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WIND TUNNEL INVESTIGATIONS OF GLIDER FUSELAGES WITH DIFFERENT WAISTINGS AND WING ARRANGEMENTS

Rolf Radespiel

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16. Abstract

The parameters fuselage waisting, glider wing arrangement and fuselage leading edge radius of ... glider configurations were investigated in a wind tunnel. Laminar separation bubbles were found on strongly waisted fuselages. These separations in the juncture between fuselage and wing are essential for harmful aerodynamic drag. Drag reduction was measured with increasing waisting and the wing arranged in the rear. These results are only valid for laminar flow on the fuselage leading edge. These results have not been attained on gliders to this date.

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Wind Tunnel Investigations of Glider Fuselages with Different Waistings and Wind Arrangements

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1. Introduction

The design of the fuselage and especially of the wing and fuselage arrangement of gliders has been dependent upon a number of generalized design recommendations to this date. Exact methods of calculation could not be utilized systematically until now due to the enormous amount of calculations involved. /1*

The amount of design parameters made it possible to draw limited conclusions based upon certain design parameters from flight attempts and wind tunnel measurements made until now.

The goal of these examinations was to systematically test the influence of the parameters

--fuselage waisting;
--wing longitudinal position;

with regard to drag.

2. Description of the Wind Tunnel Models and Examination Conditions

Figure 1 provides an overview of the examined configurations. The starting point is represented by a slightly modified fuselage of glider ASW 19 (fuselage 1, configuration 2). Waisting as well as wing longitudinal position were varied. In addition, a possible two-seat arrangement and a fuselage with a rounded nose were examined.

The models were constructed on a scale of 1:3. The fuselages were equipped with a foil, profile Fx 62K $131_{2x} = 0^{\circ}$ $\Lambda = 6$ with superficially attached winglets. The models were built according to construction plans CFK with polished lacquered surfaces. The measurements were conducted in a three meter low-speed wind tunnel of the DFVLR-AVA in Goettingen. The model was suspended on wires.

The Reynolds number relative to the wing chord amounted to $1{,}3 \cdot 10^6$.

* Numbers in the margin indicate pagination in the foreign text.

Pressure distribution measurements were conducted at different planes of the fuselage.

To assist in visualizing air flow, wooltufts and oil flow utilized.

/2

Force measurements took place on a six component sliding-weight balance with moveable weights.

3. Pressure Distribution Measurements

An attempt was made to research the influences of the examined parameters upon pressure distribution along the fuselage meridian.

As an example, figure 2 visualizes the influence of the wing longitudinal position with a fuselage of medium waisting and high lift coefficient. Figure 3 shows the influence of the waisting with a medium wing position.

4. Visualization of Air Flow

Wool tuft examinations were conducted according to the Junker // method. The tufts were filmed at different angles of attack, and then the movement of the tufts were categorized in predetermined degrees of turbulence. The surfaces of different turbulences determined in this manner were used to determine a drag surface. Graph 4 plots these drag surfaces over the lift coefficient for different configurations. For comparison, a relative measurement from Junker on the original ASW 19 is added. While there are no easily recognizable differences between the model configurations, the ASW 19 is obviously different. The difference is due to the fact that the laminar turbulent transition of the original glider occurs much sooner than on other models, as will be shown below. On the original, this results in a thicker boundary layer in the wing fuselage juncture, which is more inclined to separation.

In addition, oil flows of every configuration were prepared. These offered some interesting results:

--On the fuselages with tighter waisting, laminar separation bubbles were observed. See figure 5.

--Figure 6 shows separation in the wing fuselage juncture in the vicinity of the wing leading edge based on strong pressure increase.

The separation changes size and location according to the angle of attack. It remains to be seen if the separation can be reduced by smoothing off the wing leading edge. /3

Figure 7 shows the opposite side flow of fuselage 3, configuration 3. The flow of the wing fuselage juncture with the separation on the trailing edge of the wing and the formation of separation bubbles in the wing are recognizable (medium lift).

5. Force Measurements

Force measurements showed a high degree of agreement also during repeat measurements. The effective aspect ratio of the models evolved from the lift rise to approximately 10.

Figure 8 shows the difference in drag relative to a wing surface of a fifteen meter aircraft for different lift coefficients. The drag of the original configuration fuselage one, configuration 2 was set at zero. Drag decreases when waisting and wing longitudinal position are increased.

However, the measured drag differences of up to $2 \cdot 10^{-3}$ appear to be somewhat unrealistic. Even if one assumes that the comparable configuration were somewhat unfavorable, differences of up to $1{,}5 \cdot 10^{-3}$ still remain. These differences cannot be attributed solely to the reduction of the wetted surface by waisting and through utilization of thinner tailbooms. As demonstrated above, separation is visible in the wing fuselage juncture on the wing leading edge and trailing edge, causing pressure losses. If the foil is placed back in the area of the nearly cylindrical tail boom this pressure loss does not contribute considerably to pressure drag when the foil is in the trailing position.

Figure 9 plots the difference between the best and the comparative configuration in the Polar diagram of a standard glider. Only the non-induced drag was taken into consideration. The leading edge radius had no influence on the measurement results.

6. Summary

The parameters fuselage waisting, air-foil arrangement, and /4 fuselage leading edge radius were examined on nine different configurations in the wind tunnel.

Those fuselages with stronger waistings displayed laminar separation bubbles. The separation in the juncture of wing and fuselage appears to be significant with regard to drag increases.

Drag measurements show a reduction of drag as the waisting is increased and the wing is placed farther to the rear. The measured drag differences do, however, pose the question if the amount of increased drag with regard to total drag has been properly recognized until now.

These and other more specialized questions are supposed to be examined in yet another testing program.

In closing, it should be emphasized that especially the results for the strongly waisted fuselages are only valid for a laminar flow of the fuselage leading edge. These results have not been attained on original gliders to this date.

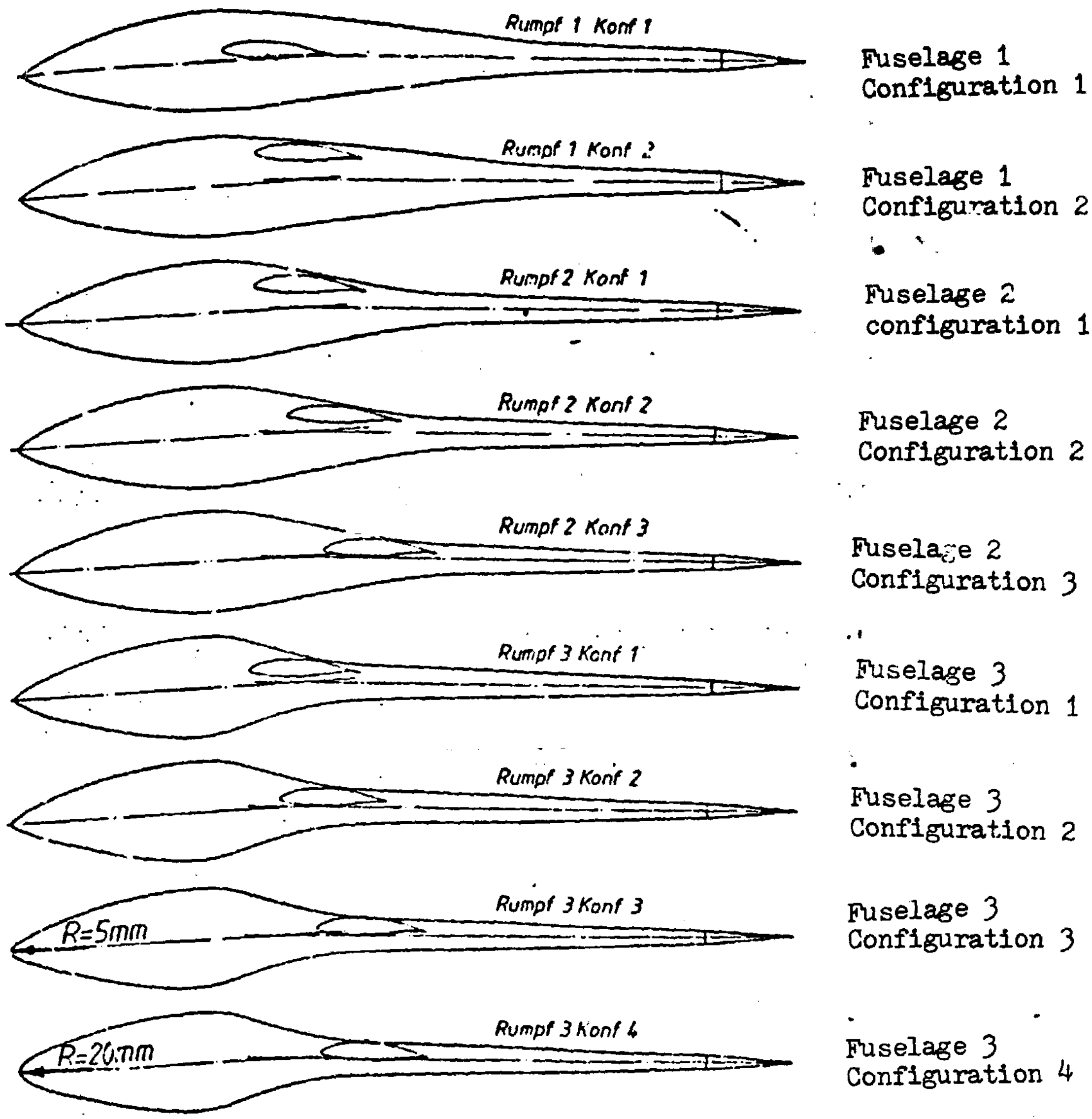

Figure 1: Model Configurations

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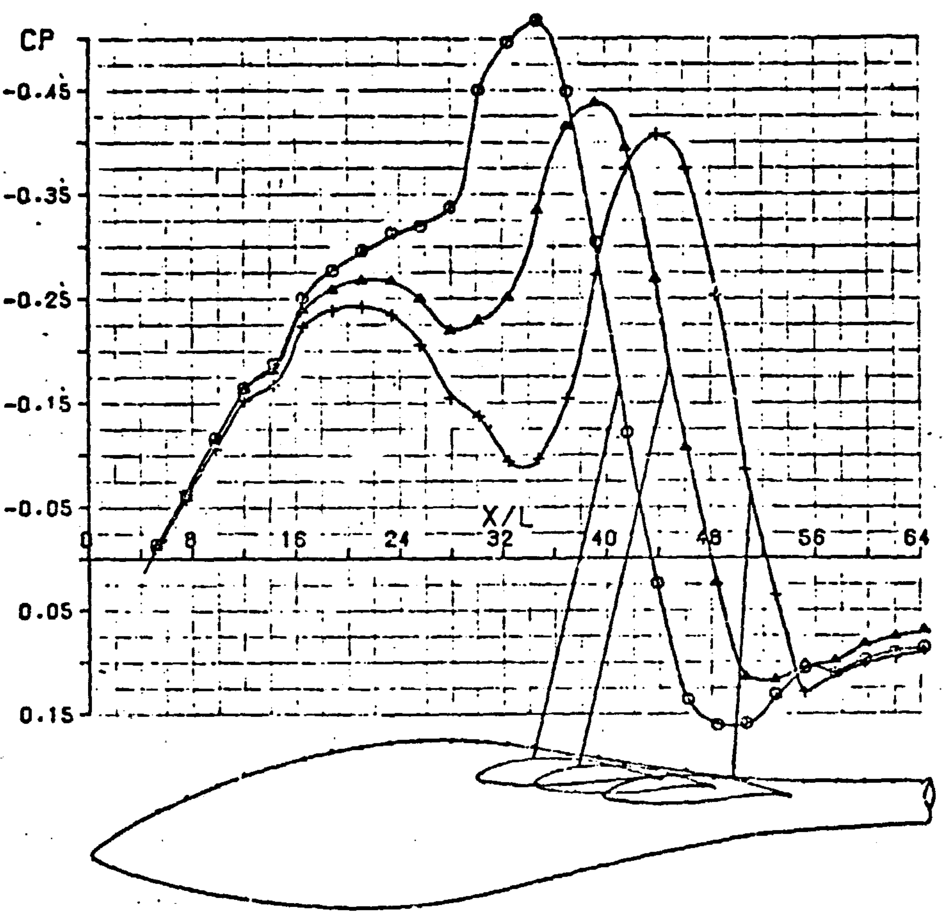

Figure 2: Influence of the Trailing Edge on Pressure Distribution

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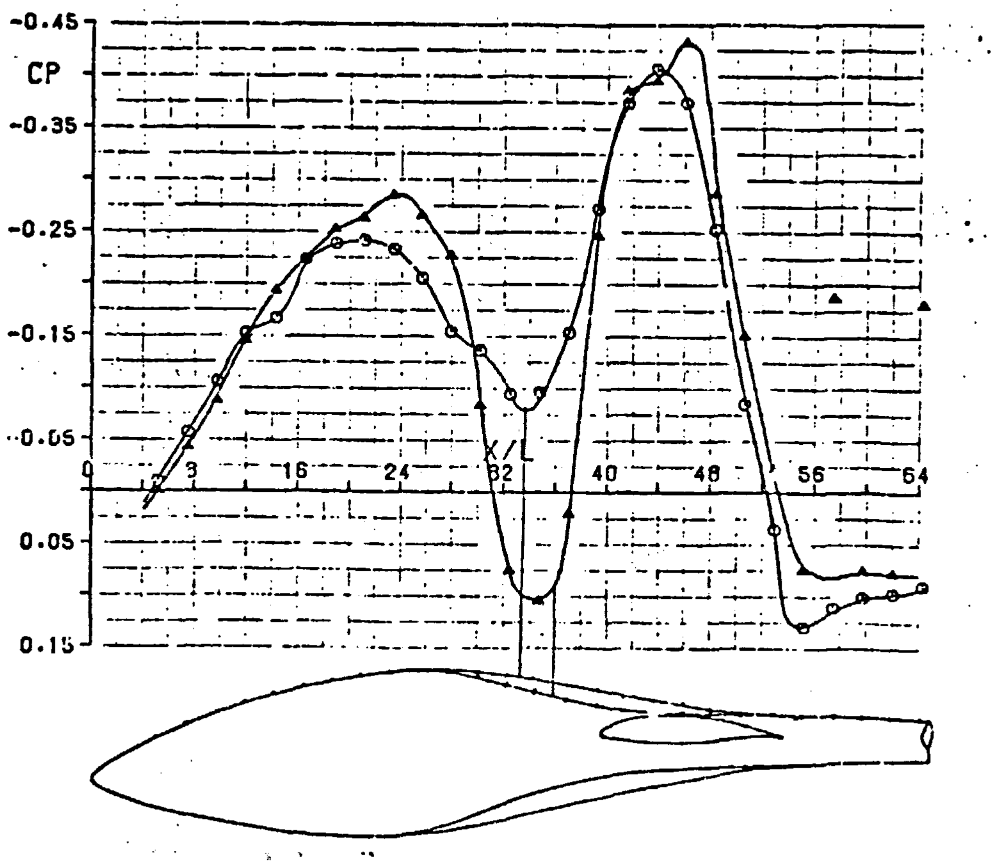

Figure 3: Influence of the **Waisting** on Pressure Distribution

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—— • —— Fuselage 1, configuration 2
—— + —— Fuselage 2, configuration 3
—— × —— Fuselage 3, configuration 1
—— ▲ —— Fuselage 3, configuration 3
– – • – – Original ASW 19

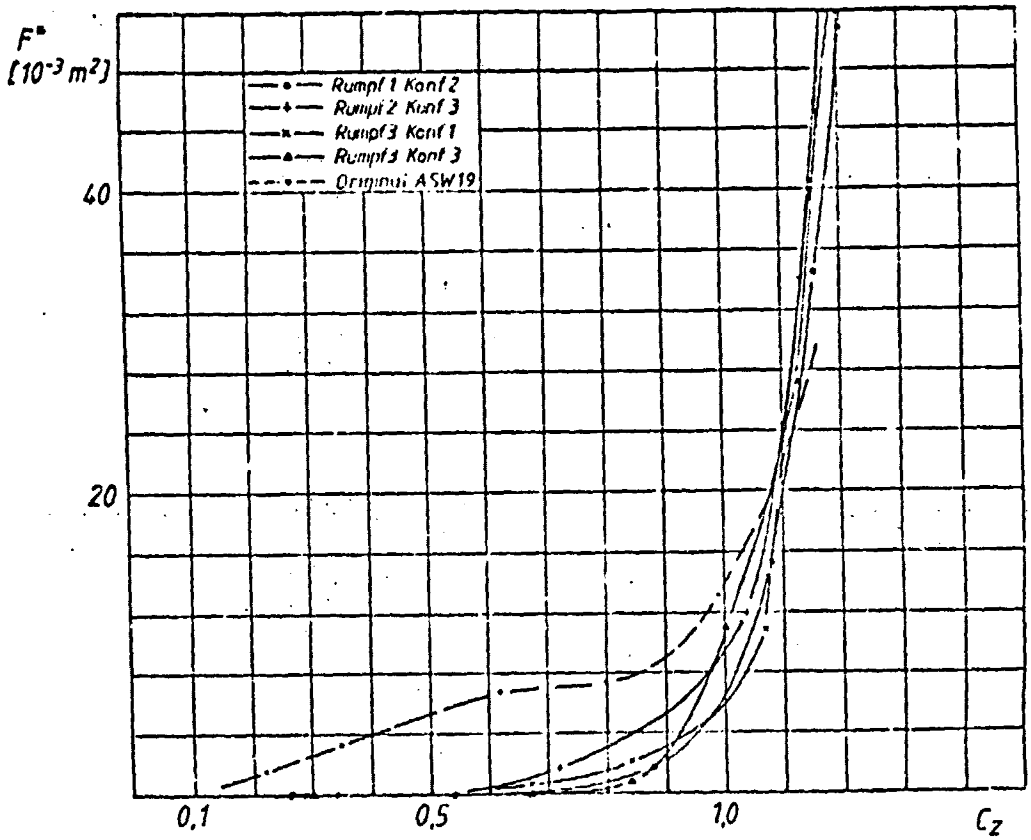

Figure 4: Drag surface resulting from Wool Tuft Movement

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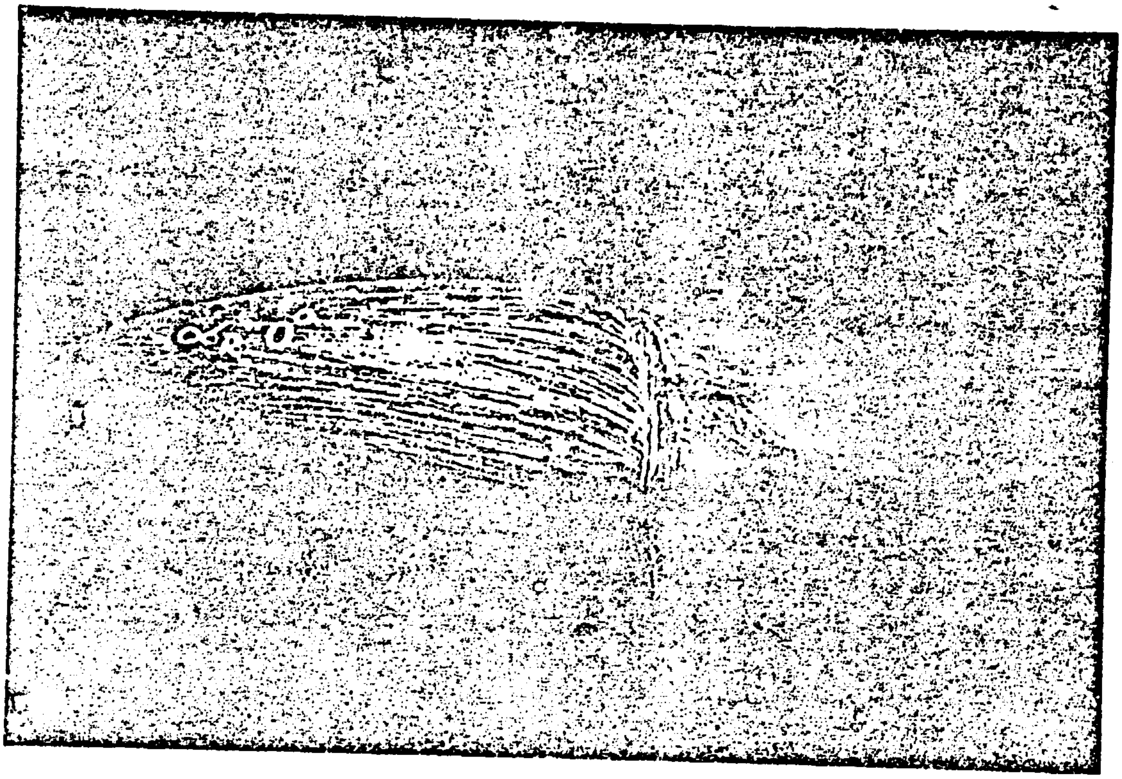

Figure 5: Laminar Bubble Separation

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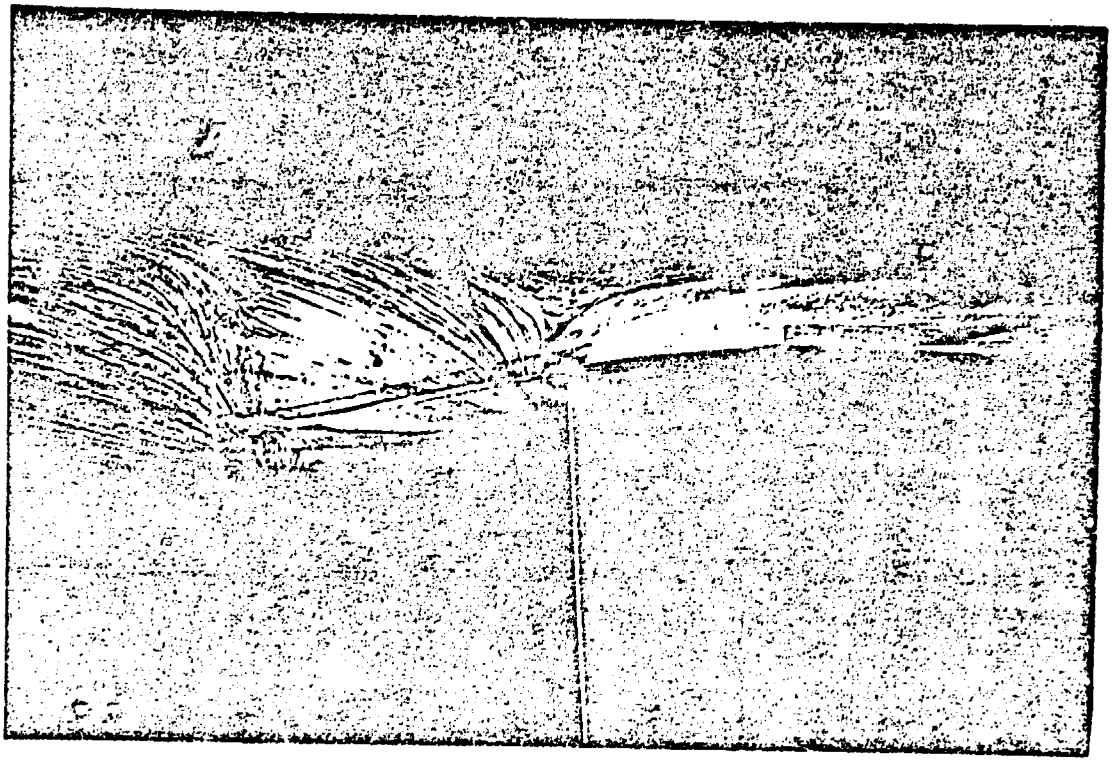

Figure 6: Separation in the Juncture of the wing and fuselage

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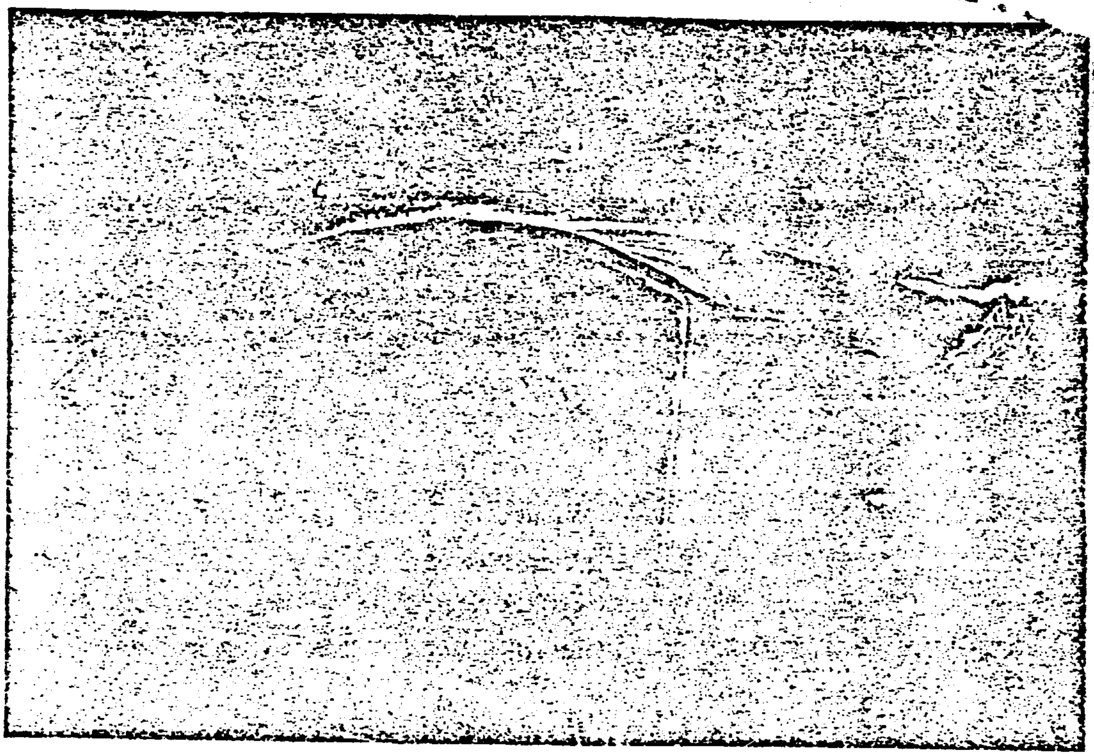

Figure 7: Top-side air flow, fuselage 3, configuration 3.

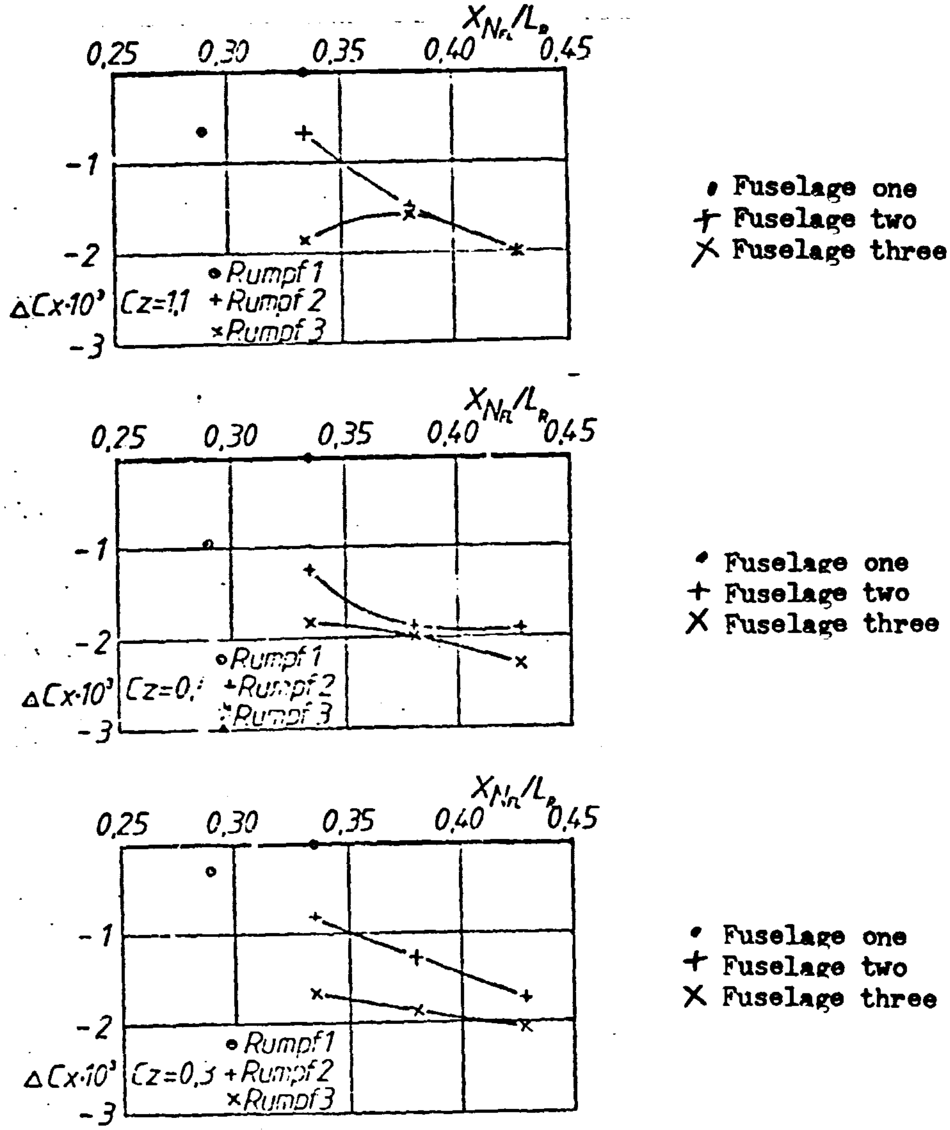

Figure 8: Measured Drag Differences relative to a standard glider.

* ——— ASW-19 FX 61-163, b = 15 m = fuselage 1, configuration 2
------Drag gain using fuselage 3, configuration 2

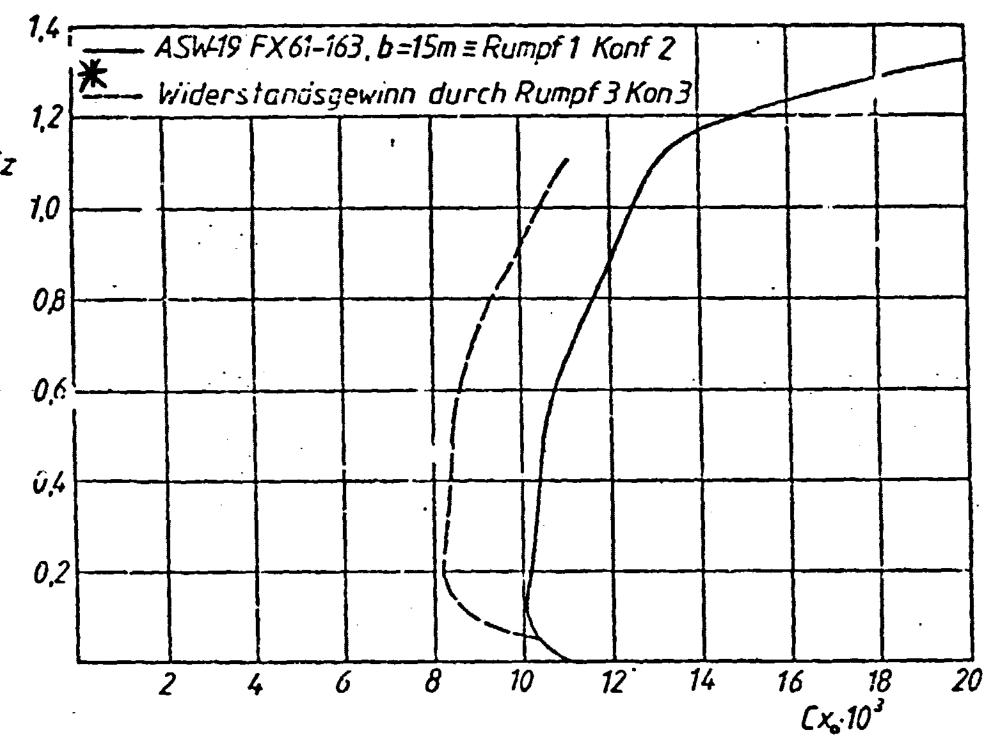

Figure 9: Largest measured drag gain in non-induced drag Polars of the ASW 19.