

Some ideas about gliders with variable geometry concerning performance and handling qualities

(D-40 of Akaflieg Darmstadt)

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Introduction

Some years ago Helmut Reichmann became winner of the world championship for the third time. His glider, the SB-11 of the Akaflieg Braunschweig was of great interest because of the variable geometry of its wings. But nowadays it seems as if this interest is gone, as it seems to be hard to prove the increase of flight performance of gliders with variable wing geometry by use.

What are the reasons for this? Is it worth constructing another glider with variable wing geometry?

Flight performance

First let us have a look at the flight performance. The adjustment of a glider's wing with variable geometry to the dif-

ferent requirements of turning and high-speed flight can be done by two different ways.

First, by changing the wing span. In this case, the aerofoil does not change, the maximum lift-coefficient does not either but the aspect ratio becomes larger. The disadvantage of changing the wing span is the large amount of energy necessary to do it. So, for example it takes too much time, to adjust the wing of the FS-29 made by Akaflieg Stuttgart.

The other possibility is to change the wing chord. This can be done either along the whole wing span, as done by the SB-11, or by a triangular flap as we do it for the D-40 (Fig. 1).

If the wing area is made larger by changing the wing chord, the aspect ratio becomes smaller. So, the induced drag

coefficient (at given lift coefficient) will increase. At the same time, the wing loading and the minimum speed are reduced.

Fig. 2 shows the Hornet-C polar curve [1], increasing the induced drag coefficient by reducing the wing loading at the same time.

To evaluate the differences at low-speed flight, models of rising warm air flow are useful. Horstmann [2] proposes to make a difference between narrow (A) and wide (B), poor (1) and strong (2) thermals. The velocity W_A is given by Horstmann depending on the radius R to

$$A 1: W_A = 3.25 - 2.25 \cdot R \quad (\text{m/s})$$

$$A 2: W_A = 5.40 - 3.20 \cdot R \quad (\text{m/s})$$

$$B 1: W_A = 2.00 - 0.42 \cdot R \quad (\text{m/s})$$

$$B 2: W_A = 3.66 - 0.55 \cdot R \quad (\text{m/s})$$

Fig. 3 shows the sinking speed depending on the radius of turn of the polar curves given in Fig. 2. If curves of constant climb speed are drawn on the diagram, the optimum climb speeds result as the tangent curve points of contact.

As expected the figure shows that in the case of the narrow thermal, an enlargement of the wing area is very useful. In the case of the wide thermal a 10% increase of wing area shows no disadvantages and even a 20% increase makes only a small difference.

In order to avoid disadvantages under specific meteorological conditions, an increase of wing area should not be too large. So, as shown, an increase of 10% to 20% appears to be the optimum depending on the aerofoil used. Besides this, changing wing chord is useful because of the good adjustment of the aerofoil to the different requirements of thermal flight and high-speed flight.

It is obvious, that advantages of performance can be realized only, if the wing construction is of high quality. Leaks or waviness as well as warping of the sealing ledge reduce performance very much. It is absolutely necessary to spend time on solving these problems.

There are also problems of handling qualities, especially concerning the efficiency of control surfaces. In the range of the fully extended flap the airflow is affected so much that a deflection of the ailerons is nearly ineffective. For exam-

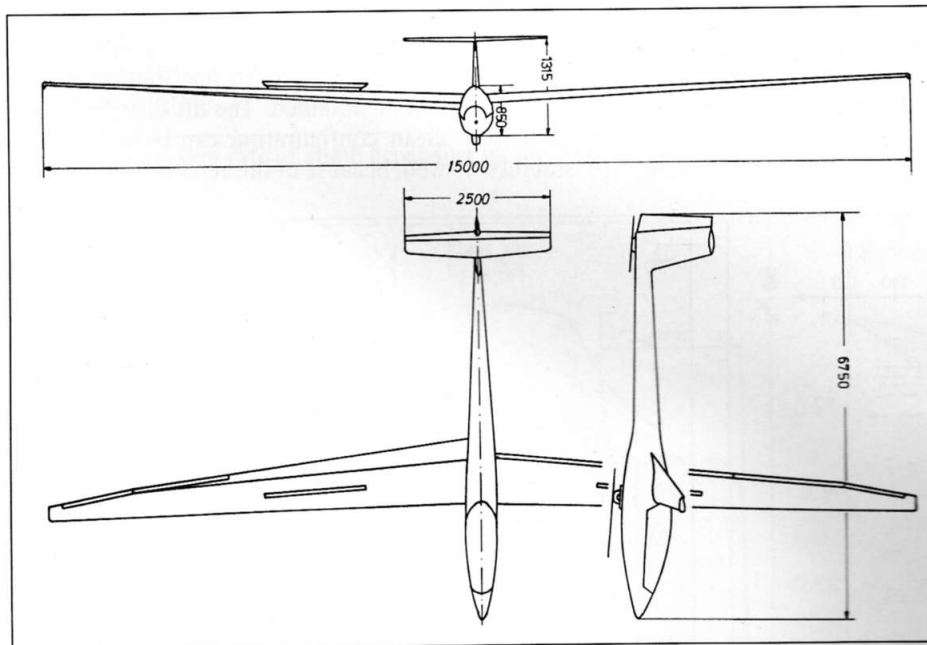


Fig. 1 Change of the wing chord by a triangular flap used by D-40 glider.

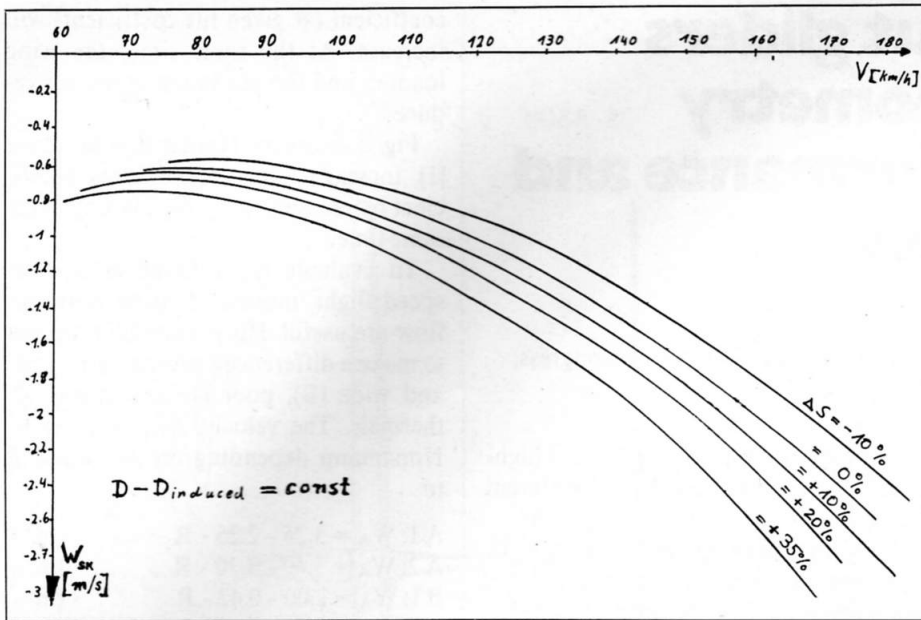


Fig. 2 Hornet-C polar curve, increasing the induced drag coefficient by reducing the wing loading.

ple the polar curves of the airfoil FX-67-VG-170/1.36 shows this clearly [3], (Fig. 4).

The roll-and-yaw factor increases with lift coefficient squared. This makes a large rudder necessary, because of the large maximum lift coefficient of the used aerofoil.

Extending the flaps, moves the aerodynamic center backwards. So larger elevator deflection angles are necessary. These considerations were proved by the measurements of the flying qualities by the Idaflieg. For example, it takes the SB-11 4.1 to 5 seconds to change from a 45-degree left turn to a 45-degree right turn at 1.4 times stall speed.

If there is a way, making it possible, to

reach good flight-handling qualities and high performance, I think, it is of great interest to construct and test a glider with variable wing geometry.

The D-40 wing

Looking at the performance of the D-40 the large aerodynamic twist of 12 degrees with flaps extended configuration attracts attention. The resulting lift distribution is shown in Fig. 5 curve 1. A notable characteristic is the quite low lift coefficient of the whole wing ($C_L = 1.25$) with a high induced drag.

If there would be a distribution of the angle of attack chosen through a built-in twist of the wings so that an elliptic lift distribution would result, for stability

very unfavourable lift distribution would be produced by clean configuration (Fig. 5, curve 2).

The question is, how far an elliptic lift distribution is desirable in low-speed flight, as, of course, then the induced drag is a maximum, but the efficiency of the control surfaces is not perfect when flying circles, so that a speed has to be chosen, which is clearly higher than stall speed. The question is, how much you can deviate from elliptic lift distribution in order to reach a maximum rate of climb turning in thermals. Fig. 6 shows how much the rate of climb becomes smaller, either if C_L is reduced or the induced drag becomes larger. As a result, you can show the factor k depending on the ratio of speed to stall speed under the condition of constant rate of climb (Fig. 7). To reach an always acceptable efficiency of the ailerons, k should not be larger than 0.88. This means a loss of the rate of climb of 4 to 5 cm/s in case of wide and poor thermal B 1, but a loss of about 10 cm/s in case of the strong and narrow A 1 thermal.

For these reasons, we tried to obtain a lift distribution for D-40, which is nearly elliptic up to the beginning of the aileron, but offers clear reserves in the area of the aileron. This was obtained first by means of a superposition of the ailerons with the flaps. On the other hand, it is found that it is still possible to build in some twist, so that the angle of attack is increased towards the wing tips. In this way, the wanted lift distribution (Fig. 8) can be obtained. The lift distribution by clean configuration can be accepted as well, because of the aeroelastic drill. Fur-

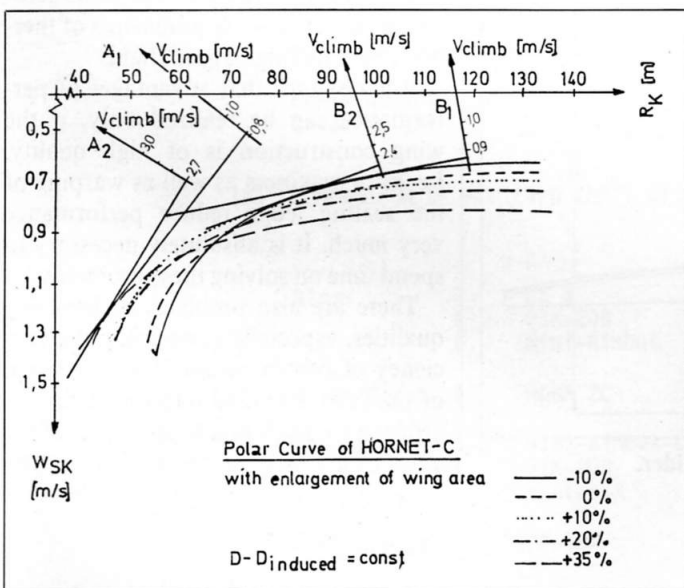


Fig. 3 Sinking speed depending on the radius of turn of polar curves in fig. 2.

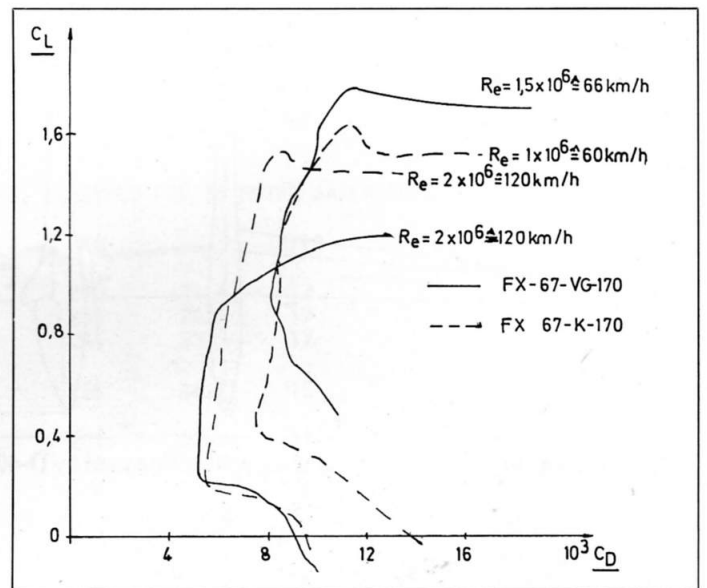


Fig. 4 Nearly ineffective deflection of the ailerons.

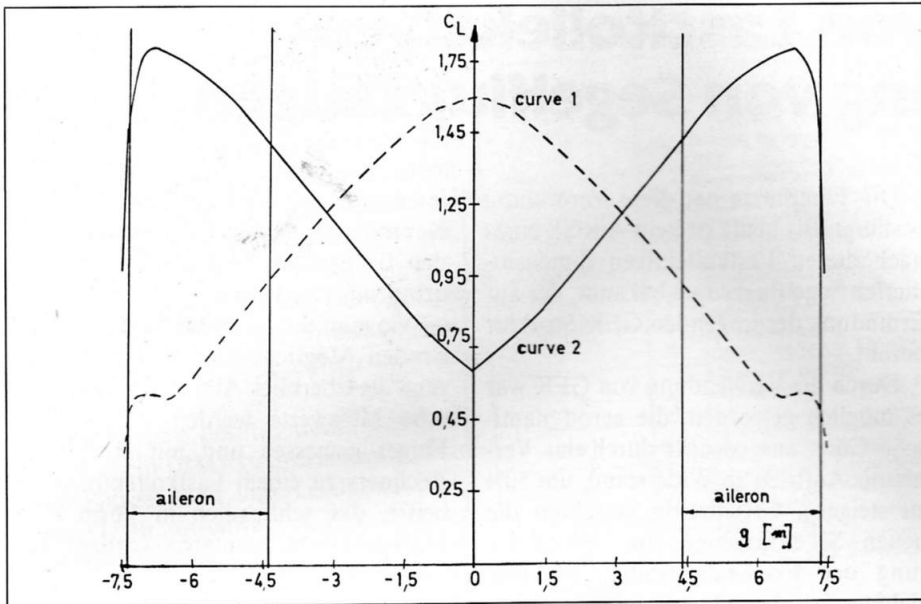


Fig. 5 Elliptic lift distribution as result of the chosen angle of attack through a built-in twist of the wings.

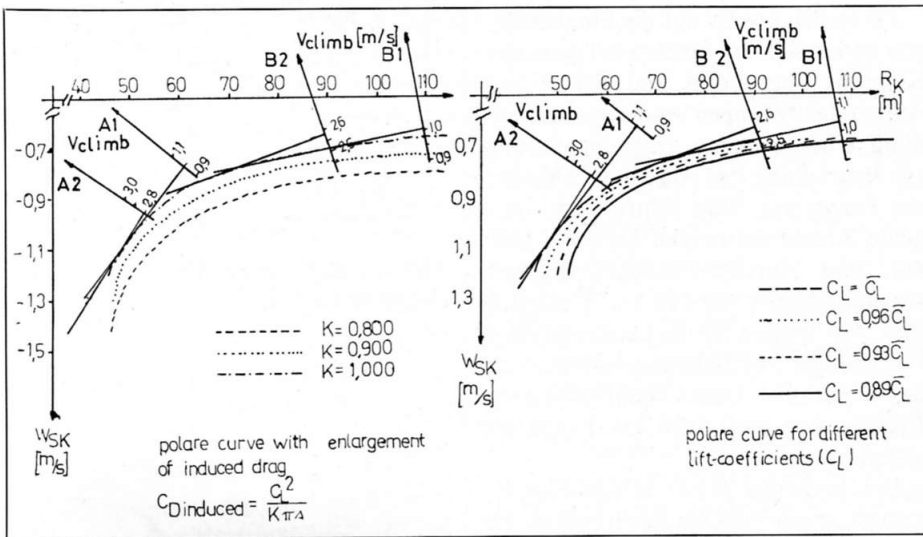


Fig. 6 Decreasing rate of climb depending on the reduction of C_L or increasing the induced drag.

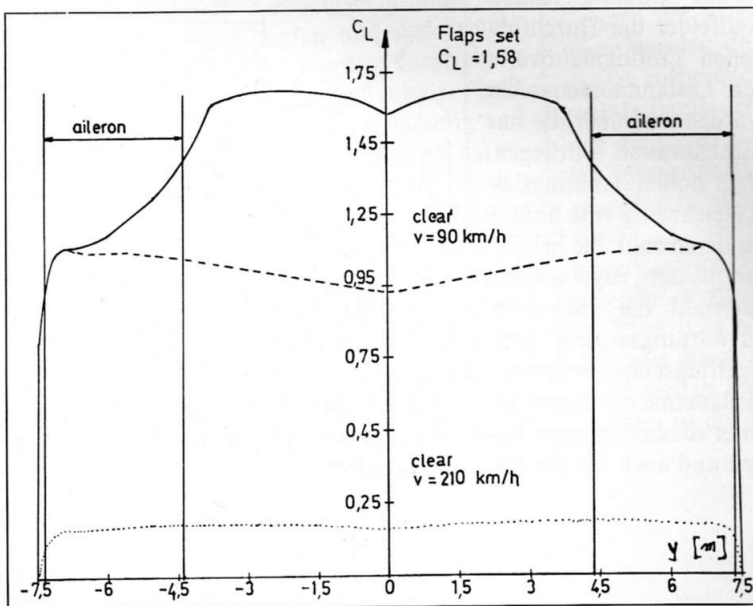


Fig. 7 Factor k depending on the ratio of speed to stall speed under the condition of constant rate of climb.

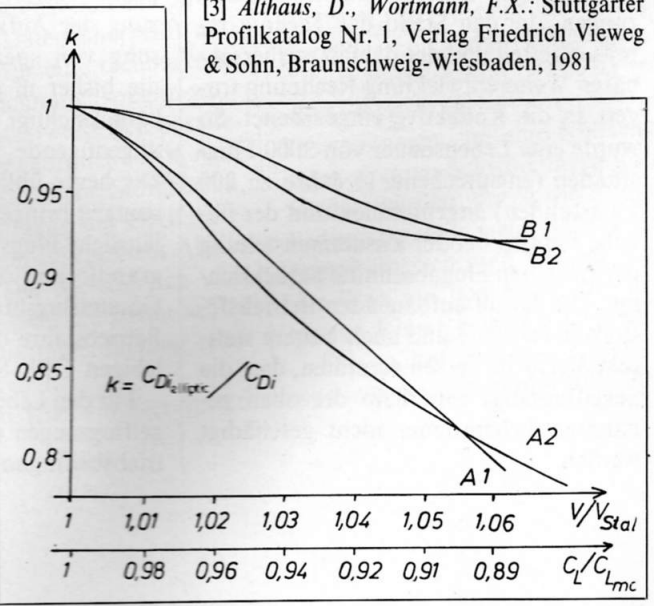


Fig. 8 Building of a wing twist with an increasing angle of attack towards the wing tips to obtain the wanted lift distribution.

thermore, it can be seen that the aerofoil of Wortmann FX-67-VG-170, which was used for the inner wing area, can be used up to the end of the flap too, as here relatively low C_L values are necessary. This aerofoil promises low drag down to the smallest C_L values, so that camberflaps are not necessary.

If the flap handling qualities are considered, it can be seen that the wing of the D-40 promises very good efficiency of the ailerons because of the large aerodynamic twist. Calculations suggest that the time needed to change from a 45-degree left turn to a 45-degree right turn at 1.4 times stall speed is less than 3 seconds so that the D-40, similar to the D-38 seems to become one of the most maneuverable gliders of its class. Furthermore the D-40 does not make so high demands as the SB-11 concerning the size of the elevator and rudder, as, because of the smaller flaps, the change of the pitching moment, as well as the roll-and-yaw factor, is a lot smaller.

The aerodynamic concept of the D-40, Akaflied Darmstadt is constructing, is a new trial to improve the advantages of gliders with variable wing geometry. We hope that improvement of performance and handling qualities can be reached by a triangular flap, requiring only a minimum of additional mechanical parts.

Literature

- [1] Stich, G.: Flugmessungen an Segelflugzeugen von 1978 und 1979, DFVLR IB 111, 1981, 11
- [2] Horstmann, K.H.: Neue Modellaufwindverteilung und ihr Einfluss auf die Auslegung von Segelflugzeugen, OSTIV Publication XIV, Räyskälä/Finnland, 1976.
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