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RESEARCH MEMORANDUM

THE TWISTING EFFECT AT TRANSONIC SPEEDS OF SPOILER AILERONS ON A 45° SWEPTBACK, ASPECT-RATIO-4, TAPERED WING

By Alexander D. Hammond and Jean C. Graven, Jr.

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RESEARCH MEMORANDUM

THE TWISTING EFFECT AT TRANSONIC SPEEDS OF SPOILER AILERONS ON A 45° SWEPTBACK, ASPECT-RATIO-4, TAPERED WING

By Alexander D. Hammond and Jean C. Graven, Jr.

SUMMARY

An investigation was made at transonic speeds in the Langley high-speed 7- by 10-foot tunnel to determine the effect of the projection of various-span inboard spoiler ailerons along the 70-percent-chord line on the twisting moment and other aerodynamic characteristics of a solid-steel 45° sweptback wing. The investigation was extended through the transonic speed range by testing in the high-velocity field over a reflection plane on the side wall of the tunnel.

The twisting-moment coefficient about the 20-percent-chord line resulting from projection of an inboard spoiler aileron of any span (including full span) depended only on the incremental lift produced by the spoiler. The chordwise location of the centers of pressure resulting from projection of an inboard spoiler aileron of any span was little affected by change in Mach number near zero angle of attack but moved forward with increase in Mach number for angles of attack above about 6°. The chordwise location of the centers of pressure moved toward the trailing edge of the wing with increase in angle of attack up to approximately 4° and moved forward with further increase in angle of attack at all Mach numbers. The magnitude of the incremental lift and twisting-moment coefficients and of the rolling-moment coefficient increased with increase in span for spoiler ailerons having spans up to 80 percent of the semispan.

INTRODUCTION

The use of spoiler-type ailerons on highly swept thin wings looks attractive from both the hinge-moment and wing flexibility points of view. Considerable work has been done in determining the effectiveness of various types and locations of spoilers on both unswept and swept wings (refs. 1 to 5). Very little work has been done in determining the aerodynamic loads resulting from spoiler-aileron projection, particularly at transonic speeds. This paper presents the results of an

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investigation, made at transonic speeds in the Langley high-speed 7- by 10-foot tunnel, to determine the aerodynamic twist about the 20-percent-chord line caused by projection of various-span inboard spoiler ailerons. The wing used in this investigation had a sweepback of 45° at the quarter-chord line, an aspect ratio of 4.0, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the free airstream. The various-span, inboard spoiler ailerons used were projected to a height of 10 percent of the local wing chord, along the 70-percent-chord line. It should be noted that the spoiler aileron of this investigation does not necessarily represent the best spoiler configuration; however, this wing and spoiler configuration are representative of configurations that might be used in high-speed flight. It is felt, therefore, that the results of this investigation give the general trends of the variation of the twisting moment about the elastic axis resulting from projection of various-span inboard spoiler ailerons.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient, $\dfrac{\text{Twice lift of semispan model}}{qS}$

C_D drag coefficient, $\dfrac{\text{Twice drag of semispan model}}{qS}$

C_m pitching-moment coefficient referred to $0.25\bar{c}$

$$\frac{\text{Twice pitching moment of semispan model}}{qS\bar{c}}$$

C_{m_t} twisting-moment coefficient about the 20-percent-chord line,

$$\frac{\text{Twisting moment of semispan model about } 0.20c}{qS\bar{c}}$$

C_l rolling-moment coefficient,

$$\frac{\text{Rolling moment of wing with spoiler} - \text{Rolling moment of plain wing}}{qSb}$$

C_n yawing-moment coefficient,

$$\frac{\text{Yawing moment of wing with spoiler} - \text{Yawing moment of plain wing}}{qSb}$$

q effective dynamic pressure over span of model, $\frac{1}{2}\rho V^2$, lb/sq ft

S twice area of semispan model, 0.125 sq ft

$\bar{c}$ mean aerodynamic chord of wing, 0.1805 ft on model, $\frac{2}{S}\int_0^{b/2} c^2 dy$

c local wing chord, ft

b twice span of semispan model, 0.7071 ft

y spanwise distance from plane of symmetry, ft

ρ mass density of air, slugs/cu ft

V average free-stream air velocity, fps

M effective Mach number over span of model

M_a average chordwise local Mach number

M_l local Mach number

R Reynolds number of model based on $\bar{c}$

α angle of attack, deg

Δ increment caused by spoiler-aileron projection

A aspect ratio, b^2/S, 4.0 on model

The forces and moments on the wing are presented relative to the axes shown in figure 1. Wing twisting moments were measured about an axis which corresponds to the 20-percent-chord line. All other forces and moments and the angles of attack were measured relative to the wind axes (fig. 1) which intersect at the plane of symmetry and the chord plane of the wing at the 25-percent-mean-aerodynamic-chord station as shown in figure 2.

MODEL AND APPARATUS

The semispan wing used in this investigation had 45° of sweepback of the quarter-chord line, an aspect ratio of 4.0, a taper ratio of 0.6,

and an NACA 65A006 airfoil section parallel to the free stream. The wing was made of steel and was constructed to the plan-form dimensions in figure 2.

The spoilers were made of brass and were soldered along the 70-percent-chord line. The spoilers had a projection of 10 percent of the local wing chord and various spans from 0.20b/2 to 1.00b/2 (fig. 3).

The data were obtained in the Langley high-speed 7- by 10-foot tunnel with the model mounted on the tunnel side wall in a manner similiar to that of the model shown in figure 4. The model was mounted to an electrical strain-gage balance through a slot in the reflection-plane turntable; this slot was sealed with a sponge-rubber-wiper seal glued to the turntable to reduce the leakage around the wing butt. The forces and moments were recorded by means of a recording galvanometer.

TESTS

The tests were made in the Langley high-speed 7- by 10-foot tunnel. Typical contours showing the Mach number distribution over the side-wall reflection plane in the vicinity of the model are presented in figure 5. Effective test Mach numbers were obtained from contour charts similiar to those in figure 5 by the relationship $M = \frac{2}{S}\int_0^{b/2} cM_a \, dy$.

For these tests a Mach number gradient generally less than 0.02 was obtained below a Mach number of 0.95, and the gradient increased to 0.05 at the higher test Mach numbers.

Force and moment measurements were made for the model through an angle-of-attack range of -5° to 10° measured in a plane perpendicular to a normal axis through the quarter-chord point of the mean aerodynamic chord. These measurements were obtained from a Mach number of 0.61 to 1.09. The variation of Reynolds number with Mach number is presented in figure 6.

In view of the small size of the wing relative to the tunnel test section, jet-boundary and blockage corrections were believed to be insignificant and were not applied to the data. No reflection-plane corrections were applied to the data of this investigation.

RESULTS AND DISCUSSION

The variations of the incremental lift, drag, pitching-moment, and twisting-moment coefficients with spoiler span for various inboard spoiler ailerons are presented in figures 7 to 10, respectively. The variation of the rolling-moment and yawing-moment coefficients with spoiler span are presented in figures 11 and 12, respectively.

The data of figures 7 to 12 indicate that for the Mach number and angle-of-attack range investigated, an increase in spoiler span results in an increase in the magnitude of the incremental lift, drag, and twisting-moment coefficients and in the rolling-moment coefficient for spoiler spans up to 0.80b/2. Spoilers having spans greater than 0.80b/2 gave values of these coefficients about the same or slightly less than those for the 0.80b/2 span spoilers. An increase in spoiler span up to 0.20b/2 results in an increasingly more negative incremental pitching-moment coefficient ΔC_m; further increase in spoiler span generally resulted in an increasingly more positive ΔC_m (fig. 9). The magnitude of the yawing-moment coefficient increased with increase in spoiler span for all spoiler spans investigated.

The variation of the incremental twisting-moment coefficient with incremental lift coefficient are presented in figure 13 for various-span inboard spoiler ailerons. The incremental twisting moments presented and discussed herein represent the change in twisting moment about an axis corresponding to the 20-percent-chord line resulting from deflection of the various-span inboard ailerons on a rigid wing. It can be seen from figure 13 that there is a nearly linear variation of the incremental twisting-moment coefficient ΔC_{m_t} with incremental lift coefficient ΔC_L for all spoiler spans at a given angle of attack and Mach number in the angle of attack and Mach number ranges investigated. This indicates that the centers of pressure of the additional load resulting from projection of the various-span inboard spoiler ailerons lie at a constant distance from the 20-percent-chord line and that the twisting moment about this axis is dependent only on the incremental lift. For all practical purposes, therefore, the loci of the centers of pressures of the additional load for the various-span inboard spoiler ailerons may be considered to lie along a constant-percent-chord line. The chord line that is coincident with the loci of the centers of pressure varies with both angle of attack and Mach number.

Since the variation of ΔC_{m_t} with ΔC_L is nearly linear, the parameter $\frac{\partial \Delta C_{m_t}}{\partial \Delta C_L}$ gives the perpendicular distance in percent of $\bar{c}$ between the 20-percent-chord line and the loci of the centers of pressure of the

additional load resulting from projection of the various-span inboard spoiler ailerons. The variation of the parameter $\frac{\partial \Delta C_{m_t}}{\partial \Delta C_L}$ with angle of attack for various Mach numbers and with Mach number for various angles of attack is presented in figure 14. From figure 14 it can be seen that the loci of the centers of pressures move toward the trailing edge with increase in angle of attack up to approximately 4° and move forward with further increase in angle of attack for all Mach numbers. Near zero angle of attack there is little change in the chordwise location of the centers of pressure with change in Mach number; however, at angles of attack of 6° and above there is, in general, a forward movement of the loci of the centers of pressure of the various inboard spoiler ailerons with increase in Mach number (fig. 14).

CONCLUSIONS

An investigation was made in the Langley high-speed 7- by 10-foot tunnel to determine the effect on the twisting moment and other aerodynamic characteristics of various-span inboard spoiler ailerons on a solid-steel, 45° sweptback, aspect-ratio-4, taper-ratio-0.6 wing. The following conclusions may be drawn from the data:

1. At a given angle of attack and Mach number, the twisting moment resulting from projection of an inboard spoiler aileron of any span about the 20-percent-chord line or any other axis approximately parallel to the 20-percent-chord line depended only on the incremental lift produced by the spoiler.

2. The loci of the centers of pressure of the additional load resulting from projection of an inboard spoiler aileron of any span moved toward the trailing edge of the wing with increase in angle of attack up to approximately 4° and moved forward with further increase in angle of attack for all Mach numbers investigated.

3. At near zero angle of attack there was little change in the chordwise location of the centers of pressure of the additional load, resulting from projection of an inboard spoiler aileron of any span, with change in Mach number.

4. In the Mach number and angle-of-attack ranges investigated, an increase in spoiler span resulted in an increase in the magnitude of the

incremental lift and twisting-moment coefficients and in the rolling-moment coefficient for inboard spoiler ailerons having spans up to 80 percent semispan.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va. October 19, 1953.

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2. Hammond, Alexander D.: Lateral-Control Investigation of Flap-Type and Spoiler-Type Controls on a Wing With Quarter-Chord-Line Sweepback of 60°, Aspect Ratio 2, Taper Ratio 0.6, and NACA 65A006 Airfoil Section - Transonic-Bump Method. NACA RM L50E09, 1950.

3. Hammond, Alexander D., and Watson, James M.: Lateral-Control Investigation at Transonic Speeds of Retractable Spoiler and Plug-Type Spoiler-Slot Ailerons on a Tapered 60° Sweptback Wing of Aspect Ratio 2 - Transonic Bump Method. NACA RM L52F16, 1952.

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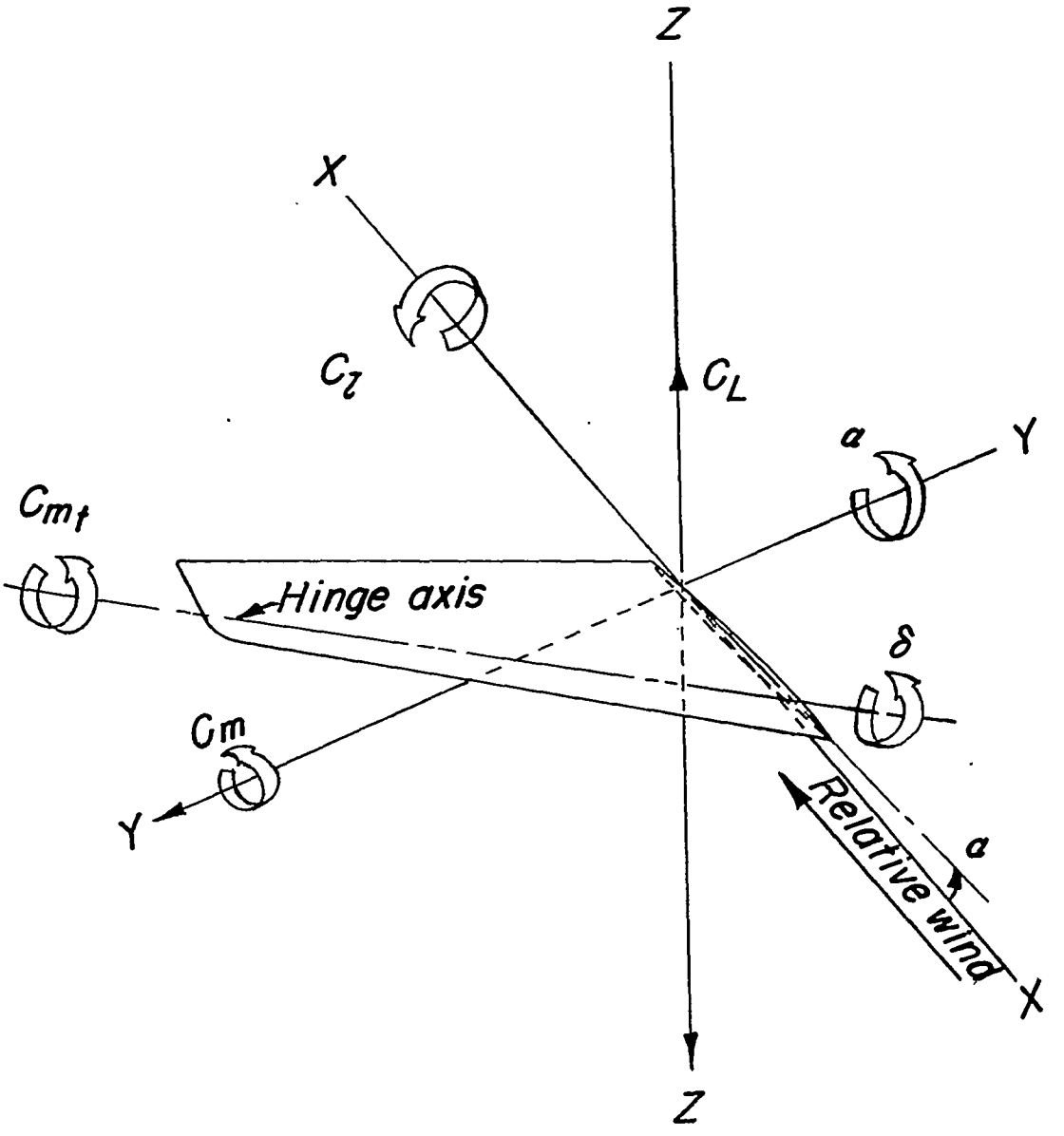

Figure 1.- System of axes, forces, moments, and deflection, positive directions denoted by arrows.

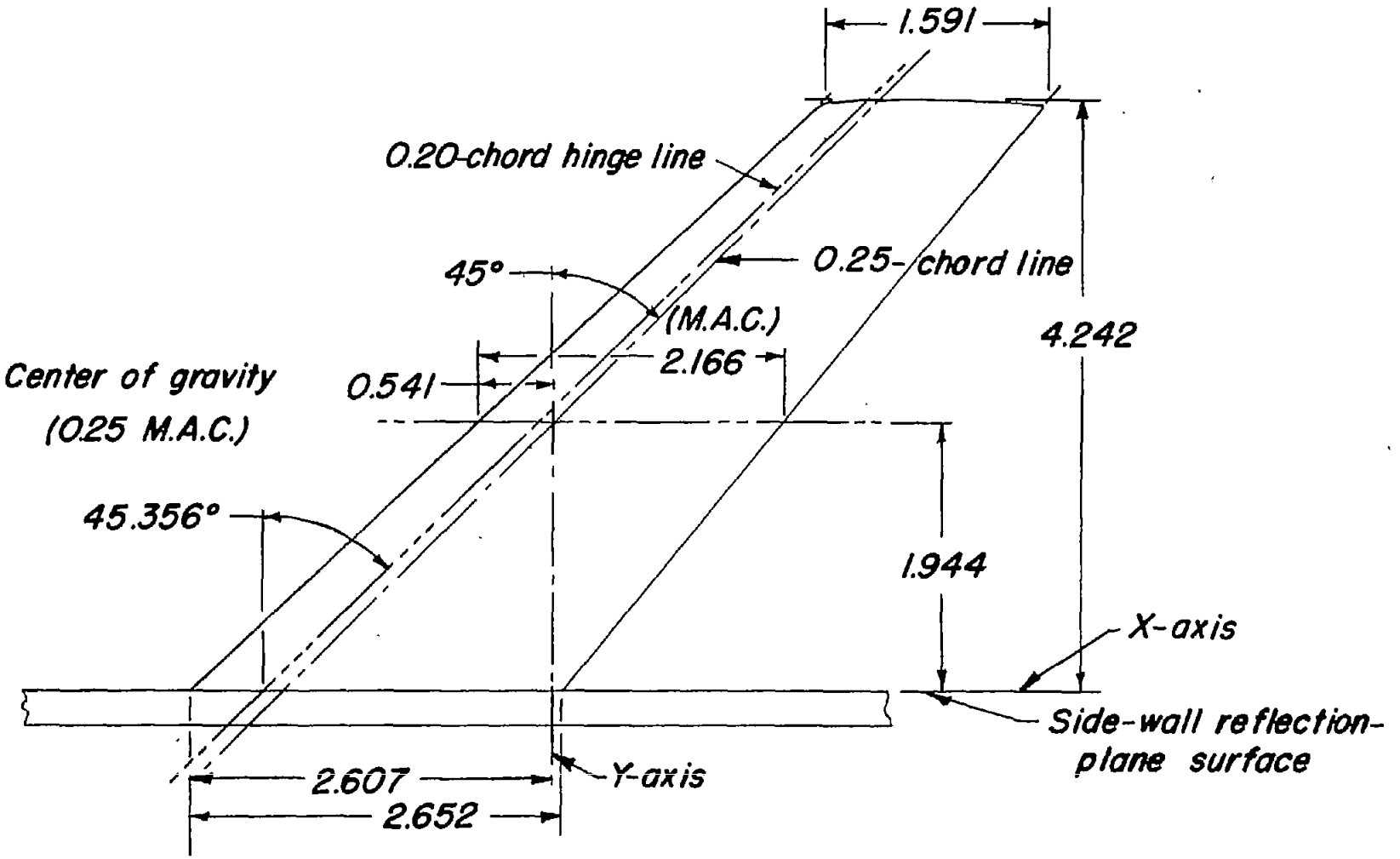

Figure 2.- Plan form and dimensions of the aspect-ratio-4, taper-ratio-0.6, 45° sweptback wing. All dimensions in inches unless otherwise noted.

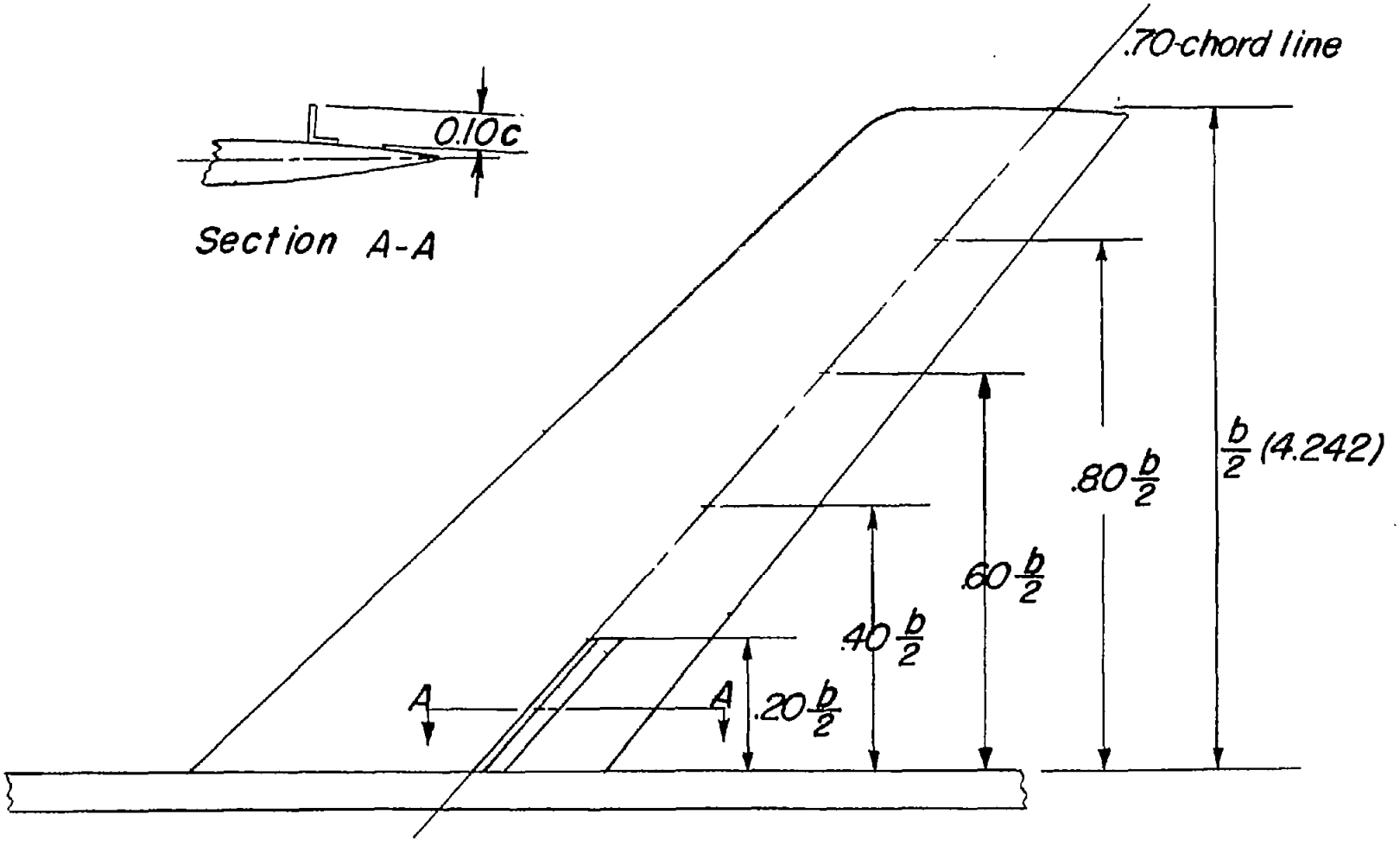

Figure 3.- Details of the various spoiler ailerons.

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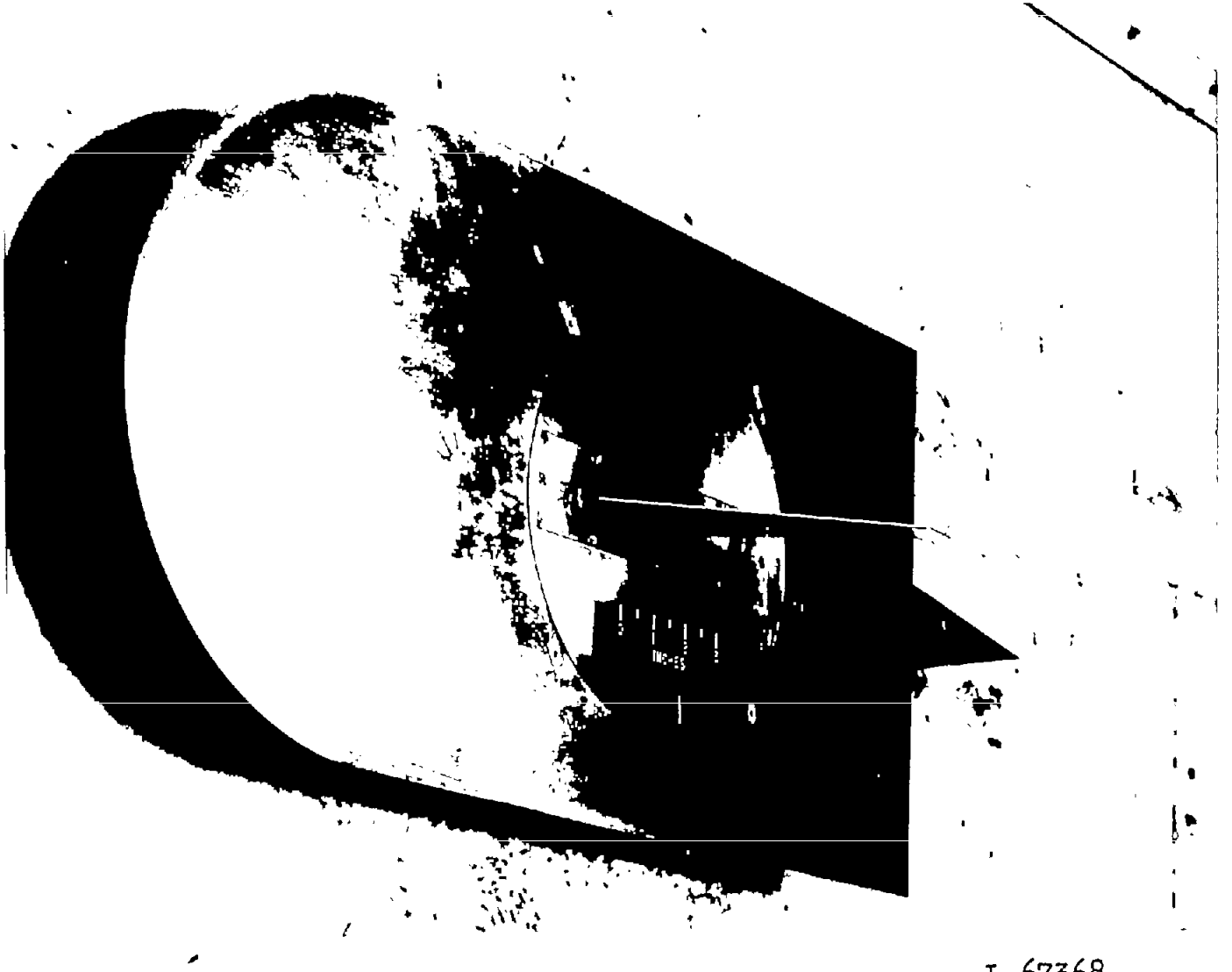

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Figure 4.- Typical side-wall model mounted in the Langley high-speed 7- by 10-foot tunnel.

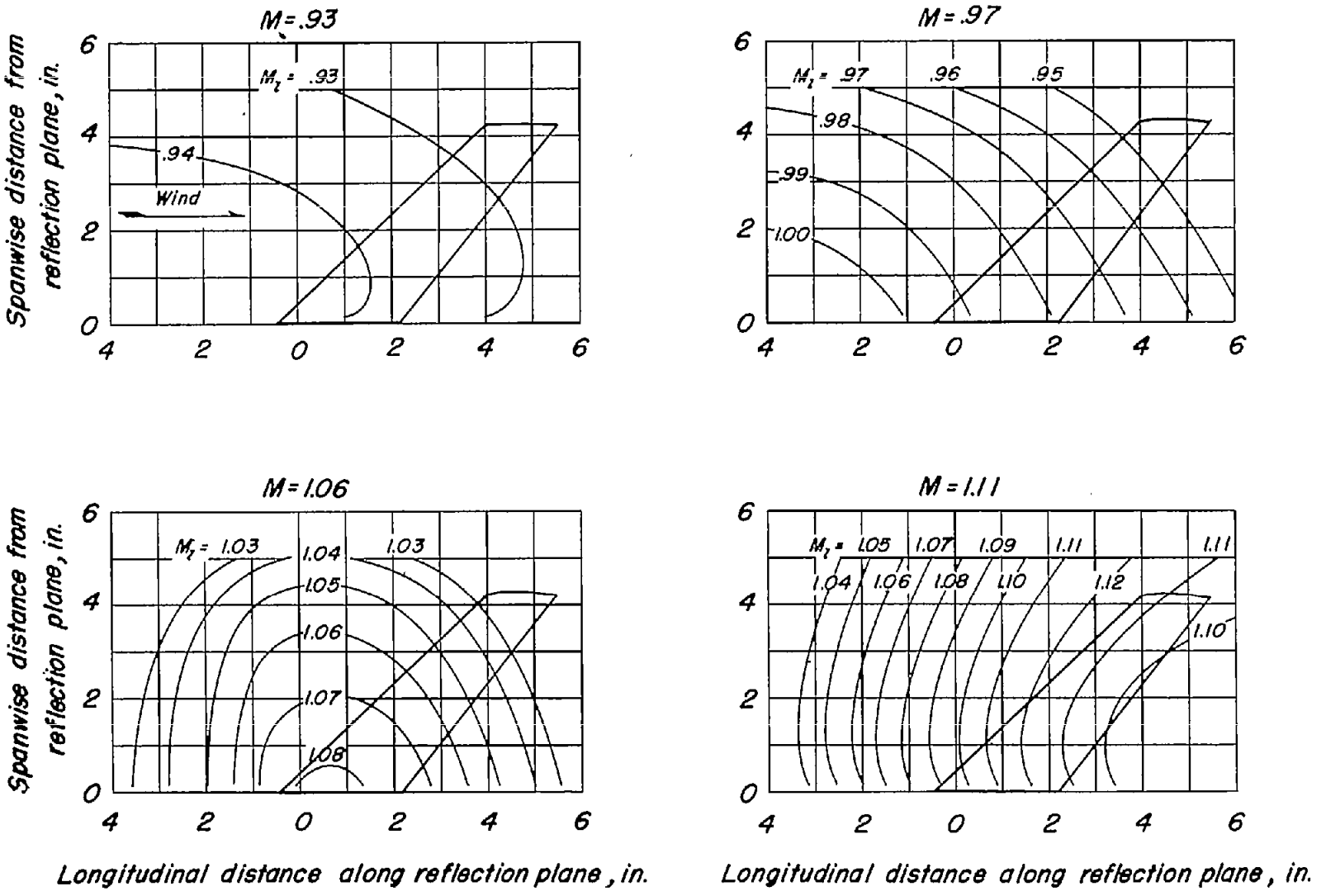

Figure 5.- Typical Mach number contours obtained over the 45° sweptback wing.

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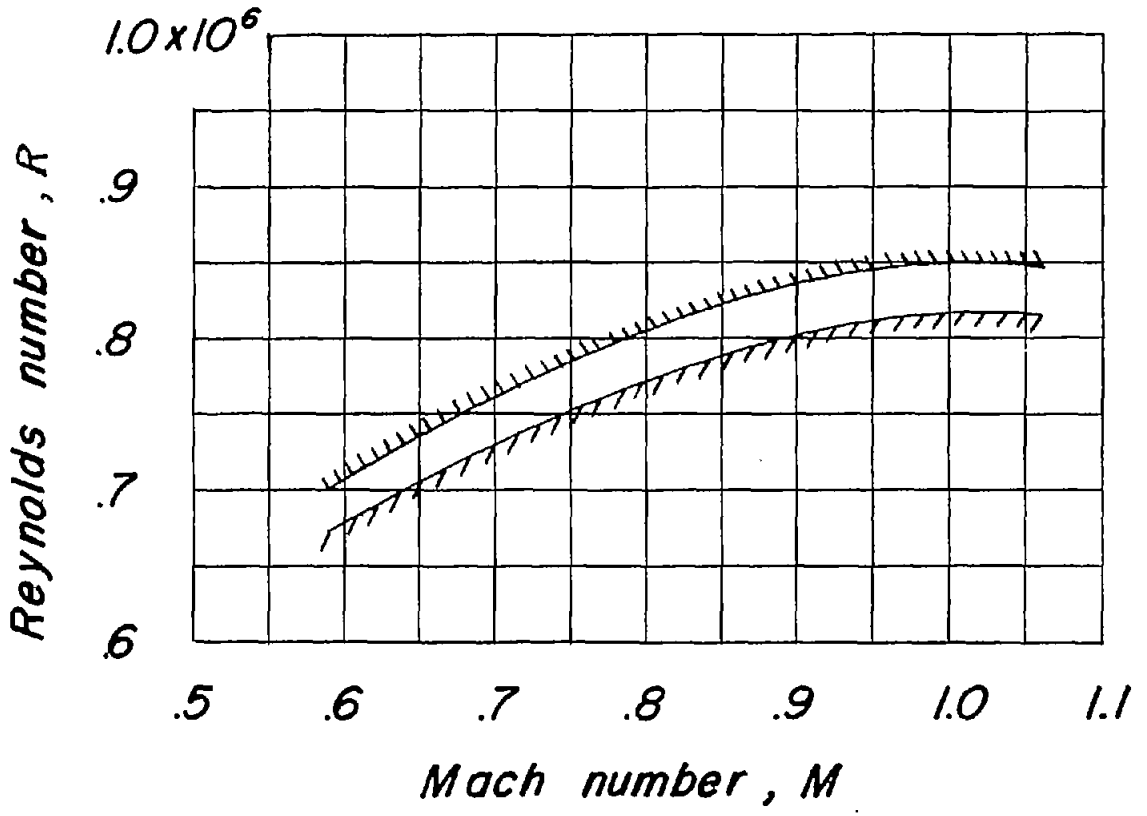

Figure 6.- The variation of Reynolds number with Mach number for tests of the 45° sweptback wing.

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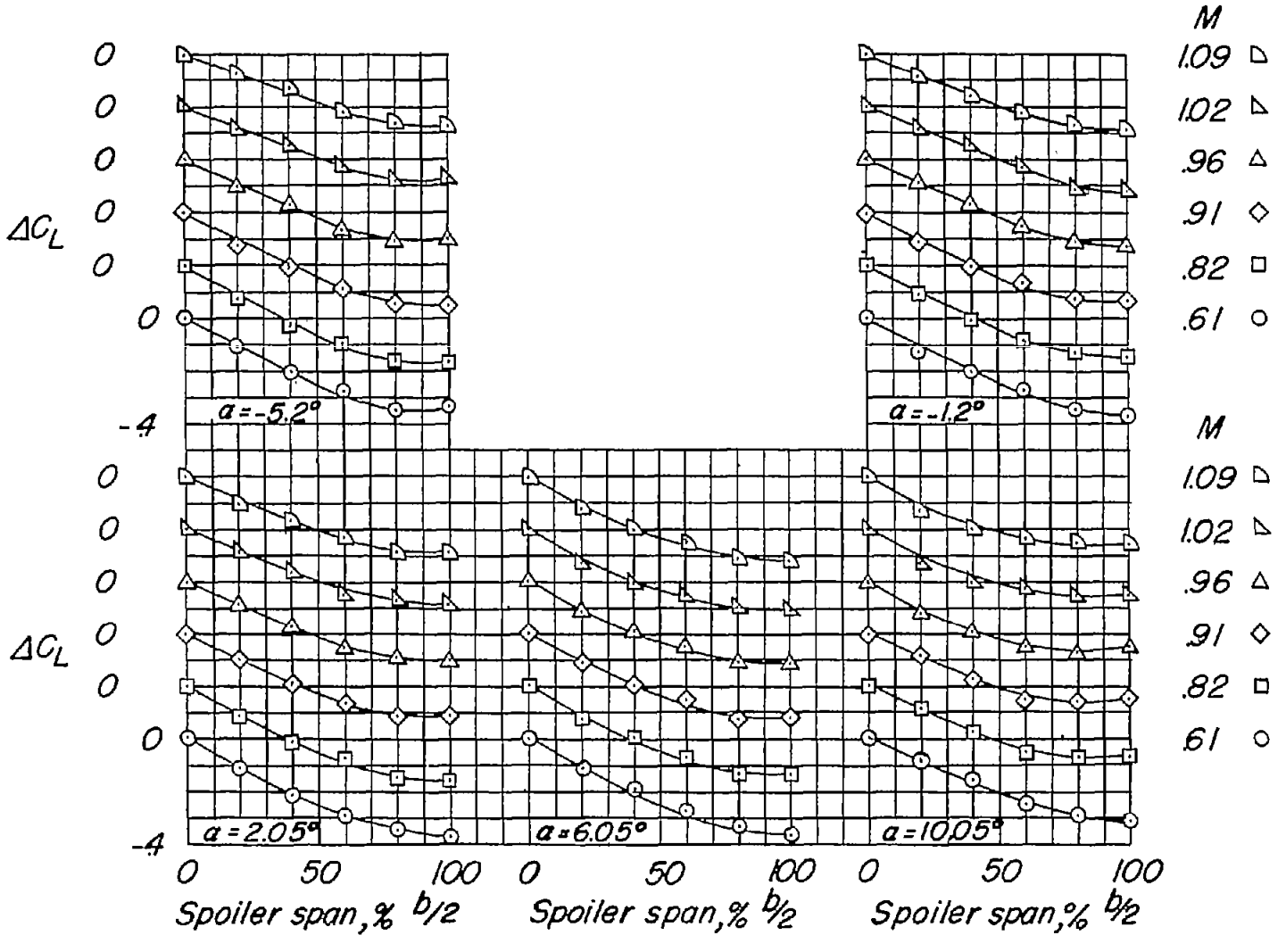

Figure 7.- The variation of the incremental lift coefficient with spoiler span at various Mach numbers and several angles of attack.

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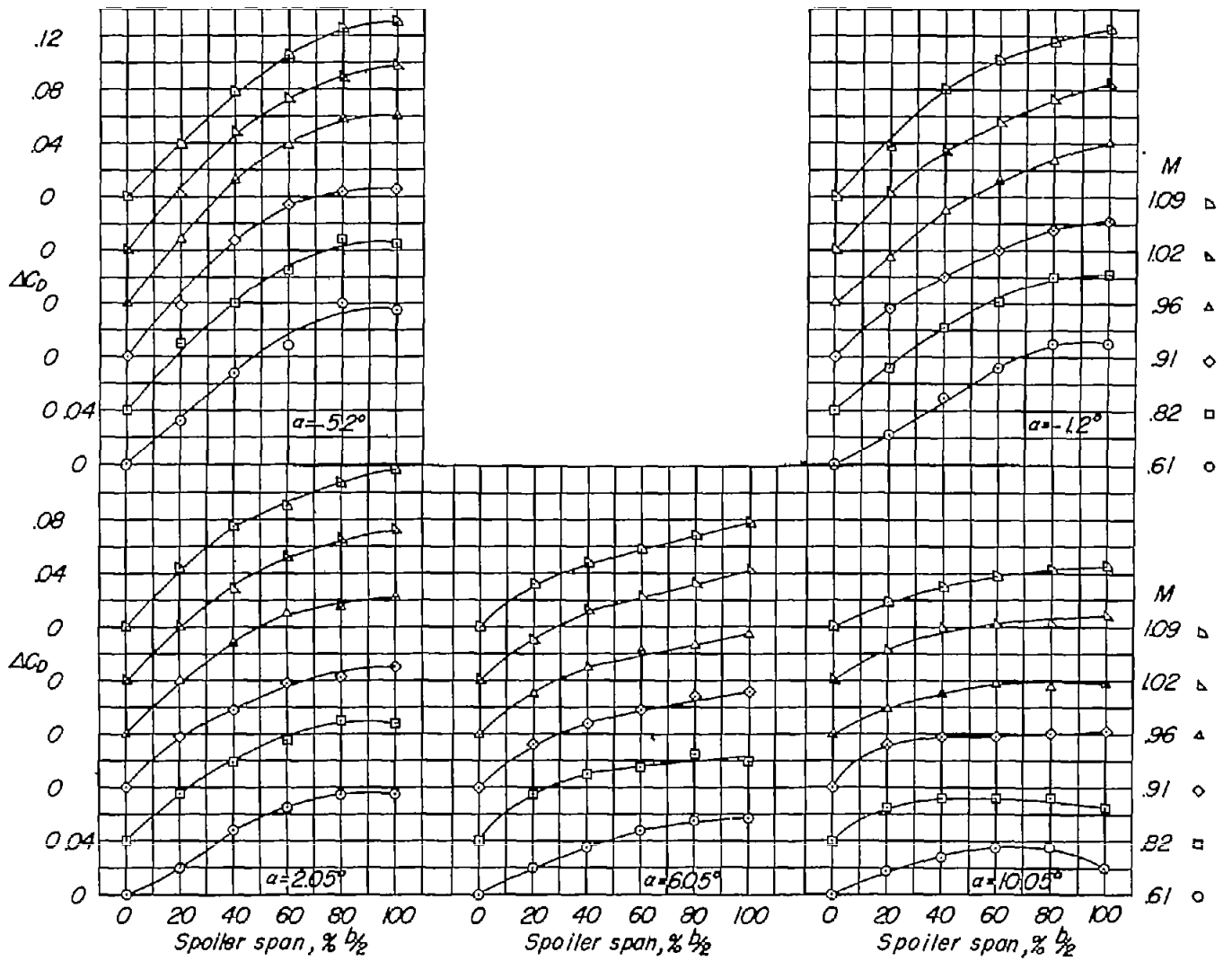

Figure 8.- The variation of incremental drag coefficient with spoiler span at various Mach numbers for several angles of attack.

[redacted]

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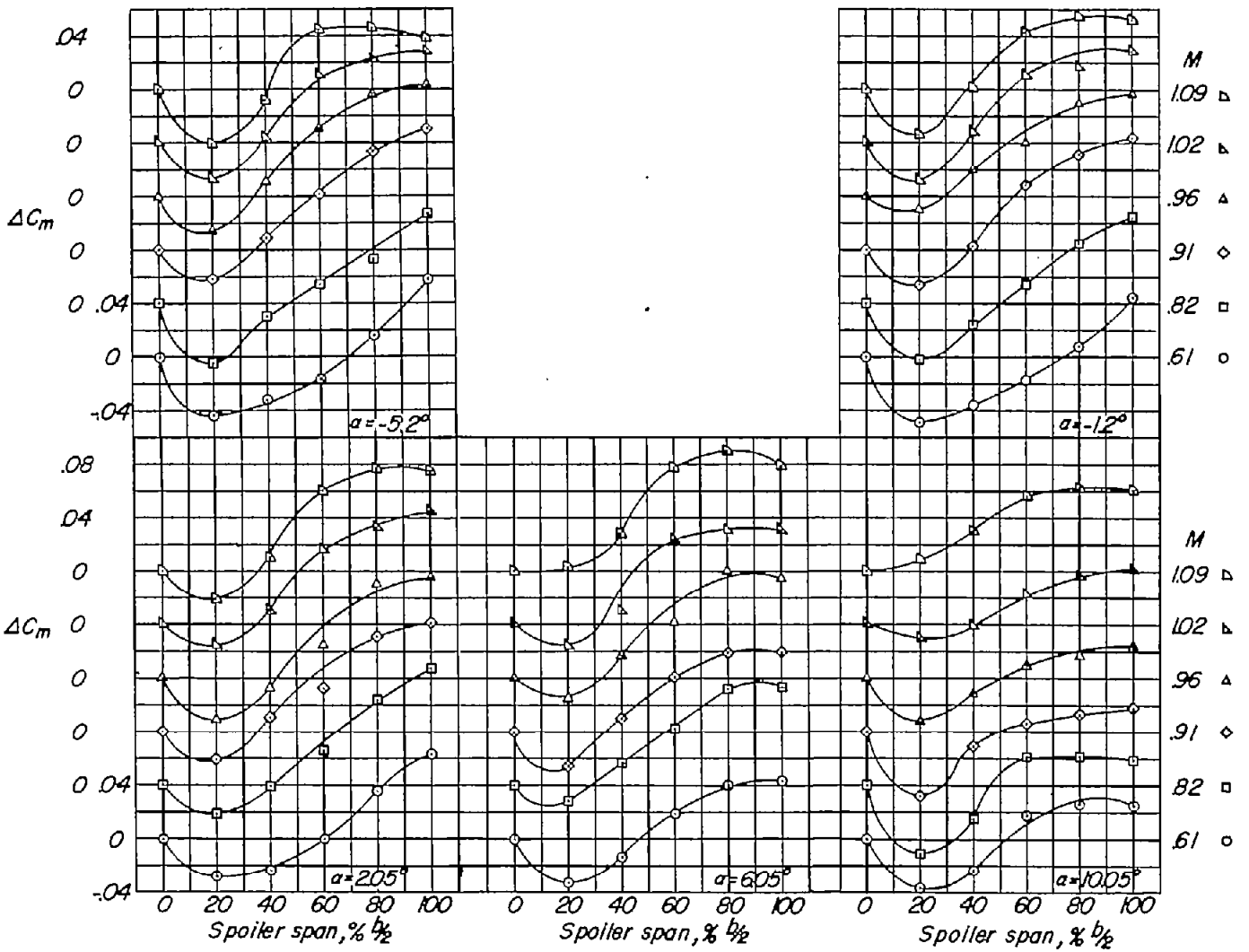

Figure 9.- The variation of incremental pitching-moment coefficient with spoiler span at various Mach numbers for several angles of attack.

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[redacted]

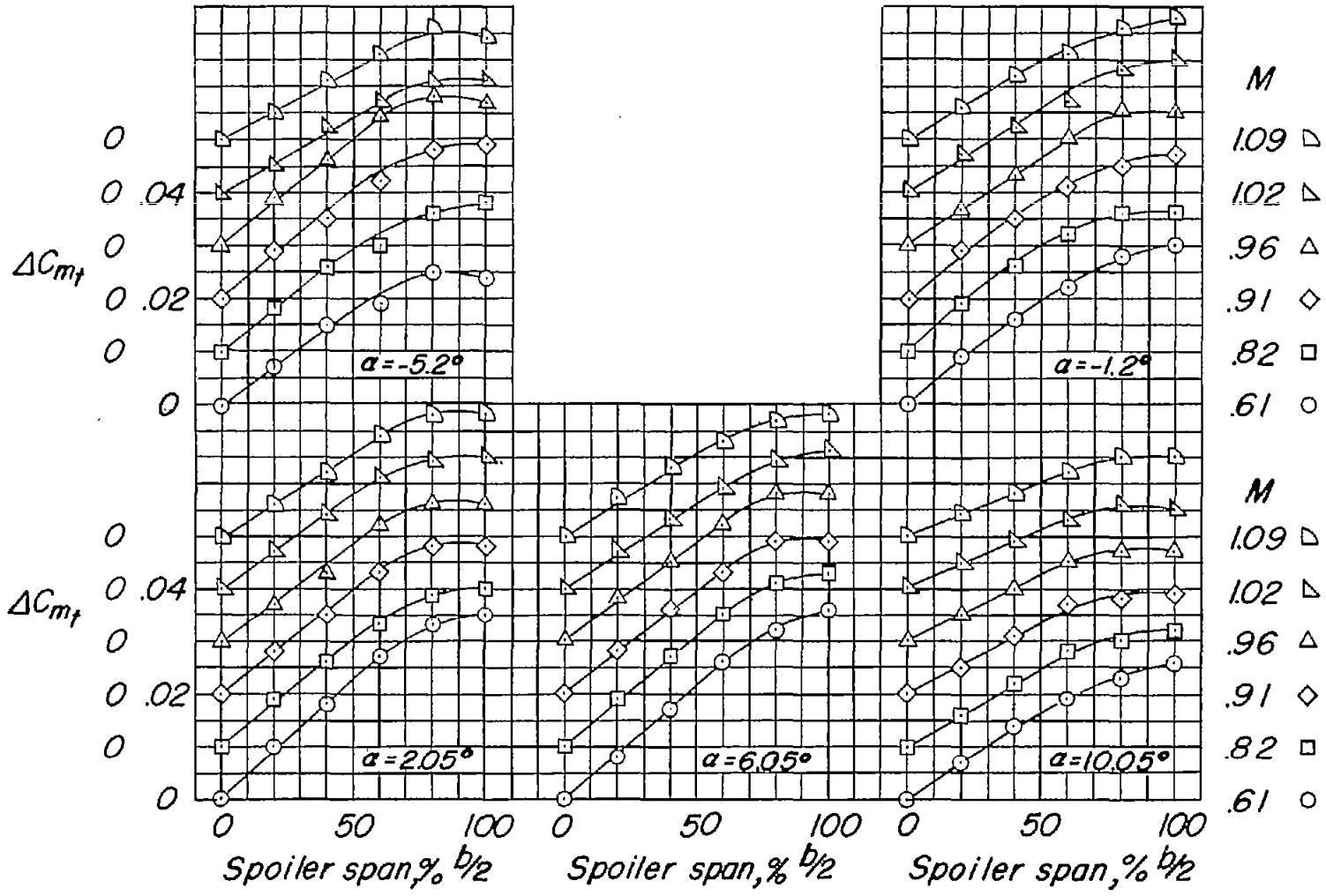

Figure 10.- The variation of the incremental twisting-moment coefficient about the 20-percent-chord line with spoiler span at various Mach numbers and several angles of attack.

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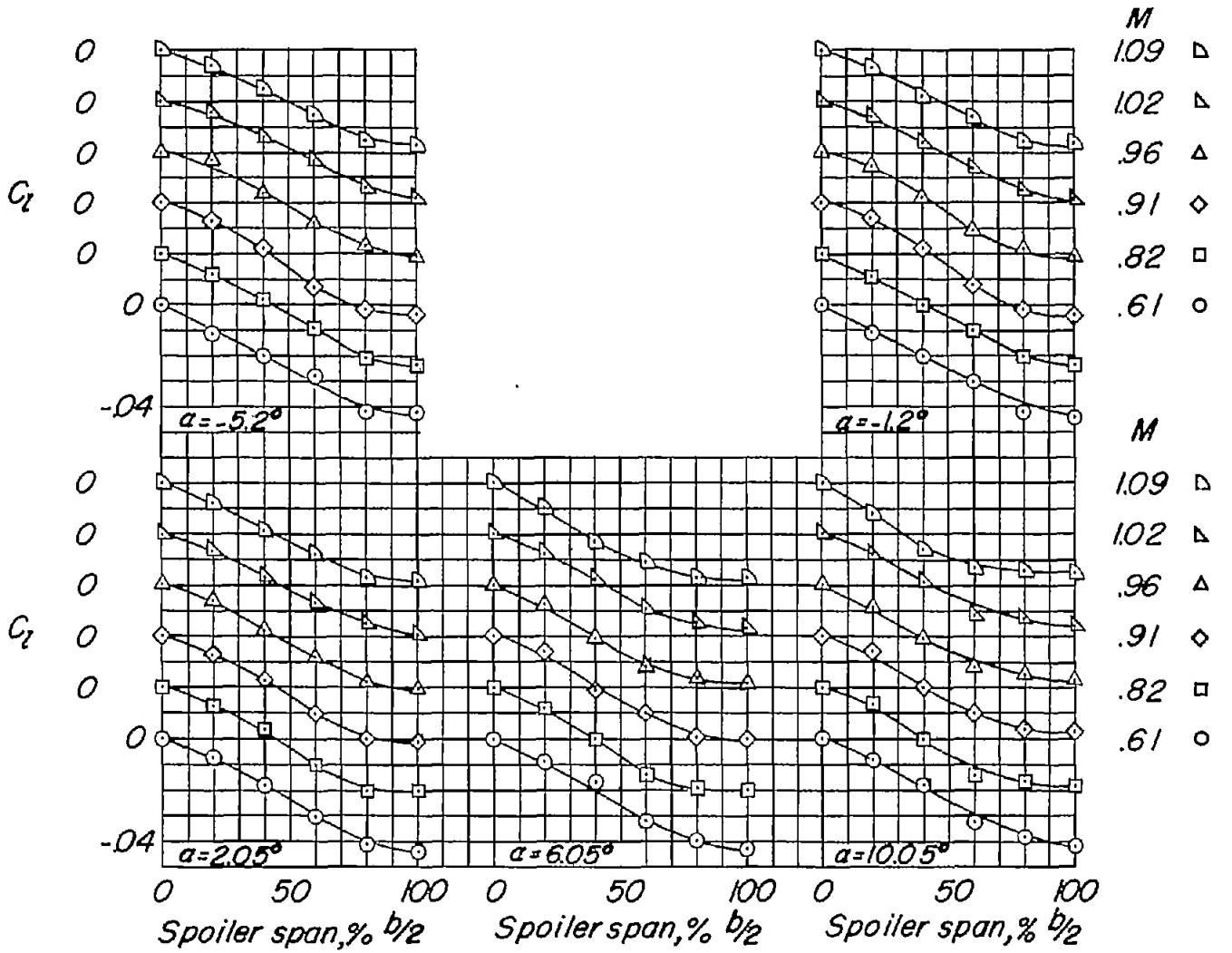

Figure 11.- The variation of the rolling-moment coefficient with spoiler span at various Mach numbers and several angles of attack.

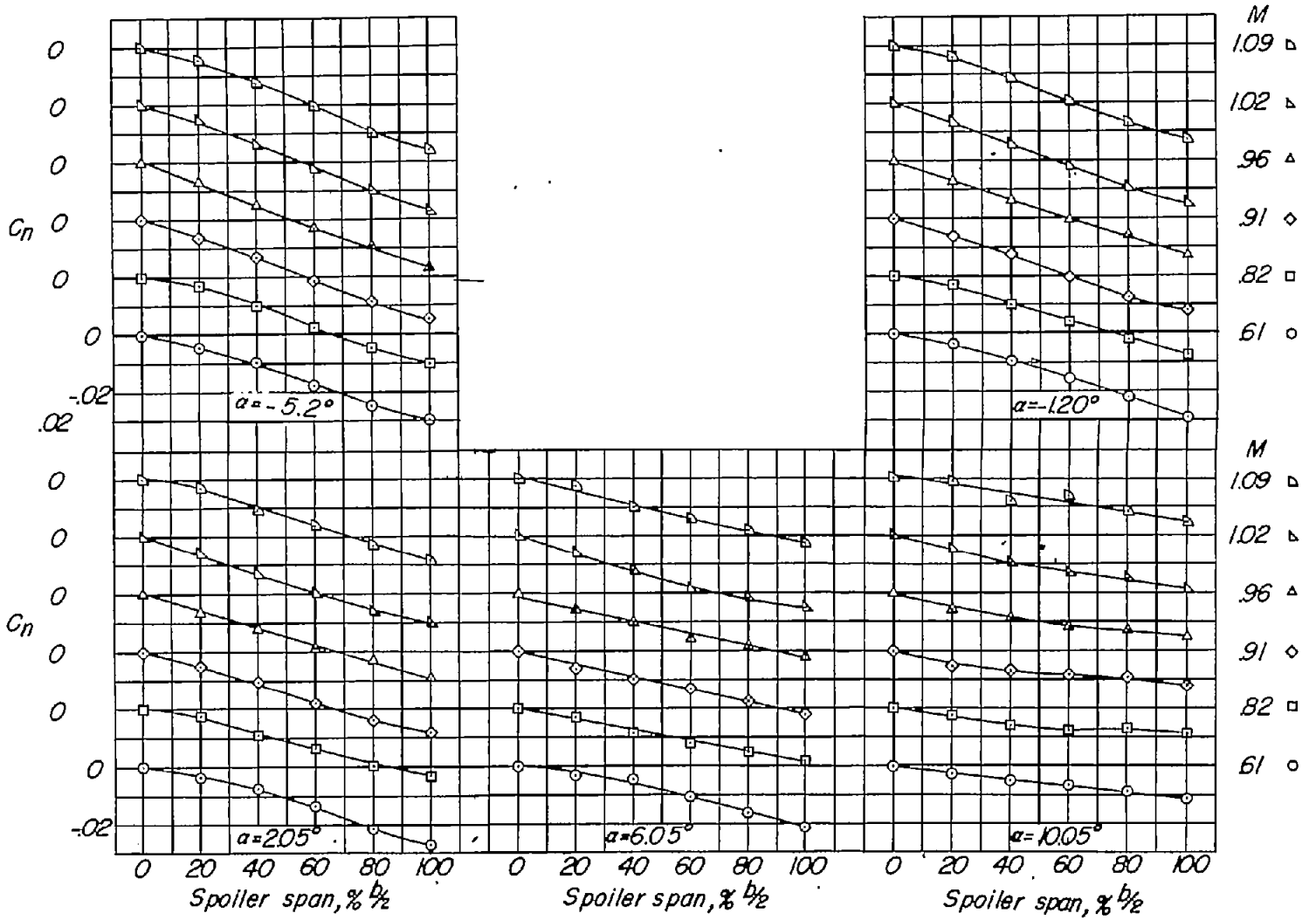

Figure 12.- The variation of the yawing-moment coefficient with spoiler span at various Mach numbers for several angles of attack.

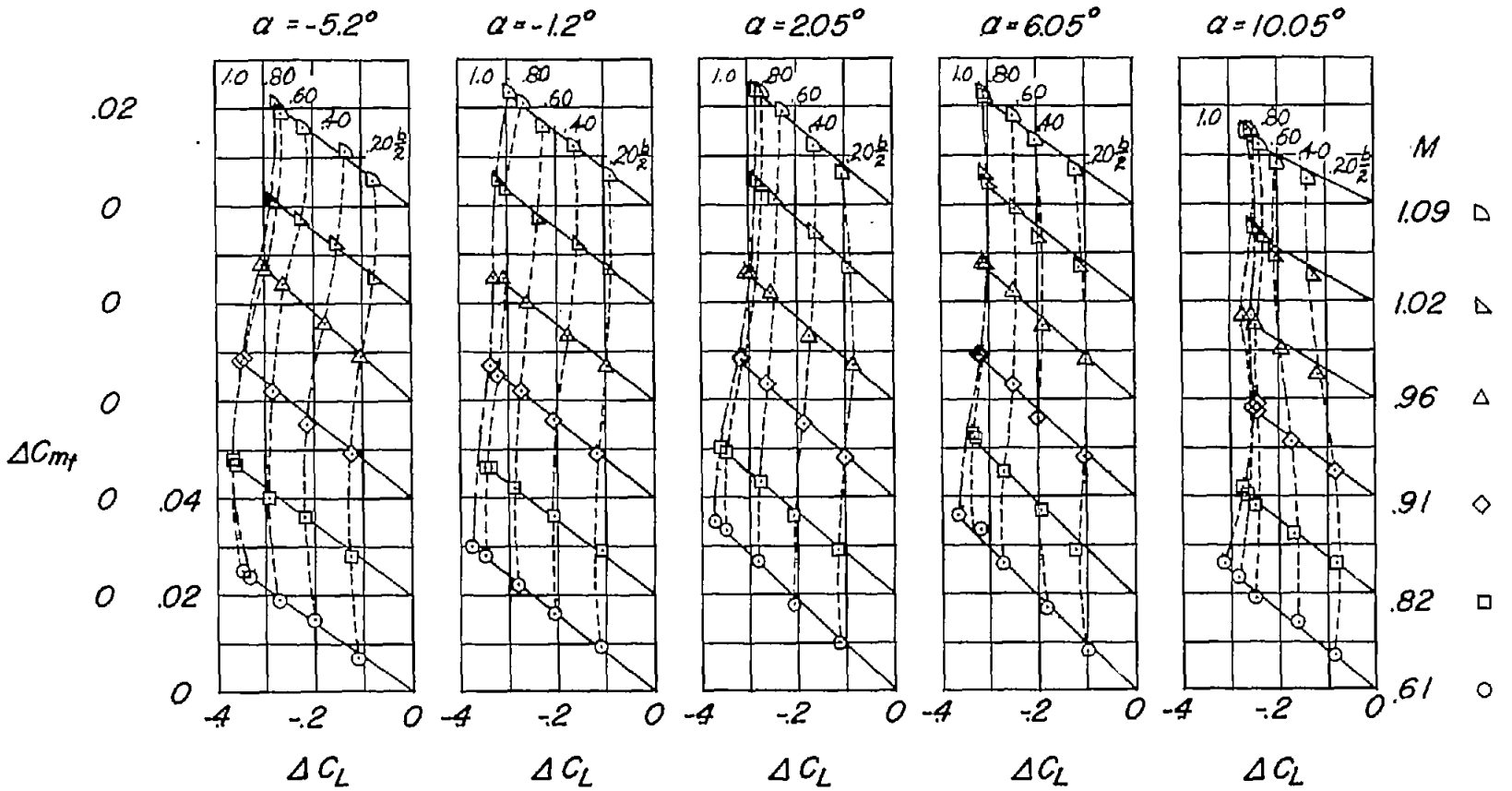

Figure 13.- The variation of the incremental twisting-moment coefficient about the 20-percent-chord line with incremental lift coefficient for inboard spoiler ailerons at various Mach numbers and several angles of attack.

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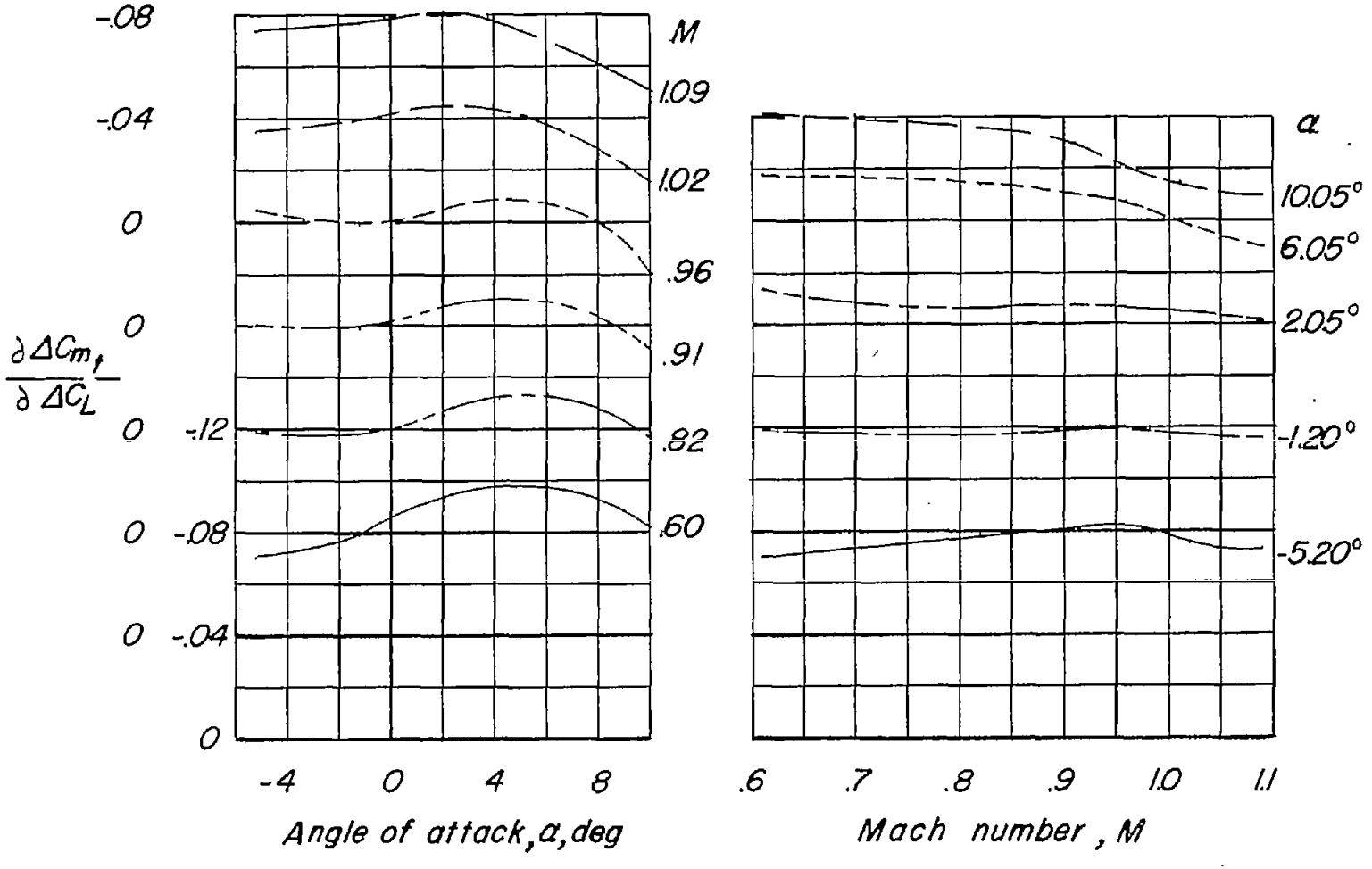

Figure 14.- The variation of the parameter $\frac{\partial \Delta C_{m_t}}{\partial \Delta C_L}$ with angle of attack for several Mach numbers and with Mach number for several angles of attack.

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