The Gö 227 airfoil for use in windmill rotor blades

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KD 698

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1 Introduction

In report R-443-D (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 most of the given airfoil graphs are too small for use in rotor blade calculations of wind turbines. Fortunately the original measuring points are given for almost all airfoils and using these points, new accurate graphs can be made. This report is no longer supplied by the UT-Eindhoven but a scan of it can be found on my website at the bottom of the list with KD-reports.

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 most of my present VIRYA-windmills with wooden blades. The characteristics and geometry of this airfoil are given in my report KD 35 (ref. 2).

The Gö 227 airfoil has a lower side which is partly convex and partly concave and so manufacture of windmill rotor blades which are provided with this airfoil requires more skills. But it has certain special qualities and therefore its characteristics are discussed in this report KD 698. A small picture of this airfoil is given at page 2-11 of R-443-D. The C_l-α and C_l/C_d curves are given at page 3-88 of R-443-D. The measuring points are given at page 3-90 of R-443-D. The airfoil geometry is given at page 3-92 of R-443-D.

This airfoil has been measured by Riegels and measurements are published in the book "Aerodynamische Profile" (ref. 3). At page 1-3 of R-443-D, it is explained in figure b, how the geometry is defined by Riegels. The x-axis or zero line of the airfoil is a line which goes through the airfoil tail and which touches the lower side. This makes that all y-coordinates are positive. The quart chord point is lying at the zero line at a distance of ¼ c from the airfoil nose. The aerodynamic centre is lying close to the quart chord point. The moment coefficient is given around the quart chord point. The direction of a clock wise moment is taken positive. However, the moment coefficient appears to be negative around the quart chord point, so in reality it means that the aerodynamic moment has a tendency to decrease the angle of attack α.

An advantage is that the Gö 227 airfoil has been measured for a rather low Reynolds value of $0.96 * 10^5$. Therefore it can be used for rather small wind turbines. A disadvantage is that it hasn't be measured for higher Reynolds values. However, the C_d/C_l ratios for higher Reynolds values will certainly be lower and using the values for $Re = 0.96 * 10^5$ for blade sections with higher Reynolds values, will therefore be acceptable.

A disadvantage is also that the airfoil has only been measured up to a maximum angle of attack $\alpha = 8.4°$. So no values are available for large angles of attack which happen during starting of the rotor. It might be allowed to use the C_l-α curve for large angles α for the Gö 623 airfoil as given in figure 5.10 of KD 35 (ref. 2).

2 The Gö 227 airfoil geometry

In table 1 the airfoil geometry is given for a chord of c = 100 mm, copied from page 3-92 of report R-443-D. The distance x is the value from the airfoil nose. 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. The airfoil geometry derived from table 1, is given on scale in figure 1.

x (mm)	y_u (mm)	y_l (mm)
0	2.9	2.9
1.25	5.4	1.2
2.5	6.6	0.6
5.0	8.6	0.1
7.5	10.2	0
10	11.4	0
15	13.3	0.2
20	14.6	0.4
30	15.4	0.8
40	15.8	1.4
50	15.8	2.6
60	15.0	3.6
70	13.0	4.3
80	10.6	4.3
90	7.5	3.8
95	4.1	2.3
100	0.3	0

table 1 Geometry of the Gö 227 airfoil for a chord c = 100 mm

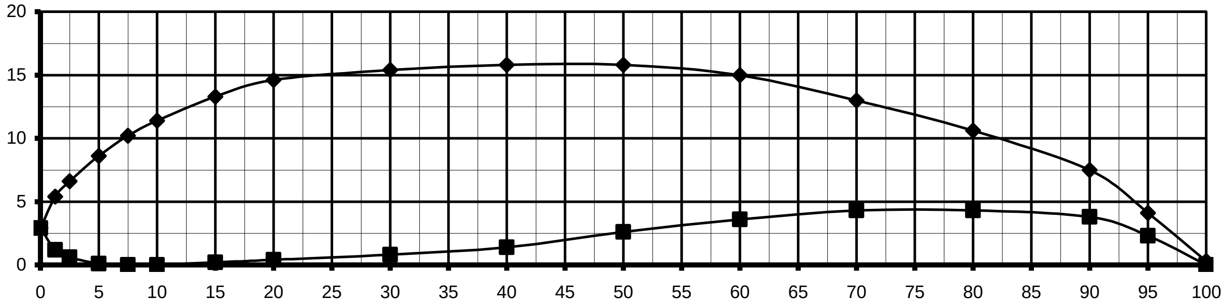

fig. 1 Gö 227 airfoil for c = 100 mm (same scale for x-axis and y-axis)

The airfoil thickness at x = 30 mm is 15.4 – 0.8 = 14.6 mm. The airfoil thickness at x = 40 mm is 15.8 – 1.4 = 14.4 mm. So this airfoil has its maximum thickness at x = 30 mm, just as most other airfoils. If the real blade chord c is a factor i larger than 100 mm, all the x-values and y-values of figure 1 have to be multiplied by the same factor i.

In figure 1 it can be seen that there is a very sudden change in both the upper and lower sides of the airfoil for x = 90 mm. More fluent curves will be obtained if it is chosen that y_u = 6.6 mm and if y_l = 3.6 mm for x = 90 mm but figure 1 wasn't changed this way.

3 The Gö 227 airfoil characteristics

In table 2, the original measuring points of the Gö 711 airfoil characteristics are given which were copied from page 3-90 of report R-443-D. In the original table, one has mentioned 100 C_d and -10C_m but I have used the real values in my table 2. The angle of attack is α (°). The lift coefficient is C_l (-). The drag coefficient is C_d (-). The moment coefficient around the quart chord point is $C_{m0.25}$ (-). The quart chord point is lying at the zero line at a distance x = 25 mm from the nose. The direction of moment coefficient is defined clock wise if the nose points to the left side. Because the moment coefficient is negative, it means that the aerodynamic moment is working anti clock wise and therefore it has a tendency to decrease the angle of attack α. For some angles α, the $C_{m0.25}$ value is missing but this is correct as these values are also missing in the original table.

The C_l-α curve, derived from table 2, is given in figure 2. The C_l/C_d curve is given in figure 3. The C_d-α curve is given in figure 4. The $C_{m0.25}$-α curve is given in figure 5.

α (°)	C_l (-)	C_d (-)	$C_{m0.25}$ (-)
-11.8	-0.054	0.1318	-0.0530
-9.0	0.017	0.1000	-0.0880
-7.9	0.112	0.0730	-0.1267
-7.1	0.282	0.0330	-0.1889
-6.0	0.400	0.0290	
-4.9	0.512	0.0280	-0.1949
-4.0	0.646	0.0270	
-2.9	0.748	0.0280	-0.1960
-1.9	0.863	0.0290	
-0.8	0.975	0.0310	-0.1979
1.3	1.196	0.0340	-0.1975
3.5	1.404	0.0410	-0.2001
5.8	1.585	0.0530	-0.1980
8.4	1.679	0.0840	-0.1958

table 2 C_l, C_d and $C_{m0.25}$ as a function of α for Re = 0.96 * 10^5

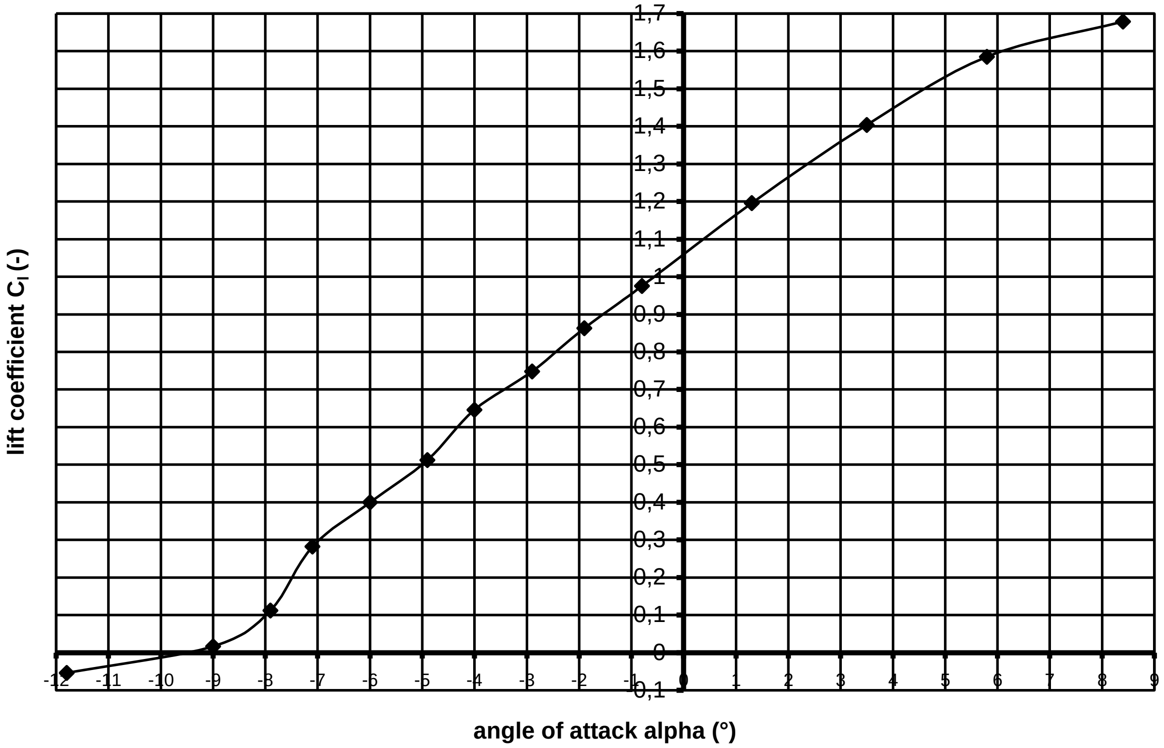

fig. 2 C_l-α curve for Gö 227 airfoil for Re = $0.96 * 10^5$.

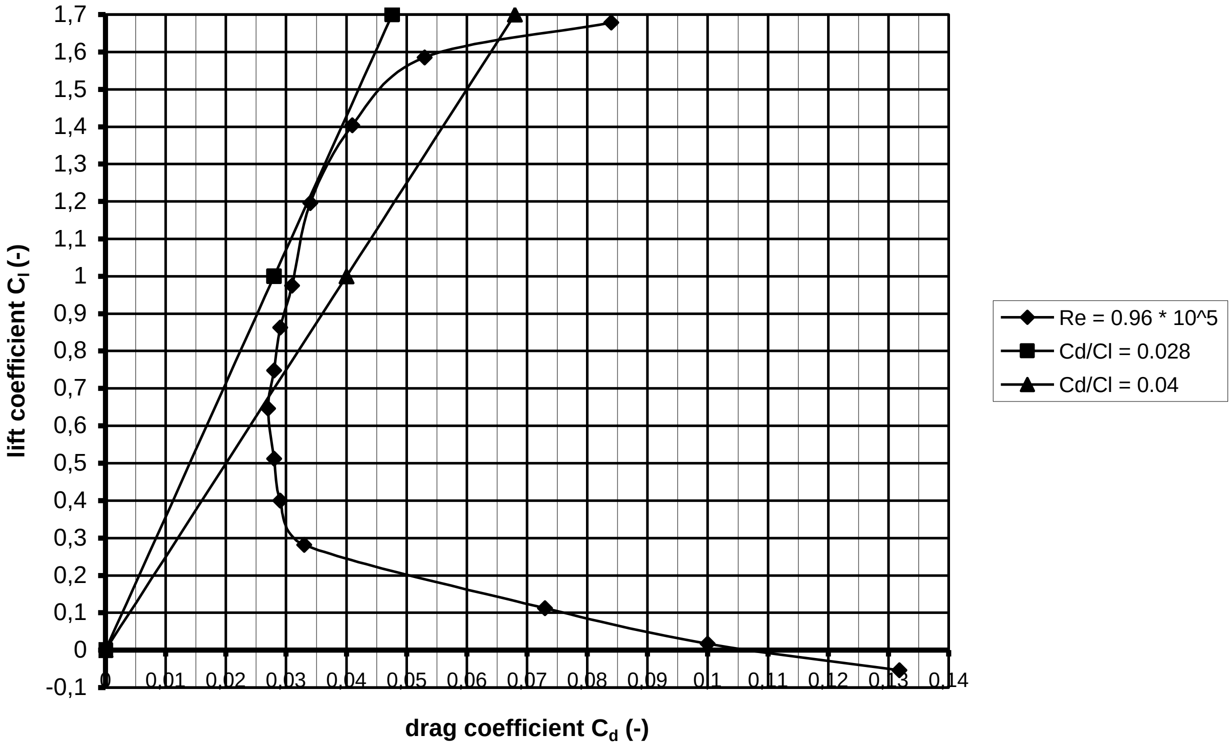

fig. 3 C_l-C_d curve for the Gö 227 airfoil for Re = $0.96 * 10^5$.

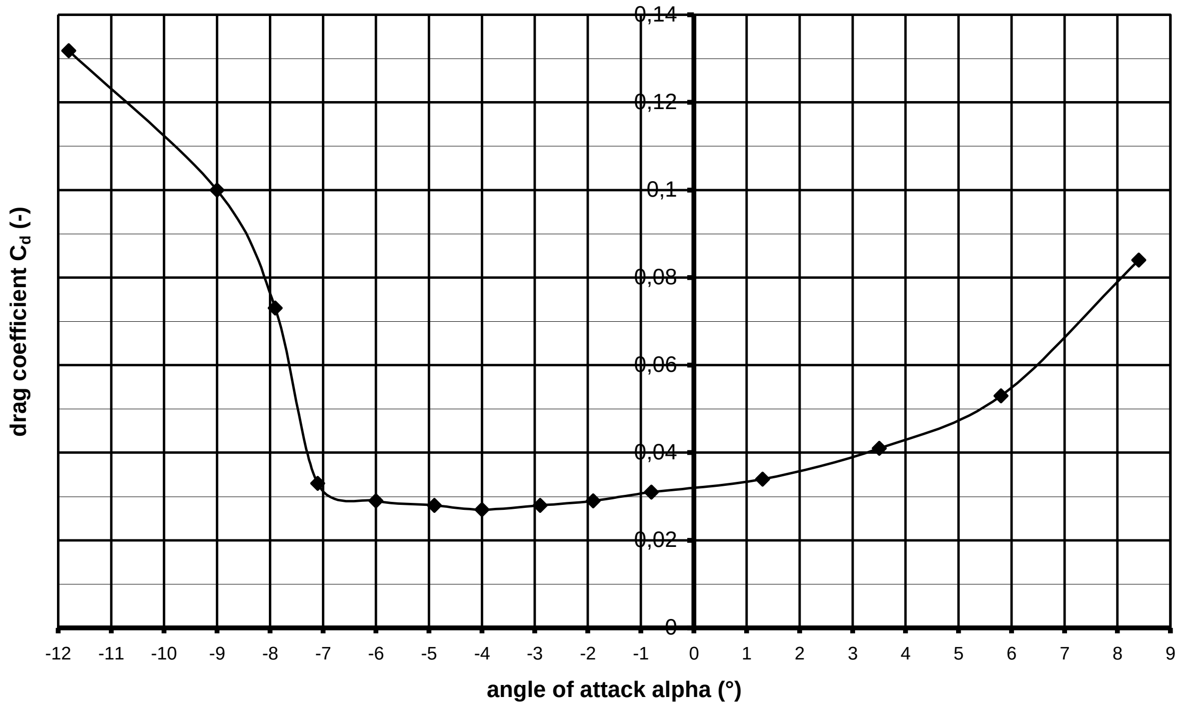

fig. 4 C_d-α curve for Gö 227 airfoil for Re = $0.96 * 10^5$.

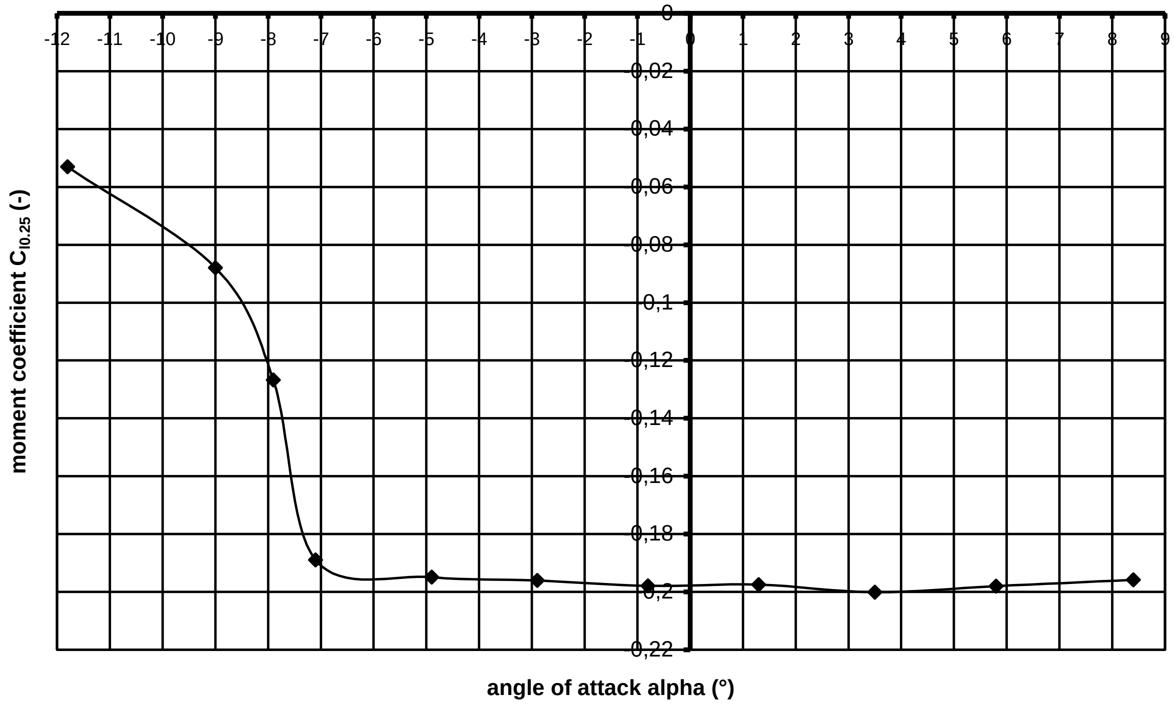

fig. 5 $C_{m0.25}$-α curve for Gö 227 airfoil for Re = $0.96 * 10^5$

The minimum C_d/C_l ratio is found in figure 3 for the straight line through the origin which touches the C_d/C_l curve. This line in drawn in figure 3. The C_d/C_l ratio for this line can easily be found by reading the C_d value for $C_l = 1$. It can be seen that $C_d/C_l = 0.028$ for this line and therefore this line is called $C_d/C_l = 0.028$. This is a rather low C_d/C_l ratio for a Reynolds value of $0.96 * 10^5$. The C_l value for the point of intersection is called the optimum C_l value and in figure 3 it can be seen that the optimum C_l value is about 1.26 which is rather high. The corresponding angle of attack α is about 2°. The maximum C_l value is about 1.68 which is also rather high.

A second straight line is drawn in figure 3 for which $C_d/C_l = 0.04$. It can be seen that this line is intersecting with the C_d/C_l curve for about $C_l = 0.67$ and for $C_l = 1.63$. In figure 2 it can be seen that these points correspond about to angles of attack $\alpha = -4°$ and $\alpha = 7°$. So if one uses the part of the C_l-α curve in between $\alpha = -4°$ and $\alpha = 7°$, C_l will be smaller than 0.04. The average C_d/C_l ratio will then be about 0.035.

Assume that this airfoil is used for a 3-bladed rotor with a design tip speed ratio of 6 and blades with a constant chord and blade angle. The design of a blade with a constant chord and blade angle is explained in example no. 2 at chapter 5.4.2 of KD 35. This blade will have a low C_l value at the blade tip and a high C_l value at the blade root. Assume that the chord is chosen such that the C_l value at the blade tip is 0.7. This blade will have an average C_d/C_l ratio of about 0.035. In figure 4.7 of KD 35 (ref. 2) it can be seen that the theoretical maximum C_p is about 0.43 for this C_d/C_l ratio and B = 3, which is acceptable.

4 References

1 Hageman A. Catalogue of Aerodynamic Characteristics of Airfoils in the Reynolds number range $10^4 – 10^6$, July 1980, Report R-443-D (no longer supplied by the TU-Eindhoven but a scan can be found on my website at the bottom of the menu KD-reports), 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.