

AERODYNAMIC CONCEPT FOR A SAILPLANE WITH A BACK-SWEPT WING

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SUMMARY

This concept explains, that learning from the results of several recent tailless sailplane projects it should be possible to achieve increased aerodynamic performance of a sailplane with a conventional tail by sweeping back the wing with an angle of 5° up to 15°. Relatively large but conventional winglets and the conventional twist of the conventionally profiled wing would contribute to the directional and pitch stability of the sailplane in the magnitude of 30°. In consequence, the conventional vertical and horizontal tail could be reduced by about 30% in surface or length. It is predicted, that the aerodynamic performance of such a wing would suffer not or neglectable from the small sweeping angle with respect of a unswept wing, while the sailplane would fully profit from the reduced drag of the reduced tail.

INTRODUCTION

This theoretical concept is based on the author's experience with ultralight sailplane concepts when he was responsible for their "Gütesiegel" certification in behalf of the German hanggliding association (DHV). Additionally the results of the tailless sailplane SB 13 and of several high end tailless model sailplane projects have been respected in this concept.

RECENT DEVELOPMENTS OF TAILLESS SAILPLANES:

Even if tailless airplanes are extremely exotic, several new projects have been developed the last few years mainly in the field of ultralight and foot launched gliders. All younger projects with tailless sailplanes have been based on a back-swept wing.

SAILPLANES:

Akaflieg Braunschweig SB 13

ULTRALIGHT SAILPLANES:

Günther Rochelt	Flair
Adalbert Netzar	NY~U
Rolf Markmann	?? (Horten-Prinzip)
Peter Erb	Rubicon
	Swift
Jürgen Lutz	Pegasus (Prototype Experience)
	+ increasing number of more or less modified copies.

SEVERAL EXPERIMENTAL MODEL AIRPLANES, SUCH AS

Brunswicker	N1
Boder, Schönherr	Stromburg
Unverferth	CEOZWO

EXPERIENCES WITH THE SB 13-PROJECT

+	The total surface of the fuselage is about 30% reduced with respect to a modern conventional standard class glider.	-	twist of the wind required for pitch stability
+	sweeping back contributes to directional and yaw stability	-	short distance from all rudders to the center of gravity. Therefore large rudders required.
		-	distribution of lift is only optimized for the special case when the elevators are in a neutral position. However, in practical flight conditions, the elevators usually are not in a neutral position.
		-	Respecting the function of the elevators as wing flaps, they are used opposite to the aerodynamically senseful orientation, i.e. negative to achieve high lift coefficients. Maximum lift coefficient of the wing is relatively low, large wing surface is required.
		-	Respecting the function of the elevators as wing flaps, they are used opposite to the aerodynamically senseful orientation, i.e. negative to achieve high lift coefficients. Maximum lift coefficient of the wing is relatively low, large wing surface is required.
		-	The connection of the wing at a most rearward position to the fuselage is aerodynamically the better solution because of less interference effects. However the sweeping back solution requires a connection at the nose of the fuselage.
		-	negative aerodynamic effects of back sweeping, induced aerodynamic flow in span direction
		-	reduced lift close to the fuselage a) because of the above mentioned effect. aerodynamic flow directed to the wing tips. b) interference effects.
		-	in consequence of the before mentioned effect: deviations from the optimal lift distribution
Σ	Aerodynamic performance still better than in the case of a conventional glider		
		-	additionally:
		-	reduced field of vision
		-	pitch oscillations because of reduced pitch damping
		-	high dependence of the flight characteristics from the position of the center of gravity
		-	torsional stiffness of the win is very critical
Σ	In practical flight disadvantages with respect of conventional standard class sailplanes		

CONCLUSIONS:

1. Obviously a back-sweeping of 15° does not necessarily cause significant aerodynamic disadvantages.
2. If it would be possible to avoid or to reduce significantly the negative list (above) an optimization of aerodynamic performance should result from the back sweeping of the wing.

THE DISCUS CONCEPT

The DISCUS wing has a back sweeping angle of 4° (t/4-axis) (Fig. 1) Any other effects than the optimization of the aerodynamic performance of the wing have obviously not been considered by the layout of the wing.

Such additional effects could be:

- improved directional stability (could allow for a smaller vertical tail)
- pitch stability effect of the twisted tail (could allow for a smaller horizontal tail)
- additional directional stability provided by winglets on a back-swept wing

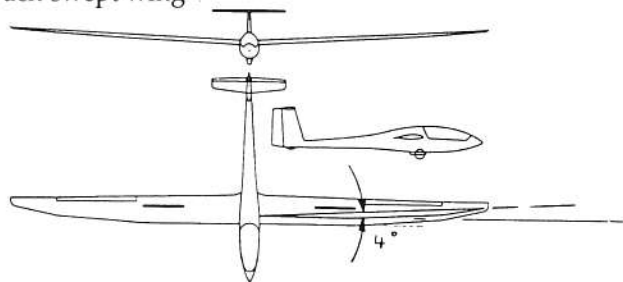


Figure 1: The DISCUS wing has a back sweeping of 4° with respect of the t/4-axis

CONCLUSION:

A small back sweeping of the wing has no negative but positive effects on the aerodynamic performance.

NOTE:

Although winglets have in some degree the same aerodynamic effects as the back sweeping of the outer DISCUS wing (reduction of streamline components parallel to the wing), the combination of both elements seem to increase the aerodynamic performance on a wide part of the practically relevant speed range.

WINGLETS

On conventional wings winglets improve

- the performance at high lift coefficients
- The yaw stability of the plane

but may make worse (in the same degree?)

- the performance at low lift coefficients (in some concepts the performance and the flight characteristics seem to be improved on the whole practically used speed range. In some concepts the influence of the winglet on the total lift of the wing is higher than the effect of a wing tip which is larger than the winglet and oriented in span direction (DG-500/22 fi DG-505/20).
- On back-swept wings winglets improve (additionally?):
- The directional stability, so that they may partly or completely replace the conventional vertical tail.
- (It is doubtful, if winglets improve the performance of a back swept wing in the same extent as in the case of a conventional wing, but the experience of the DISCUS indicates, that they do so at least in the case of low sweeping angles).

CONCLUSION:

- Winglets can be applied in such a manner that positive effects clearly dominate in case of a conventional unswept wing

- Winglets may work even better on a back swept wing where they automatically have the effect of a vertical tail.

TOTAL CONCLUSION:

A back swept wing can be designed for sailplanes which has no relevant disadvantage in performance with respect of a conventional unswept wing, but which may profit significantly from the stability effects of the winglets and of the twisted wing, so that the conventional tail of the sailplane may be reduced and that the total drag of the complete sailplane may be reduced.

CONCEPT OF A SAILPLANE WHICH PROFITS FROM THE BENEFITS OF A BACK SWEEPED WING WITHOUT HAVING ITS TYPICAL PROBLEMS.

- sweep angle: $5^\circ \dots 15^\circ$
- increasing from 0° close to the fuselage to the wing tip
- conventional profile
- conventional twist
- conventional, but relatively large winglets
- vertical and horizontal tail reduced by 20-40% (length or surface)

LAYOUT PROPOSAL (FIGURE 2)

- sweep angle 8° (t/4) 0° close to the fuselage, increasing in three steps to 15° close to the wingtip)
- span 18 m, surface 12.8m
- twist 1.5°
- biplace (a monoplace would have the wing/fuselage connection close to the center of gravity of the pilot, what might be technically difficult to solve and would strongly interfere with the field of vision of the pilot.)
- winglets of 70 cm length. Rudders are integrated in both winglets. Total surface of both winglets together $0,65 \text{ m}^2$
- A conventional t-tail is used with a fuselage of 6,3 m length vertical tail $1,1 \text{ m}^2$, horizontal tail $0,85 \text{ m}^2$ (typical for standard class).
- Wing flaps or ailerons are used in combination with the elevator and the rudders of the winglets and of the vertical tail are used together.

The contributions to the stabilizing moments are shown by table 1:

	length of lever-arm l_n [m]	surface A [m^2]	moment $l_n \times A$ [m^3]
horizontal tail	3,68	1,1	4,05
outer wing	0,65	2,0	1,3
vertical tail	3,68	0,85	3,13
winglets	1,25	0,7	0,875

TABLE 1:

It is shown by table 1 that the contribution of the wing and of the winglets to the stabilizing moment may be in the magnitude of 30%.

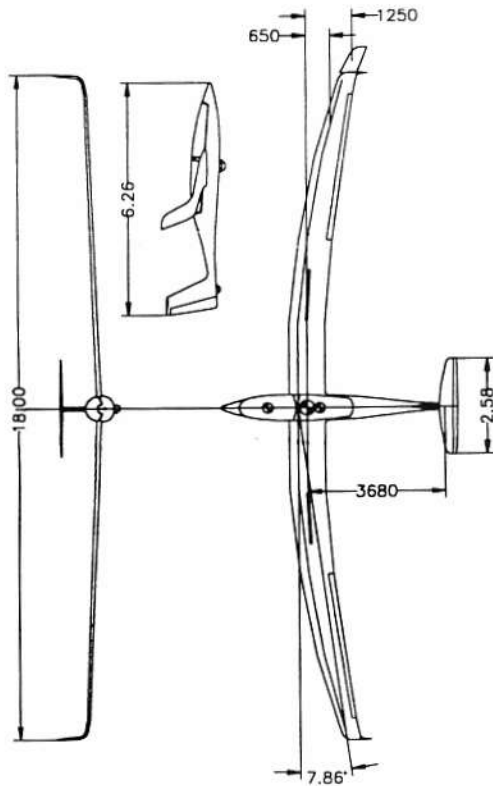


Figure 2: Illustration of the proposed layout

The total stabilizing moment seems to be by far sufficient for a 18 m-sailplane as shows the relation to existing sailplanes such as a Kestrel 17 (Fig. 3, table 2) or SB 13 (Fig. 4, table 3).

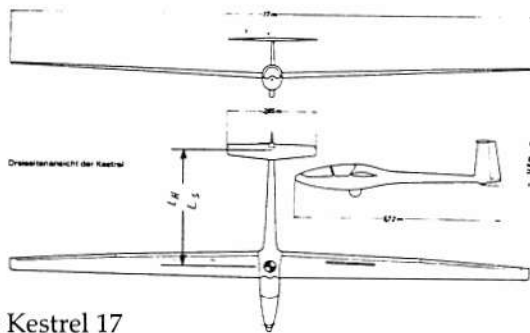


Fig. 3: Kestrel 17

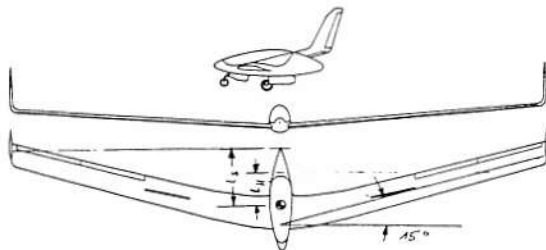


Fig. 4

	length of lever-arm l_h [m]	surface A [m ²]	moment $l_h \times A$ [m ³]
horizontal tail	4	1,28	5,12
vertical tail	4	1,0	4,0

TABLE 2: Stabilizing moments of the Kestrel 17 sailplane

	length of lever-arm l_h [m]	surface A [m ²]	moment $l_h \times A$ [m ³]
outer wing	0,85	2,5	2,125
winglets	1,5	1,35	2,025

TABLE 3: Stabilizing moments of the SB 13 tailless sailplane

IMPROVEMENTS

It is assumed that the low sweeping angle does not reduce the aerodynamic performance of the wing. Also torsion problems are much less severe than in a tailless concept like SB 13. However the following elements are without any questions clear benefits of the presented concept:

1. The fuselage is about 1 m shorter than the fuselage of a comparable conventional sailplane. This effect reduces at least the boundary drag of the fuselage due to less surface. It also reduces the weight of the fuselage in the magnitude of 20-30 kg.
2. The horizontal and the vertical tail are smaller and only as big as in the case of conventional standard class sailplanes. This causes reduced drag of the tail as well as reduced weight in the magnitude of 5 kg.

All of the above mentioned problems of a tailless sailplane are avoided:

- a) The ailerons which shall be combined to the elevator as in the case of a typical tailless sailplane, are combined only in the case of a maximum maneuver. Therefore in stationary flight conditions the ailerons remain in neutral position. In the same way also the rudders in the winglets are used only in maximum maneuvers and remain neutral in all other situations. Therefore the lift distribution along the span is not depending on the flight conditions and can be optimal in the whole range of stationary conditions.
- b) Pitch oscillations will not be a problem because of an almost conventional fuselage and tail.
- c) The field of view for the pilot in the front seat is not restricted and the same or even better (because the wingtips are more back and outside the field of view) than in the case of a conventional glider. (The field of view of the passenger in the back seat however will be very poor in case of the solution illustrated in figure 2.)

OPTIONS:

- A. Figure 2 shows a wing without flaps. However flaps could be introduced perfectly into the concept. In this case it would be recommended to combine the flaps in the inner part of the wing with the elevator instead of the ailerons. Positive flaps would have a pitch up effect that would be aerodynamically correct. Moreover it might be considered to use the flaps only in combination with the elevator and never independently, but this would need to be subject of a further consideration.
- B. A biplace concept is not the only solution to give the pilot a satisfying position without restriction of the field of view. Another solution would be a single place powered glider with its engine placed inside the fuselage significantly back of the total center of gravity. A third concept would be a single or biplace with the fuselage hanging below the wing.