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WIND-TUNNEL INVESTIGATION OF PLAIN AILERONS
FOR A WING WITH A FULL-SPAN FLAP CONSISTING
OF AN INBOARD FOWLER AND AN OUTBOARD
RETRACTABLE SPLIT FLAP

By Thomas A. Harris and Paul E. Purser

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SUMMARY

An investigation was made in the NACA 7- by 10-foot wind tunnel of three plain ailerons on an NACA 23012 wing with full-span combinations of Fowler and split-type flaps. The static rolling, yawing, and hinge moments were determined and are presented for several angles of attack and flap deflections. In addition, the lateral-control characteristics were computed for a typical pursuit airplane with two of the arrangements.

The results indicated that a plain sealed aileron with internal balance will provide lateral control for airplanes equipped with full-span combinations of slotted and split-type flaps. Flight tests of at least one of the combinations are recommended.

INTRODUCTION

The NACA has undertaken an extensive investigation for the purpose of developing lateral-control devices suitable for use on wings equipped with full-span trailing-edge high-lift devices. In this investigation, a plug-type, spoiler-slot aileron has been developed that gave satisfactory lateral control on a wing with a full-span slotted flap but was unsatisfactory for use with a split flap. A more complicated lateral-control system, which consists of a plain aileron on the trailing edge of a slotted flap in conjunction with a slot-lip aileron, has also been developed. (See references 1 and 2.) From the wind-tunnel results, both of these devices appear satisfactory for use on a wing with a full-span slotted flap;
flight tests are planned. A type of lateral-control device that has proved satisfactory for use with full-span retractable split flaps is the plain aileron. Wind-tunnel and flight tests of this device are reported in references 3 and 4.

The present tests were made to determine the characteristics of a plain aileron on a wing with an outboard retractable split-type flap and an inboard flap of a type giving a higher lift and lower drag than the split flap. The Fowler flap was selected for the inboard location because it is believed to be a representative slotted-type flap and it gave the largest increment in maximum lift coefficient of any of the single slotted flaps investigated. (See reference 5.)

From the test results the lateral-control characteristics were computed for a typical pursuit airplane with plain sealed ailerons with and without balance and two combinations of Fowler and split-type flaps.

**APPARATUS AND METHODS**

All tests were made in the NACA 7- by 10-foot closed-throat wind tunnel (reference 5) at an air speed of about 40 miles per hour, corresponding to a test Reynolds number of approximately 1,440,000. The test set-up is shown schematically in figure 1. The 0.30c Fowler flap was installed on the inboard 0.63 b/2 of the 4- by 8-foot NACA 23012 wing and the ailerons and the split-flap arrangements (references 3, 4, and 6) were installed on the outboard 0.37 b/2 of the wing.

The wing was suspended horizontally in the wind tunnel with the inboard end attached to the tunnel wall to simulate the semispan of a 16-foot wing. The attachment at the wall restrained the wing in pitch but not in roll or yaw. The forces necessary to restrain the outboard end of the wing were measured by the regular balance system. The rolling moments were computed from the difference in the vertical reactions at the outboard end with the aileron neutral and deflected; the yawing moments were similarly computed from the horizontal reactions. The lift coefficients of the wing with aileron and flaps neutral were computed from the vertical outboard reaction and the assumption that the lateral center of pressure of
the semispan was 0.45 \( \frac{b}{2} \) from the plane of symmetry. This method of computation was not used with flaps down because the deflection of the flaps changed along the span. The lift coefficients for the wing with the flaps deflected were estimated from data in references 5, 6, 7, 8, and 9.

The aileron was manually operated by a crank outside the tunnel near the inboard end of the wing, and the hinge moments were computed from the twist of a calibrated torque rod connecting the crank and the aileron.

The aileron-flap combinations tested are shown in figure 2.

RESULTS AND DISCUSSION

Coefficients

The results of the tests are presented in figures 3 to 19 as curves of rolling-, yawing-, and hinge-moment coefficients plotted against aileron deflection at several angles of attack for each aileron-flap combination.

The symbols used in presenting the results are:

- \( C_L \) lift coefficient \( (L/qS) \)
- \( C_{L1} \) rolling-moment coefficient \( (L'/qbs) \)
- \( C_{n1} \) yawing-moment coefficient \( (N'/qbs) \)
- \( C_h \) aileron hinge-moment coefficient \( (H_a/qS_{ac_a}) \)
- \( c \) wing chord
- \( c_a \) aileron chord measured along the airfoil chord line from the hinge axis of the aileron to the trailing edge of the airfoil
- \( b \) twice span of semispan model
- \( S \) twice area of semispan model
- \( S_{a} \) aileron area behind hinge line
L twice lift on semispan model
L' rolling moment about wind axis
N' yawing moment about wind axis
H_a aileron hinge moment
q dynamic pressure of air stream
\( \delta_{f_1} \) deflection of inboard Fowler flap
\( \delta_{f_2} \) deflection of outboard split flap
\( \alpha \) angle of attack of wing in tunnel

A positive value of L' or C_la' corresponds to a decrease in lift on the model, and a positive value of N' or C_n' corresponds to an increase in drag on the model. Twice the actual lift, area, and span of the model were used in the reduction of the results because the model represents half of a complete wing, as has been previously stated. No corrections have been made to the data for the effect of the tunnel walls. Such corrections may be relatively large for this set-up.

Wind-Tunnel Data

Plain sealed aileron and plain split flap.— The aero-
dynamic characteristics of the plain aileron with a grease
seal and the outboard plain split flap are shown in fig-
ures 3 to 7. The rolling-moment coefficients produced by
the aileron are largest with only the inboard flap de-
flected and decreased as the outboard flap was deflected,
especially for positive aileron deflections when the flap
blanketed the aileron. As reported in references 3 and 4,
the adverse yawing-moment coefficients encountered with
the outboard flap neutral were decreased when the flap
was deflected. The aileron had large hinge-moment coef-
ficients and an up-floating tendency with the split flap
neutral but had smaller hinge-moment coefficients and a
down-floating tendency with the flap deflected. One test
made with the gap at the nose of the aileron unsealed
(fig. 3) showed that the presence of even a small gap
(0.0007c) decreased the aileron effectiveness. This
result is in agreement with previous data.
Balanced \((0.30c_a)\) sealed aileron and plain split flap.— The aerodynamic characteristics of the aileron with a sheet rubber seal and with a \(0.30c_a\) unfaired balance and the outboard plain split flap are presented in figures 8 to 12. These data indicate that, in general, this combination provided slightly smaller rolling- and yawing-moment coefficients than the plain sealed aileron and that the balance was not as effective as expected.

Balanced \((0.30c_a)\) sealed aileron and balanced split flap.— The aerodynamic characteristics of the aileron with a sheet rubber seal and with a \(0.30c_a\) unfaired balance and the balanced split flap are given in figures 13, 14, and 15. The results show that when the outboard flap was deflected, this combination was more effective for lateral control than the same aileron with a plain split flap and that it had smaller hinge-moment coefficients but about the same down-floating tendency. The dip in the hinge-moment coefficient curve at \(\delta_a\) of about \(-20^\circ\) with the outboard flap deflected was probably caused by the fact that the nose of the aileron, when deflected, extended below the lower surface of the main wing. (See fig. 2(d).)

Balanced \((0.35c_a)\) sealed and faired aileron and balanced split flap.— The aerodynamic characteristics of the aileron with a sheet rubber seal and with \(0.35c_a\) faired balance and the balanced split flap are shown in figures 16 through 19. The aileron with the \(0.35c_a\) balance was slightly more effective than the aileron with the \(0.30c_a\) balance, probably because the one with the \(0.35c_a\) balance had a better shape (arc at top and bottom instead of sharp corners) and a different hinge location (midway between the surfaces instead of near the lower surface). With the flaps deflected \(40^\circ\) the rolling-moment coefficient curve was steep at small negative aileron deflections (fig. 18). This abrupt change was smoothed out by locating the nose of the balanced split flap \(0.01c\) below the lower surface of the wing (figs. 2(e) and 19). The change in flap-nose location also practically eliminated the dip in the hinge-moment coefficient curve.

Application of Data

The lateral-control characteristics have been computed for a typical pursuit airplane (fig. 20) equipped
with a 0.30c inboard Fowler flap and with two combina-
tions of 0.15c by 0.37 b/2 sealed ailerons and 0.20c by
0.37 b/2 outboard retractable split-type flaps. The com-
binations investigated were: (1) the plain aileron and
plain-split flap (fig. 2(b)) and (2) the balanced aileron
with 0.35c a balance and the balanced split flap located
0.01c below the wing lower surface (fig. 2(e)). An equal
up-and-down deflection of the ailerons was assumed for all
computations because of the change in floating tendency
of the ailerons from the flap-neutral to the flap-deflected
condition and also, in general, the rolling-moment coef-
cient produced for a given deflection was greatest for
the equal up-and-down deflection arrangement.

The lateral-control characteristics presented in fig-
ure 21 were computed from the data in figures 3, 6, 16,
and 19, using the aerodynamic characteristics of the
aileron without any corrections and without taking ac-
count of the difference in wing plan form. The lift coe-
ficient of the airplane at any particular angle of attack
and flap deflection was assumed to be that of the wing in
the tunnel, computed as described under Apparatus and
Methods. These lift coefficients may not, however, be
realized on the airplane.

The results (fig. 21(a)) show that both the plain
aileron and the balanced aileron give about equal rolling-moment
coefficients with the flap completely retracted. The ad-
verse (negative) yawing-moment coefficients for a given
rolling-moment coefficient are, however, less for the
plain aileron than for the balanced aileron; whereas the
stick forces, as would be expected, are less for the bal-
anced aileron. The maximum stick force with full aileron
deflection for the high-speed flight condition is about
25 percent less for the balanced aileron than for the
plain aileron.

With both flaps extended and deflected (fig. 21(b)),
the rolling-moment coefficients are greater for the bal-
canced aileron in combination with the balanced split flap
than for the plain aileron and plain split flap combina-
tion. This result was anticipated because the wind-tunnel
data previously presented showed the ailerons to be more
effective with the balanced than with the plain split flap.
The adverse (negative) yawing-moment coefficients for a
given rolling-moment coefficient are less with the flaps
extended and deflected than with the flaps retracted.
For the low angle-of-attack condition the yawing-moment coefficients are favorable (positive). The stick forces, as is to be expected, are less for the balanced aileron but in no case are they very large because of the relatively low speeds considered.

Computations made, as outlined in reference 10, of the reduction in stick force due to rolling showed that neither of the aileron arrangements would be over-balanced.

CONCLUDING REMARKS

The results of the tests indicated that lateral control could be obtained with plain sealed ailerons on a wing with an inboard Fowler flap and an outboard split-type flap. The rolling-moment coefficients produced by a given aileron deflection were larger for the aileron in combination with a deflected retractable balanced split flap than with the deflected retractable plain split flap. It is believed, moreover, that the lateral control system will work equally well with any other type of inboard flap.

Flight tests of a wing with an inboard flap of the slotted type, a sealed aileron with a faired $0.35c_a$ balance, and an outboard retractable balanced split flap located 0.01c below the wing lower surface are recommended.

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REFERENCES


Figure 2.- NACA 23012 wing with a 0.30\(c\) by 0.63\(\frac{3}{4}\) inboard Fowler flap and four combinations of outboard sealed aileron and outboard retractable split flap. Aileron 0.15\(c\) by 0.31\(\frac{1}{4}\) in; flap 0.20\(c\) by 0.37\(\frac{1}{4}\) in.
Aerodynamic characteristics of a 0.15c by 0.37 b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f2).

Figure 3. - $\delta_{f1} = 0^\circ$; $\delta_{f2} = 0^\circ$.

Figure 4. - $\delta_{f1} = 40^\circ$; $\delta_{f2} = 0^\circ$. 

Aerodynamic characteristics of a 0.15c by 0.37 b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f2).
Aerodynamic characteristics of a 0.15c by 0.37 b/2 plain sealed aileron on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap (f1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap (f2).
Figure 7. - $\delta_{f_1} = 40^0; \delta_{f_2} = 60^0$. Plain sealed aileron. Figure 8. - $\delta_{f_1} = 0^0; \delta_{f_2} = 0^0$. Sealed aileron. Aerodynamic characteristics of a 0.15c by 0.37 b/2 aileron with a 0.30c by 0.63 b/2 inboard Fowler flap ($f_1$) and a 0.20c by 0.37 b/2 outboard retractable plain split flap ($f_2$).
Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with 0.30c balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f2).
Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with 0.30c_a balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f_1) and a 0.20c by 0.37 b/2 outboard retractable plain split flap(f_2).
Figure 13. $\delta_{f1} = 40^\circ$; $\delta_{f2} = 20^\circ$.

Figure 14. $\delta_{f1} = 40^\circ$; $\delta_{f2} = 40^\circ$.

Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with 0.30c balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap($f_1$) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap($f_2$).
Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap (f1) and a 0.20c by 0.37 b/2 outboard retracted balanced split flap (f2).
Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with a 0.35c balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap (f1) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap (f2).
Figure 19.- Aerodynamic characteristics of a 0.15c by 0.37 b/2 sealed aileron with a 0.35c balance on an NACA 23012 wing with a 0.30c by 0.63 b/2 inboard Fowler flap(f1) and a 0.20c by 0.37 b/2 outboard retractable balanced split flap(f2). \( \delta_{f1} = 40^\circ \); \( \delta_{f2} = 40^\circ \).

Nose of "f2" is located 0.01c below lower surface of wing.
Figure 20: Wing arrangement for typical pursuit airplane.
<table>
<thead>
<tr>
<th>( \alpha, \text{deg} )</th>
<th>( C_l, \text{V, mph} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain sealed aileron</td>
<td>(-0, 0.17, 257)</td>
</tr>
<tr>
<td>and plain split flap.</td>
<td>(-0.15, 1.40, 30)</td>
</tr>
<tr>
<td>Data from figure 3</td>
<td>(-0.15, 3.04, 61)</td>
</tr>
<tr>
<td>Balanced sealed aileron with</td>
<td>(-0.17, 0.17, 257)</td>
</tr>
<tr>
<td>0.35( \alpha ) balance and balanced split flap. Data from figure 19</td>
<td>(-0.15, 1.40, 30)</td>
</tr>
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**Figure 22.** Lateral-control characteristics of typical pursuit airplanes with a 0.30c inboard Fowler flap \( \delta_1 \), and with two arrangements of 0.15c by 0.37c ailerons and 0.20c by 0.37c outboard retractable split-type flaps \( \delta_2 \).
Tests were conducted on a NACA 23012 wing with full-span combinations of Fowler and split-type flaps to determine their control characteristics. Data for roll, yaw, and hinge moments were obtained at air speeds of 40 mph and at several angles of attack and flap deflections. Results indicated that a plain sealed aileron with internal balance will provide lateral control for planes equipped with full-span combinations of slotted and split-type flaps.
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Wind Tunnel Investigation of Plain Ailerons For a Wing With a Full Span Flap Consisting of An Inboard Fowler and An Outboard Retractable Split Flap.

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