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PROBLEM OF THE SLOTTED WING.

A Communication from the Aerodynamic Institute of the Aachen Technical High School.

By W. Klemperer.

From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," October 31, 1921.

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It is to be expected that the advantageous properties, hitherto discovered in many slotted wing sections, depend very largely on the contour of the slot and the structural details of the wing. The formation of the slot presents many difficulties to the constructor. In the first place, the larger number of sharp curves requires a complicated wood or metal construction. The attaching of the ailerons, the struts and the stay wires demand special consideration. With unsupported wings with several spars there is the further task of finding a way for the slots between the spars. Lastly, it is not inconceivable that the dihedral, sweep-back and the interruption of the slot in the middle by the fuselage may cause surprises. It is therefore of interest, aside from measurements on wings of constant cross-section along the span, to measure also wing models in which the structural details have already been given practical consideration. Such an experiment was performed in the aerodynamic laboratory of the Aachen Technical High School by the writer in company with Mr. Fromm.

The experiments were made with a model of an unsupported monoplane wing, which had the following measurements. Its ground

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plan was trapezoidal (Fig. 1). The middle dash line is the line of maximum cross-sectional thickness, which was located in the forward third of the ribs. The V-shape has the ratio of 1 : 10 along the top surface on the line of the maximum thickness. The section perimeter p - p is similar to No. 422 of the Göttingen experiments. The sections at other points of the span are obtained from this one by extending its coordinates. Their perimiters are determined by the data which are written at several points of the wing for the maximum height of the ribs. The surface was first tested without slot. Then a slot was made and the test repeated. Then the slot was closed for verification and, since the result was less than the original value, other methods were tried in order to reproduce perfectly the original unimpaired shape. Thereupon several systematic modifications in the shape of the slot were tried.

In introducing the slot, and indeed, only a single one, allowance had to be made for the employment of three spars in the unsupported front section of the wing. The slot was accordingly placed between the front and main spar, the location of which is indicated in the drawing. As a result of the diminishing thickness of the wings toward their outer ends, the slot was quite steep in the middle of the wing and became flatter toward the ends. The front side of the slot was S-shaped, while its rear side was intended to form a sort of leading edge of the adjoining part of the wing section. The modifications made in the slot affected its width and the concavity of the upper portion of its front side. The slot shapes are shown in Fig. 2. The slots were not extended the whole length of the span, but were interrupted in the middle (where in actual practice they would be interrupted by the fuselage) for a distance of about one-tenth of the span. Moreover, the slot was interrupted in the middle and at the end of each semi-span for the sake of holding the two portions of the wing together. The remaining wood partition was somewhat rounded or sharpened, but perhaps this shaping was not aerodynamically perfect. No fuselage was included in the model. The airplane model was copied from the design of an airplane glider provided with a slot.

Since a multi-component balance was not available for the experiments and was moreover not necessary for the demonstration of the normal effect of the slot (increasing the maximum angle of attack and the maximum lift), the lift component was first measured as a function of the angle of attack. Any very accurate determination of the reference line for the angle of attack was not essential, since the angle of vanishing lift was very accurately determined. It was about -7°, measured with reference to the chord.

The measuring device consisted essentially of a balance, to one arm of which one end of the wing was attached by means of a spindle, so that the air force component normal to the air stream could alone exert a torsion moment, with known lever arm, on the balance beam. The free end of the wing was attached to the end of the balance beam by a small steel wire. To the end of the balance beam was attached an oil damping device, with a damping factor adjustable during the measurement. Between the balance arm supporting the model and the one holding the scale pan there was, during the experiment, a changeable conversion device, which, on account of the importance of maintaining the sensitiveness was employed only within moderate limits.

The wing model was not installed in the middle, but nearer the edge of the two-meter diameter air stream at a point where the latter was the most uniform and where the dynamic pressure did not vary more than 2% from the readings of the stationary Pitot tube, as shown by tests with a second movable tube. By this manner of installing, it was possible to get along with so little suspended apparatus, that its influence on the measurements could be disregarded. The accuracy of the balance adjustment for high lift values was well within 2% of the maximum lift and was somewhat greater for smaller angles of attack. The determination of the mean value of the dynamic pressure (by means of a Prandtl micromanometer) probably attained an accuracy of 1%.

The moment of the drag component was offset by the lateral loading of the balance beam, so that the balance knives were equally loaded.

As a matter of secondary importance, a separate measurement of the drag was undertaken, by turning the balance 90° and taking up the lift by means of a steel wire anchored in a line passing through the knife edges of the balance. The accuracy of the determination of the angle of attack from the values of the lift measurement was within about 1/2%.

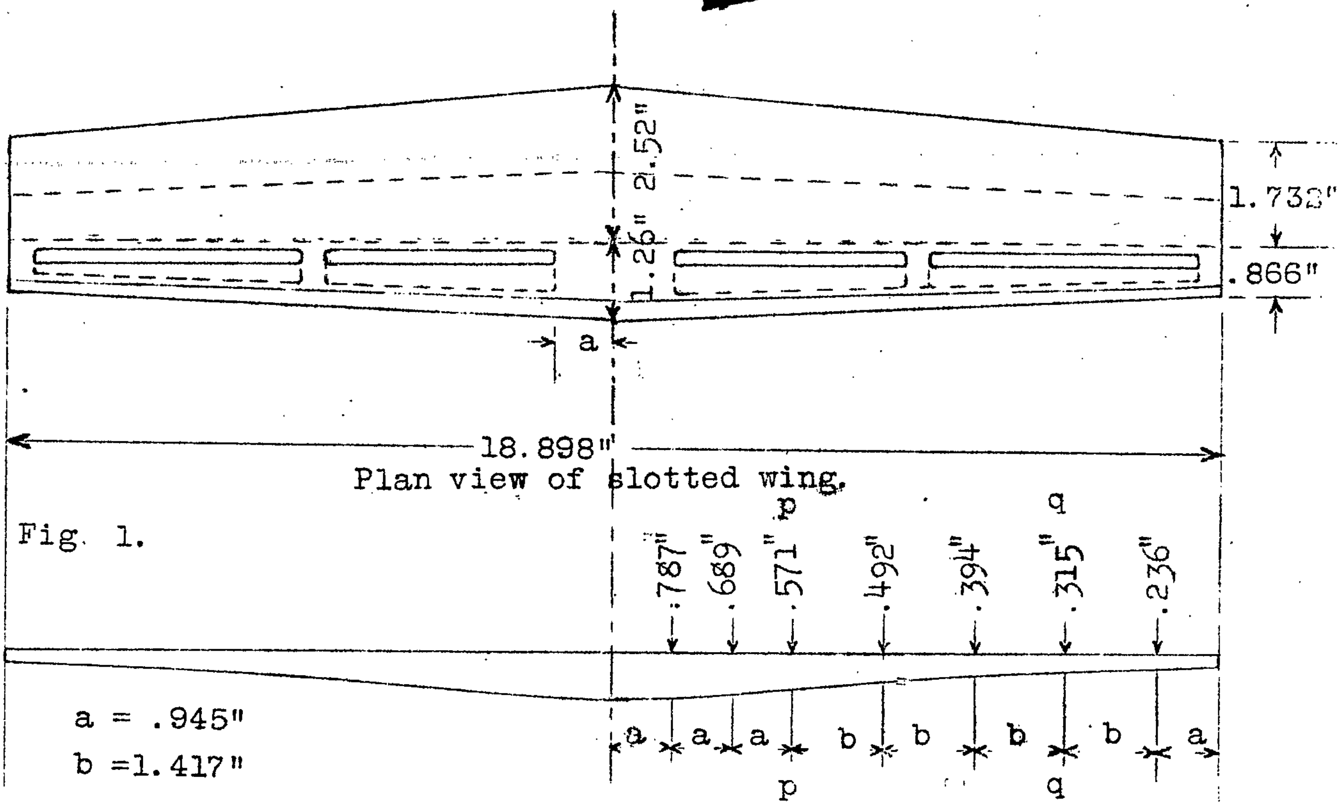
The results of the lift measurements are shown collectively by Fig. 3. The surprising result is the decided superiority of the first model without slot. The maximum lift of $C_a = 147$ could not subsequently be again fully attained by closing the slot with paper or paraffin or plaster of Paris. That the first curve must nevertheless be considered accurate, follows from the fact that two experiments performed on different days agreed well. The utilizable angular range of the wing extended from -7° to about 15°. Experiments with the slot now showed a noteworthy decrease in lift from small angles of attack up. No further increase of the lift up to very large angles was observed, although there was not so decided a decrease from 15 to 20°, as with the unslotted wings. In no case, did the slotted wings give better results than the unslotted. Hence, in the experiments with slotted wings, those with the narrowest slots naturally gave better results. It is also to be noted that, with the slotted wings at angles between 15 and 20°, where accordingly the real effect of the slot would be expected, a whistling sound was clearly audible, which may have been connected with the unexpected disturbance of the air flow. While with an unslotted wing section, the balance adjustment experienced strong oscillations in the vicinity of 18 to 20° and consequently the lift value was temporarily very unsteady, this was less noticeable with slotted wings. It was not possible to polish the wing model. In order to determine whether the influence of the roughness of the wood could have caused the non-appearance of the "Lachmann effect," the wing was covered with a collodion film and again tested both with and without the slot. The differences in the results were however so slight, that they were not introduced in the diagram.

The measurements of the drag (only made for the unslotted wing) are plotted in Fig. 4, and give the best L/D (of about 13) between 0 and 1°. The result was due to the roughness of the surface.

The experiments were performed in an air stream of 20 to 25 m/sec. Confirmatory experiments at a lower velocity showed no dependence on this.

In so far as it is allowable in this sort of experiments, to draw conclusions from a model for the full size, with 15 to 20 times larger dimensions, it may be inferred that the special form of slot, tested in these experiments, would not simply give no advantage, but would do positive harm. To what these disappointing facts are due has not yet been fully explained. It is however possible and even probable that the non-appearance of the "Lachmann effect" is due to the interruption of the slot. A continuation of the experiments should settle this point. In any event, however, the experiments show what a complicated problem that of the slotted wing is, in that structural consideration can exert such an extraordinary influence on its aerodynamic properties and that it consequently appears necessary to pursue this particular problem still further with experiments on models, while taking into account the practical details of construction.

Translated by the National Advisory Committee for Aeronautics.



Plan view of slotted wing.

Fig. 1.

Front elevation of main spar.

Wing section p-p.

Fig. 2.

Wing section q-q.

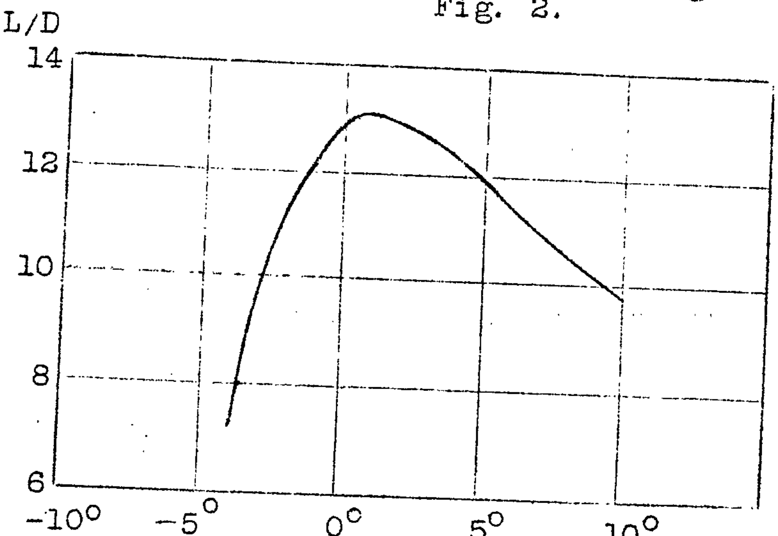


Fig. 4. Angle of attack.

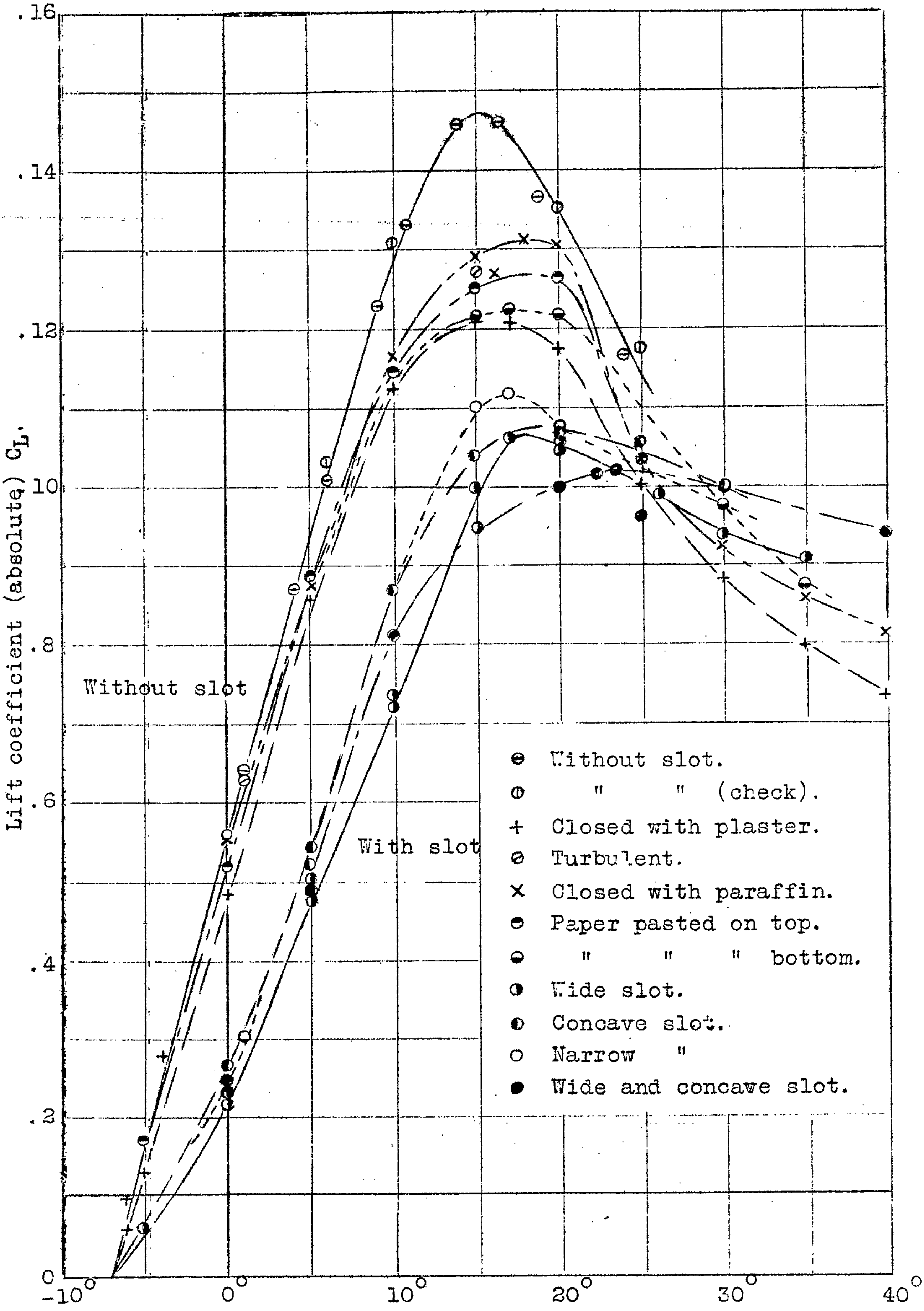


Fig. 3. Angle of attack. → α