

**The Gö 622, Gö 623, Gö 624 and Gö 625 airfoils with thickness/chord ratios of respectively 8 %, 12 %, 16 % and 20 % for use in windmill rotor blades**

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Contains	page
1 Introduction	3
2 The Gö 622, Gö 623, Gö 624 and Gö 625 airfoil geometry	3
3 The Gö 622, Gö 623, Gö 624 and Gö 625 airfoil characteristics	5
4 Determination of $C_{mh}$ for the Gö 623 for $Re = 4.2 * 10^5$	9
5 Determination of $C_{mh}$ for the Gö 624 for $Re = 4.2 * 10^5$	12
6 References	13

## 1 Introduction

In report R443D (ref. 1) of the former Wind Energy Group of the University of Technology Eindhoven, about eighty airfoils are assembled which have been measured for low Reynolds numbers. A problem with this report is that it is no longer available and that most of the given airfoil graphs are too small for use in rotor blade calculations. Fortunately the original measuring points are given for almost all airfoils and using these points, new accurate graphs can be made.

Airfoils with a flat lower side are of interest for windmill rotor blades, especially if they are manufactured from massive wood. The Gö 623 airfoil which has a maximum thickness of 12 % of the chord is used in all my present VIRYA-windmills with wooden blades. The characteristics and geometry of this airfoil are given in my report KD 35 (ref. 2). Sometimes thinner or thicker airfoils are needed. The four airfoils Gö 622, Gö 623, Gö 624 and Gö 625 with thickness/chord ratios of respectively 8 %, 12 %, 16 % and 20 % have originally been measured by Riegels (ref. 3). These measurements are also given in R443D (ref. 1). The  $C_l$ - $\alpha$  and  $C_l$ - $C_d$  curves are generally given for three Reynolds values at page 3-70 of R443D. Tables with measuring points are given at page 3-72 of R443D but only for two values of Reynolds  $1.1 * 10^5$  (or  $1.2 * 10^5$ ) and  $4.2 * 10^5$  (except for the Gö 625 which has been measured for many Reynolds values). The curves for  $2.2 * 10^5$  (or  $2.3 * 10^5$ ) are estimated by copying the given curves as accurate as possible.

## 2 The Gö 622, Gö 623, Gö 624 and Gö 625 airfoil geometry

The airfoil geometry for all four airfoils is copied from the tables given on page 3-76 of R443D. The distance  $x$  is the value from the airfoil nose for an airfoil with a chord of 100 mm. The distance  $y_u$  is the corresponding value for the upper part of the airfoil. The distance  $y_l$  is the corresponding value for the lower part of the airfoil.

x (mm)	Gö 622		Gö 623		Gö 624		Gö 625	
	$y_u$ (mm)	$y_l$ (mm)	$y_u$ (mm)	$y_l$ (mm)	$y_u$ (mm)	$y_l$ (mm)	$y_u$ (mm)	$y_l$ (mm)
0	2.40	2.40	3.25	3.25	4.00	4.00	5.50	5.50
1.25	3.75	1.45	5.45	1.95	7.15	2.25	9.00	3.30
2.5	4.50	1.05	6.45	1.50	8.50	1.65	10.80	2.35
5.0	5.45	0.60	7.90	0.90	10.40	0.95	13.30	1.25
7.5	6.15	0.35	9.05	0.35	11.75	0.60	14.95	0.75
10	6.60	0.25	9.90	0.20	12.85	0.40	16.35	0.40
15	7.30	0.15	10.95	0.10	14.35	0.15	18.25	0.15
20	7.70	0.05	11.55	0.05	15.30	0.05	19.30	0.10
30	8.00	0	12.00	0	16.00	0	20.00	0
40	7.80	0	11.70	0	15.40	0	19.05	0
50	7.10	0	10.65	0	14.05	0	17.35	0
60	6.15	0	9.15	0	12.00	0	15.05	0
70	5.00	0	7.35	0	9.50	0	12.10	0
80	3.55	0	5.15	0	6.60	0	8.60	0
90	1.95	0	2.80	0	3.55	0	4.75	0
95	1.15	0	1.60	0	2.00	0	2.75	0
100	0.20	0	0.30	0	0.50	0	0.65	0

table 1 Geometry of the Gö 622, Gö 623, Gö 624 and Gö 625 airfoils for a chord  $c = 100$  mm

The  $y_u$ -values for  $x = 100$  are very small. Sometimes the airfoil trailing edge is taken somewhat thicker to prevent damage of the blades during transport. It is expected that the effect of this increase of the thickness on the airfoil characteristics, can be neglected.

It may be expected that the airfoil thickness of a thicker airfoil is found by multiplying the  $y$ -factors of a thinner airfoil by a certain value but this is not true as the  $y$ -value of the Gö 624 for  $x = 0$  is not exactly double the  $y$ -value of the Gö 622. The four airfoils are given on scale in figure 1, 2, 3 and 4.



fig. 1 Gö 622 airfoil for  $c = 100$  mm

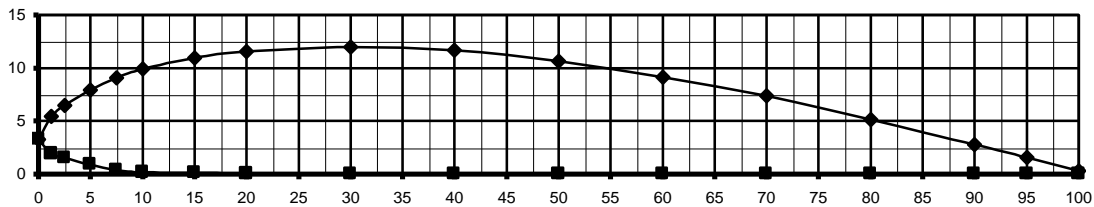


fig. 2 Gö 623 airfoil for  $c = 100$  mm

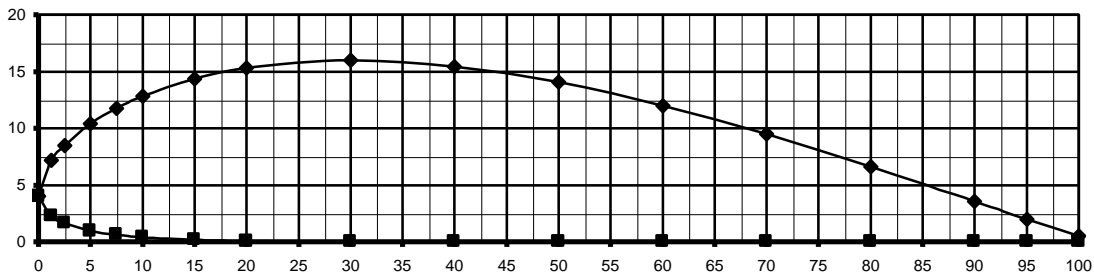


fig. 3 Gö 624 airfoil for  $c = 100$  mm

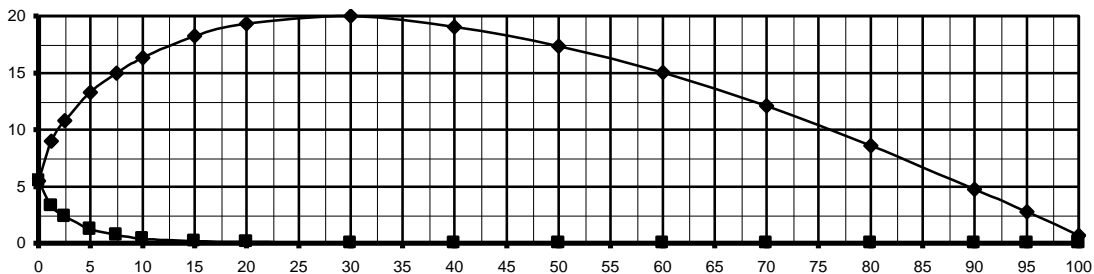


fig. 4 Gö 625 airfoil for  $c = 100$  mm

If the real blade chord  $c$  is a factor  $i$  larger than 100 mm, all the  $x$ -values and  $y$ -values of figure 4 have to be multiplied by the same factor  $i$ . The strength of a beam is determined by the moment of resistance  $W$  which is proportional to the thickness  $h^2$ . The ratio of the strength of the four airfoils with the same chord is therefore 1 : 2.25 : 4 : 6.25. The thicker airfoils are normally only used near the blade root because the bending moment is largest there.

### 3 The Gö 622, Gö 623, Gö 624 and Gö 625 airfoil characteristics

The  $C_l$ - $\alpha$  curves are given in figure 5, 7, 9 and 11. The  $C_l$ - $C_d$  curves are given in figure 6, 8, 10 and 12.  $\alpha$  is the angle of attack.  $C_l$  is the lift coefficient.  $C_d$  is the drag coefficient. The moment coefficient  $C_m$  around the quart chord point was also measured by Riegels for some airfoils and for some Reynolds values. But for the calculation of the geometry of a windmill rotor with fixed blades, only the  $C_l$ - $\alpha$  and the  $C_l$ - $C_d$  curves are of interest and so the  $C_m$ - $\alpha$  curves are not given (but they are given in chapter 4 for the Gö 623 for  $Re = 4.2 \cdot 10^5$ ).

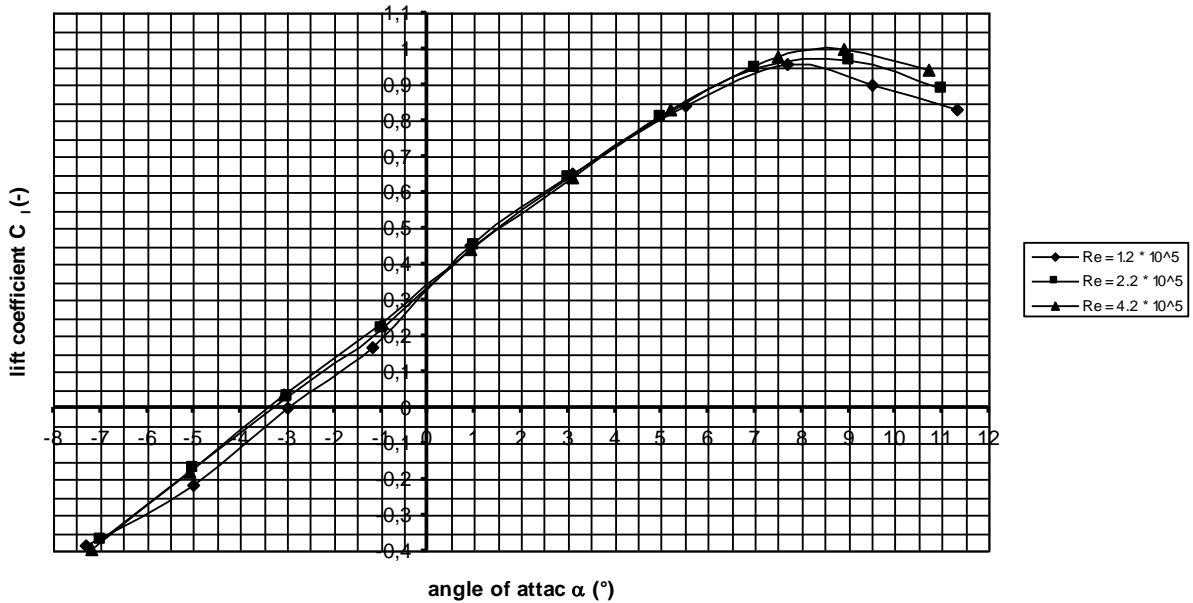


fig. 5  $C_l$ - $\alpha$  curves for the Gö 622 for  $Re = 1.2 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.2 \cdot 10^5$

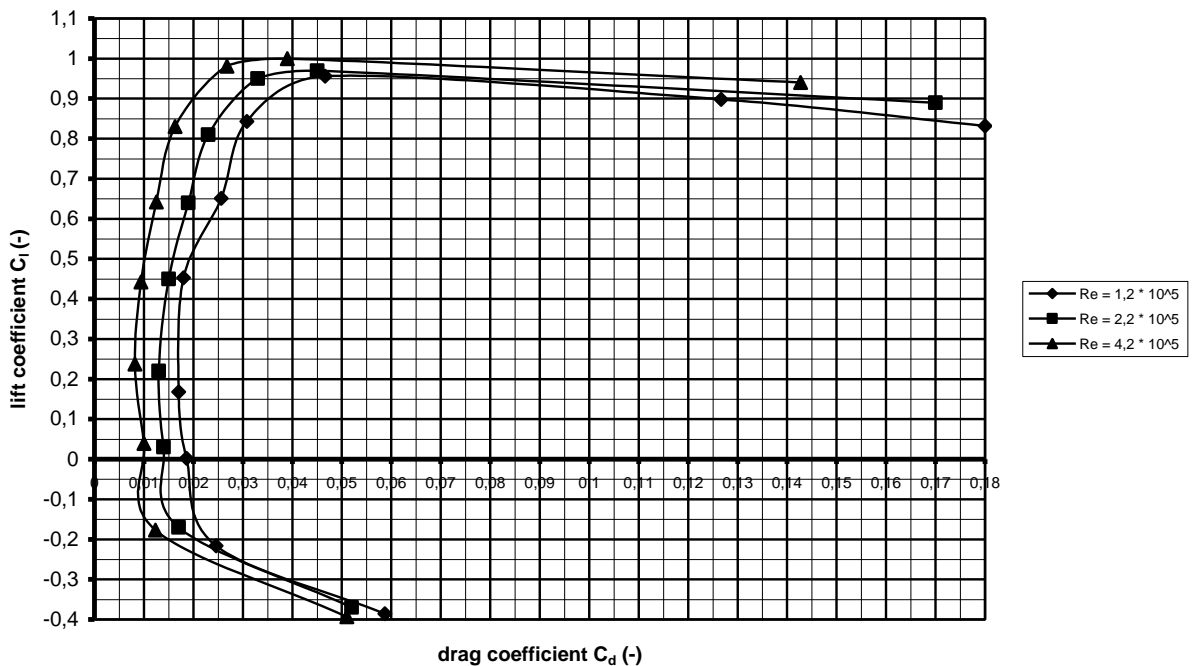


fig. 6  $C_l$ - $C_d$  curves for the Gö 622 for  $Re = 1.2 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.2 \cdot 10^5$

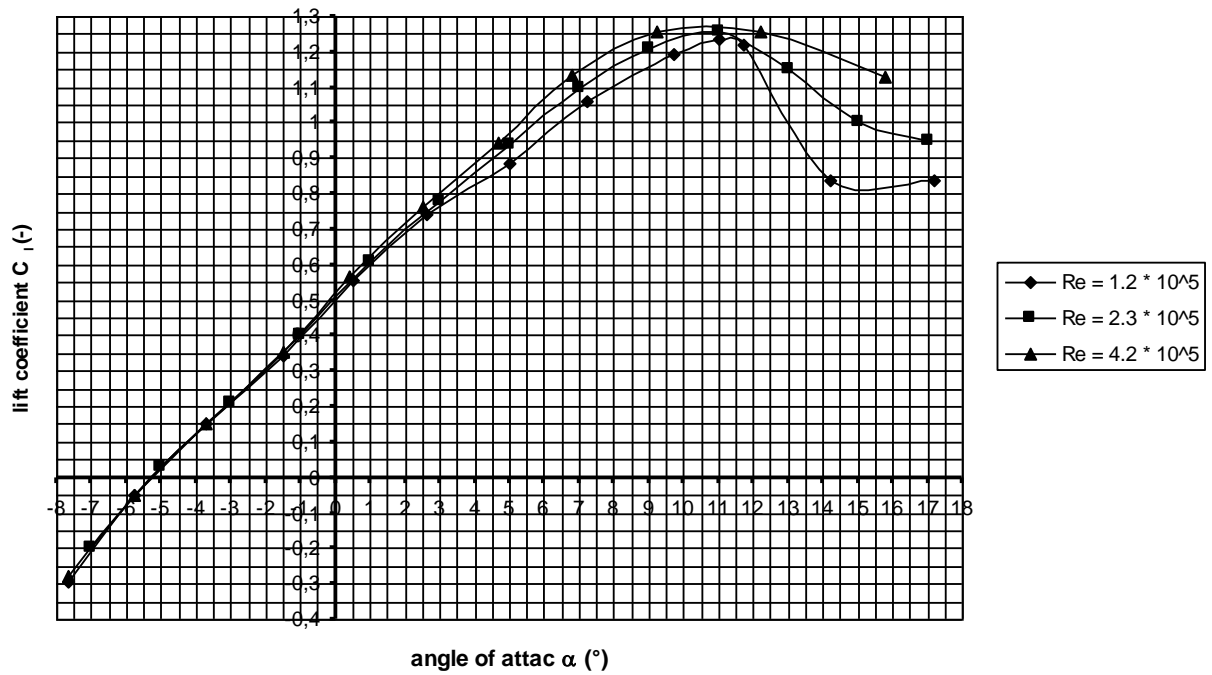


fig. 7  $C_l$ - $\alpha$  curves for the Gö 623 for  $Re = 1.2 \cdot 10^5$ ,  $2.3 \cdot 10^5$  and  $4.2 \cdot 10^5$

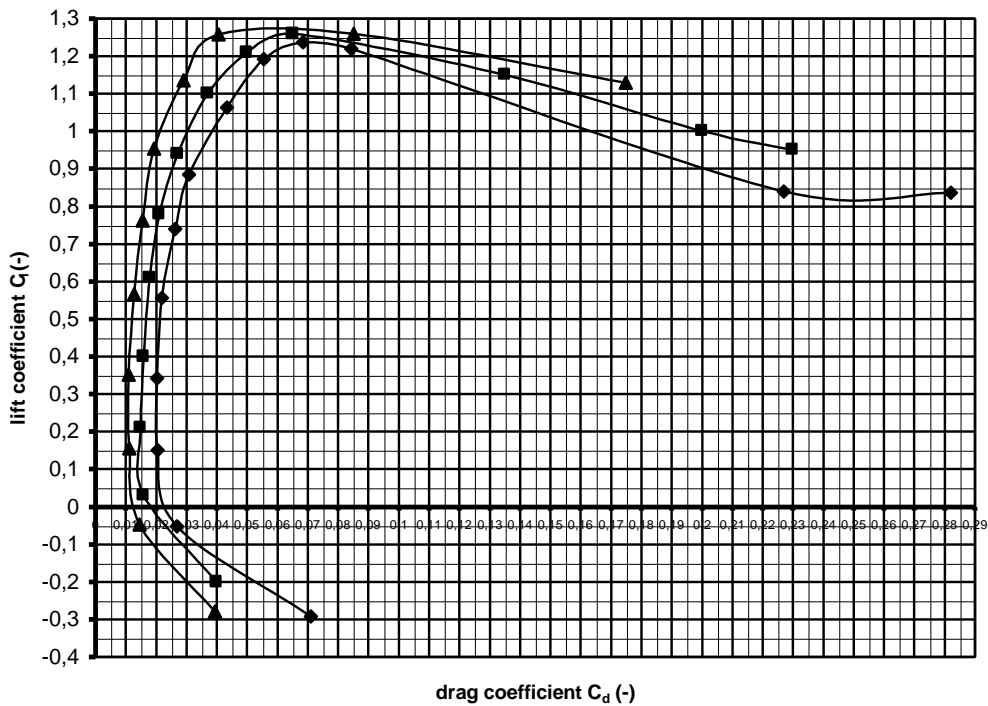


fig. 8  $C_l$ - $C_d$  curves for the Gö 623 for  $Re = 1.2 \cdot 10^5$ ,  $2.3 \cdot 10^5$  and  $4.2 \cdot 10^5$

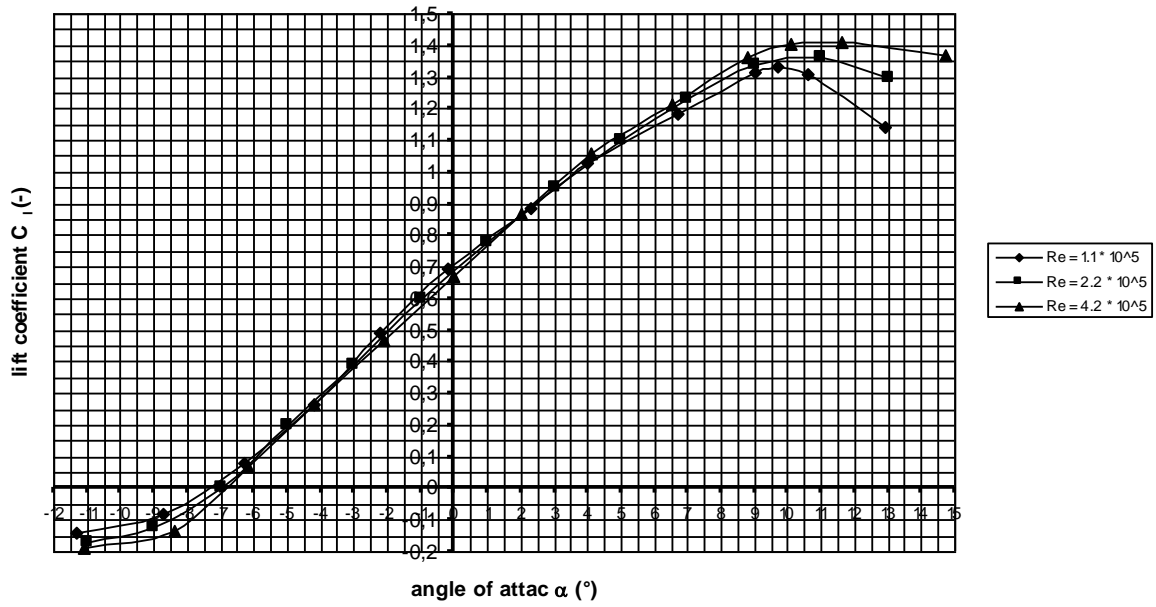


fig. 9  $C_l$ - $\alpha$  curves for the Gö 624 for  $Re = 1.1 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.2 \cdot 10^5$

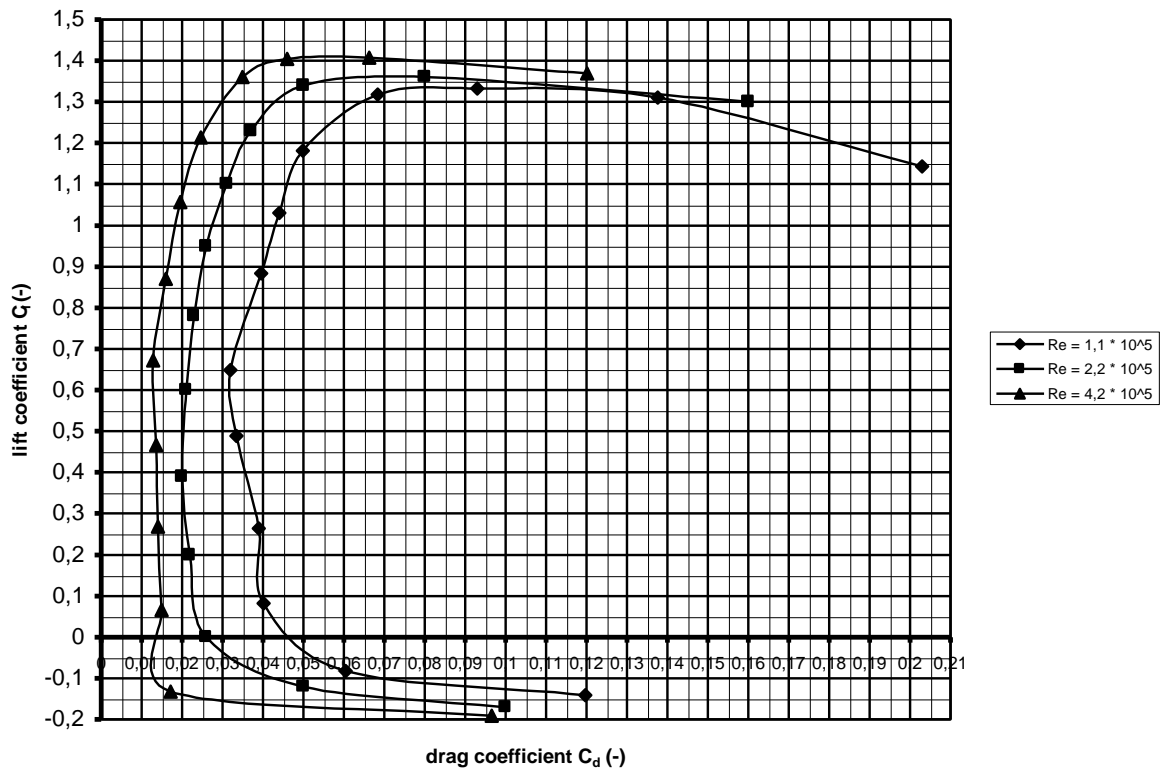


fig. 10  $C_l$ - $C_d$  curves for the Gö 624 for  $Re = 1.1 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.2 \cdot 10^5$

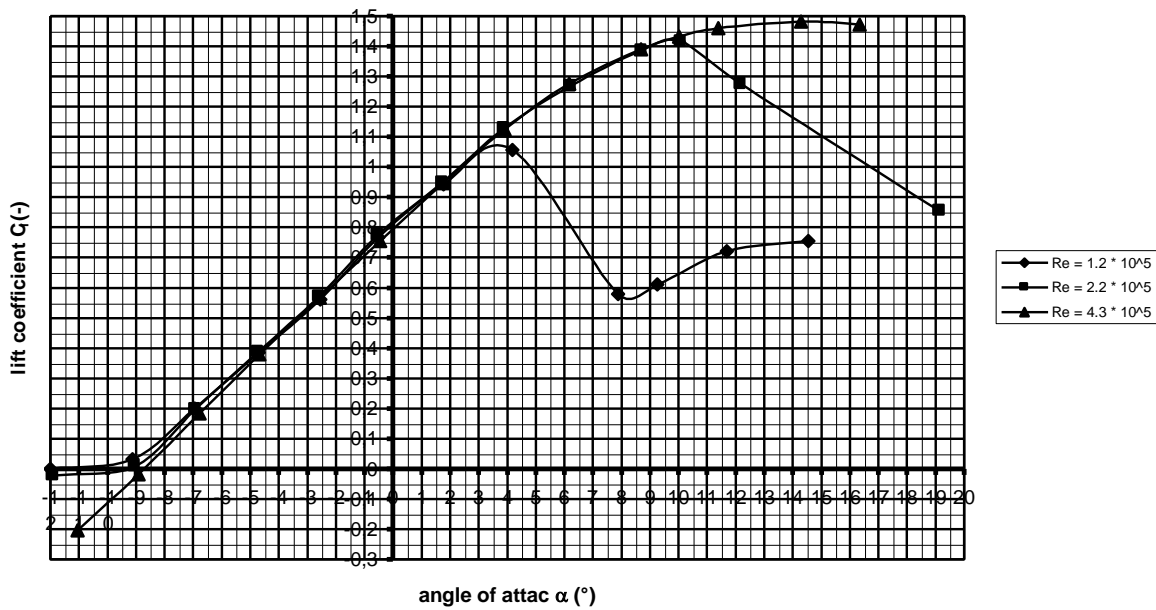


fig. 11  $C_l$ - $\alpha$  curves for the Gö 625 for  $Re = 1.2 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.3 \cdot 10^5$

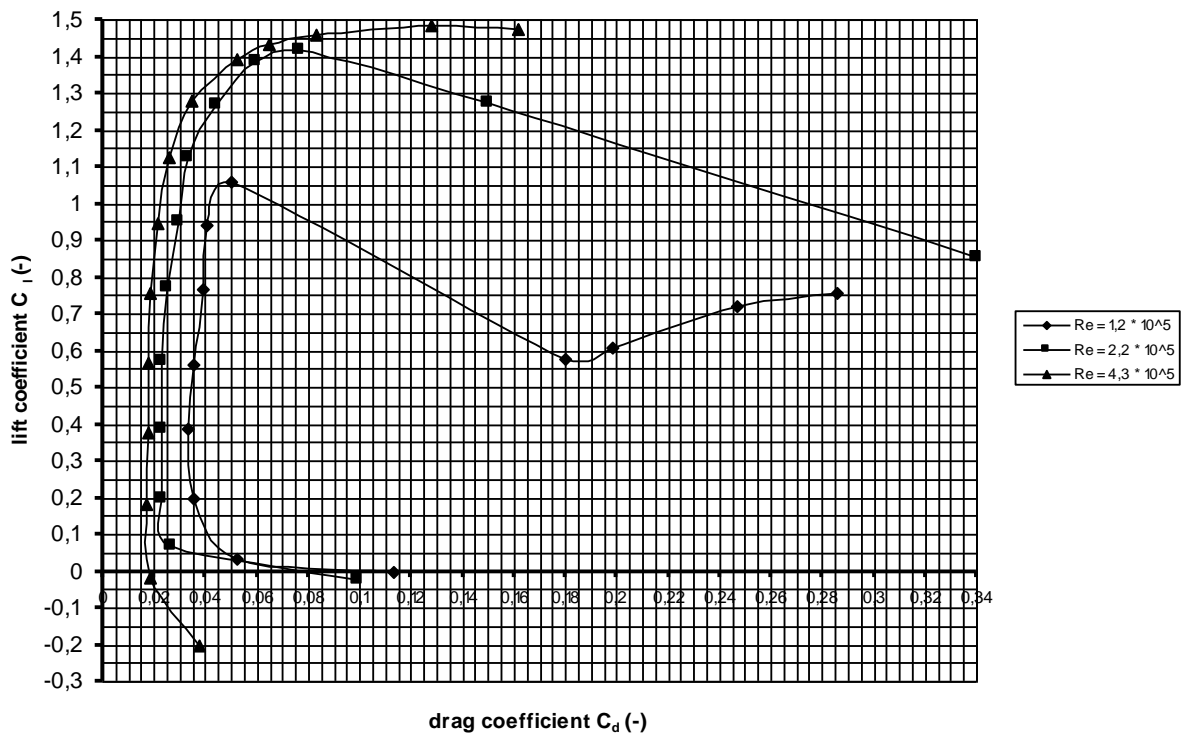


fig. 12  $C_l$ - $C_d$  curves for the Gö 625 for  $Re = 1.2 \cdot 10^5$ ,  $2.2 \cdot 10^5$  and  $4.3 \cdot 10^5$

In figure 11 it can be seen that the Gö 625 airfoil is stalling at rather low values of  $\alpha$  for low Reynolds values. Stalling means that the  $C_l$ -value drops suddenly at increasing  $\alpha$ .

The minimum  $C_d/C_l$  ratio for a certain Reynolds value is found by drawing a line through the origin which touches the  $C_d$ - $C_l$  curve for that Reynolds value. This line intersects with the line  $C_l = 1$ . The  $C_d$  value for the point of intersection is the minimum  $C_d/C_l$  ratio. The thinnest airfoils have the lowest minimum  $C_d/C_l$  ratio for the highest Reynolds value.



#### 4 Determination of $C_{mh}$ for the Gö 623 for $Re = 4.2 * 10^5$

Sometimes a pitch control system is used with which the blade angle (or blade pitch)  $\beta$  is varied to influence the starting behaviour or to limit the rotor speed at high wind speeds. Variation of  $\beta$  means variation of the angle of attack  $\alpha$ . The pitch control system is influenced by the aerodynamic moment  $M$  and the aerodynamic moment depends on the position of the axis of rotation around which the blade angle  $\beta$  is varied. The aerodynamic moment coefficient is normally given around the quart-chord point which lies on the zero line of the airfoil at a distance of  $0.25 c$  from the airfoil nose. But it is possible to determine the moment coefficient around another point H. The moment coefficient around point H is called  $C_{mh}$ .

The Gö 623 is the most commonly used airfoil of the given series of airfoils for so  $C_{mh}$  is determined for the Gö 623 airfoil. The moment coefficient around the quart chord point is called  $C_{m0.25}$ . The moment coefficient is given in report R443D (ref. 1) only for a Reynolds value of  $Re = 4.2 * 10^5$ . The original measuring points for  $C_l$ ,  $C_d$  and  $C_{m0.25}$  as a function of  $\alpha$  as given on page 3-72 of R443D are copied in table 1.

$\alpha$ (°)	$C_l$ (-)	$C_d$ (-)	$C_{m0.25}$ (-)	$(C_l \cos\alpha + C_d \sin\alpha)$	$C_{m0.3}$ (-)	$C_{m0.35}$ (-)	$C_{m0.4}$ (-)	$C_{m0.2}$ (-)
-7.7	-0.279	0.0394	-0.0155	-0.2818	-0.0296	-0.0437	-0.0578	-0.0014
-5.8	-0.047	0.0146	-0.0762	-0.0482	-0.0786	-0.0810	-0.0834	-0.0738
-3.7	0.155	0.0111	-0.0724	0.1540	-0.0647	-0.0570	-0.0493	-0.0801
-1.5	0.352	0.0110	-0.0700	0.3516	-0.0524	-0.0348	-0.0173	-0.0876
0.4	0.566	0.0128	-0.0681	0.5661	-0.0398	-0.0115	0.0168	-0.0964
2.5	0.763	0.0156	-0.0678	0.7630	-0.0297	0.0085	0.0467	-0.1069
4.7	0.954	0.0192	-0.0665	0.9524	-0.0189	0.0287	0.0764	-0.1141
6.8	1.135	0.0290	-0.0644	1.1304	-0.0079	0.0486	0.1052	-0.1209
9.2	1.258	0.0406	-0.0572	1.2483	0.0052	0.0676	0.1300	-0.1196
12.2	1.260	0.0852	-0.0644	1.2495	-0.0019	0.0606	0.1230	-0.1269
15.8	1.129	0.1749	-0.0902	1.1340	-0.0335	0.0232	0.0799	-0.1469

table 1  $C_l$ ,  $C_d$ ,  $C_{m0.25}$ ,  $C_{m0.3}$ ,  $C_{m0.35}$  and  $C_{m0.4}$  as a function of  $\alpha$ .  $Re = 4.2 * 10^5$

The Gö 623 airfoil with the lift  $L$ , the drag  $D$  and  $M_{0.25}$  acting on it, is given in figure 13.  $M_h$  is given around point H. Point H is lying at a distance  $p$  from the quart chord point and the line through the quart chord point and point H makes a clock wise angle  $\gamma$  with the flat lower side of the air foil (see figure 13).

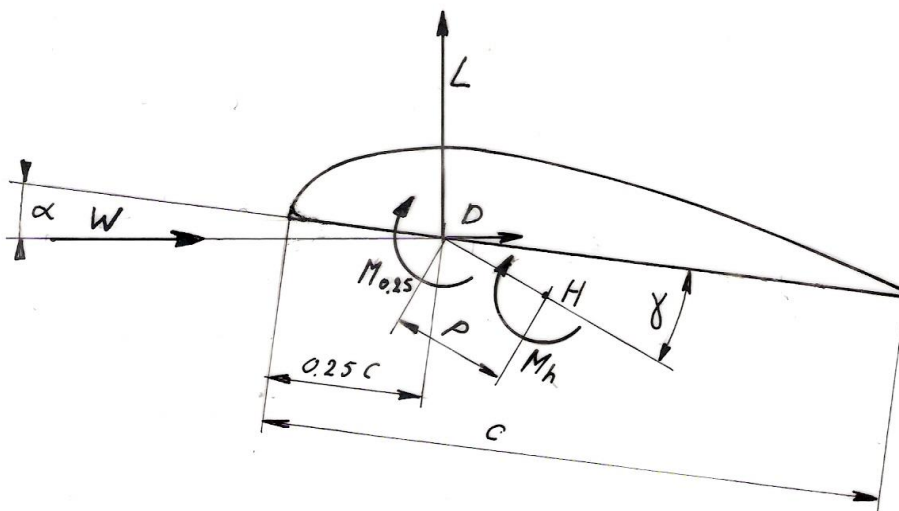


fig. 13  $L$ ,  $D$ ,  $M_{0.25}$  and  $M_h$  around point H at a distance  $p$  from the quart chord point

The right hand direction of  $M_{0.25}$  and  $M_h$  is defined positive. As  $C_{m0.25}$  is negative for the whole range of  $\alpha$  values, it means that the real direction of  $M_{0.25}$  is such that it has a tendency to decrease the angle of attack  $\alpha$ . The real direction of  $M_h$  depends on the value of  $p/c$ .

It can be proven that the moment coefficient around point H,  $C_{mh}$  is given by:

$$C_{mh} = C_{m0.25} + p/c \{C_l \cos(\alpha + \gamma) + C_d \sin(\alpha + \gamma)\} \quad (-) \quad (1)$$

If point H is lying on the zero line of the airfoil,  $\gamma = 0^\circ$ . So for this condition formula 1 changes into:

$$C_{mh} = C_{m0.25} + p/c (C_l \cos\alpha + C_d \sin\alpha) \quad (-) \quad (\text{for } \gamma = 0^\circ) \quad (2)$$

If point H is lying on the zero line at a distance 0.3 c from the nose,  $p = 0.3 c - 0.25 c = 0.05 c$ . So  $p/c = 0.05$ . This value of  $C_{mh}$  is called  $C_{m0.3}$ . So  $C_{m0.3}$  is given by:

$$C_{m0.3} = C_{m0.25} + 0.05 (C_l \cos\alpha + C_d \sin\alpha) \quad (-) \quad (3)$$

If point H is lying on the zero line at a distance 0.35 c from the nose,  $p = 0.35 c - 0.25 c = 0.1 c$ . This value of  $C_{mh}$  is called  $C_{m0.35}$ . So  $C_{m0.35}$  is given by:

$$C_{m0.35} = C_{m0.25} + 0.1 (C_l \cos\alpha + C_d \sin\alpha) \quad (-) \quad (4)$$

If point H is lying on the zero line at a distance 0.4 c from the nose,  $p = 0.4 c - 0.25 c = 0.15 c$ . This value of  $C_{mh}$  is called  $C_{m0.4}$ . So  $C_{m0.4}$  is given by:

$$C_{m0.4} = C_{m0.25} + 0.15 (C_l \cos\alpha + C_d \sin\alpha) \quad (-) \quad (5)$$

Sometimes the axis of rotation of the blade is chosen in front of the quarter-chord point. This might be the case for a pitch control system which is only steered by the aerodynamic moment and if one wants a larger moment than for  $p/c = 0.25$ . If point H is lying on the zero line at a distance 0.2 c from the nose,  $p = 0.2 c - 0.25 c = -0.05 c$ . So  $p/c = -0.05$ . This value of  $C_{mh}$  is called  $C_{m0.2}$ . So  $C_{m0.2}$  is given by:

$$C_{m0.2} = C_{m0.25} - 0.05 (C_l \cos\alpha + C_d \sin\alpha) \quad (-) \quad (6)$$

The calculated values for  $(C_l \cos\alpha + C_d \sin\alpha)$  and for  $C_{m0.3}$ ,  $C_{m0.35}$ ,  $C_{m0.4}$  and  $C_{m0.2}$  are also given in table 1. The  $C_{m0.25}-\alpha$  curve, the  $C_{m0.3}-\alpha$  curve, the  $C_{m0.35}-\alpha$  curve, the  $C_{m0.4}-\alpha$  curve and the  $C_{m0.2}-\alpha$  curve can be derived from table 1. These curves are given in figure 14.

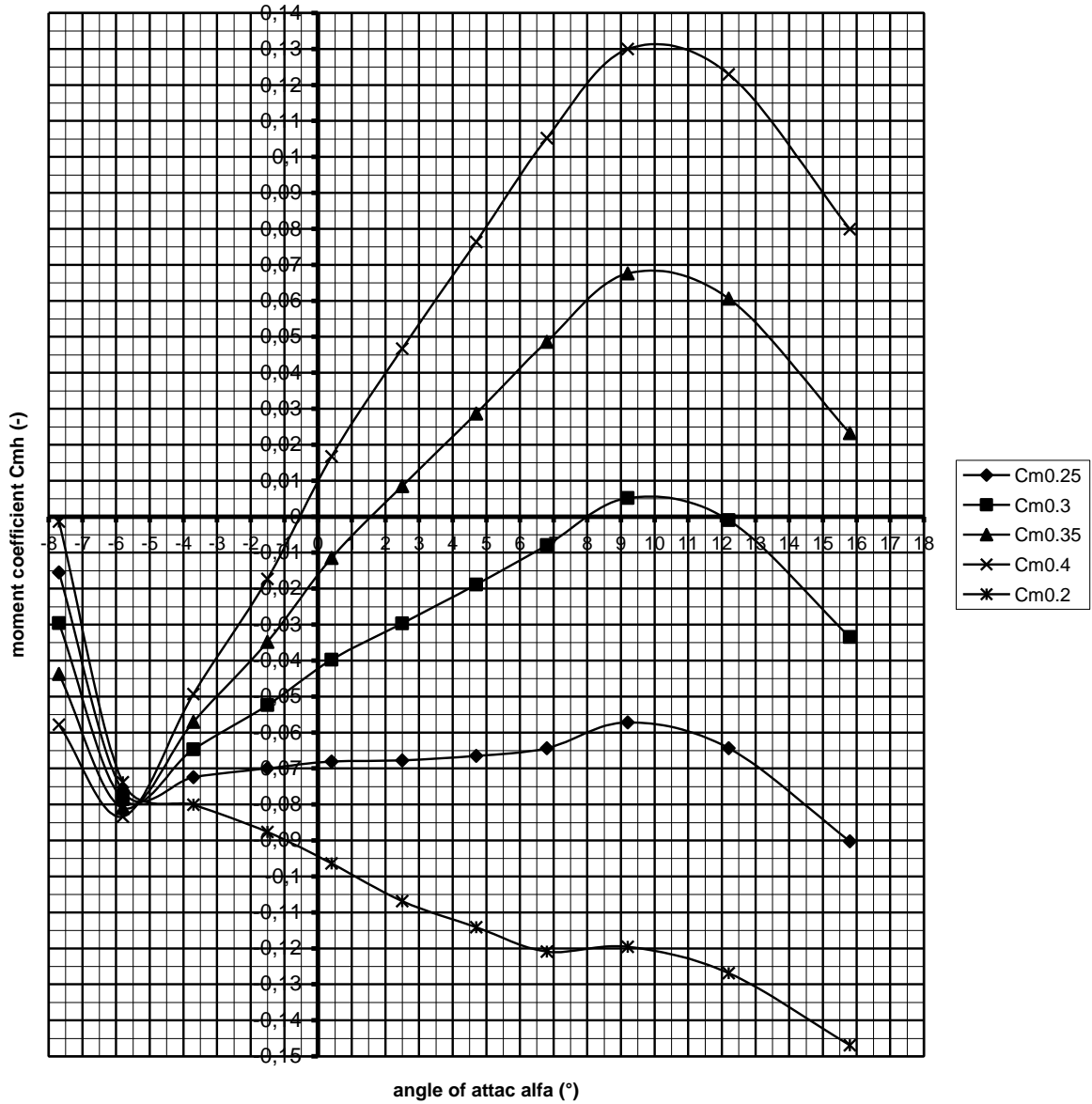


fig. 14  $C_{m0.25}$ - $\alpha$  curve,  $C_{m0.3}$ - $\alpha$  curve,  $C_{m0.35}$ - $\alpha$  curve,  $C_{m0.4}$ - $\alpha$  curve and  $C_{m0.2}$ - $\alpha$  curve for the Gö 623 airfoil for  $Re = 4.2 \cdot 10^5$

### 5 Determination of $C_{mh}$ for the Gö 624 for $Re = 4.2 * 10^5$

The Gö 623 is the most commonly used airfoil of the given series of airfoils. This airfoil is especially advised for massive wooden blades. However, a thicker airfoil with a higher bending moment of resistance might be needed if the airfoil is made out of foam covered with layers of glass fiber and epoxy. The Gö 625 stalls easily at low Reynolds values (see figure 11) but the Gö 624 with a thickness of 16 % of the chord performs well at  $Re = 1.1 * 10^5$  (see figure 9) and has rather low  $C_d/C_l$  values (see figure 10). So it seems useful to determine the  $C_{mh}-\alpha$  curves for this airfoil too.

The procedure is the same as for the Gö 623 airfoil and the same formulas can be used. But the correct values of  $\alpha$ ,  $C_l$ ,  $C_d$  and  $C_{m0.25}$  have to be used. The moment coefficient is given in report R443D (ref. 1) only for a Reynolds value of  $Re = 4.2 * 10^5$ . The original measuring points for  $C_l$ ,  $C_d$  and  $C_{m0.25}$  as a function of  $\alpha$  as given on page 3-73 of R443D are copied in table 2. The calculated values of  $(C_l \cos\alpha + C_d \sin\alpha)$ ,  $C_{m0.3}$ ,  $C_{m0.35}$ ,  $C_{m0.4}$  and  $C_{m0.2}$  are also given in table 2.

$\alpha$ (°)	$C_l$ (-)	$C_d$ (-)	$C_{m0.25}$ (-)	$(C_l \cos\alpha + C_d \sin\alpha)$	$C_{m0.3}$ (-)	$C_{m0.35}$ (-)	$C_{m0.4}$ (-)	$C_{m0.2}$ (-)
-11.1	-0.191	0.0966	-0.0300	-0.2060	-0.0403	-0.0506	-0.0609	-0.0197
-8.4	-0.132	0.0171	-0.0947	-0.1331	-0.1014	-0.1080	-0.1147	-0.0880
-6.2	0.066	0.0149	-0.0899	0.0640	-0.0867	-0.0835	-0.0803	-0.0931
-4.2	0.268	0.0141	-0.0863	0.2662	-0.0730	-0.0597	-0.0464	-0.0996
-2.1	0.467	0.0136	-0.0842	0.4662	-0.0609	-0.0376	-0.0143	-0.1075
0.0	0.672	0.0129	-0.0865	0.6720	-0.0529	-0.0193	0.0143	-0.1201
2.0	0.870	0.0160	-0.0888	0.8700	-0.0453	-0.0018	0.0417	-0.1323
4.1	1.056	0.0196	-0.0875	1.0547	-0.0348	0.0180	0.0707	-0.1402
6.5	1.214	0.0247	-0.0853	1.2090	-0.0249	0.0356	0.0961	-0.1458
8.8	1.360	0.0349	-0.0820	1.3493	-0.0145	0.0529	0.1204	-0.1495
10.1	1.404	0.0459	-0.0786	1.3903	-0.0091	0.0604	0.1299	-0.1481
11.6	1.408	0.0662	-0.0818	1.3926	-0.0122	0.0575	0.1271	-0.1514
14.7	1.370	0.1201	-0.0795	1.3556	-0.0117	0.0561	0.1238	-0.1473

table 2  $C_l$ ,  $C_d$ ,  $C_{m0.25}$ ,  $C_{m0.3}$ ,  $C_{m0.35}$  and  $C_{m0.4}$  as a function of  $\alpha$ .  $Re = 4.2 * 10^5$

The  $C_{m0.25}-\alpha$  curve, the  $C_{m0.3}-\alpha$  curve, the  $C_{m0.35}-\alpha$  curve, the  $C_{m0.4}-\alpha$  curve and the  $C_{m0.2}-\alpha$  curve can be derived from table 2. These curves are given in figure 15.

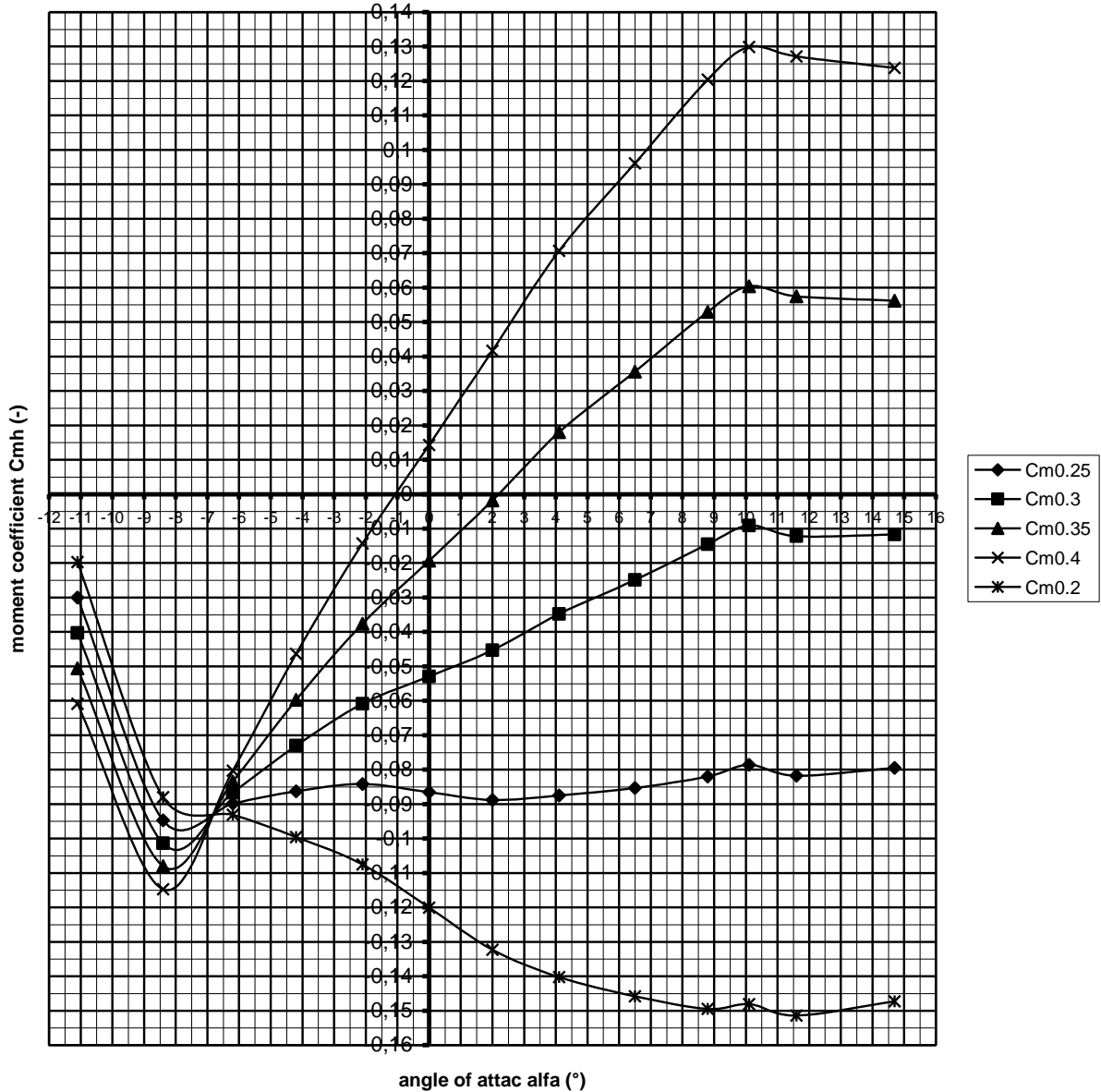


fig. 15  $C_{m0.25}$ - $\alpha$  curve,  $C_{m0.3}$ - $\alpha$  curve,  $C_{m0.35}$ - $\alpha$  curve,  $C_{m0.4}$ - $\alpha$  curve and  $C_{m0.2}$ - $\alpha$  curve for the Gö 624 airfoil for  $Re = 4.2 \cdot 10^5$

## 6 References

- 1 Hageman A. Catalogue of Aerodynamic Characteristics of Airfoils in the Reynolds number range  $10^4 - 10^6$ , July 1980, Report R443D (no longer supplied by the TU-Eindhoven but available on the Internet if the correct title is typed at Google), Laboratory of Fluid Dynamics and Heat Transfer, Department of Physics, University of Technology Eindhoven.
- 2 Kragten A. Rotor design and matching for horizontal axis wind turbines, January 1999, reviewed February 2017, free public rapport KD 35, engineering office Kragten Design, Populierenlaan 51, 5492 SG Sint-Oedenrode, The Netherlands.
- 3 Riegels F. W. Aerodynamische Profile (in German), Oldenbourg, R. München, 1958.