Comments on Performance and Handling Qualities of Gliders with Variable Geometry (D-40 of Akaflieg Darmstadt)

Klaus-Jurgen Heer
Akaflieg Darmstadt

Presented at the XVIIth OSTIV Congress
Paderborn, Germany, 1981

INTRODUCTION

Some years ago Helmut Reichmann won the World Championships for the third time. His glider, the SB-11 of the Akaflieg Brauschweig, 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 contructing another glider with variable wing geometry?

FLIGHT PERFORMANCE

First, let us look at flight performance. The adjustment of a glider's wing with variable geometry to the different requirements of turning and high speed flight can be done in two different ways.

First, by changing the wing span. In this case neither the airfoil nor the maximum lift-coefficient changes, but the aspect ratio becomes larger. The disadvantage of changing the wing span is the large amount of energy necessary to do it. 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 with the SB-11, or by a triangular flap as with the D-40 (Fig. 1).

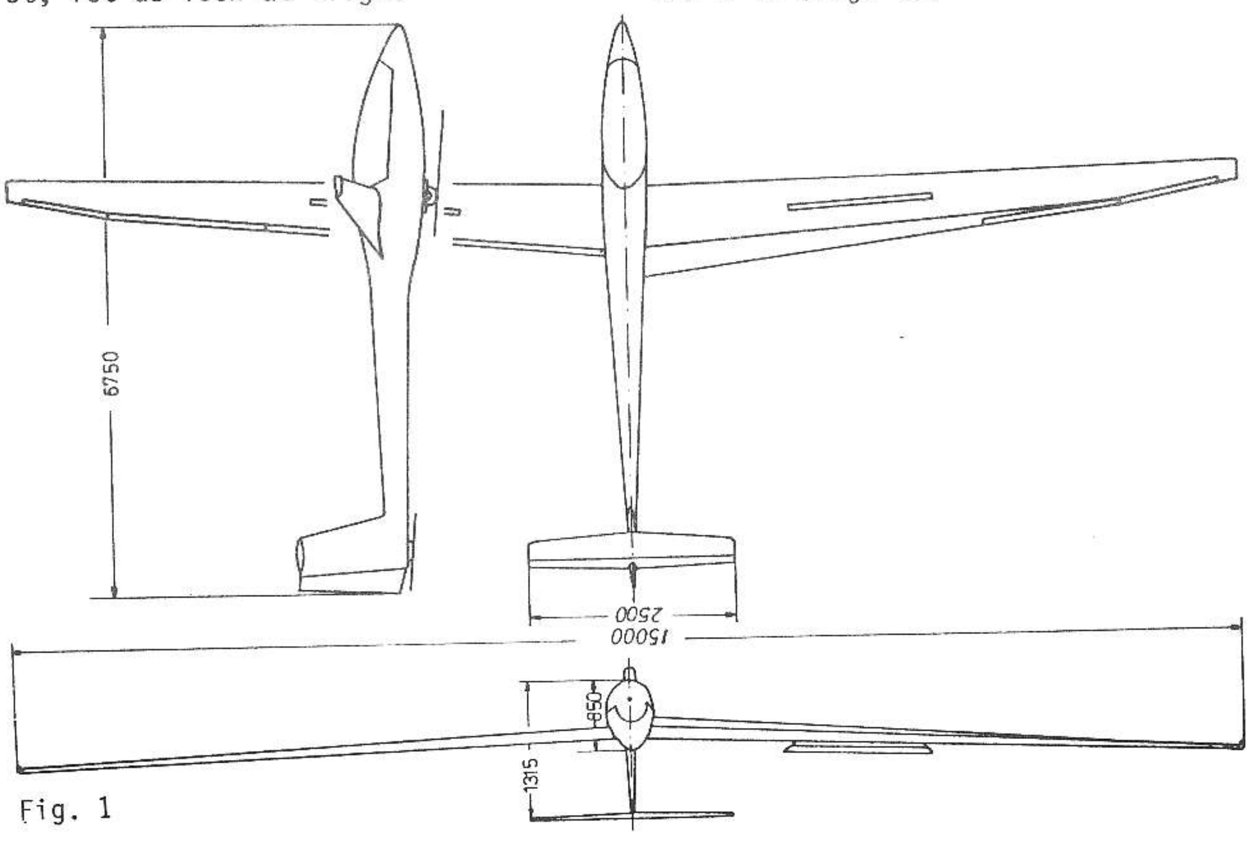


Fig. 1

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

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%

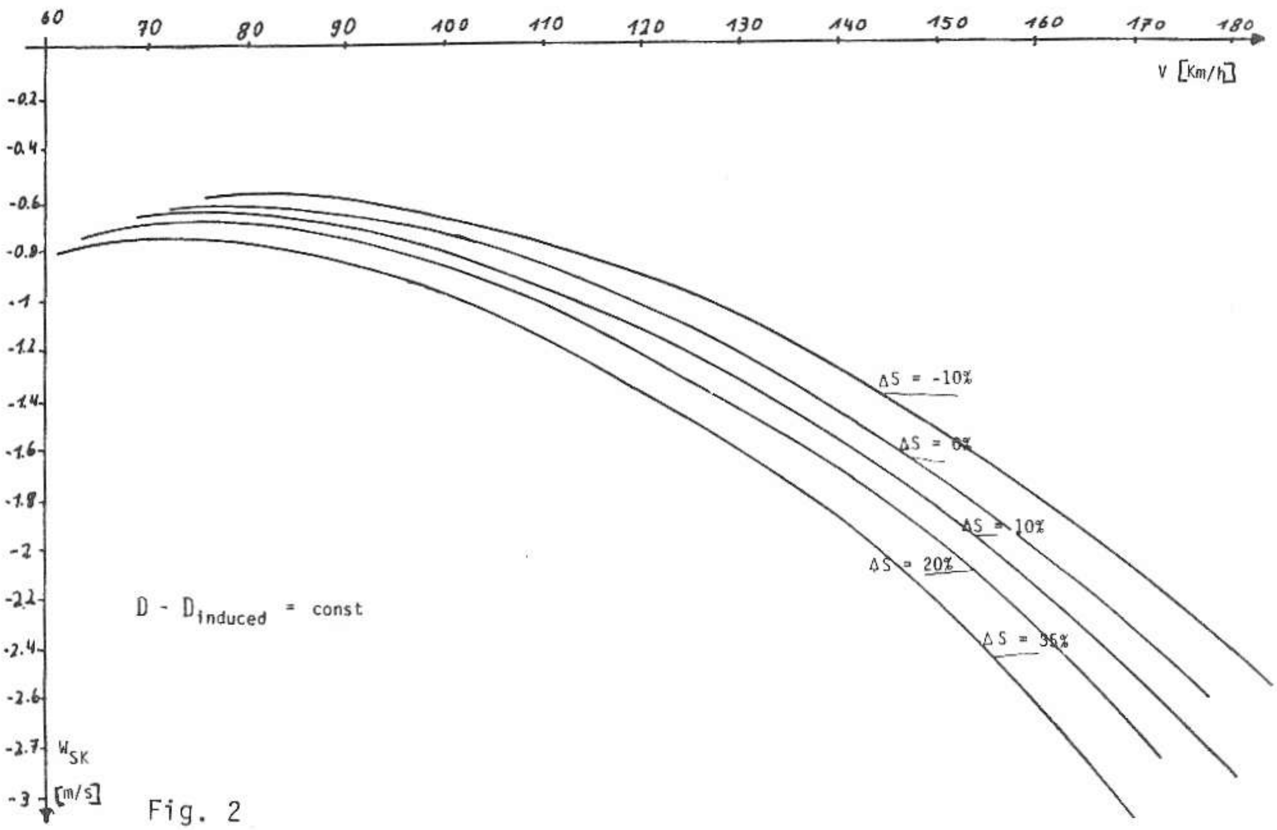


Fig. 2

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 $W_A=3.25 - 2.25 \times R$ (m/s)

A 2 $W_A=5.40 - 3.20 \times R$ (m/s)

B 1 $W_A=2.00 - 0.42 \times R$ (m/s)

B 2 $W_A=3.66 - 0.55 \times R$ (m/s)

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

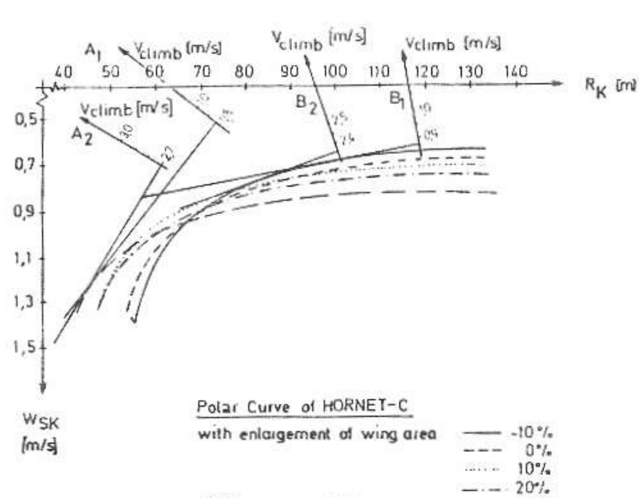


Fig. 3

to 20% appears to be the optimum depending on the airfoil used.

Besides this, changing wing chord is useful because of the good adjustment of the airfoil 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 leading edge, reduce performance considerably. It is absolutely necessary to spend time solving these problems.

There are also problems with handling qualities, especially concerning the efficiency of control surfaces. In the range of fully extended flaps the airflow is affected so much that a deflection of the ailerons is nearly ineffective. For example, the polar curves of the airfoil FX-67-VG-170/1.36 show this clearly[3] (Fig. 4).

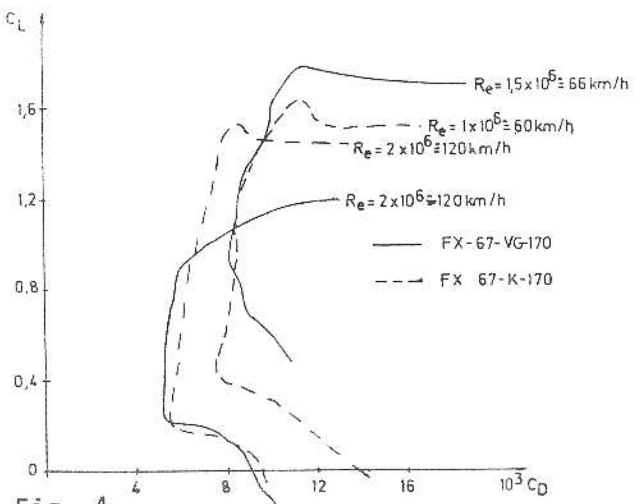


Fig. 4

The roll and yaw factor increases with lift coefficient squared. This makes a larger rudder necessary because of the large maximum lift coefficient of the airfoil.

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

If there is a way to attain good flight handling qualities and high performance, it would be very interesting 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° 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.

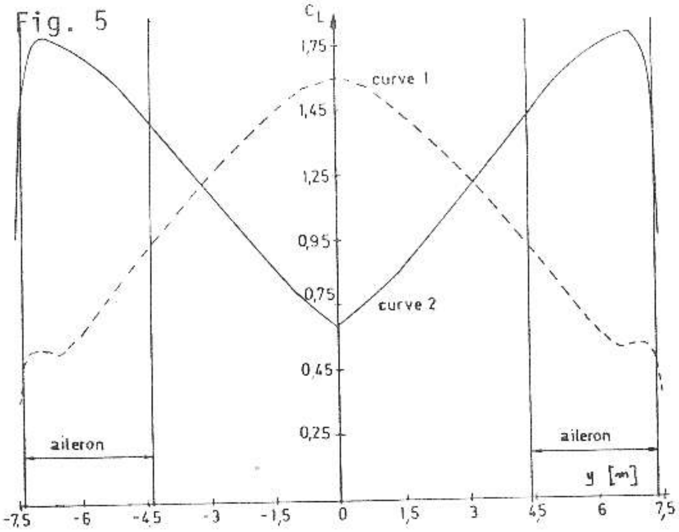
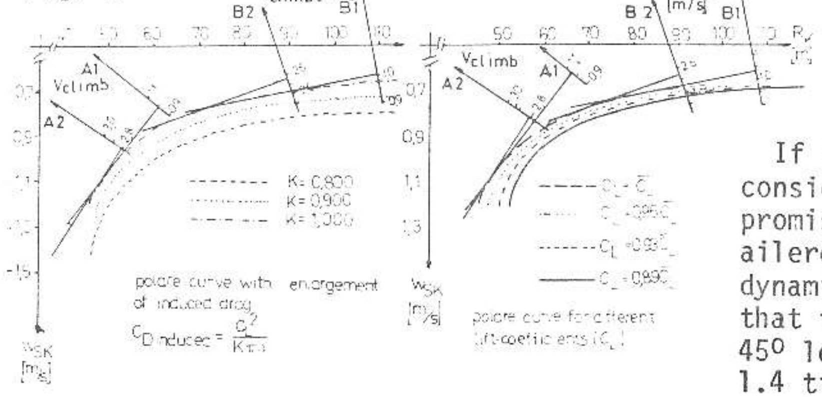


Fig. 5

If there could 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, unfavorable lift distribution for stability would be produced by clear configuration (Fig. 5, Curve 2). The question is how much 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. This makes it necessary to choose a speed which is clearly higher than stall speed. So, how much can you deviate from elliptic lift distribution in order to reach a maximum rate of climb turning in thermals?

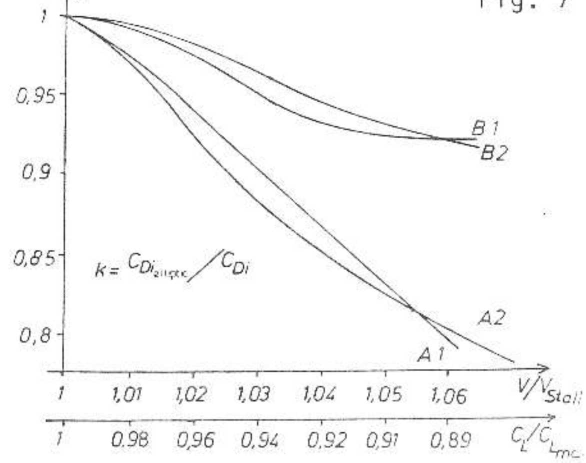
Fig. 6 shows how much the rate of climb decreases, either if C_L is reduced or the induced drag becomes larger. As a result, you can show the factor k

Fig. 6



depending on the ratio of speed to stall speed under the condition of constant rate of climb (Fig. 7). To reach an 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 the case of a wide and poor thermal B1; a loss of about 10 cm/s in case of the strong and narrow A1 thermal.

Fig. 7

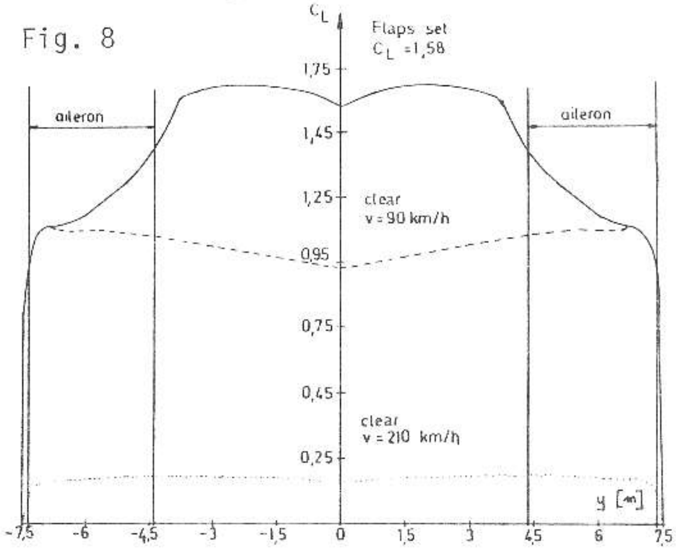


For these reasons, we tried to obtain a lift distribution for D-40, which is nearly elliptic up to the beginning of the aileron, but offers clear reserves in the area of the aileron. This was obtained first by means of a superposition of the ailerons with the flaps.

On the other hand, we found it is possible to build in some twist so that the angle of attack is increased toward 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 good, because of the aeroelastic drill. Furthermore, it can be seen that the airfoil 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 where relatively low C_L values are necessary. This airfoil promises low drag to the smallest C_L values so camber flaps are not necessary.

If the flap handling qualities are considered, 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° left turn to a 45° 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.

Fig. 8



Furthermore, the D-40 does not make such high demands as the SB-11 concerning the size of the elevator and rudder; 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 the Akaflieg Darmstadt is constructing, is a new test to improve the advantages of gliders with variable wing geometry. We hope that improvement of performance and handling qualities can be reached by use of a simple triangular flap requiring only a minimum of additional mechanical parts.

REFERENCES

1. IDAFLIEG-Flugleistungsmessung 1979.
2. Horstmann, K.H.: "Neue Modellaufwindverteilung und ihr Einfluß auf die Auslegung von Segelflugzeugen," OSTIV, Publication XIV.
3. Stuttgarter Profilekatalog Institut für Aerodynamik und Gasmechanik der Universitat Stuttgart.