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WING PROFILE DESIGN OF THE WORLD CHAMPIONSHIP SAILPLANE SB 11

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Translation of "Tragflügelprofilentwurf für das Weltmeisterschafts-Segelflugzeug SB 11," DFVLR-Nachrichten, Nov. 1979, p. 18-20.

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16. Abstract

Attention is given to the conflicting performance demands which glider wings must meet. It is noted that a glider should be capable of climbing while circling in an updraft at low speed with a great amount of lift while it should be able to glide to the next updraft at high speed and with minimal altitude loss. It is shown how the featured design alleviates several problems and leaves no gap between wind and flap as in the commonly used Fowler flap configuration. The use of a constant thickness flap eliminates the need for a flexible contour section which in turn reduces control effort. In addition, the conventional method of banking with ailerons is retained. Finally, test results are present demonstrating the improved performance.

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WING PROFILE DESIGN FOR THE WORLD CHAMPIONSHIP SAILPLANE SB 11

K. H. Horstmann and A. Quest

During the sailplane world championships in 1978 at /18*
Chateauroux (Central France) Dr. Helmut Reichmann won first prize with the sailplane SB 11 in the 15 meter class of the FAI (International Aeronautics Federation). The SB 11 is a new design which was only finished a few weeks before the world championship, and it was fabricated by the Academic Pilot Group in Braunschweig. The aircraft was built and designed over about three years with an expenditure of 20,000 hours by students of the group. The Institute for Design Aerodynamics designed the wing profile for the SB 11 and also was in charge of measuring this profile and evaluating it. The following contribution gives a short summary of the West German sailplane industry, it describes a profile design with a new construction for performance improvement and the used measurement configurations for free flight measurements of wing profiles. There are also some data about the construction of the SB 11.

The sailplane industry is certainly no very important economic branch of German aviation industry, going by the number of people employed and the volume. However, it does take on a position which is unusual in the aviation industry of the Federal Republic of Germany. The nine German manufacturers of sailplanes have a dominant position on the world market. Out of the 79 sailplanes entered in the world championships in 1979, 72 were made in Germany.

This success in sailplane design can be attributed to the fact that the firms have very widely exploited the technology of composite fiber materials. Today already, the highly loaded mass produced parts of sailplanes are made of carbon fibers, in contrast to the civilian transportation aircraft industry.

*Numbers in margins indicate foreign pagination.

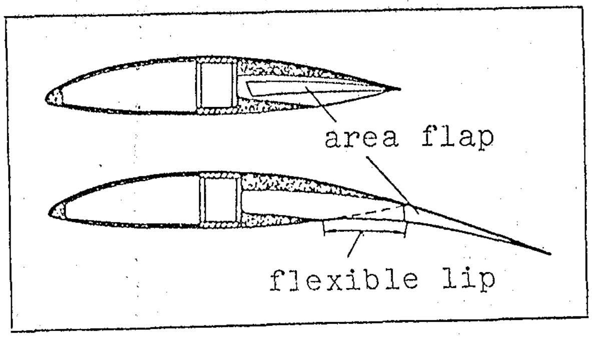

Figure 1: Wing profile with area flap and a flexible lip.

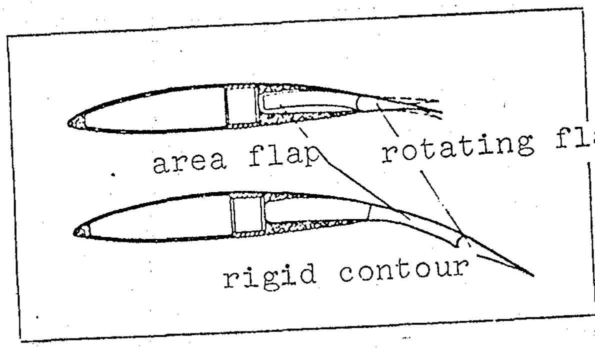

Figure 2: SB-11 Profile with area flap of constant thickness and rigid lip.

In addition, the load drag laminar profiles have been used extensively and have been investigated.

One possibility of maintaining the lead over foreign manufacturers is to use advanced technologies, which lead to an increase in performance. Such a new technology is a flap which enlarges the area, as shown in Figure 1. Just like in commercial aircraft, which increase the wing chord by extending a flap for takeoff and landing in order to achieve a higher lift coefficient, this principle can also be used for sailplanes during the ascent phase.

However, in commercial aircraft, fowler flaps are used which produce a gap between the wing and the flap. The configuration shown in Figure 1 is characterized by a continuous contour variation on the prop side of the profile, which is not disturbed by extending a flap. In this way, one accepts a somewhat reduced lip than for a gap-flap configuration, but the drag savings is large. The method for increasing the performance of a sailplane discussed here was used for the design of the wing of the SB 11, and its profile design will now be discussed in the next section.

Profile Design

Sailplanes are optimized essentially according to two design requirements:

- ascending flight in circles in a thermal upwind with a low speed and a high lift coefficient;

- gliding flight from a sufficient altitude to the next upwind position with a high speed (low lift coefficient) with the minimum possible altitude loss.

It is very difficult to satisfy both requirements in one design, because measures which are positive with respect to one requirement have disadvantages for the second requirement. A sailplane design is therefore always a compromise between opposing requirements.

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The use of area-enlarging flaps (area flaps) allows one to have a better matching of the wing to the two design criteria, and this brings about a performance improvement of the sailplane. The possibility of improved performance by area flaps has been known some time. The successful use of this concept however has failed up to the present time because the mechanical and aerodynamic development of the profiles using such flaps led to substantial difficulties, both in the manipulation and in the steering. Using a different flap concept.

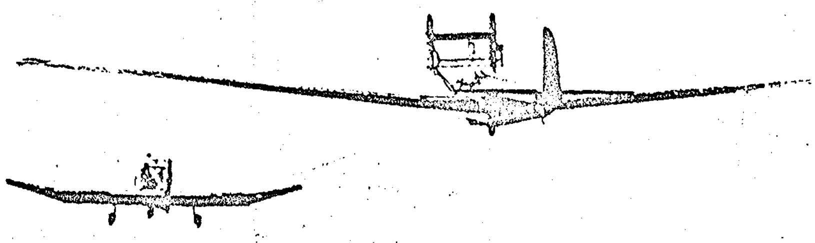

Figure 3: Kranich III with
model wing being towed.

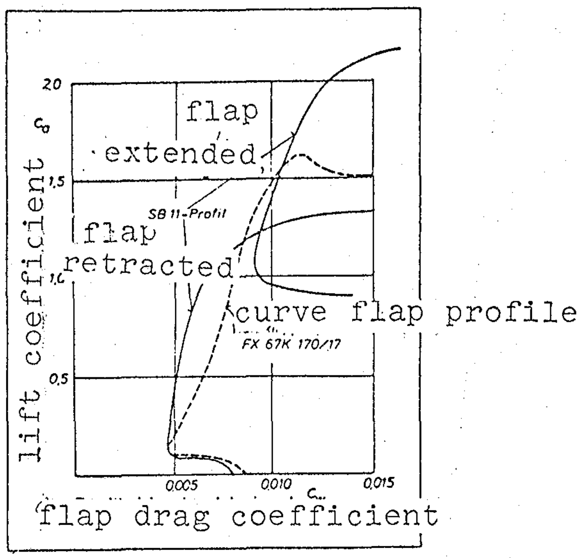

Figure 4. Measured polar of the
SB 11 profile compared with the
curved flap profile FX67K170/17

(Figure 2), in the design of the wing profile for the SB 11 we avoided a number of difficulties to begin with.

- By introducing an area flap with a constant thickness, the use of flexible contour elements is superfluous (see Figure 1). In this way the hand forces for operating the flap are substantially reduced.

- By adding a rotating flap to the area flap, the normal steering of the aircraft by means of the rudder can be maintained, and the proven curved flap profiles can be selected as a point of departure.

The design of the wing profile was done using the well-known Wortmann profile FX62K131/17. This profile was made thicker to increase the bending stiffness of the wing from 13.1% to 14.4%. In addition the chord of the rotating flap was increased from 17% to 21%. Using an iteration calculation and by improving the profile contour with the extended area flap the pressure distribution over the profile was optimized. In this way a profile with an area flap was designed whose aerodynamic performances are substantially better than the more recent curved flap profiles. The demonstration of this was made in a free flight measurement test.

Profile Measurements Under Free Flight Conditions

When measuring the design profile, we used an unusual method. The model wings carried end disks on the side and these were installed on a Kranich III sailplane, and measurements were performed under free flight conditions (Figure 3). This measurement configuration has the advantage over usual measurements in wind tunnels that real test conditions prevail with respect to turbulence of the incident flow. This is especially important for determining the drag of wing profiles. Using pressure measurements over the profile contour, the lift and the pitch moment of a wing profile was determined. The drag was then also determined at the same time by a wake measurement.

Figure 4 shows the measured profile polar of the SB 11 wing profile using a lift-drag coefficient diagram. We show the curves of the profile with the area flap retracted and extended. For comparison, Figure 4 shows the profile polar of the often used curved flap profile FX67K170/17 by means of a dashed line. One can clearly see the aerodynamic improvements of the SB 11 profile compared with the comparison profile. In the range of average lift coefficients $c_a < 1.0$ the /20

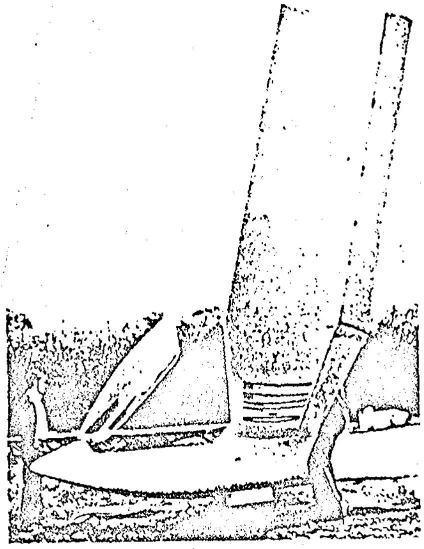

Figure 5: SB 11 with retracted area flap.

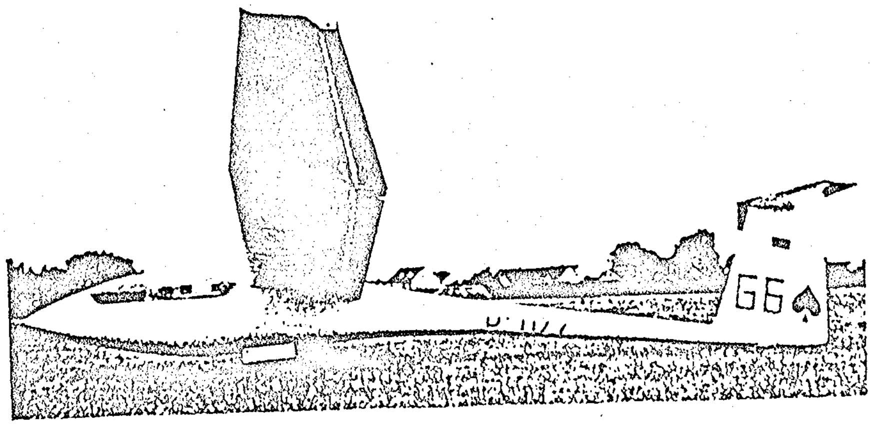

Figure 6: Overall view of the SB 11 with extended area flap.

drag is noticeably lower. The maximum lift is clearly higher and is $c_a = 2{,}0$ which is $\Delta c_a \approx 0{,}5$ higher than for the comparison profile. In this way the sailplane can fly a smaller circular trajectory in an upwind and is better able to exploit the higher upwind speeds in the core of the upwinds. The wing of the sailplane SB 11 was designed based on this profile.

Sailplane SB 11

In addition to the aerodynamic problems which were solved by using the area flap, the design of the wing required new methods of design to ensure wing stiffness and wing weight. The SB 11 was therefore made completely using a CFK (carbon reinforced plastic) design method. This probably means that it is one of the first aircraft which is made completely of this modern material. Compared with conventional glass fiber composite design (GFK) the aircraft weight was reduced by between 10% to 15%, and the stiffness was doubled at the same time.

The maiden flight of the SB 11 shown in Figures 5 and 6 (page 6) with extended and retracted flap occurred on May 14, 1978. The SB 11 is easy to fly and the slow flight characteristics are favorable. Even with an extended area flap the aircraft does not have the tendency to sudden tipping or a tailspin. The flight performance is very good which was confirmed by the fact that the aircraft won an award during the world championships.

The Future

The performance potential of the wing with area-enlarging flaps is probably not completely exploited by the SB-11 wing. One can hardly expect even higher maximum lift coefficients. The drag for small lift coefficients however may be reduced by further matching of the profile to the principle of the extendable area flap.

The method of free flight measurements proved itself well. For this reason the Institute for Design Aerodynamics is now developing the "Janus" research aircraft of the DFVLR, and is using such a measurement installation for profiles. In this way measurements in flows without turbulence, with gust turbulence and for real profile contamination by insects can be carried out. The measurement installation can be used both for sailplane profiles as well as for profiles of aircraft used in general aviation.