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FLIGHT TESTS OF MODIFICATIONS TO IMPROVE THE AILERON CONTROL CHARACTERISTICS OF A NORTH AMERICAN XP-51 AIRPLANE

(A.C. NO. 41-38)

By M. D. White and Herbert H. Hoover

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Langley Field, Va.

NACA

WASHINGTON

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MEMORANDUM REPORT

for

Army Air Forces

FLIGHT TESTS OF MODIFICATIONS TO IMPROVE

THE AILERON CONTROL CHARACTERISTICS

OF A NORTH AMERICAN XP-51 AIRPLANE

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SUMMARY

In an attempt to improve the aileron control characteristics of the XP-51 airplane, the deflection range was increased 70 percent to increase the effectiveness and the original concave section was changed to a thick section with beveled trailing edge to provide increased aerodynamic balance.

The effects of the modifications were determined in flight by means of NACA recording instruments, the data obtained being in suitable form for direct comparison with those for the original ailerons (reference 1).

The results show that the modified ailerons produced a value of $pb/2V$ of about 0.084 with full stick deflection. This value represents an increase in effectiveness over the original aileron installation of about 70 percent at low speed and about 55 percent at high speeds.

At high speeds, the rate of roll for a 30-pound stick force was increased by about 20 percent.

Additional tests of the modified ailerons at diving speeds are considered desirable to investigate possible effects of compressibility but should be made with new ailerons of lighter construction than those used in the present tests.

The effect of the aileron modification on the airplane drag is now being investigated.

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INTRODUCTION

Previous tests of a North American XP-51 airplane (A.C. No. 41-38) conducted by the NACA at Langley Field had indicated the desirability of improving the aileron control characteristics (reference 1).

At the request of the Army Air Forces, the NACA undertook to improve the ailerons so as to obtain greater effectiveness without increasing the stick forces. This report presents the results of tests of the modified ailerons in which increased effectiveness was obtained by increasing the deflection range and improved balancing was achieved by modifying the aileron profile.

AILERON MODIFICATIONS

The aileron system of the XP-51 airplane was modified in two respects simultaneously.

First, the aileron travel was increased from the previous range of ±10° to a range of 17.5° up and 16.5° down on the left aileron and 16.5° up and 17.5° down on the right aileron. The control linkage was altered so that the stick movement remained substantially unchanged.

The other modification was a change in aileron section from the original slightly concave surfaces to a beveled trailing-edge contour (figs. 1 and 2). In figure 2, the ordinates for the modified section are tabulated. Intermediate sections were determined by connecting corresponding chordwise stations with straight lines.

The modified ailerons were constructed by fastening 1/2-inch wide mahogany ribs to the surface of the original ailerons at each rib station. A single aluminum sheet was then bent around the ribs, fastened to them with wood screws, and riveted to the original surface along the leading edge.

TESTS, RESULTS, AND DISCUSSION

The procedure used in the present tests was the same as that used to obtain the results given in reference 1. Standard NACA recording instruments were used to obtain records as the pilot abruptly applied aileron control from laterally level flight at various airspeeds (rudder held fixed at each trim position).

For evaluating the aileron effectiveness, the helix angle, pb/2V, in which p is rolling velocity in radians per second, b is span in feet, and V is true airspeed in feet per second, has been used as the criterion (reference 2).

The results obtained are presented in figure 3.

Figure 3 shows the variation of control force and pb/2V with control surface deflection at various speeds for the modified ailerons. By comparison with the results obtained for the original ailerons, which are reproduced in figure 4, it will be seen that, for a given surface deflection, the hinge moments are, on the average, reduced by about 59 percent of the original values.

Compared on the basis of equal effectiveness or pb/2V for the high-speed condition, however, the hinge moments are reduced by about 51 percent of the original value. This difference is due to a decrease in effectiveness per unit control deflection of about 15 percent suffered with the modified ailerons in the low angle-of-attack range.

The variation of pb/2V with control deflection remained constant at all speeds tested for the modified ailerons. This is in contrast with results obtained with the original ailerons which showed a greater pb/2V at high speeds than at low speeds for a given deflection.

In addition, the loss in available control deflection attributed to flexibility in the control system with the

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Figure 5 was constructed from the data of figures 3 and 4 to show the variation of pb/2V and rolling velocity with indicated airspeed. For comparison, the aileron characteristics of the P-40 airplane are included.

The curves shown represent the rolling response for full stick deflection and for a 30-pound stick force, this value being a reasonable upper limit for pursuit airplanes.

At indicated airspeeds up to about 200 miles per hour full deflection of the stick gave values of pb/2V of 0.084; this value is about 70 percent higher than equivalent values for the original ailerons at low speeds and about 55 percent higher at high speeds. At speeds higher than 200 miles per hour the stick force limitation results in a decrease in values of pb/2V so that at the highest test speed the improvement in effectiveness over the original ailerons for a 30-pound stick force is about 20 percent. A comparison of forces and response for full stick deflection at high speeds indicates a usable additional effectiveness available with the modified ailerons if larger forces could be tolerated; for the original ailerons, on the other hand, full control was restricted largely by deflection.

As a result of this improvement the aileron characteristics of the airplane are nearly sufficient to meet the requirement suggested in reference 3; that is, that a value of $pb/2V$ of 0.07 be obtained at 0.8 of the maximum indicated level-flight airspeed with a stick force of 30 pounds. The force required exceeds this amount by about 6 pounds.

The original tests of the modified ailerons were made with tufts on the upper surface of the entire wing. To determine whether the balance characteristics of the modified ailerons were sensitive to changes of boundary-layer characteristics, the tests were repeated for the following wing-surface conditions:

1. Clean wing — tufts removed.
2. Strip located spanwise along upper and lower surfaces of wing ahead of the ailerons at 10-percent wing chord to produce transition in the boundary layer. Strip dimensions were 0.013 inch high by 1/4 inch wide.
3. Strip located spanwise on upper and lower surface of ailerons at beginning of bevel to simulate lap joint in the covering. Strip dimensions were 0.01 inch high by 1 inch wide.

None of these modifications tested independently had any measurable effect on the aileron characteristics.

It is anticipated that the modified ailerons may have some effect on the wing drag. Tests to determine the magnitude of the effect are under way.

It should be noted too that, as shown in figure 1(b), a fairly large gap existed between the aileron and the wing. Unpublished wind-tunnel data indicate that a gap is conducive of overbalancing of the ailerons at low deflections. No evidence of this effect was observed in any of the results for the cruising condition; a slight evidence of overbalance was noted in the data for the original ailerons in the landing condition, but the amount was so small as to be obscured by friction and was not observed by the pilot.

CONCLUDING REMARKS

The results presented in the foregoing report indicate that within the limits tested, beveled trailing edges offer an effective means for reducing aileron control forces. Although the modified version of the XP-51 ailerons tested did not quite fulfill suggested requirements, the improvement in aileron control achieved was very marked, particularly at low speeds and in the usual maneuvering range. The necessity for attempting further reduction of the hinge moments is somewhat questionable since the deficiency in aileron performance is so slight. It is possible that increased bluntness of the trailing edge could be employed to further lighten the ailerons, if desired, but the possibility of overbalance at small deflections indicates the necessity for caution in applying such a modification. The possibility of encountering trouble at very high speeds might also be greater if the bluntness were increased.

Tests at very high speeds were not attempted in the present case because of doubt about the effect the increased weight of the ailerons might have on the critical flutter speed and lack of knowledge of the strength of the ailerons and wing as regards abrupt aileron deflections at high speeds. Since there appears to be a possibility of some critical change in flow over the beveled trailing edges at high speeds, tests at high speeds should be made with ailerons of normal weight.

The possibility that the beveled trailing edges increase the wing drag by an appreciable amount must also be borne in mind. Flight tests are now being made to determine the magnitude of this effect.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 20, 1942.

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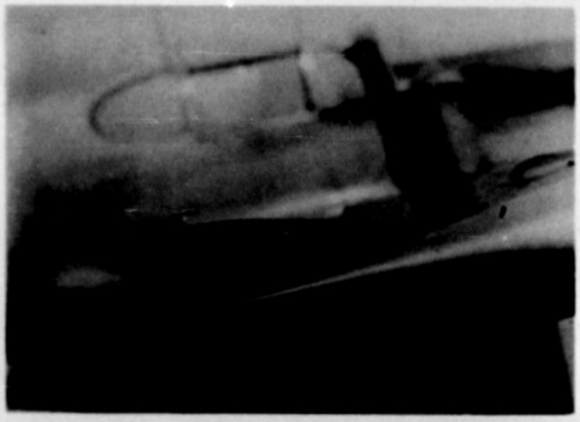


Figure 1a.- End view of beveled trailing-edge aileron showing modified and original section contours and method of construction.

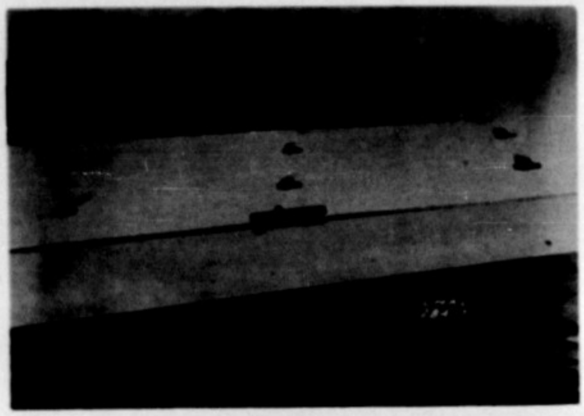
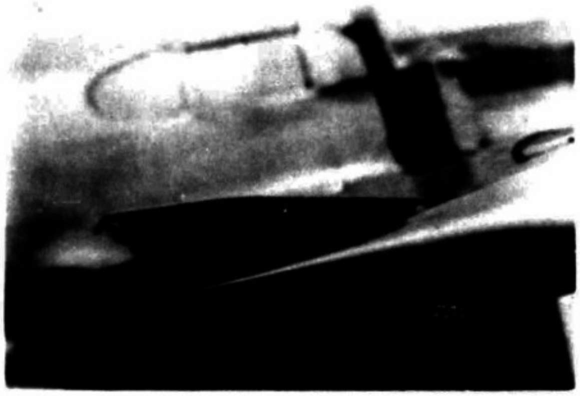


Figure 1b.- View of right aileron from behind and above showing gap between aileron and main part of wing.



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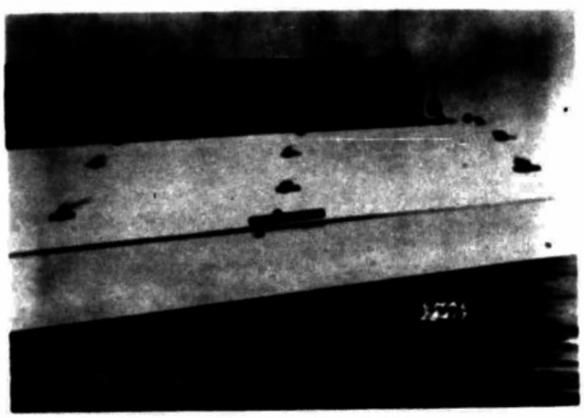

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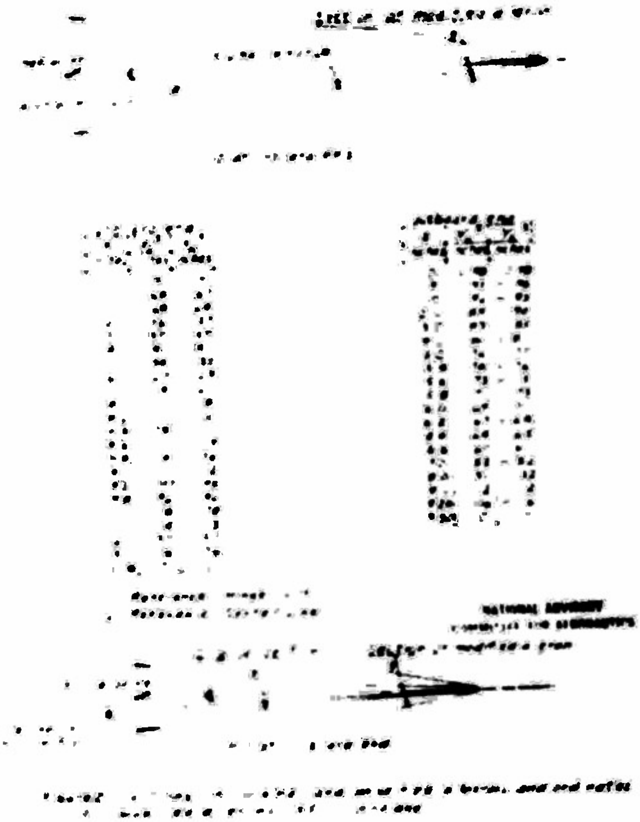
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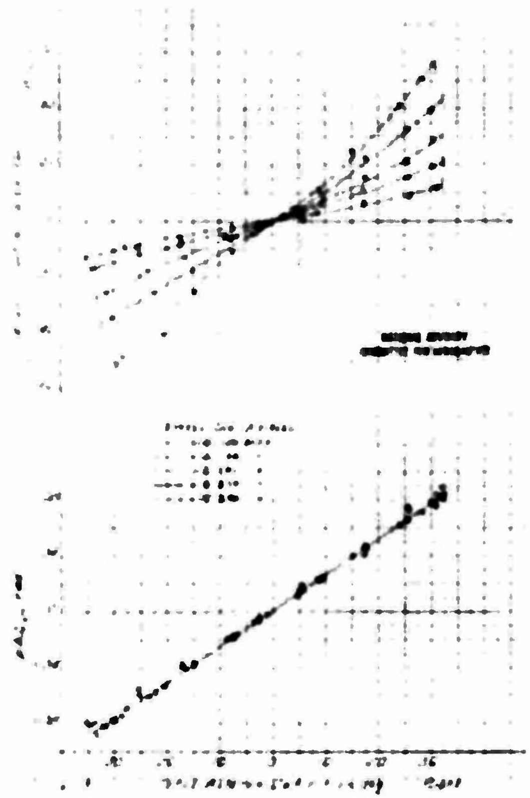

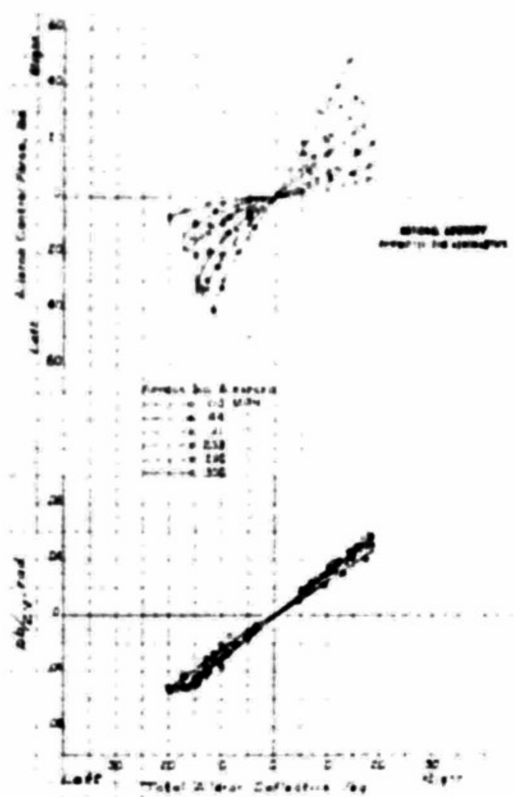
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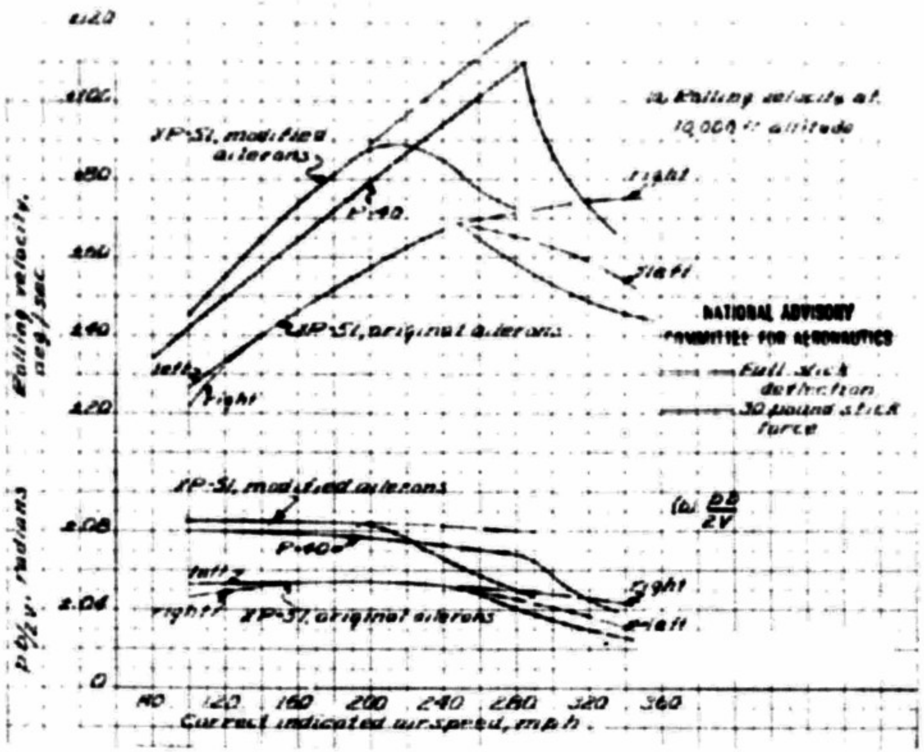

Fig. [illegible] - Aileron characteristics of North American XP-51 airplane (A.C. No. [illegible]) with modified and original ailerons in aileron rolls with 30 pounds stick force and with full stick deflection.

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