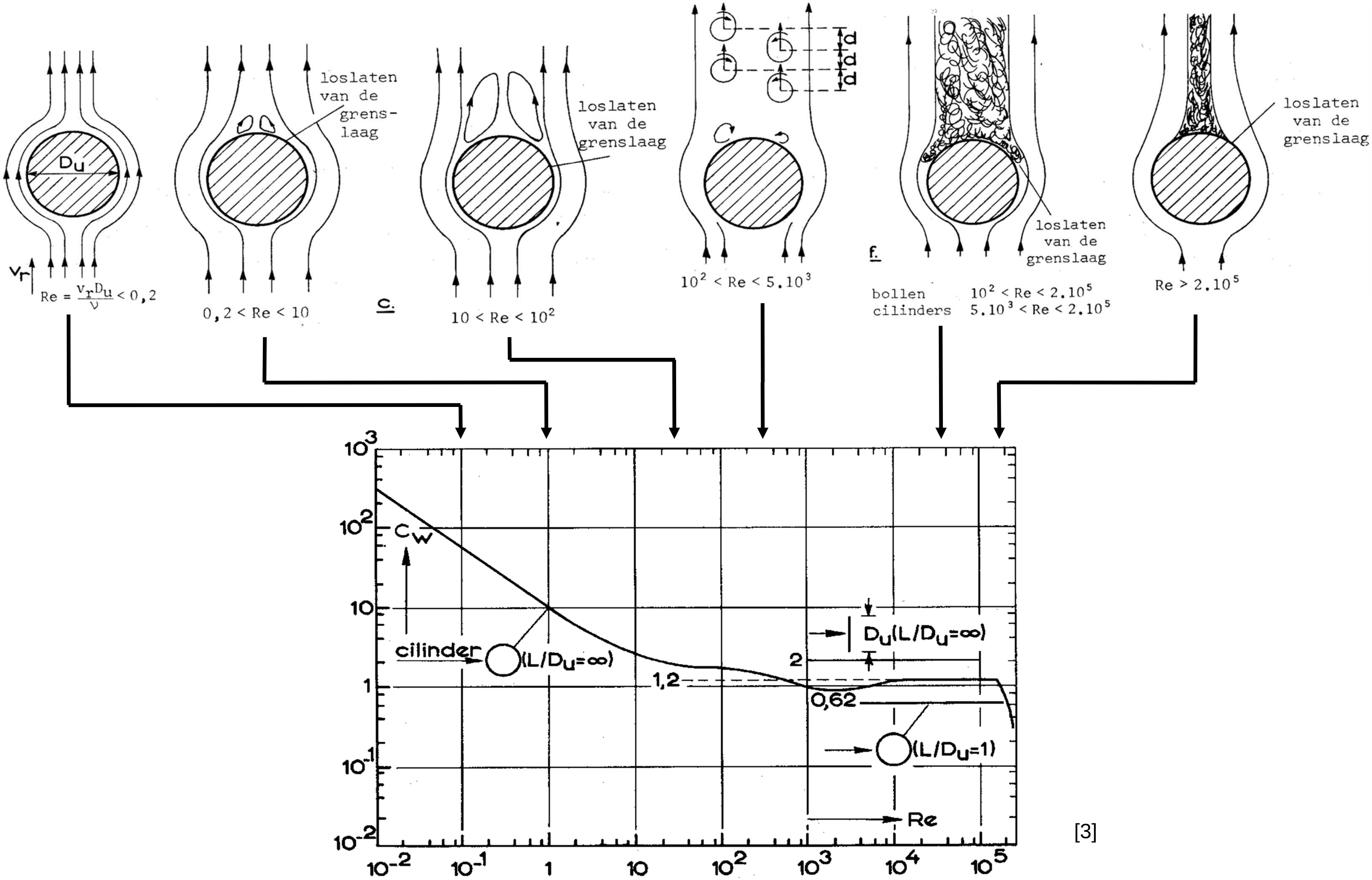
Body	C_D based on frontal area							
Cone:	θ:	10°	20°	30°	40°	60°	75°	90°
	C_D:	0.30	0.40	0.55	0.65	0.80	1.05	1.15
Short cylinder, laminar flow:	L/D:	1	2	3	5	10	20	40	∞
	C_D:	0.64	0.68	0.72	0.74	0.82	0.91	0.98	1.20

Porous parabolic dish [23]:	Porosity:	0	0.1	0.2	0.3	0.4	0.5
	← C_D:	1.42	1.33	1.20	1.05	0.95	0.82
	→ C_D:	0.95	0.92	0.90	0.86	0.83	0.80

Average person: → $C_D A \approx 9\ ft^2$; ↑ $C_D A \approx 1.2\ ft^2$

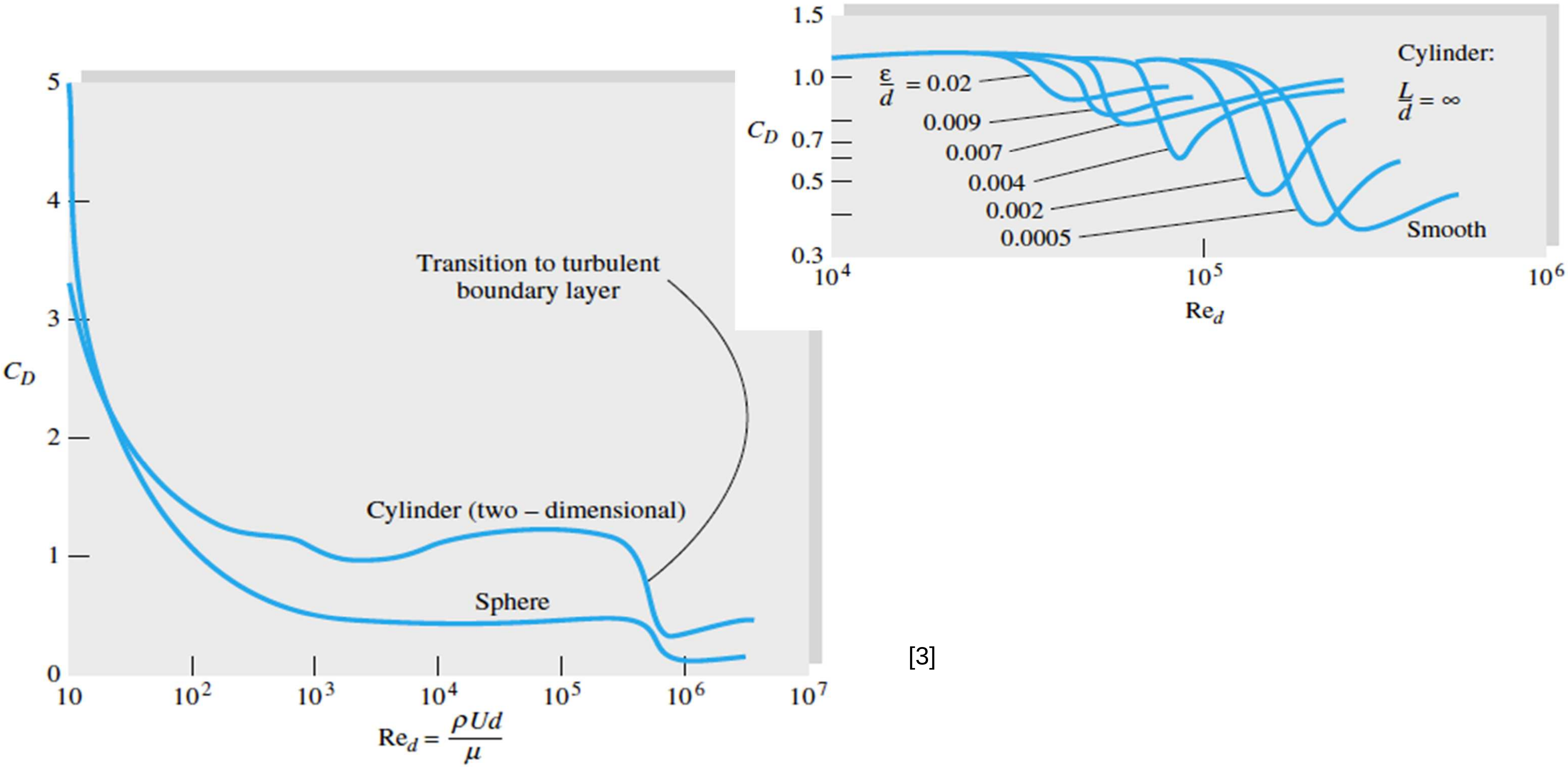
Pine and spruce trees [24]:	U, m/s:	10	20	30	40
	C_D:	1.2 ± 0.2	1.0 ± 0.2	0.7 ± 0.2	0.5 ± 0.2

[3]

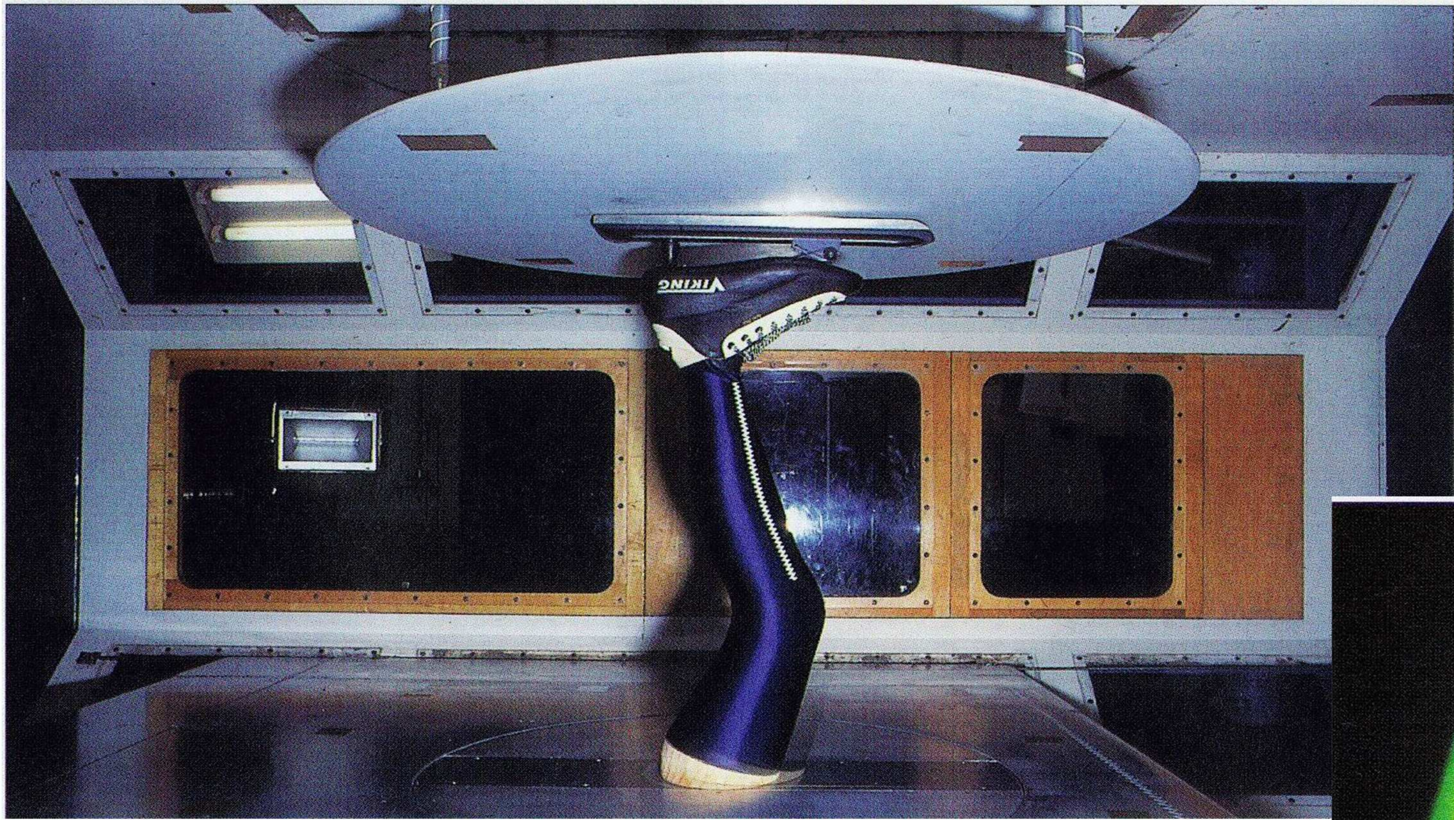

loslaten
van de
grens-
laag
loslaten
van de
grenslaag
d
d
d
loslaten
van de
grenslaag
loslaten
van de
grenslaag
Du
vr
Re = vrDu/ν < 0,2
0,2 < Re < 10
c.
10 < Re < 10²
10² < Re < 5.10³
f.
bollen
cilinders
10² < Re < 2.10⁵
5.10³ < Re < 2.10⁵
Re > 2.10⁵
cw
cilinder
(L/Du=∞)
1,2
2
0,62
Du(L/Du=∞)
(L/Du=1)
Re
10³
10²
10
1
10⁻¹
10⁻²
10⁻²
10⁻¹
1
10
10²
10³
10⁴
10⁵

[3]

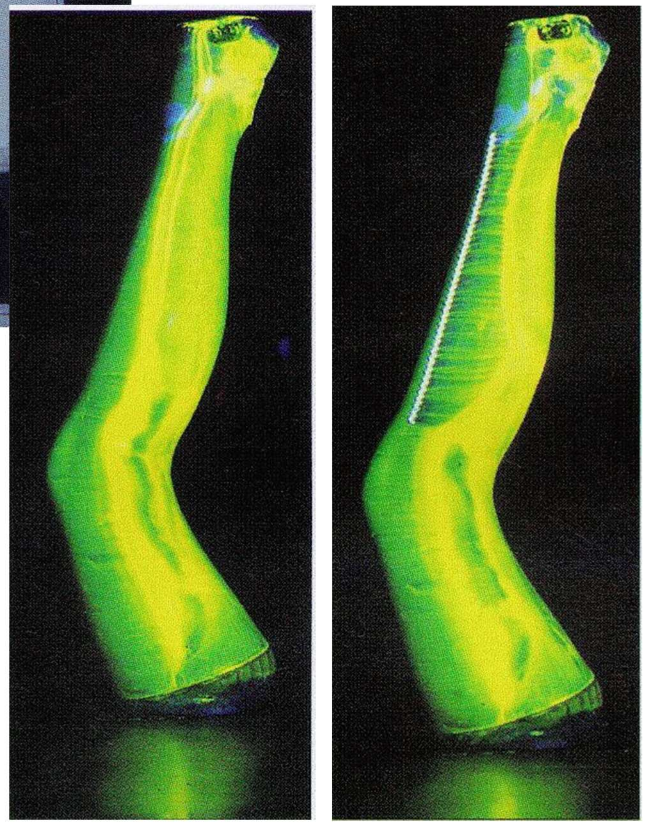
Drag reduction

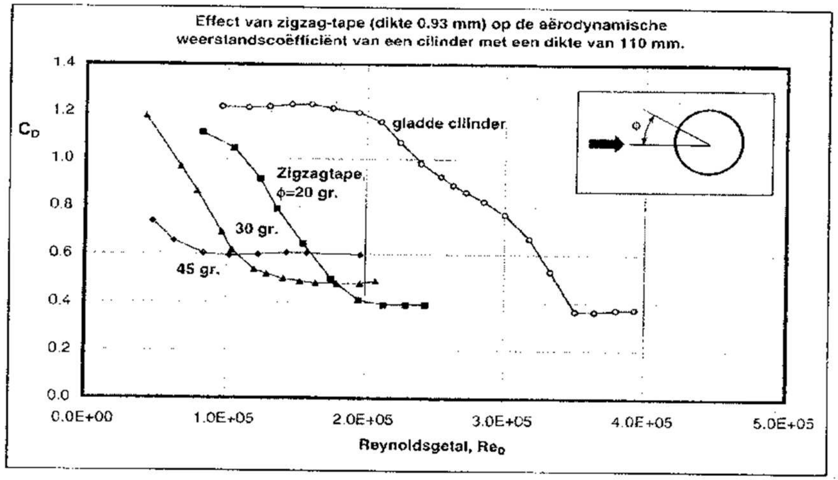


[3]

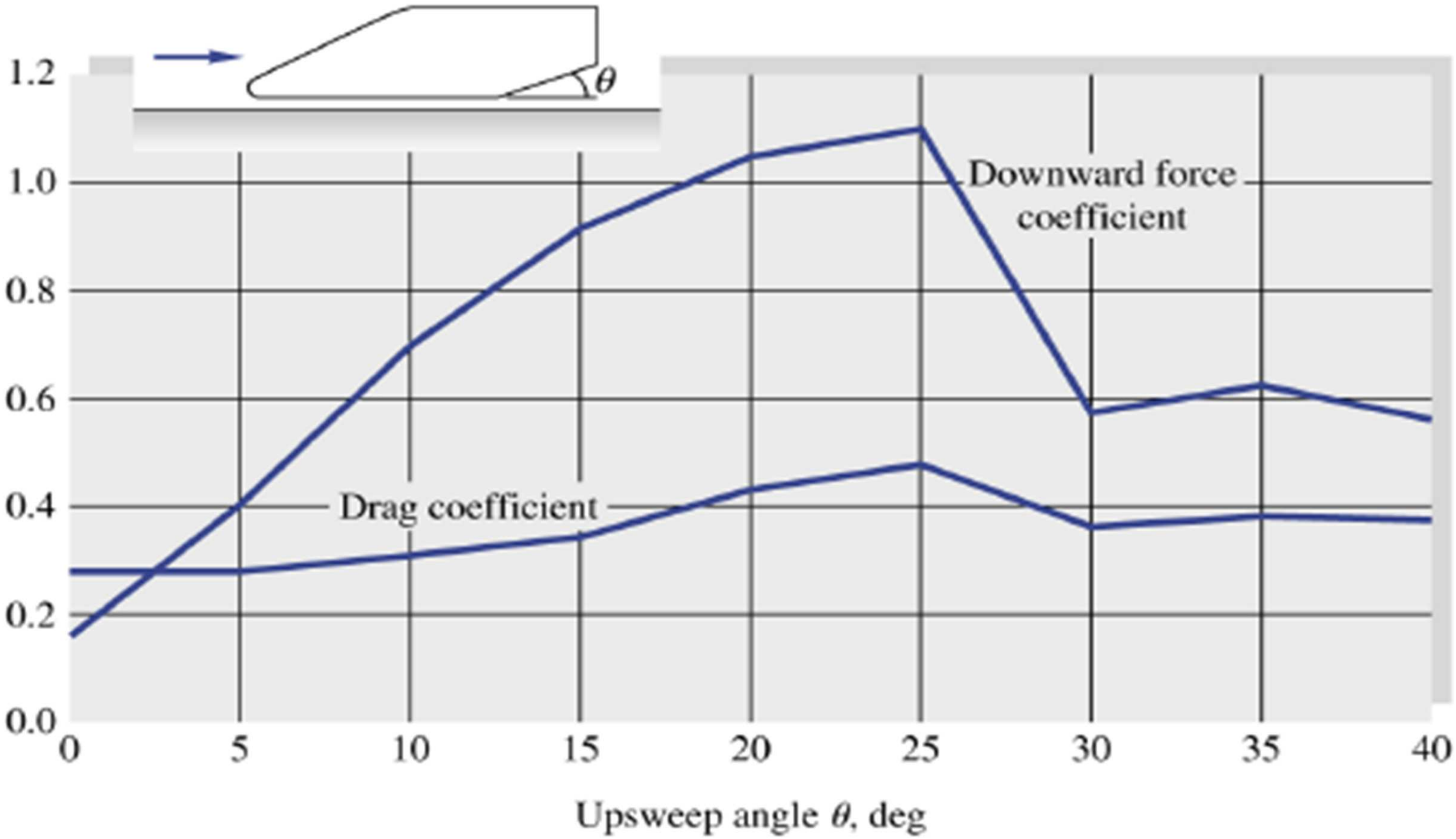

VIKING

[4]



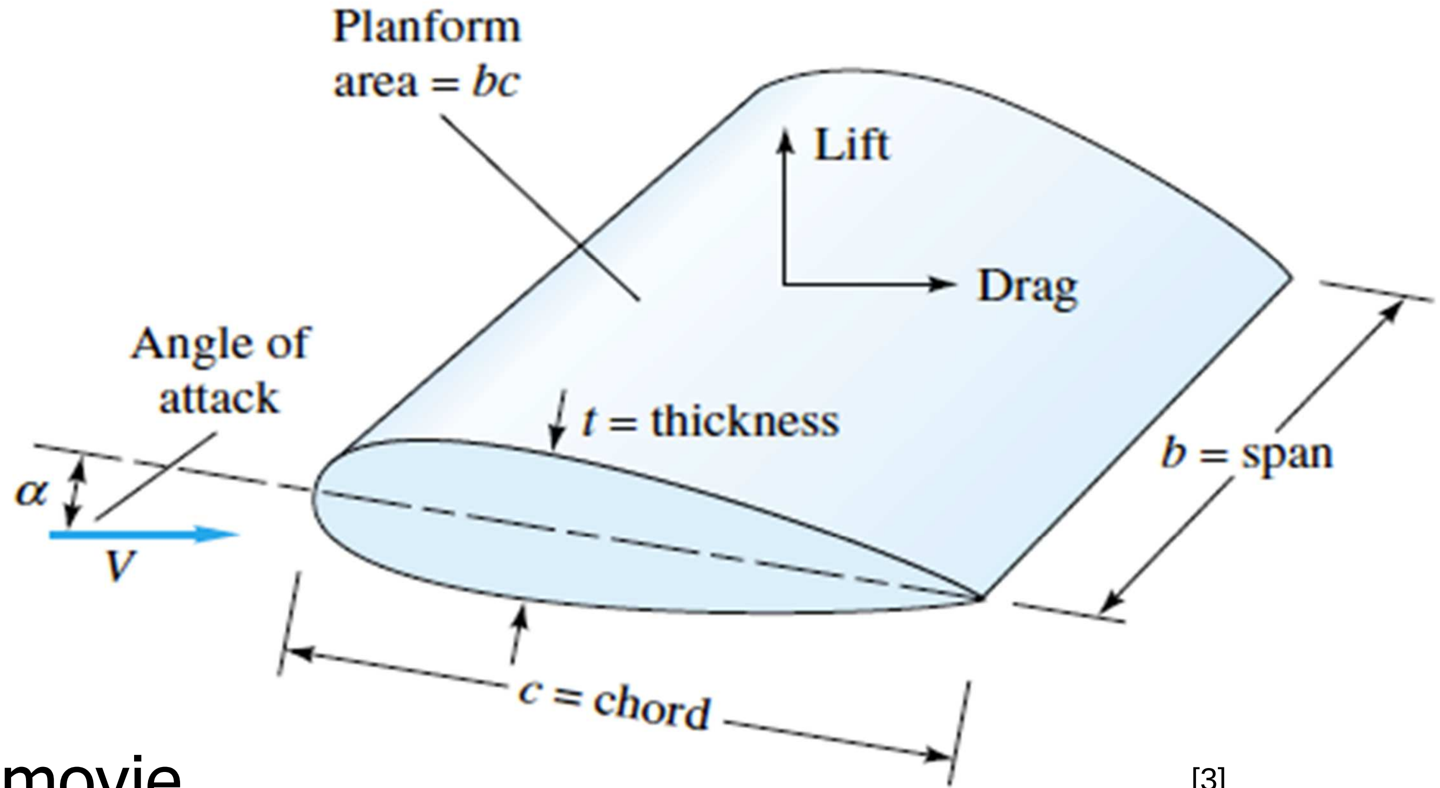

Effect van zigzag-tape (dikte 0.93 mm) op de aërodynamische weerstandscoëfficiënt van een cilinder met een dikte van 110 mm.
C_D
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
gladde cilinder
Zigzagtape, ϕ=20 gr.
30 gr.
45 gr.
ϕ
0.0E+00
1.0E+05
2.0E+05
3.0E+05
4.0E+05
5.0E+05
Reynoldsgetal, Re_D

Race car aerodynamics



[3]

Airfoils



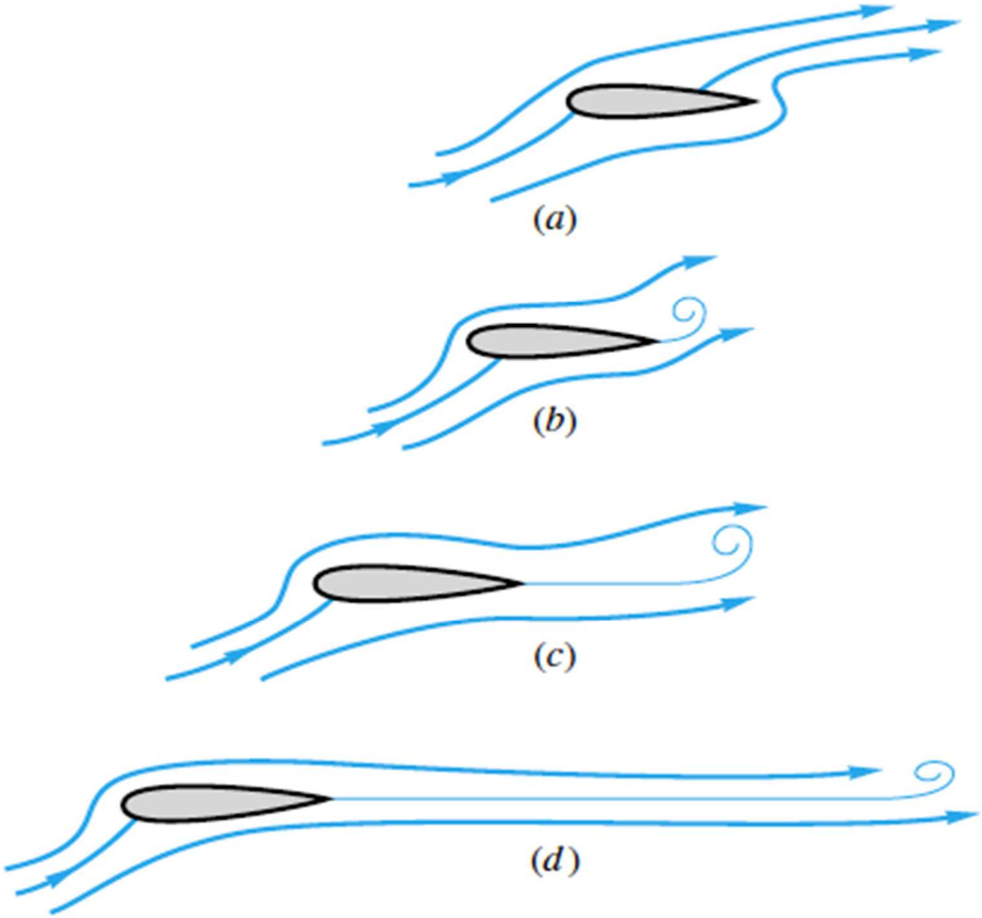
$$C_L = \frac{L}{\frac{1}{2}\rho V^2 A_p}$$

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A_p}$$

movie

[3]

Development of lift



[3]

movie

Lift vs. drag

lift force: $L = \pi \rho c V^2 \sin\theta_0 = 2\pi \sin\theta_0 \cdot c \cdot \frac{1}{2}\rho V^2$ (Joukowsky condition)

lift coefficient: $C_L = 2\pi \sin\theta_0$

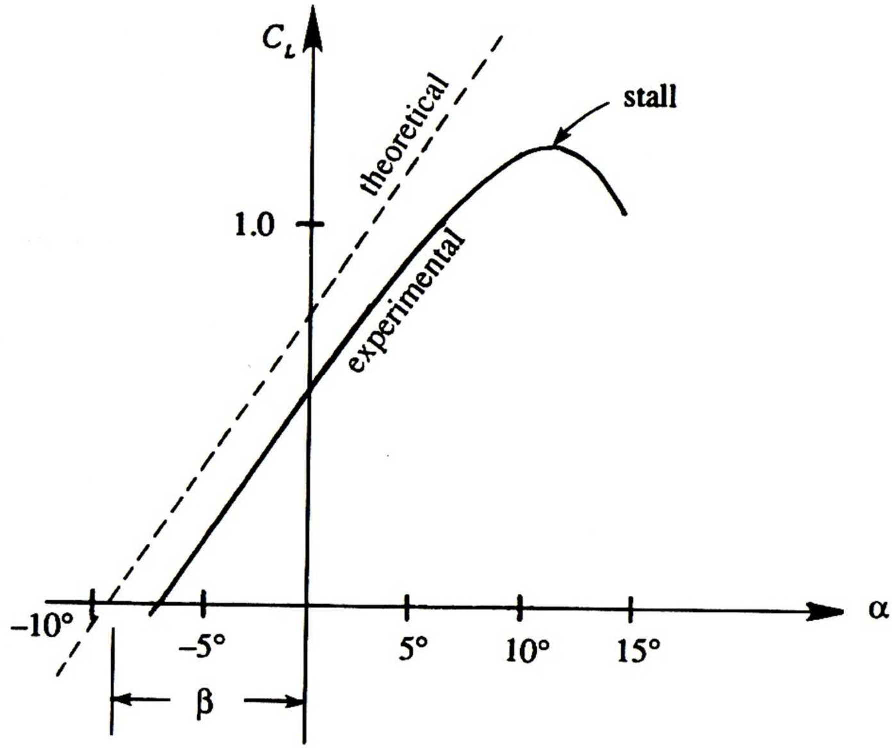
practice: drag: $C_D = f(\alpha)$

slender sections

$$C_L = 2\pi \sin\alpha \rightarrow dC_L / d\alpha = 2\pi \cos\alpha$$

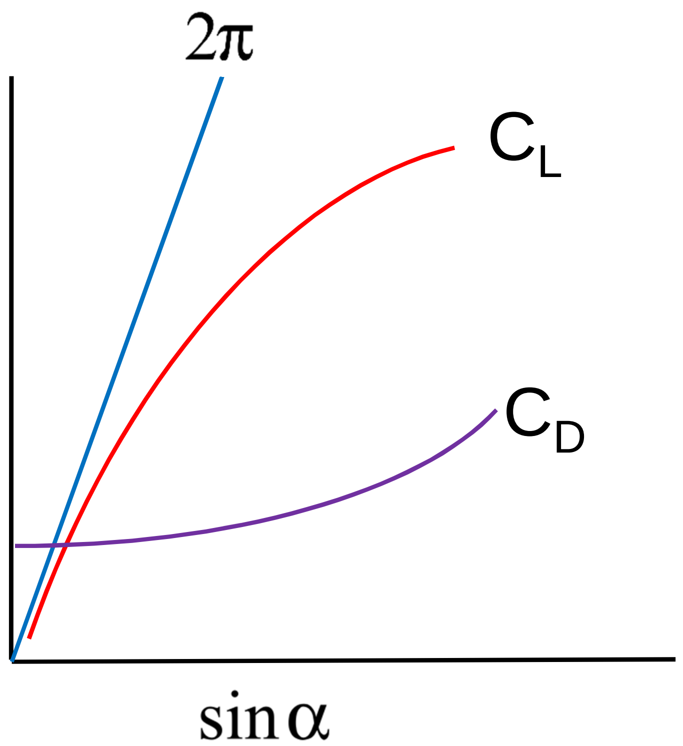
$$C_D = C_{D,0} + B\alpha^2 \rightarrow dC_D / d\alpha = 2B\alpha$$

symmetric airfoil



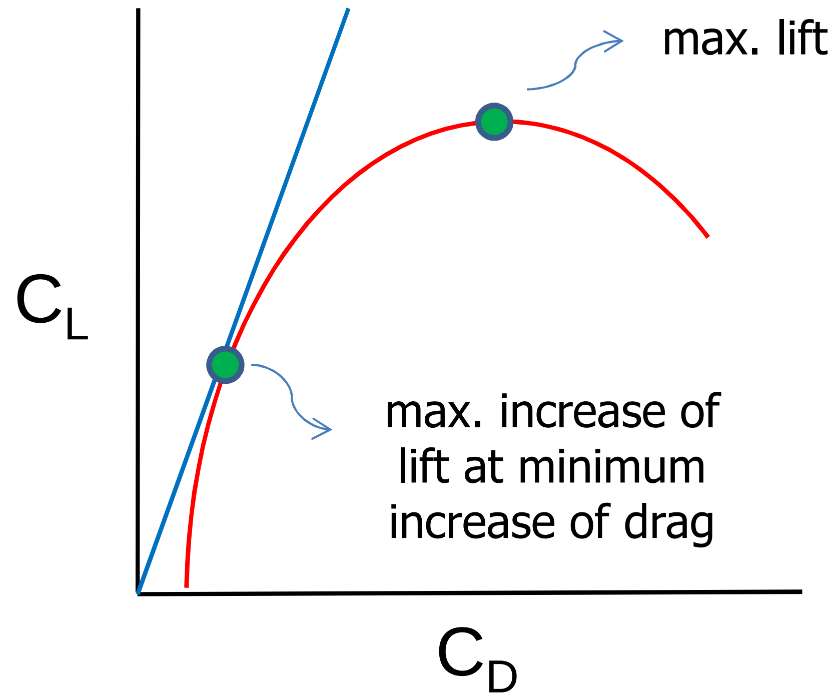
high angle of attack: boundary layer separation & stall

Airfoil performance

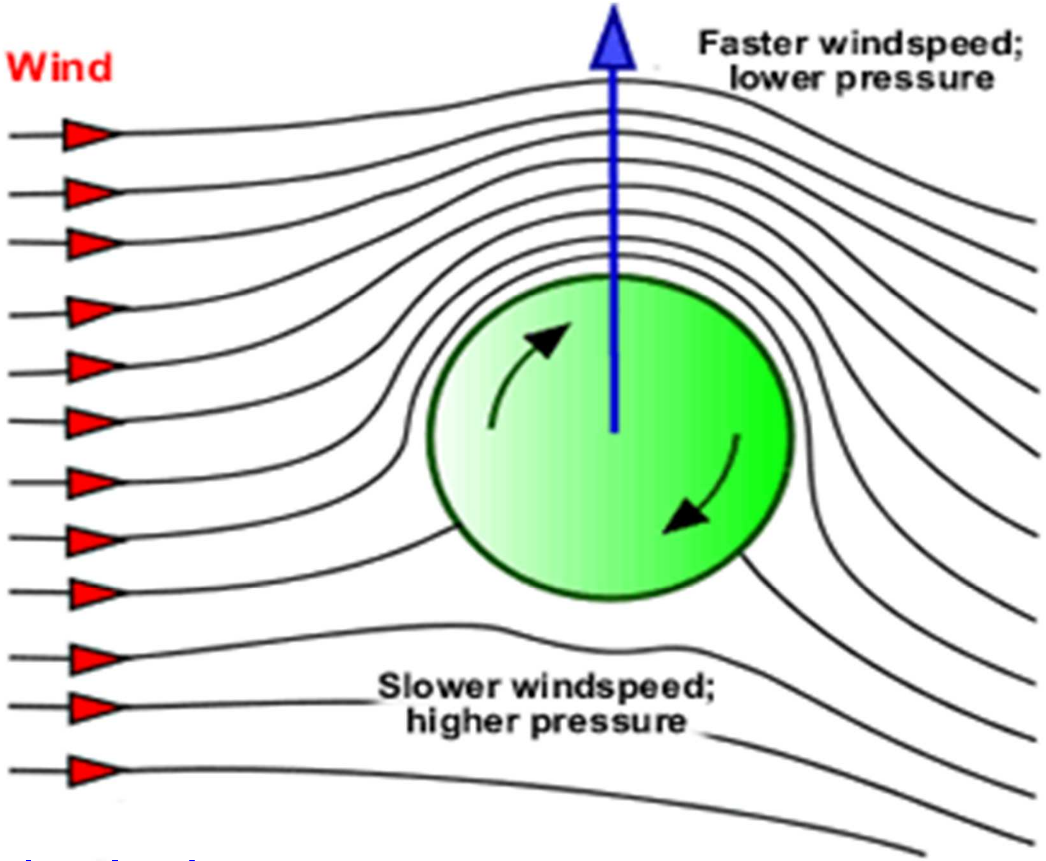


$$C_L = 2\pi \sin\alpha \rightarrow dC_L/d\alpha = 2\pi\cos\alpha$$

$$C_D = C_{D,0} + B\alpha^2 \rightarrow dC_D/d\alpha = 2B\alpha$$



Magnus effect



[5]

Movie: Flow around cylinder [6]

Movie: Magnus effect [7]

Source

1. Tacoma Narrows Bridge Collapse "Gallopin' Gertie“, *http://youtu.be/j-zczJXSxnw*,
2. New fast iceskating suit, photo courtesy of ANP
3. Frank M. White, *Fluid Mechanics*, McGraw-Hill Series in Mechanical Engineering
4. Testing an iceskating suit for less friction, photo courtesy of TU Delft, faculty of Aerospace Engineering
5. The Magnus effect, royalty free picture
6. Flow around cylinder, *http://www.youtube.com/watch?v=j6yB90vno1E*
7. Magnus effeect, *http://www.youtube.com/watch?v=MUf5RwKXNQ0*