NACA TN 423

[redacted]

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 423

EFFECT OF LENGTH OF HANDLEY PAGE TIP SLOTS ON THE LATERAL-STABILITY FACTOR, DAMPING IN ROLL

By Fred E. Weick and Carl J. Wenzinger
Langley Memorial Aeronautical Laboratory

Washington
July, 1932

19

NOTICE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 423

EFFECT OF LENGTH OF HANDLEY PAGE TIP SLOTS ON THE LATERAL-STABILITY FACTOR, DAMPING IN ROLL

By Fred E. Weick and Carl J. Wenzinger

SUMMARY

Tests have been made in the N.A.C.A. 7 by 10 foot wind tunnel on a Clark Y wing model equipped with various lengths of Handley Page slots extending inward from the wing tips. The slot lengths tested ranged from 20 to 100 per cent of the semispan. The effect of slot lengths on damping in roll was determined by means of both free-autorotation and forced-rotation tests. In addition, the maximum lift coefficient was found with each slot length.

The optimum length of slot for satisfactory damping in roll over a large range of angles of attack was found to be slightly over 50 per cent of the semispan for the form of slot tested.

INTRODUCTION

Handley Page type wing-tip slots have been found to give improved lateral stability at angles of attack above that corresponding to the stall of a plain wing. A considerable amount of work has been done on finding the best shape of the slat or movable portion and on its location with respect to the wing proper. The fact has also been well established that the outboard end of the slot should approach as closely to the tip of the wing as the plan form will allow. Practically nothing seems to have been done, however, to determine the best length or position of the inboard end of the slot for good stability.

As part of a general program of research on safety of aircraft, the present report covers a wind-tunnel study with a Clark Y basic airfoil having Handley Page slots of various lengths from zero to full span, to determine the effect of the slot length on damping in roll by means of both free-autorotation and forced-rotation tests. In addition, the effect of the slot length on the maximum lift coefficient was found. The cross-sectional shape of the slot was that which gave the highest value of $C_{L\ max}$* found in a previous series of tests on a Clark Y airfoil with a full-span slot in the N.A.C.A. vertical wind tunnel. (Reference 1.)

APPARATUS AND METHODS

The wing model, which had previously been used for other tests, was originally a plain rectangular 10 by 60 inch Clark Y airfoil made of laminated mahogany and equipped with conventional ailerons. For the present tests the ailerons were locked in the neutral position and the gaps were filled with Plasticine. The first tests, representing the zero slot length, were made with the airfoil in the original condition. The nose was then reshaped for the slot, as shown in Figure 1. The slat, which covered the entire span in the next tests, was made of aluminum alloy and fastened to the main airfoil in five places by small metal plates. The wing was arranged for different lengths of tip slots by cutting off the portion of the slat in the center and attaching it to the main portion of the wing. The joints were then faired with Plasticine, forming the original Clark Y section. The lengths of slot first tested were 20, 40, 60, 80, and 100 per cent of the semispan. After these tests had been completed it was evident that the critical range was between 40 per cent and 60 per cent, and further tests were made with the slots 50 per cent of the semispan in length.

The tests were made in the N.A.C.A. 7 by 10 foot wind tunnel, which has an open jet and a single closed return passage, and is described in detail, together with the balance, in reference 2. The present tests were all made on the portion of the balance used for rotation tests.

---

*It is possible that a more desirable effect on damping in roll might be obtained by means of a slot which stalled at a very high angle of attack than with the slot giving the highest lift coefficient. If the use of slots is of great importance, a more detailed investigation on the best shape for stability would be desirable.

Each length of slot was subjected to three kinds of test - free-autorotation, forced-rotation, and force tests - to determine the maximum lift coefficient. The rotation tests were made with the wing turning in both clockwise and counterclockwise directions. A comparison of the test results obtained with opposite directions of rotation gives a good idea of the accuracy of the results, which are critically affected by the accuracy of the form of the models. The free-autorotation tests covered only a small range of angles of attack to find the angle above which autorotation was self-starting. The forced-rotation tests were made with the wing rotating at a rate corresponding to the maximum rate of roll likely to be encountered in gusty air while attempting to fly straight. This rotation was taken to correspond to a value of the coefficient $\frac{p'b}{2V} = 0.05$, p' being the rate of roll about the tunnel axis, b the span, and V the air velocity.

The maximum lift coefficient was found with the wing locked in the horizontal position on the rotation gear. With this installation the maximum lift coefficient is slightly lower than with the same wing mounted on the regular force-test support, apparently due to interference, but the values are mainly of relative interest and in this respect are considered satisfactory.

All the tests were made at an air speed of 80 m.p.h., giving a Reynolds Number of 609,000 based on the 10-inch chord of the basic airfoil.

RESULTS AND DISCUSSION

The results of the free-autorotation tests, which show the angle of attack above which autorotation was self-starting, are shown for the different slot lengths by the dotted curve in Figure 2. The solid curve in the same figure shows the angle of attack above which the wings had autorotative moments and below which they had damping moments while rotating at $\frac{p'b}{2V} = 0.05$. The latter values are slightly lower than the former, due partly to the different air flow over the wing when rotating, and possibly to some extent due to the slight friction of the ball bearing supports in the free-autorotation tests. Both sets of tests show that, for slot lengths up to and including 40 per cent of the semispan, the angle of attack above which the damping in roll is negative and aids rotation is very close to the angle of attack corresponding to the stall of the unslotted portion of the wing but that as the length is increased to 50 per cent the angle of attack for initial instability is delayed to over 30°. As the slot length is further increased the angle is reduced again to a point corresponding to the stall of the wing with full-span slot.

The rolling moments tending either to damp or to aid the rotation while the wing was rotating at $\frac{p'b}{2V} = 0.05$, are given for the different slot lengths in Figures 3 to 9, inclusive. The moments are expressed in terms of the coefficient $C_\lambda = \frac{\lambda}{qbS}$, where λ is the rolling moment measured while the wing is rolling, q is the dynamic pressure, b the span, and S the area of the wing. It will be seen that the 20 per cent and 40 per cent slot lengths have two ranges of angles of attack with autorotative moments, one corresponding to the stall of the unslotted portion of the wing and the other to the stall of the slotted portion. The 50 per cent length was the shortest which had no autorotative moments due to the stall of the unslotted portion of the wing, and the 60 per cent length was the shortest of those tested which had substantial damping moments throughout the entire angle-of-attack range up to the stall of the slotted portion of the wing. These points are brought out more clearly by the cross plots of the maximum values of C_λ corresponding to the stall of the unslotted and slotted portions of the wing separately in Figure 10. For the slot lengths of less than 45 per cent of the semispan the stalling of the unslotted portion of the wing was the predominating factor, but with greater slot lengths the stalling of the slotted portion caused greater autorotative moments. In fact, for lengths greater than 50 per cent, no autorotative moment was associated with the stall of the unslotted portion of the wing. With all slot lengths tested, however, autorotative moments were found at angles of attack just above the stall of the slotted portion of the wing.

The portion of the lift curve in the region of the maximum lift coefficient is given for the various slot lengths by the dotted lines in Figures 3 to 9, inclusive. In each case with tip slots the lift curve has two peaks, and with the 50 per cent length both of these peaks had the same value. With shorter slots the peak corresponding to the unslotted portion of the wing was the predominating one. With the longer slots the peak associated with the stall of the slotted portion of the wing was the higher of the two, the other being in effect an interruption in the upward slope of the lift curve.

The angle of attack corresponding to the stall of the slotted portion of the wing increased 9° as the length of the slot decreased from 100 per cent to 40 per cent of the semispan, there being no definite peak with the 20 per cent slot length. This condition is an indication that the slotted portion on each tip of the wing operates to some extent as a separate wing, the slope of the lift curve decreasing as the aspect ratio of the slotted portion is decreased.

The effect of the slot length on the maximum lift coefficient is shown in Figure 11. The maximum lift coefficient is slightly lower with the short tip slots than with the original plain wing, and it does not increase appreciably until the slot length is increased beyond 50 per cent of the semispan. As the length is increased beyond 50 per cent the maximum lift coefficient is increased substantially, but the curves C_L against angle of attack have discontinuities at the stall of the unslotted portion of the wing that would probably be undesirable.

CONCLUSIONS

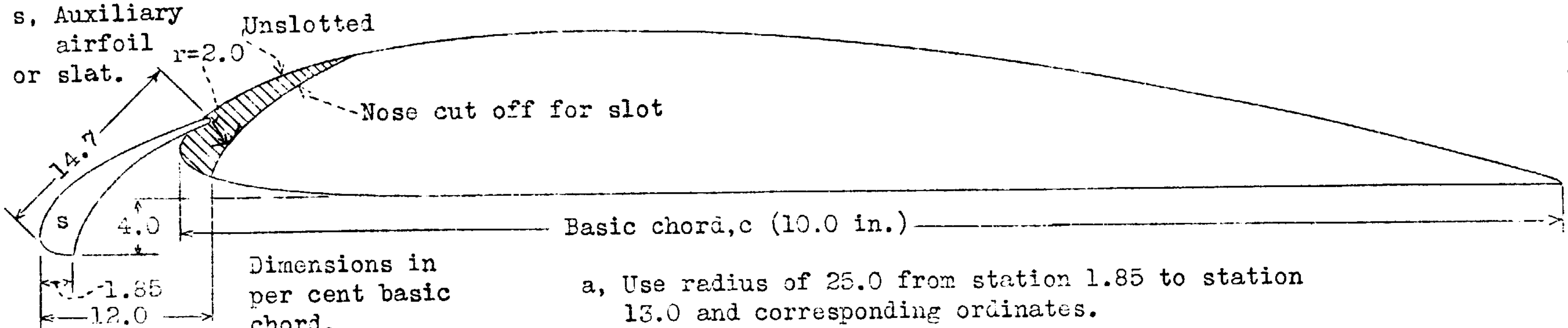
The optimum length of slot for satisfactory damping in roll throughout a large range of angles of attack was found to be slightly over 50 per cent of the semispan for the wing tested.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 15, 1932.

REFERENCES

1. Wenzinger, Carl J., and Shortal, Joseph A.: The Aerodynamic Characteristics of a Slotted Clark Y Wing as Affected by the Auxiliary Airfoil Position. T.R. No. 400, N.A.C.A., 1931.

2. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.



Dimensions in per cent basic chord.

a, Use radius of 25.0 from station 1.85 to station 13.0 and corresponding ordinates.

Basic Clark Y		
Ordinates		
(Per cent basic chord)		
Sta.	Upper	Lower
0	3.50	3.50
1.25	5.45	1.93
2.50	6.50	1.47
5.00	7.90	0.93
7.50	8.85	0.63
10.00	9.60	0.42
15.00	10.69	0.15
20.00	11.36	0.03
30.00	11.70	0.00
40.00	11.40	0.00
50.00	10.52	0.00
60.00	9.15	0.00
70.00	7.35	0.00
80.00	5.22	0.00
90.00	2.80	0.00
95.00	1.49	0.00
100.00	0.12	0.00
Leading edge radius = 1.50		

Cut-off Clark Y		
Ordinates		
(Per cent basic chord)		
Sta.	Upper	Lower
0	-	-
1.85	1.65	1.65
2.50	a	1.47
5.00	a	0.93
7.50	a	0.63
10.00	a	0.42
13.00	10.07	-
15.00	10.69	0.15
20.00	11.36	0.03
30.00	11.70	0.00
40.00	11.40	0.00
50.00	10.52	0.00
60.00	9.15	0.00
70.00	7.35	0.00
80.00	5.22	0.00
90.00	2.80	0.00
95.00	1.49	0.00
100.00	0.12	0.00

Slat		
Ordinates		
(Per cent slat chord)		
Sta.	Upper	Lower
0	11.60	11.60
1.25	15.80	7.24
2.50	17.70	4.56
5.00	19.85	0.00
7.50	21.00	1.30
10.00	21.60	2.43
15.00	22.55	4.60
20.00	23.15	6.35
30.00	23.20	9.27
40.00	22.10	10.94
50.00	20.05	11.66
60.00	17.25	11.35
70.00	13.78	10.14
80.00	10.00	7.73
90.00	5.68	4.38
95.00	3.52	2.12
100.00	1.20	0.00

Fig.1 Cross section and ordinates of Clark Y wing with Handley Page slot.

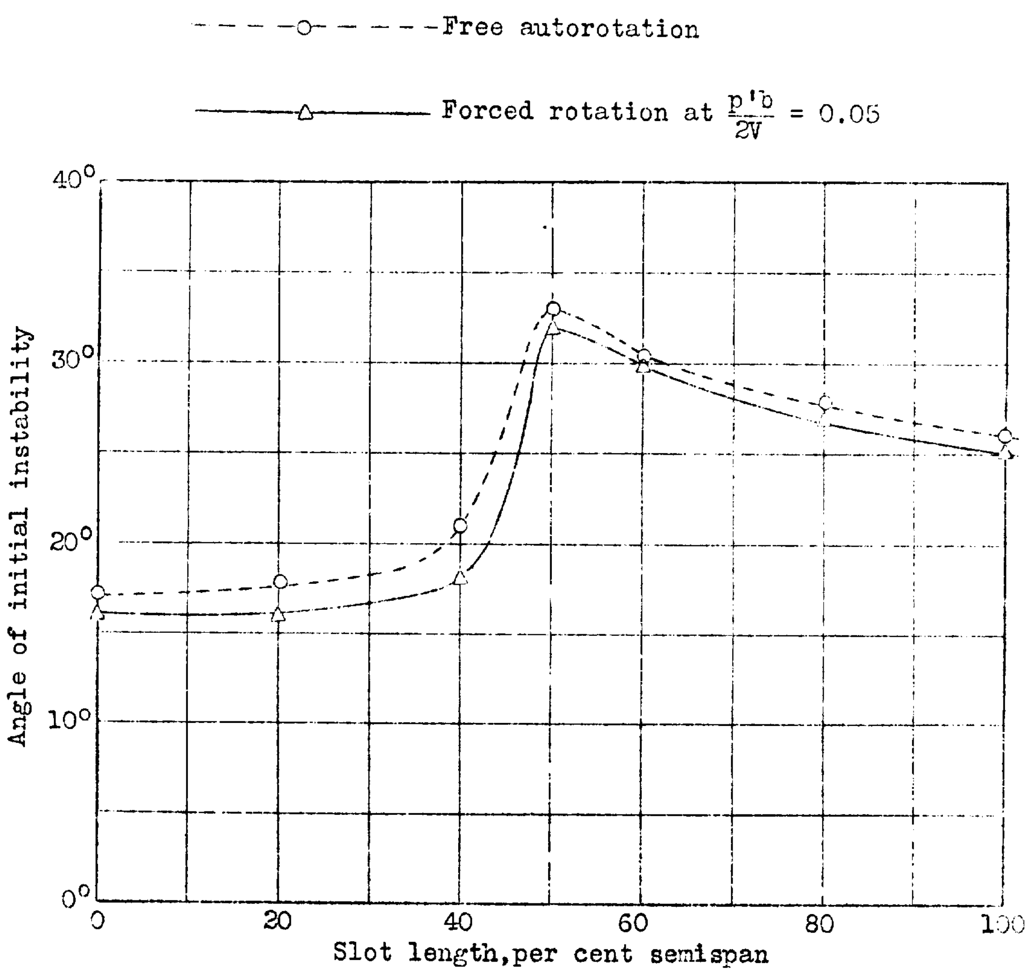


Fig.2 Angles of attack above which autorotational tendency exists. Clark Y wing with Handley Page type slots.

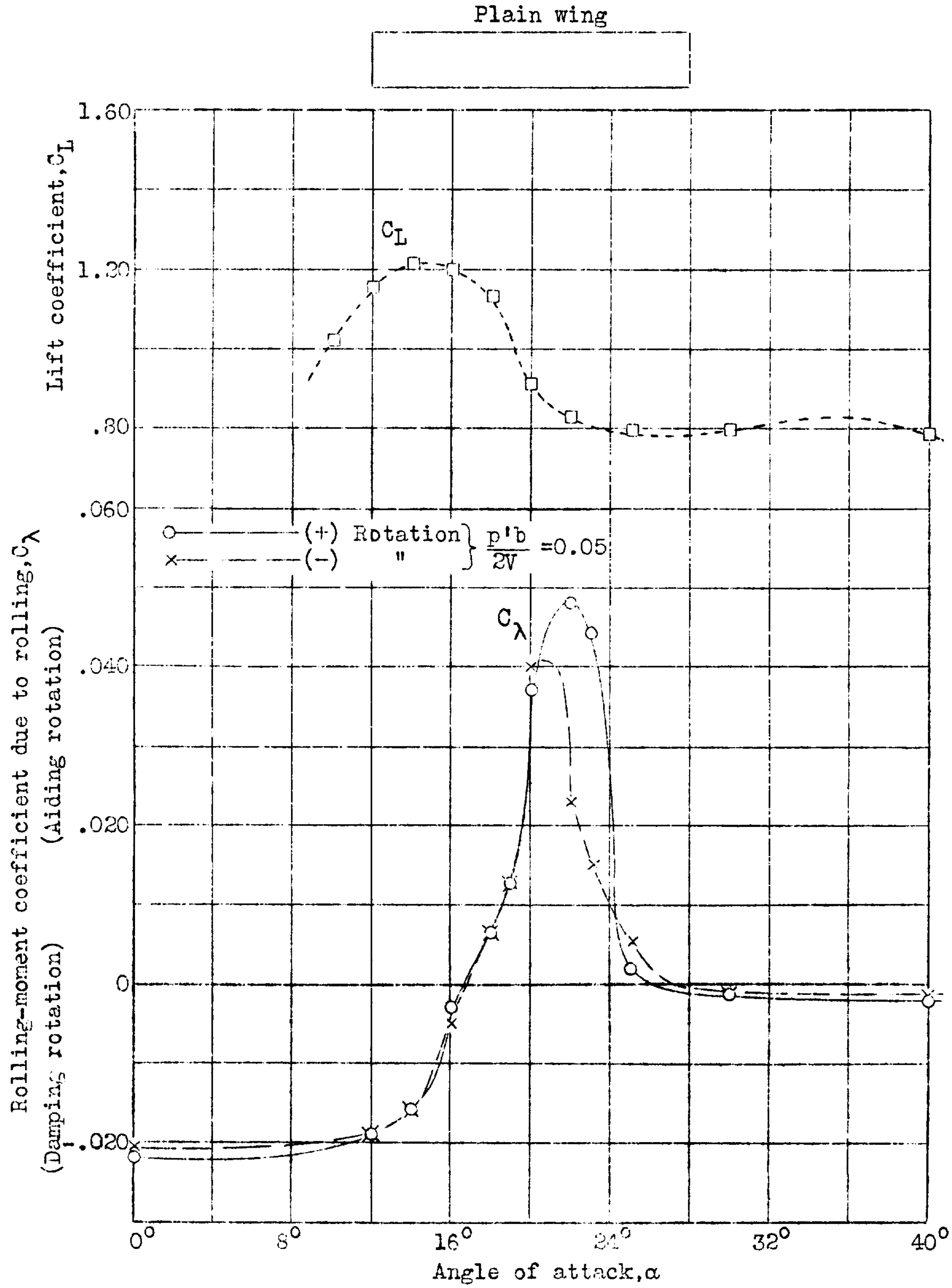


Fig.3 Damping in roll of plain Clark Y wing.

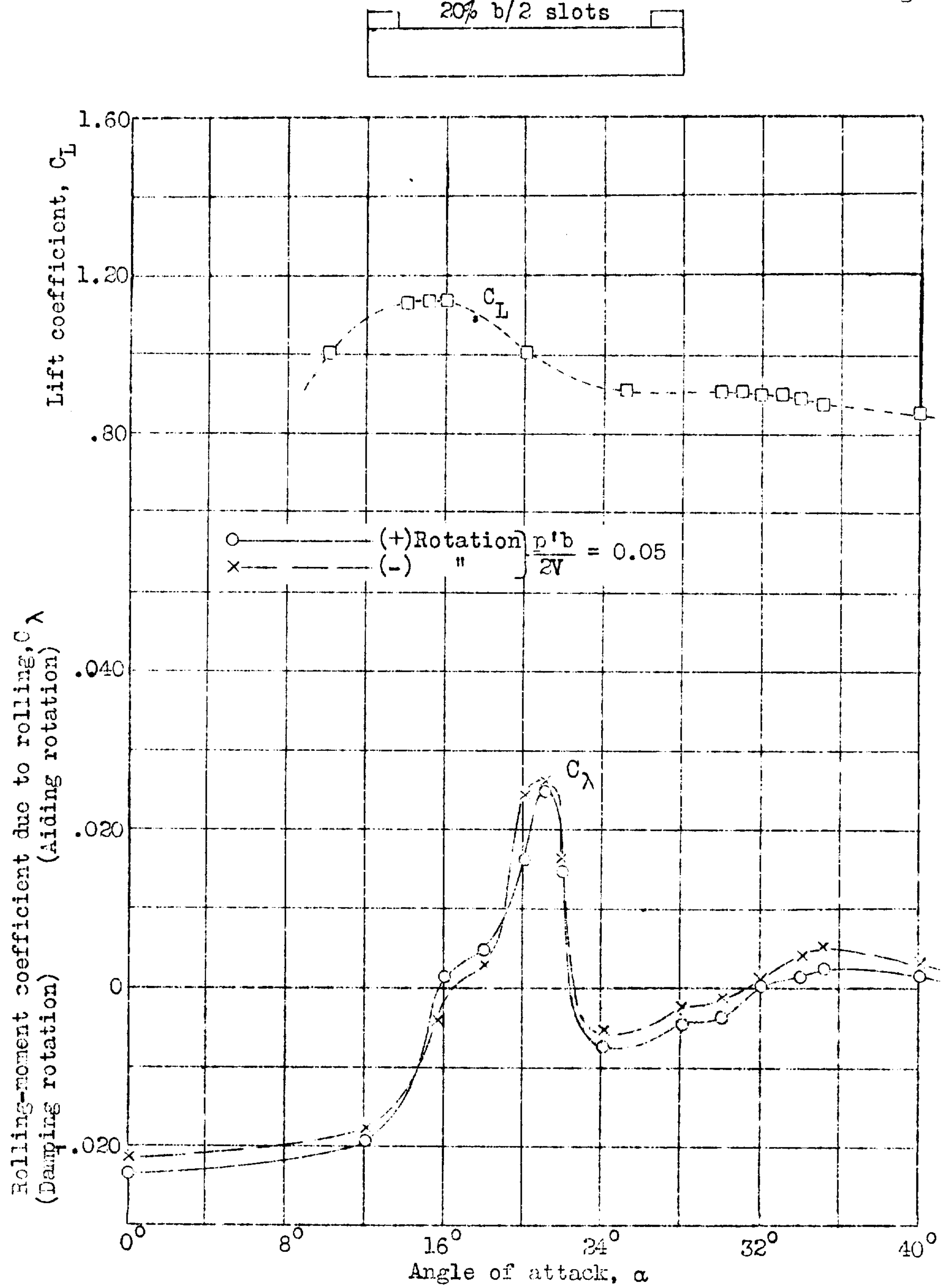


Fig.4 Effect of 20 per cent b/2 tip slots on damping in roll.

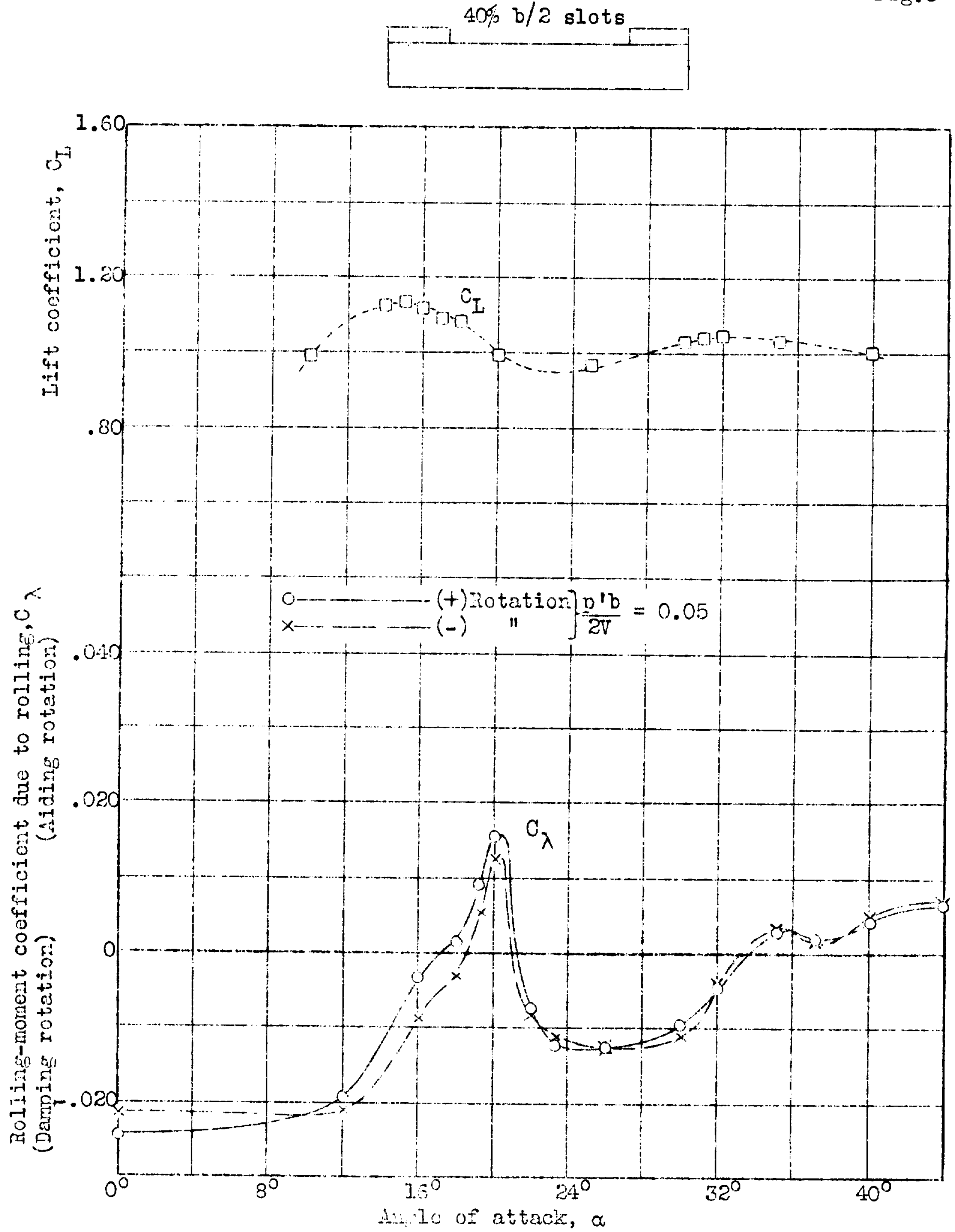


Fig.5 Effect of 40 per cent b/2 tip slots on damping in roll.

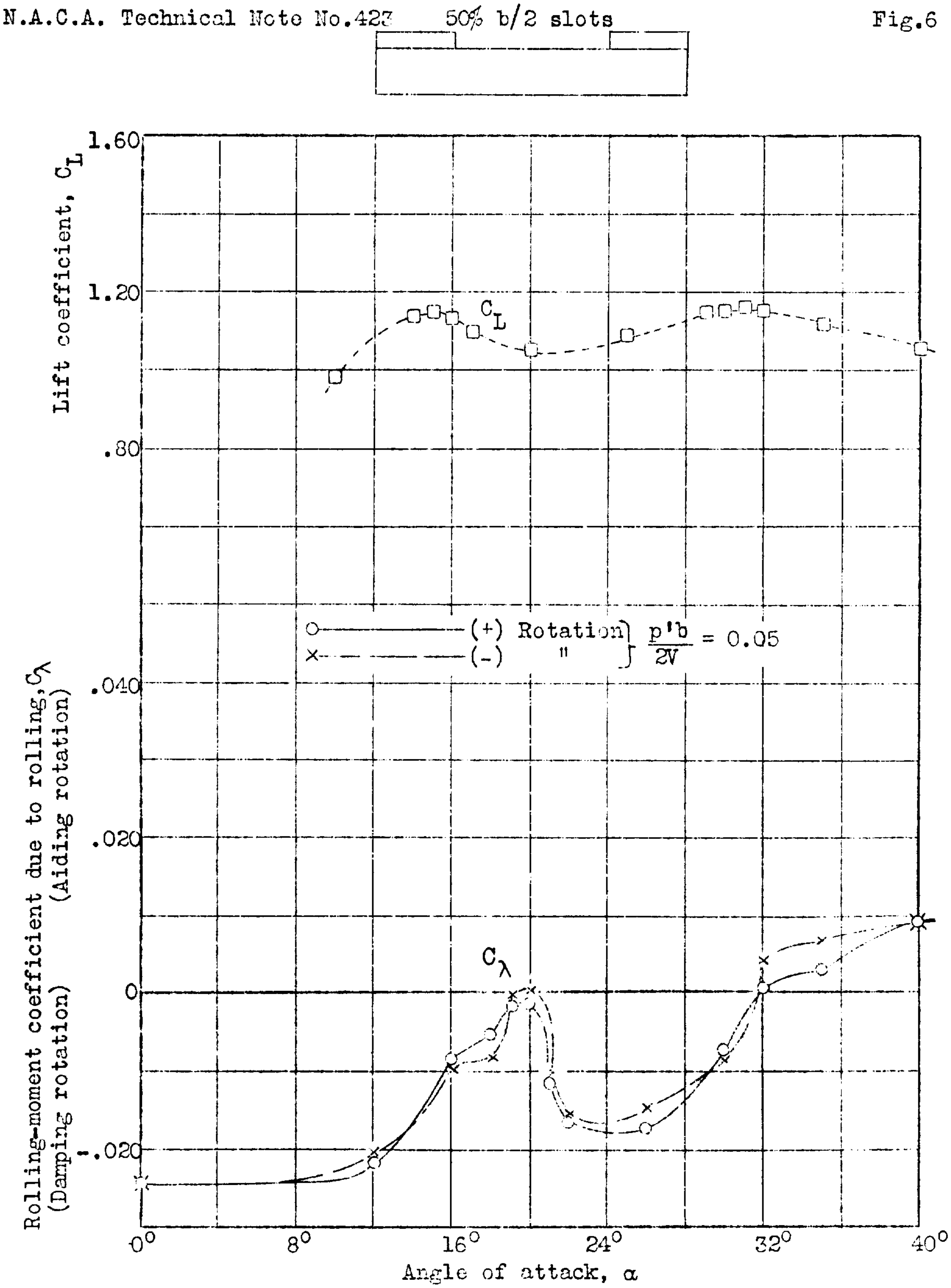


Fig.6 Effect of 50 per cent b/2 tip slots on damping in roll.

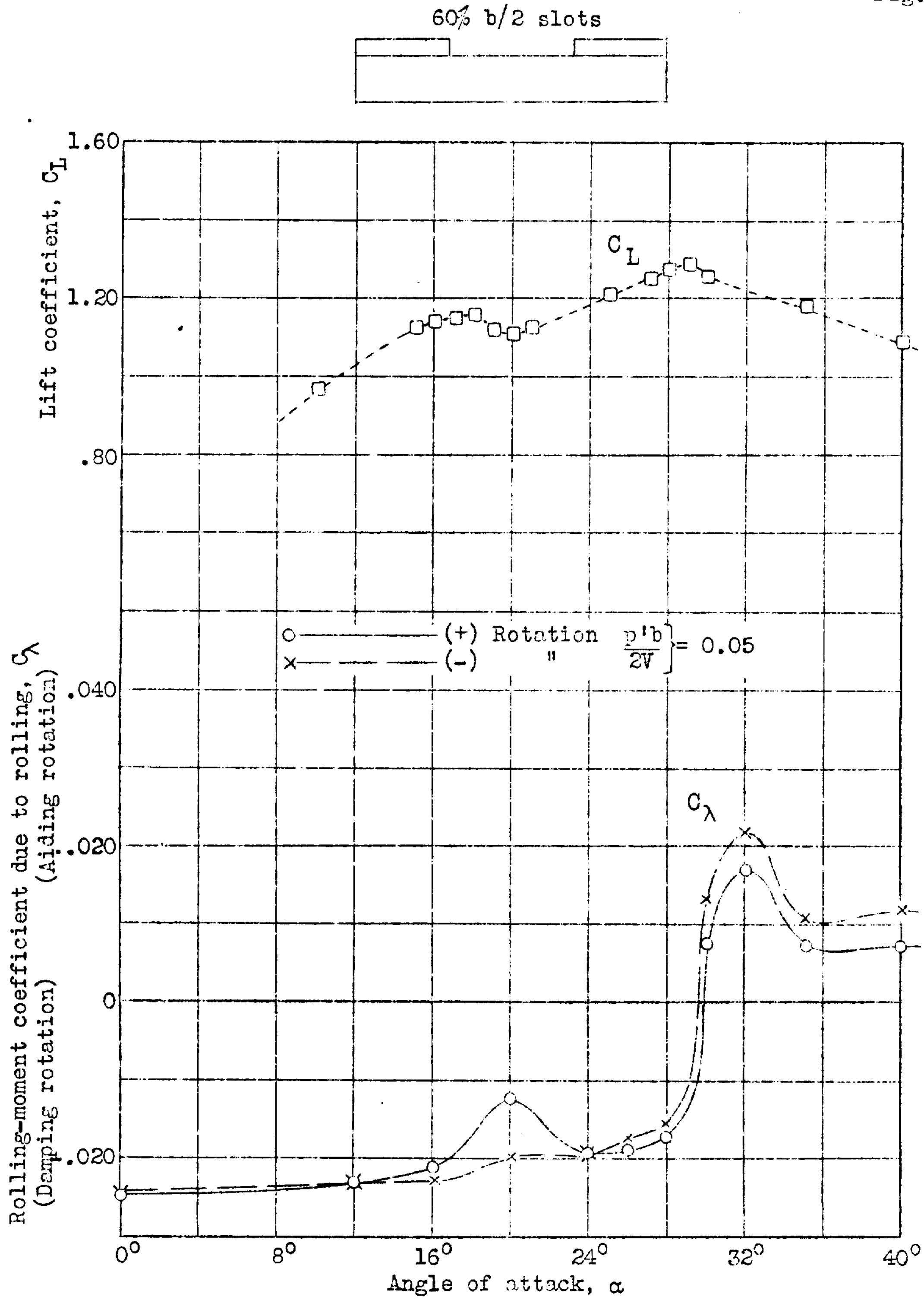


Fig.7 Effect of 60 per cent b/2 tip slots on damping in roll.

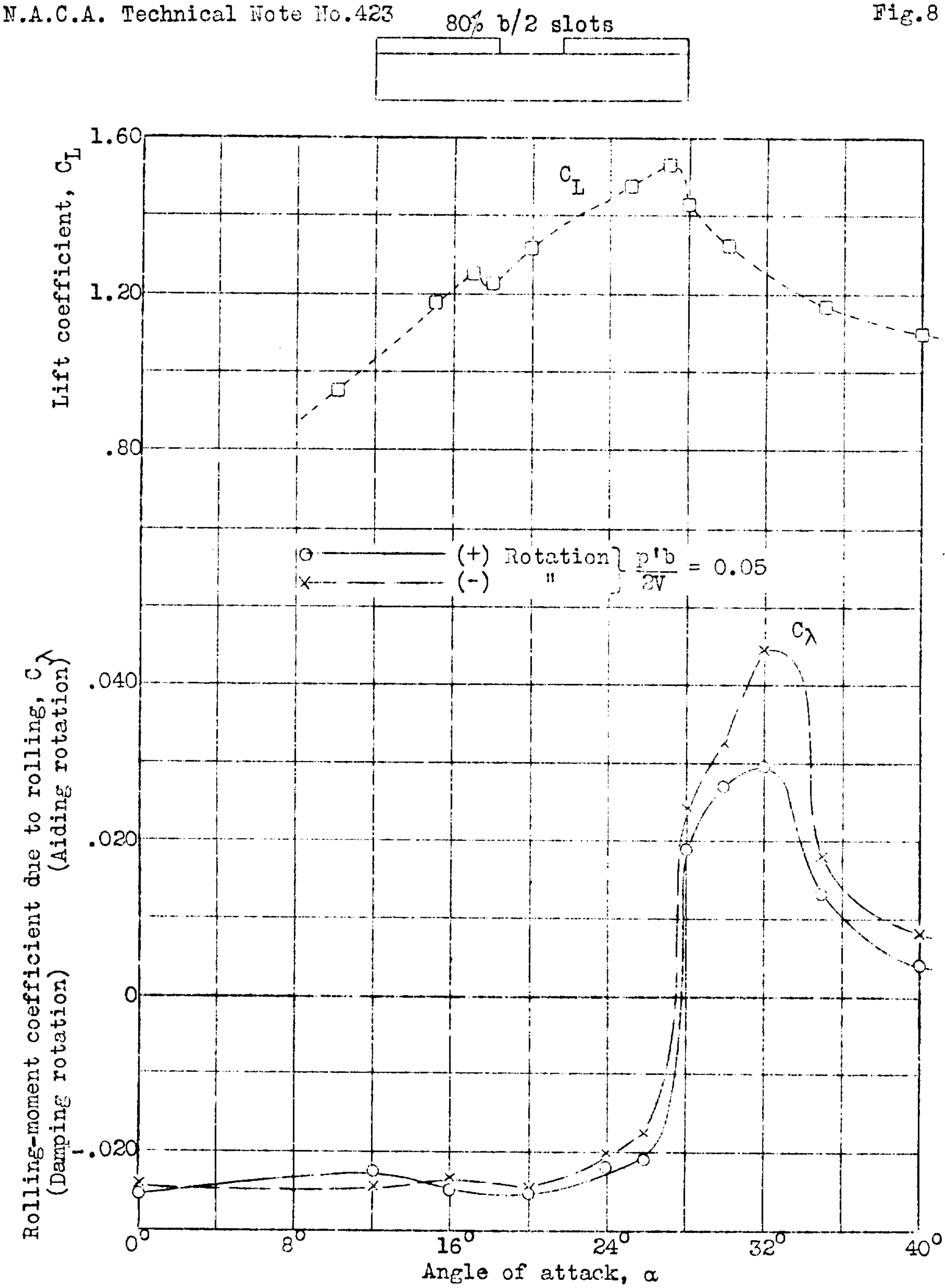


Fig.8 Effect of 80 per cent b/2 tip slots on damping in roll.

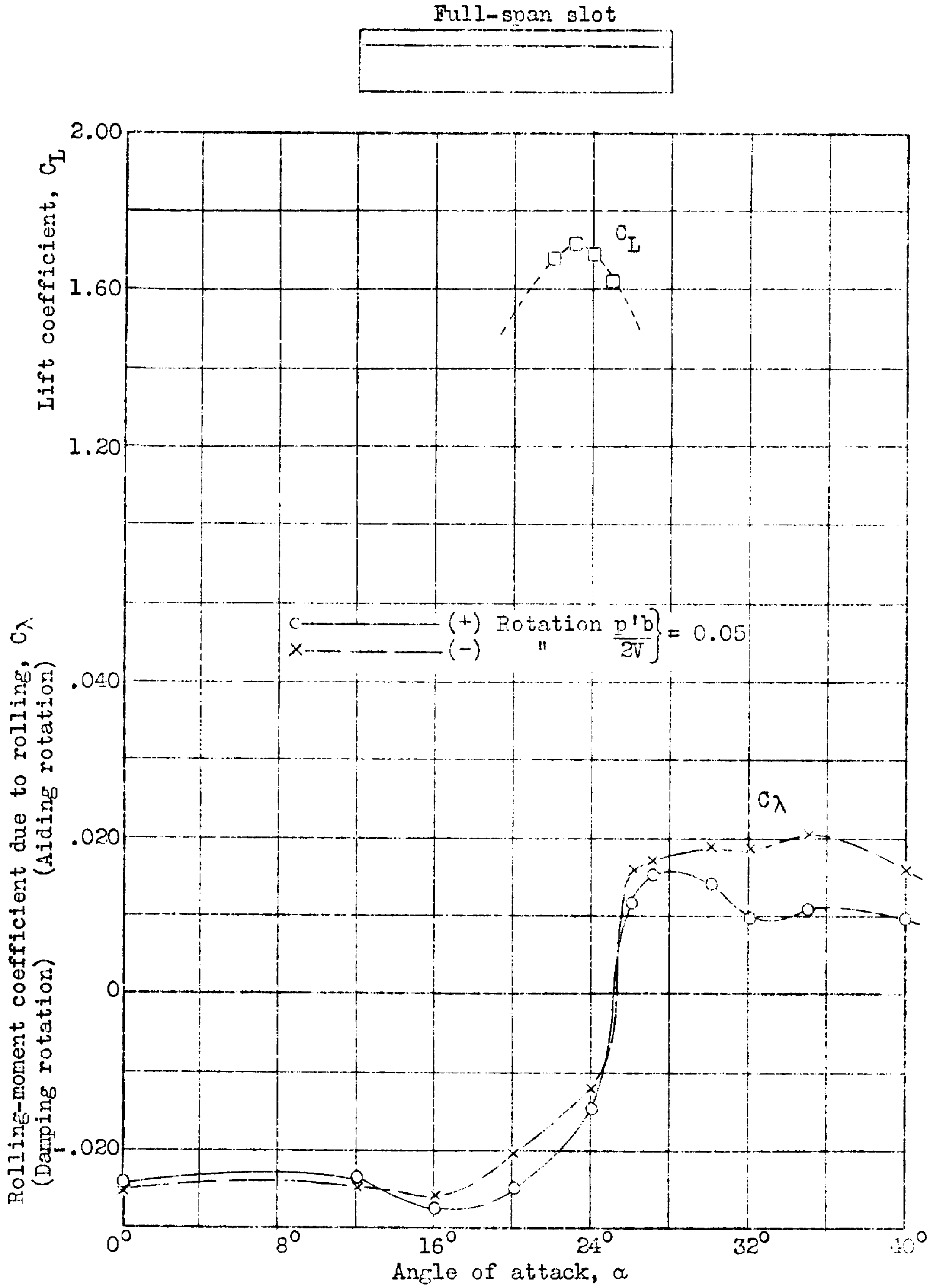


Fig.9 Effect of full-span slot on damping in roll.

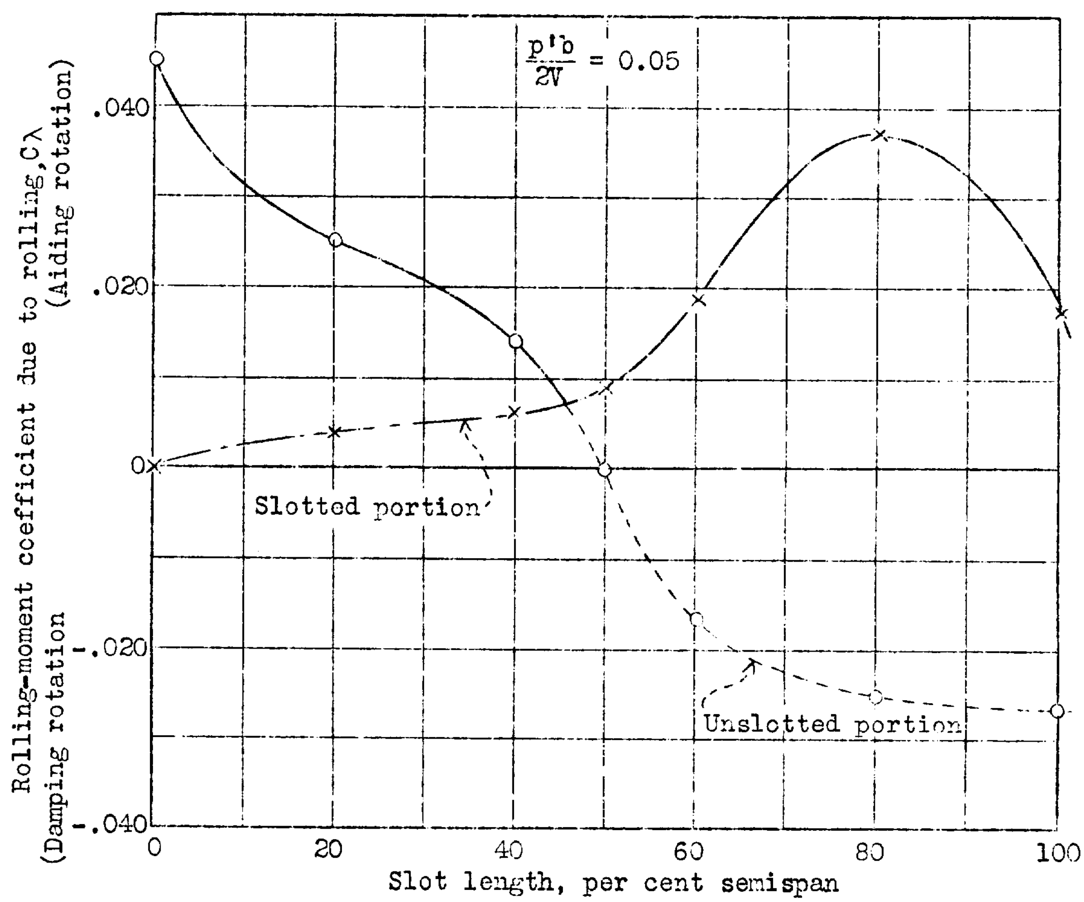


Fig.10 Maximum coefficients of rolling moment due to rolling at the angles of attack corresponding to stalls of slotted and unslotted portions of wing.

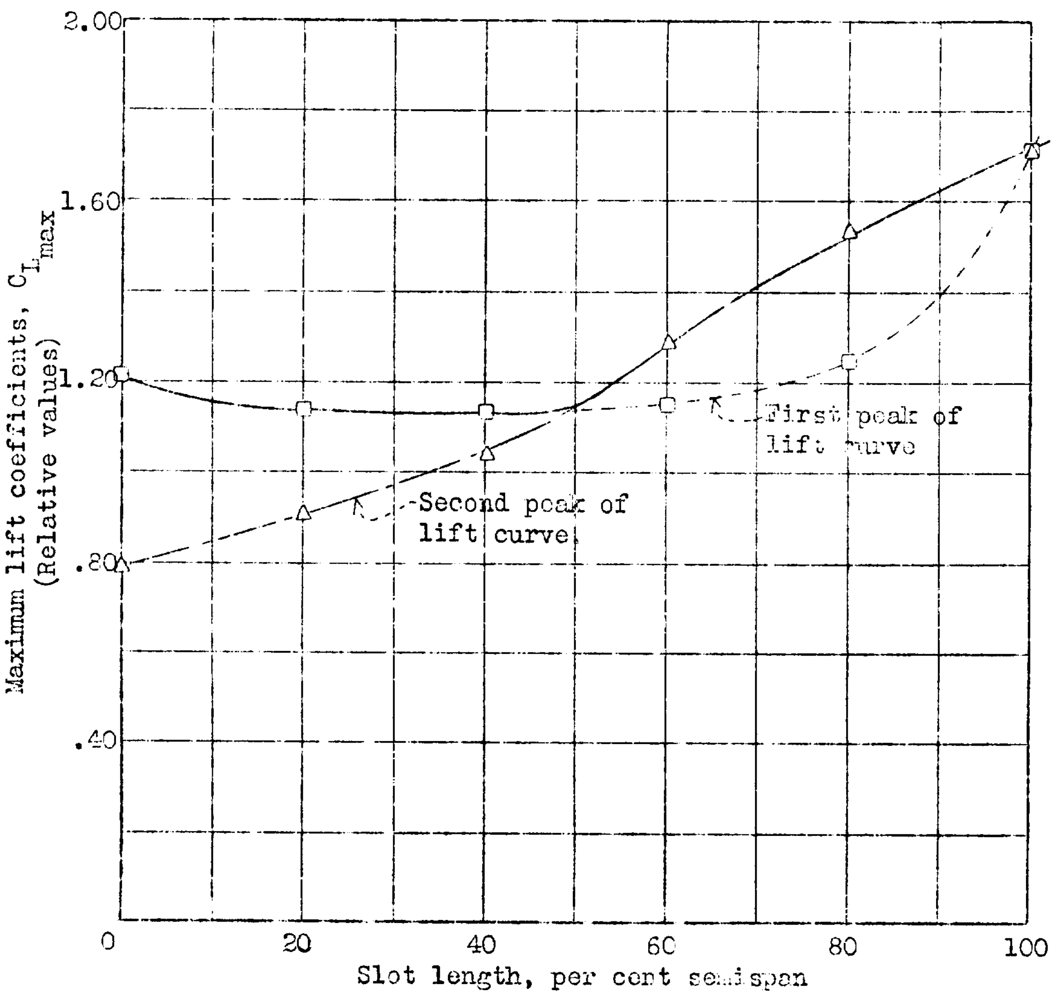


Fig.11 Effect of slot length on the maximum lift coefficients.