TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 515

AERODYNAMIC EFFECTS OF A SPLIT FLAP ON THE SPINNING CHARACTERISTICS OF A MONOPLANE MODEL

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SUMMARY

The investigation described in this report was made to determine the change in aerodynamic forces and moments produced by split flaps in a steady spin. The tests were made with the spinning balance in the N.A.C.A. 5-foot vertical wind tunnel. A low-wing monoplane model was tested with and without the split flaps in 12 spinning attitudes chosen to cover the probable spinning range. The changes in coefficients produced by adding the split flaps are given for longitudinal force, normal force, and rolling and yawing moments about body axes.

The results obtained indicate that the use of split flaps on an airplane is unlikely, in any case, to have much beneficial effect on a spin, and it might make the spin dangerous. The change in the spin will depend upon the aerodynamic and inertia characteristics of the particular airplane. A dangerous condition is most likely to be attained with airplanes which are statically stable in yaw in the spinning attitude and which have large weights distributed along the wings.

INTRODUCTION

Split flaps are being used on airplanes to decrease the landing speed, to increase the range of possible glide angles, and to shorten the landing run. Since they are used at slow flying speeds where the airplane may possibly spin, some data on their effects on the spin seemed desirable. Regular wind-tunnel tests of split flaps have been reported in references 1 to 3 and rotation tests with $\frac{\Omega b}{2V} = 0.05$ in reference 4.

In order to determine the effects of split flaps on the forces and moments in spinning attitudes, the present investigation was made with a monoplane model on the spinning balance in the N.A.C.A. 5-foot vertical wind tunnel.

MODEL AND APPARATUS

The model used in these tests was a low-wing monoplane. Side and plan views are given in figure 1. The areas of the tail surfaces and the length of the fuselage represent average present-day practice. The wing, of a symmetrical section, was tapered 2:1 in plan form and 1.55:1 in thickness, the thickness being 18.5 percent of the root chord at the root section. The span of the wing was 30 inches and the aspect ratio 6. The dihedral angle was such that the maximum upper-surface section ordinates were in a horizontal plane.

The split flap was made of 1/32-inch steel and attached to the lower surface of the wing as shown in figure 1. The chord of the flap was 20 percent of the wing chord and tapered with the wing. The flap was set down 60° from the chord line to simulate maximum lift conditions.

The spinning balance, which measures all six components of force and moments, is described in reference 5 and a description of the 5-foot vertical wind tunnel may be found in reference 6.

TESTS

Tests were made with and without the split flaps in each of 12 attitudes chosen to cover the probable spinning range.

The attitudes were computed for each angle of attack for a balance between assumed values of normal force and pitching moments due to the air forces, and the weight of the airplane, the centrifugal force, and the gyroscopic pitching moment due to the rotation.

The attitudes are defined by the following table:

ϕ	β	Rotational velocity Ω	Radius of spin	Tunnel air speed W"	$\frac{p}{\Omega}$	$\frac{q}{\Omega}$	$\frac{r}{\Omega}$
Degrees	Degrees	Rad./sec.	Inches	Ft./sec.			
40	6	27.1	4.36	65	0.7294	0.2511	0.6359
	0	27.1	4.36	65	.7457	.1484	.6495
	-10	27.1	4.36	65	.7534	-.0253	.6571
50	10	28.5	3.28	65	.6018	.2883	.7448
	0	28.5	3.28	65	.6250	.1178	.7716
	-10	28.5	3.28	65	.6284	-.0561	.7758
60	10	33.7	2.14	65	.4697	.2625	.8429
	0	33.7	2.14	65	.4851	.0909	.8697
	-10	33.7	2.14	65	.4853	-.0834	.8704
70	10	32.2	.97	55	.3280	.2201	.9187
	0	32.2	.97	55	.3363	.0465	.9406
	-10	32.2	.97	55	.3335	-.1279	.9341

where p, q, and r are the rotational velocities in radians per second about the X, Y, and Z axes, respectively; and β is the angle between the resultant wind and its projection on the XZ plane, positive in a right spin with inward sideslip.

Both the elevator and the rudder were fixed neutral for all tests. The tunnel air speed was reduced at 70° angle of attack because of the high rate of rotation. The Reynolds Number, based on a 5-inch chord and an air speed of 65 feet per second, was about 165,000.

Additional tests were made at 50° angle of attack and zero sideslip with the tail surfaces and rear part of the fuselage removed to determine the interference effect of the split flaps on the fin, rudder, and the rear part of the fuselage. These tests gave no indication of interference.

RESULTS

The change in the coefficients (body axes) of normal force (ΔC_Z), longitudinal force (ΔC_X), rolling moment (ΔC_l), and yawing moment (ΔC_n), produced by the addition of the split flaps is given for right spins in figures 2 to 5. The change in side force (ΔC_Y) is small and of no particular importance. The change in pitching-moment coefficient (C_m) measured was within the experimental accuracy. The results, however, indicated a larger diving moment.

The coefficients in each case were obtained by the following relations:

$$C_X = \frac{X}{\frac{1}{2}\rho V^2 S}$$

$$C_Z = \frac{Z}{\frac{1}{2}\rho V^2 S}$$

$$C_l = \frac{L}{\frac{1}{2}\rho V^2 S b}$$

$$C_n = \frac{N}{\frac{1}{2} \rho V^2 S b}$$

where X and Z are the forces

L and N, the moments

S, the area of the wing

b, the span of the wing.

The changes in force and moment coefficients (ΔC) were obtained from faired curves and the values are the coefficients obtained with the split flap minus the coefficients obtained without the split flap. All data are given with conventional signs for right spins.

Test results can usually be repeated within ±0.020 for ΔC_X, ±0.080 for ΔC_Z, and ±0.010 for ΔC_l and ΔC_n.

DISCUSSION

The necessary condition for a steady spin is that all the aerodynamic forces and moments must exactly equal and oppose the inertia moments, weight of the airplane, and centrifugal force. The forces and moments used throughout the discussion are those in the body system of axes.

The effects, on a spin, of changes in the aerodynamic forces C_X, C_Y, and C_Z are of secondary importance because they are usually balanced by small changes in attitude or velocity without materially affecting the spin. A moderate change in aerodynamic rolling moment C_l during a spin is usually balanced by a change in sideslip. An increase in the pitching moment $-C_m$ (diving moment), if it is not applied too suddenly, is usually balanced by an increase in the rotational velocity. An increase in the yawing moment opposing the spin $-C_n$, however, is usually balanced by a decrease in rotational velocity which in turn decreases the gyroscopic stalling moment and the airplane may spin at a lower angle of attack or stop spinning. In other words, the yawing moment is the only force or moment that cannot usually be balanced by small changes in attitude or velocity without materially affecting the spin. Although the other forces and moments do not directly materially affect the spin, their indirect effects may be of considerable importance and in the case under consideration the effect of rolling moment on yawing moment, because of the large rolling moment given by the split flap, should be considered. The balance of rolling moments is the important factor which determined the angle of sideslip and the sideslip in turn affects both the aerodynamic and inertia yawing moments. Increasing the sideslip in the outward sense increases the aerodynamic yawing moment, produced by the fin and rudder, opposing the spin.

The sideslip also affects the yawing moments produced by the other parts of the airplane depending upon its static stability in yaw for a particular attitude and upon its moments of inertia.

The changes in C_X and C_Z (figs. 2 and 3), as mentioned above, are not of great importance to the spin.

The changes in C_l (fig. 4), produced by the split flaps, are in a sense to aid the rotation which would tend to make the airplane spin with more positive (inward) sideslip than it would without the split flaps. It is very probable that a conventional airplane with split flaps would spin with inward sideslip.

The indicated increase in $-C_m$ (diving moment) would be expected to increase the rotational velocity or angle of attack.

The changes in C_n (fig. 5) are small and in a sense to oppose the rotation with outward and zero sideslip and to aid the rotation with inward sideslip.

Considering the combined effects of the measured quantities upon the spin, a few generalized statements can be made. The increased rolling moment will tend to make the airplane spin with more positive (inward) sideslip. As a result of the change in sideslip: The yawing moment produced by the fin and rudder opposing the spin will be reduced; an increment of yawing moment aiding the spin will be produced if the airplane is statically stable in yaw in the particular attitude and the opposite will be true if the airplane is statically unstable; and an increment of inertia yawing moment aiding the spin will be produced if $A > B$ (weight distributed along the wings, A and B being the moments of inertia along the X and Y axes, respectively), or will be zero or very small if A and B are about equal, or will oppose the spin if $A < B$ (weight distributed along the fuselage). If the change in rolling moment is sufficient to produce considerable inward sideslip, the aerodynamic yawing moment produced by the split flaps will aid the spin.

From the foregoing brief discussion it is apparent that the effects of the measured quantities are so interrelated and so dependent upon the particular aerodynamic and inertia characteristics of any airplane that no definite general prediction of the effect of flaps on a spin can be made. If, however, an airplane were statically stable in yaw and had a mass distribution such that $A > B$ (weights distributed along the wings), it is likely that the split flaps would have a detrimental effect on the spin and might be dangerous. It seems unlikely in any event that any beneficial effects that might be obtained from the flaps would be sufficient to prevent the spin.

CONCLUSION

Split flaps are unlikely to have much beneficial effect on a spin and on some particular airplanes they might make the spin dangerous.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 20, 1934.

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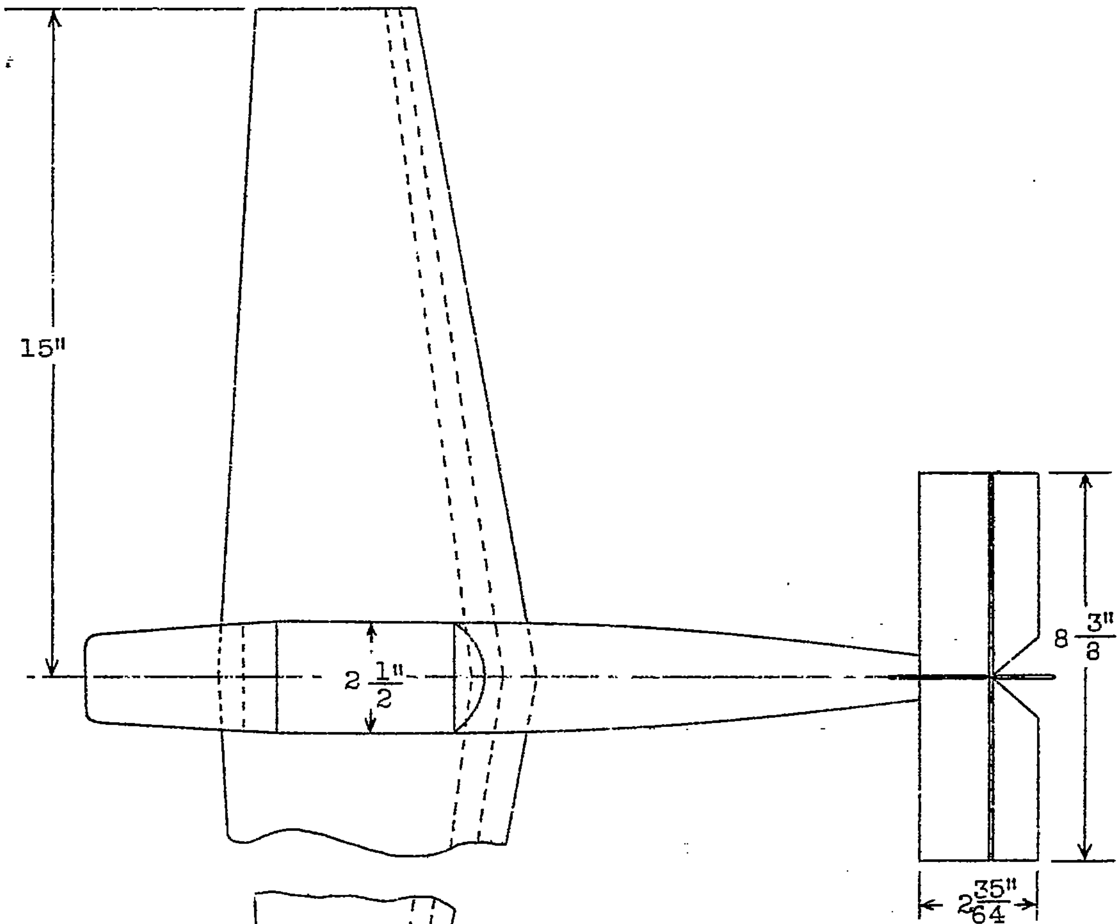


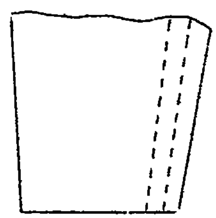
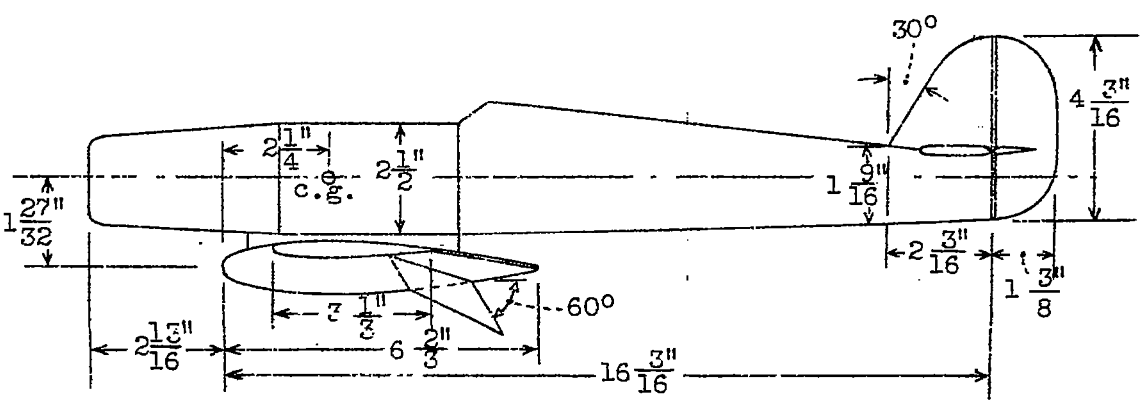


Figure 1.- Side and plan view of model with split flaps.



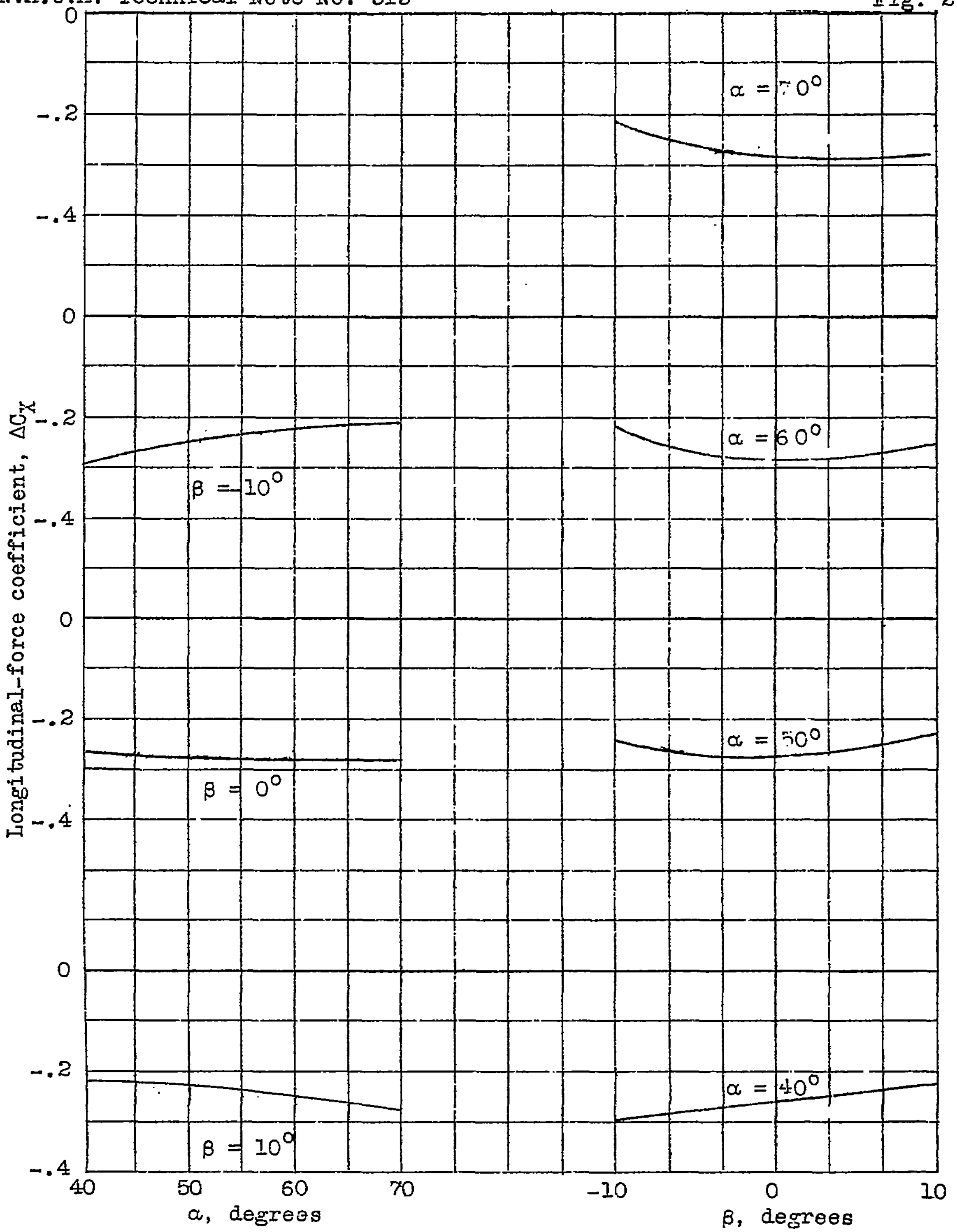


Figure 2.-Change in longitudinal-force coefficient (from faired C_X curves), body axes,produced by adding split flaps. Coefficients with split flaps minus coefficients with plain wing. Right spin.

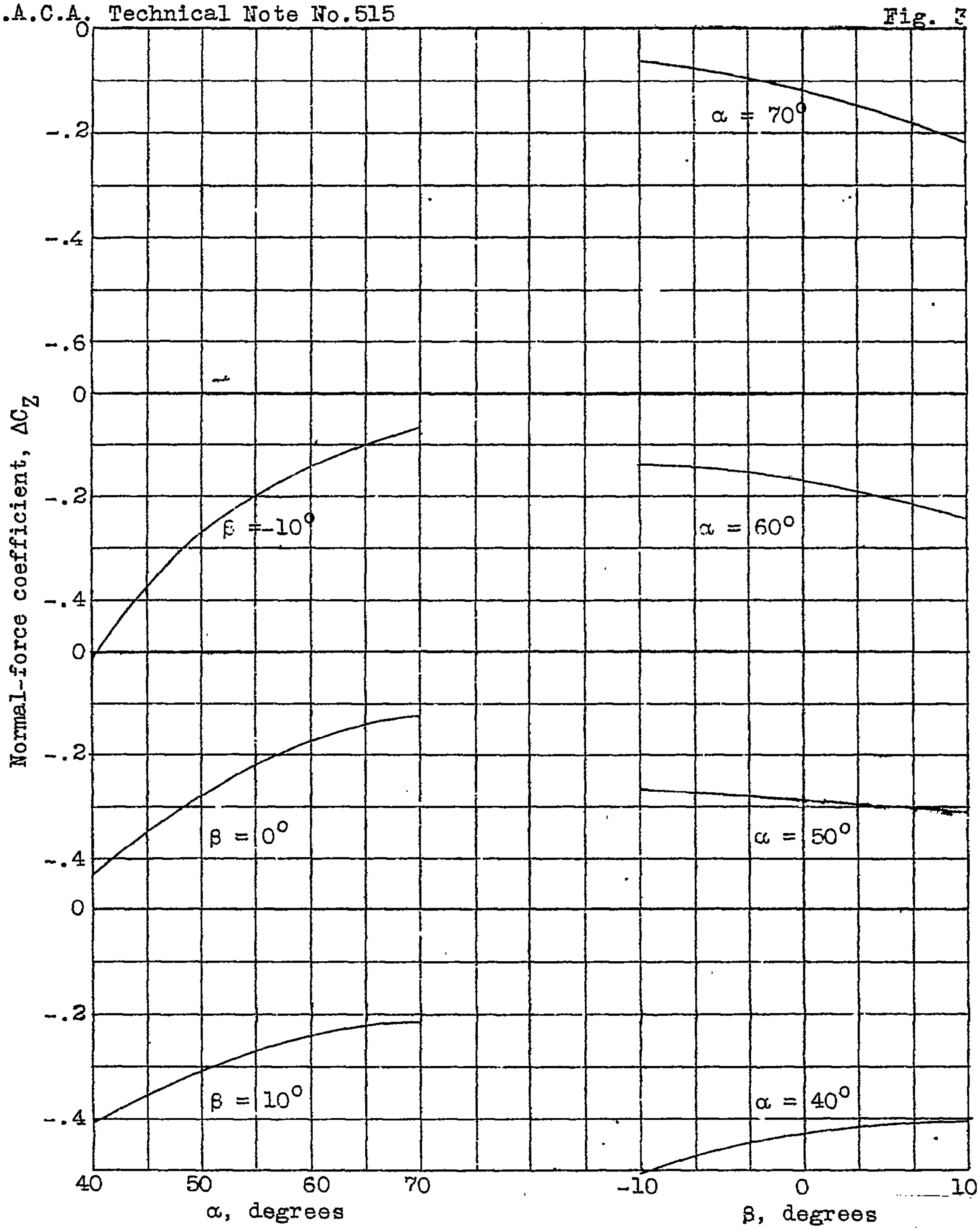


Figure 3.-Change in normal-force coefficients (from faired C_Z curves), body axes, produced by adding split flaps. Coefficients with split flaps minus coefficients with plain wing. Right spin.

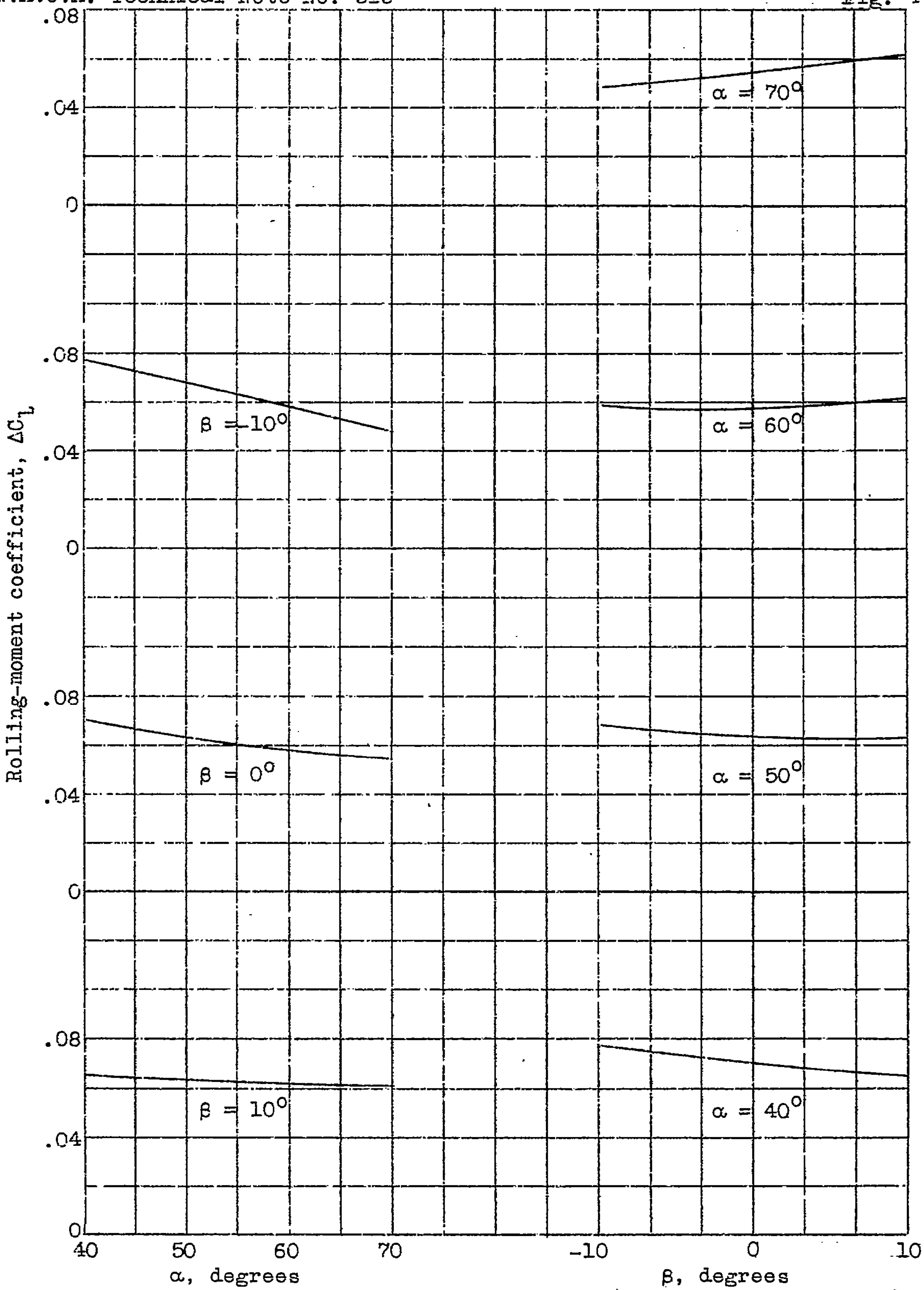


Figure 4.-Change in rolling-moment coefficients (from faired C_l curves), body axes produced by adding split flaps. Coefficients with split flaps minus coefficients with plain wing. Right spin.

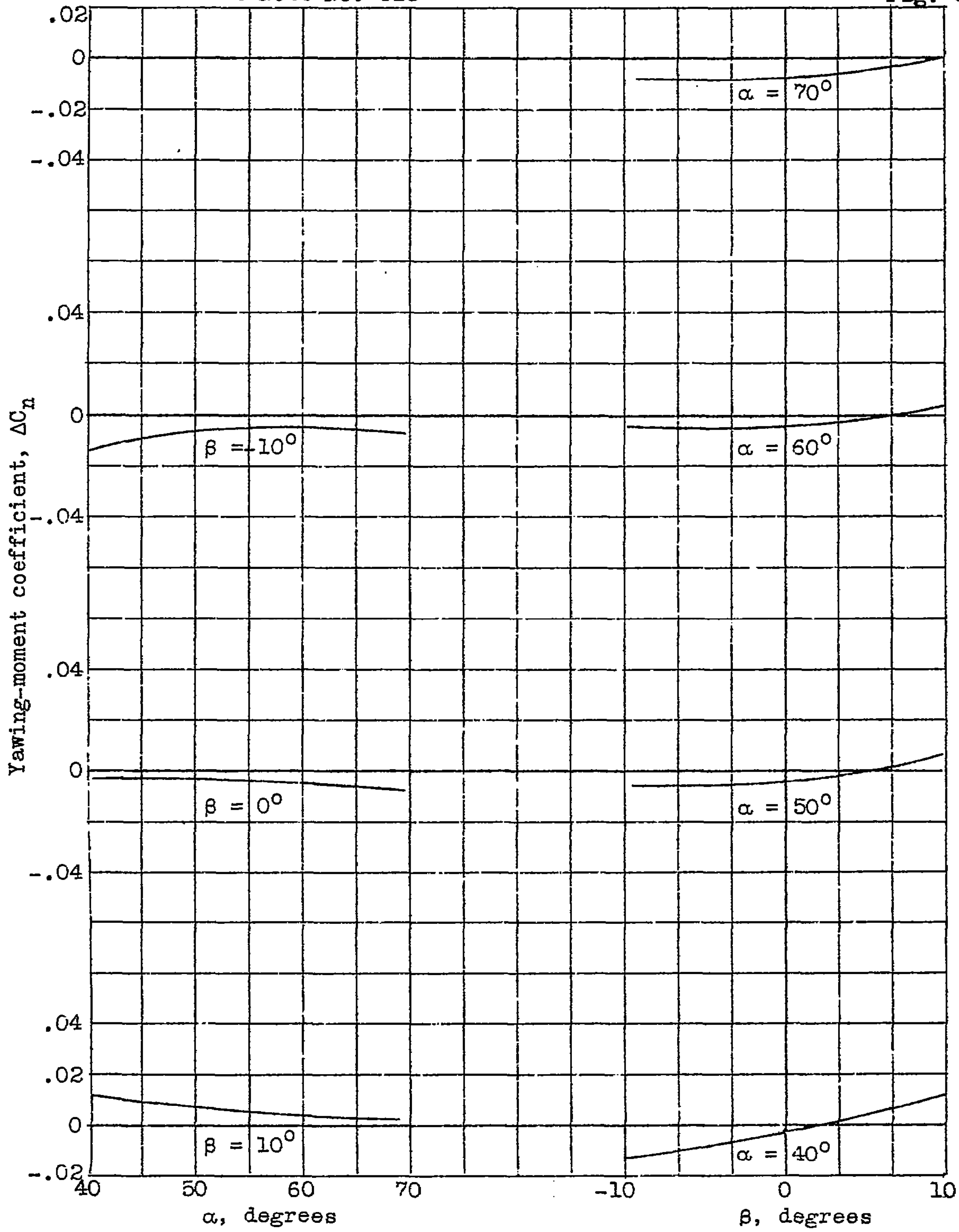


Figure 5.-Change in yawing-moment coefficient (from faired C_n curves), body axes, produced by adding split flaps. Coefficients with split flap minus coefficient with plain wing. Right spin.