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RESEARCH MEMORANDUM

SOME WIND-TUNNEL RESULTS OF AN INVESTIGATION OF THE FLUTTER OF SWEPTBACK- AND TRIANGULAR-WING MODELS AT MACH NUMBER 1.3

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Flutter tests of untapered, low-aspect-ratio, sweptback-wing models and of triangular-wing models of solid magnesium, aluminum, and steel construction have been made in an intermittent supersonic wind tunnel at Mach number 1.3. Flutter data are presented for 31 sweptback-wing models with 0°, 30°, 45°, and 60° sweepback and for 24 triangular-wing models. The flutter boundaries are indicated on plots of streamwise thickness ratio and aspect ratio. No attempt has been made to correlate the results with analytical developments.

INTRODUCTION

Many designers of aircraft and missiles that are intended to travel at supersonic speeds are faced with the problem of predicting flutter speeds for wing plan forms for which there is no generally acceptable analytical solution. Experimental information is also very limited. A few flutter data have been obtained in the transonic-speed range with techniques involving rocket-propelled vehicles and freely falling bodies (references 1 to 3). Wind-tunnel flutter data obtained at Mach number 1.3 are reported in references 4 and 5.

As part of the general program of the National Advisory Committee for Aeronautics to study wing flutter at supersonic Mach numbers, the present paper reports the results of a systematic series of wind-tunnel experiments on the flutter of sweptback and triangular missile-type wing models made of solid magnesium, aluminum, and steel at Mach number 1.3. Results are presented for 31 sweptback-wing models with symmetrical hexagonal-section shapes and with various sweep angles of 0°, 30°, 45°, and 60° and for 24 triangular-wing models of essentially flat-plate construction. Model parameters have been tabulated and flutter boundaries are indicated on plots of streamwise thickness ratio and full-span aspect ratio.

Although the information provides material for correlation with analytical developments, no correlation is attempted in this paper. Many of these data have, however, been used in reference 6 for evaluating an empirical flutter criterion.

SYMBOLS

c	streamwise root chord, inches
t	section thickness, inches
A	full-span aspect ratio
Λ	angle of sweepback of leading edge, degrees
Δ	angle between leading edge and trailing edge on arrcwhead wings, degrees
f_h	first natural frequency, cycles per second
f_α	first natural frequencies which appeared to be predominantly torsion, cycles per second
f_f	flutter frequency, cycles per second
l	length of leading edge for swept wings and distance from root to tip, measured perpendicular to root, for triangular-wing models, inches
w	weight of wing model, pounds per inch of span
γ	density of material, pounds per cubic inch

MODELS AND TESTING METHOD

All the wing models tested were made from standard-gage sheets of aluminum, magnesium, and steel. The untapered sweptback models were made from 2-inch strips with 3/8 inch of the leading and trailing edges beveled to form a symmetrical hexagonal airfoil-section shape. The triangular models had 1/8 inch of the leading and trailing edge beveled. Figure 1 illustrates the plan forms of the models tested and table I lists the model parameters at flutter.

The wind tunnel used for these tests is a two-dimensional blowdown tunnel having a 9.24 × 18.23 inch test section operating from atmospheric stagnation pressure to a vacuum chamber. The tests were run at a Mach number of 1.3. Since the 0°, 30°, and 45° swept models would have fluttered and probably failed during the starting transient tunnel flow, these models were injected into the fully developed flow through a slot in the tunnel side wall. The models were clamped in jaws that formed a small half-body at the model root as illustrated in figure 2.

Since the tunnel operates at a fixed Mach number and air density, it was necessary to vary the wing parameters in order to obtain the point of neutral stability. For these experiments the wing span was increased by increments of about 10 percent on successive runs until flutter occurred. The flutter frequencies were detected by strain gages attached at the root of the models and were recorded by an oscillograph.

The first natural frequency, which was predominantly a bending mode, was obtained before each flutter run by flicking the wing in bending and recording the frequency. Forced-vibration tests were made on the untapered swept wings to determine the lowest frequency which had the appearance of a torsion mode of vibration and these frequencies are recorded as f_α in table I(a). No frequencies higher than the first natural bending mode were obtained, however, for the triangular wings.

RESULTS AND DISCUSSION

The model parameters and flutter boundaries at Mach number 1.3 and at an air density which corresponds to 30,000 feet altitude are given in table I.

Flutter boundaries for the untapered sweptback models are presented graphically in figure 3 by plotting streamwise thickness ratio against full-span aspect ratio. A curve has been drawn through the flutter points for the aluminum models to indicate the general flutter trend. A comparison of this curve with the flutter points for the magnesium and steel models indicates the effect of different materials which have very nearly the same ratio of stiffness to density. At a given aspect ratio the magnesium models require the greatest thickness ratio at the flutter boundary and the steel models, the least. From these experiments the geometric dimensions and physical properties of the wings at the flutter boundary at a Mach number of 1.3 could be determined. Since the tests were run at a fixed Mach number it was not possible to determine whether the flutter region extended to higher or lower speeds. Previous experience, however, as well as the results of references 1, 3, and 4, indicate that the flutter region extends to lower Mach numbers for most of the wings tested. Further discussions of this phenomenon are given in references 3 and 7.

Some of the magnesium and aluminum models swept back 45° were tested with half the wing tip cut off perpendicular to the air stream as shown in figure 1. Cutting off the wing tip in this manner had a pronounced favorable effect and allowed a 16- to 37-percent reduction in thickness ratio at a given aspect ratio. A comparison of the flutter boundaries of the regular and the clipped-tip aluminum models is shown in figure 4. The magnesium models exhibit the same trends, as can be seen by a comparison of the results in table I(a).

Flutter boundaries for six triangular-wing plan forms are presented in figure 5 on the basis of streamwise thickness ratio at the model root and the full-span aspect ratio. Sketches of the model plan forms are located above their corresponding flutter boundaries. Because of the limited amount of data available no attempt is made to generalize about the effect of plan form on flutter. Similar models made of magnesium, aluminum, and steel show the same effect as that which was observed on the untapered sweptback models; the magnesium models required the greatest thickness ratio at the flutter boundary and the steel models, the least. A few triangular models with 0° sweep were tested but they diverged before flutter could be obtained.

The data presented are intended to provide flutter information at Mach number 1.3 for wings of various plan forms, such as those used on missile wings and tail fins. The data may also provide material for correlation with analytical developments.

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REFERENCES

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2. Lauten, W. T., Jr., and Sylvester, Maurice A.: Flutter Investigation of a Pair of Thin, Low-Aspect-Ratio, Swept, Solid, Metal Wings in the Transonic Range by Use of a Free-Falling Body. NACA RM L51K28a, 1951.

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5. Tuovila, W. J., Baker, John E., and Regier, Arthur A.: Initial Experiments on Flutter of Unswept Cantilever Wings at Mach Number 1.3. NACA RM L8J11, 1949.

6. Martin, Dennis J.: Summary of Flutter Experiences as a Guide to the Preliminary Design of Lifting Surfaces on Missiles. NACA RM L51J30, 1951.

7. Regier, Arthur A., and Martin, Dennis J.: Recent Experimental Flutter Studies. NACA RM L51F11, 1951.

TABLE I.- PARAMETERS AND FLUTTER BOUNDARIES

[Tunnel Conditions: Air Density = 0.0009 slug per foot^3; velocity = 1430 feet per second; Mach number = 1.3]

(a) Untapered sweptback-wing models

Model	Λ	l	t	t/c	A	Material	W	f_α	f_h	f_f
1	0	7.50	6.4×10^{-2}	3.2×10^{-2}	7.50	Magnesium	7.0×10^{-3}	280.0	32.0	128.0
2	0	3.00	3.3	1.65	3.00	Magnesium	3.6	400.0	100.0	210.0
3	0	5.00	4.0	2.0	5.00	Aluminum	8.3	270.0	45.0	154.0
4	0	1.52	1.9	.95	1.52	Aluminum	3.4	450.0	197.0	267.0
5	0	3.88	3.2	1.6	3.88	Steel	16.8	288.0	47.0	108.0
6	0	2.00	1.8	.9	2.00	Steel	9.45	308.0	115.0	160.0
7	30	6.26	6.4	2.77	4.70	Magnesium	7.0	358.0	48.4	153.0
8	30	2.76	3.3	1.43	2.06	Magnesium	3.6	428.0	129.0	250.0
9	30	7.24	6.3	2.73	5.44	Aluminum	10.5	305.0	35.0	118.0
10	30	4.06	4.0	1.74	3.04	Aluminum	8.3	325.0	72.7	168.0
11	30	1.92	1.9	.824	1.36	Aluminum	3.4	380.0	167.0	284.0
12	30	4.00	3.2	1.385	3.00	Steel	16.8	270.0	50.0	100.0
13	30	2.26	1.8	.78	1.69	Steel	9.45	268.0	116.0	155.0
14	45	6.00	6.4	2.26	3.00	Magnesium	7.0	433.0	57.0	152.0
15*	45	7.00	6.4	2.26	3.77	Magnesium	7.0	350.0	51.5	140.0
16	45	3.00	3.3	1.166	1.50	Magnesium	3.6	380.0	120.0	250.0
17*	45	3.25	3.3	1.166	1.92	Magnesium	3.6	490.0	145.0	282.0
18	45	7.00	6.3	2.23	3.50	Aluminum	10.5	351.0	41.0	120.0
19*	45	7.94	6.3	2.23	4.25	Aluminum	10.5	290.0	36.4	129.0
20	45	4.26	4.0	1.414	2.13	Aluminum	8.3	300.0	71.0	169.0
21*	45	4.75	4.0	1.414	2.65	Aluminum	8.3	345.0	75.0	162.0
22	45	2.25	1.9	.67	1.13	Aluminum	3.4	320.0	140.0	275.0
23*	45	2.56	1.9	.67	1.60	Aluminum	3.4	402.0	162.0	280.0
24	45	4.26	3.2	1.13	2.12	Steel	16.8	250.0	53.0	106.0
25	45	2.76	1.8	.636	1.38	Steel	9.45	228.0	85.0	154.0
26	60	4.00	3.3	.825	1.00	Magnesium	3.6	330.0	83.5	195.0
27	60	9.00	6.3	1.575	2.25	Aluminum	10.5	273.0	28.0	89.0
28	60	5.50	4.0	1.00	1.38	Aluminum	8.3	360.0	52.0	135.0
29	60	2.62	1.9	.474	.66	Aluminum	3.4	440.0	110.0	266.0
30	60	6.76	3.2	.80	1.69	Steel	16.8	240.0	28.3	91.0
31	60	3.76	1.8	.45	.94	Steel	9.45	306.0	59.5	140.0

*Clipped tip models.

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TABLE I.- PARAMETERS AND FLUTTER BOUNDARIES - Concluded

(b) Triangular-wing models

Model	Λ	Δ	l	t	c	t/c	A	Material	γ	f_h	f_f
1	15	30	6.00	3.3×10^{-2}	3.22	1.03×10^{-2}	7.45	Magnesium	0.065	59.0	320.0
2	15	30	6.50	3.1	3.48	0.89	7.45	Aluminum	.10	46.0	155.0
3	15	30	3.25	1.6	1.75	.92	7.45	Aluminum	.10	85.0	240.0
4	15	30	5.50	1.8	2.95	.61	7.45	Steel	.283	37.0	240.0
5	30	30	5.50	3.3	3.17	1.04	6.94	Magnesium	.065	64.0	224.0
6	30	30	6.50	3.1	3.75	.83	6.94	Aluminum	.10	45.0	156.0
7	30	30	3.25	1.6	1.88	.85	6.94	Aluminum	.10	88.0	314.0
8	30	30	5.13	1.8	2.96	.61	6.94	Steel	.283	41.0	130.0
9	45	30	4.75	3.3	3.48	.95	5.46	Magnesium	.065	75.0	257.0
10	45	30	5.25	3.1	3.84	.81	5.46	Aluminum	.10	56.0	183.0
11	45	30	4.25	1.8	3.11	.58	5.46	Steel	.283	50.0	175.0
12	30	45	3.25	1.6	2.74	.58	4.74	Aluminum	.10	90.0	275.0
13	22.5	45	6.00	3.3	4.98	.66	4.82	Magnesium	.065	56.0	230.0
14	22.5	45	7.00	3.1	5.81	.53	4.82	Aluminum	.10	40.0	203.0
15	22.5	45	3.25	1.6	2.61	.61	4.82	Aluminum	.10	93.0	175.0
16	22.5	45	4.00	1.8	3.32	.54	4.82	Steel	.283	56.0	144.0
17	45	45	4.75	3.3	4.75	.70	4.00	Magnesium	.065	85.0	250.0
18	45	45	5.75	3.1	5.75	.54	4.00	Aluminum	.10	57.0	175.0
19	45	45	3.31	1.6	3.31	.47	4.00	Aluminum	.10	90.0	307.0
20	45	45	3.81	1.8	3.81	.47	4.00	Steel	.283	65.0	170.0
21	60	60	4.13	3.3	7.16	.46	2.31	Magnesium	.065	105.0	227.0
22	60	60	5.88	3.1	10.15	.31	2.31	Aluminum	.10	49.5	128.0
23	60	60	2.75	1.6	4.76	.34	2.31	Aluminum	.10	114.0	260.0
24	60	60	3.75	1.8	6.50	.28	2.31	Steel	.283	62.0	139.0

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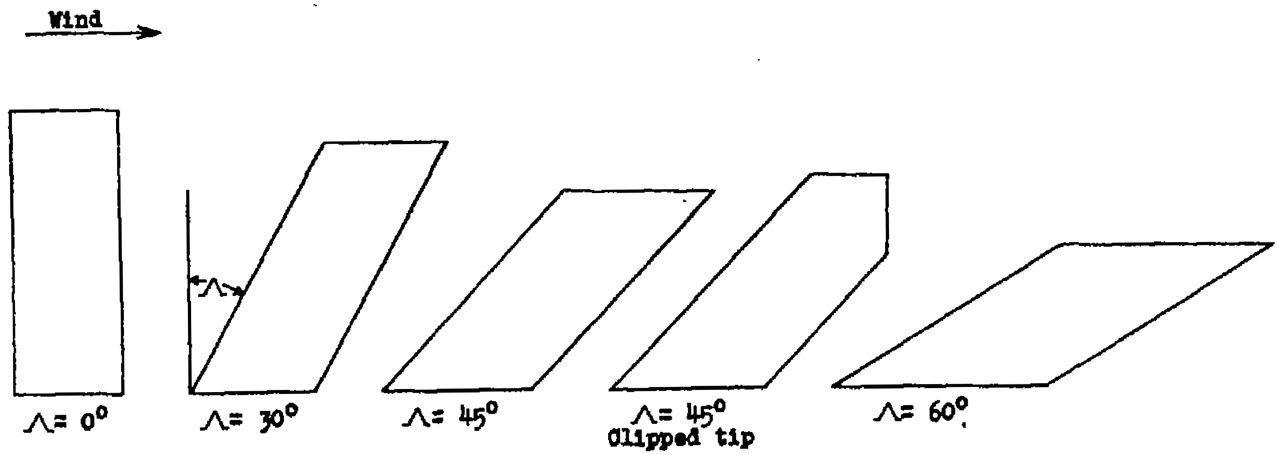
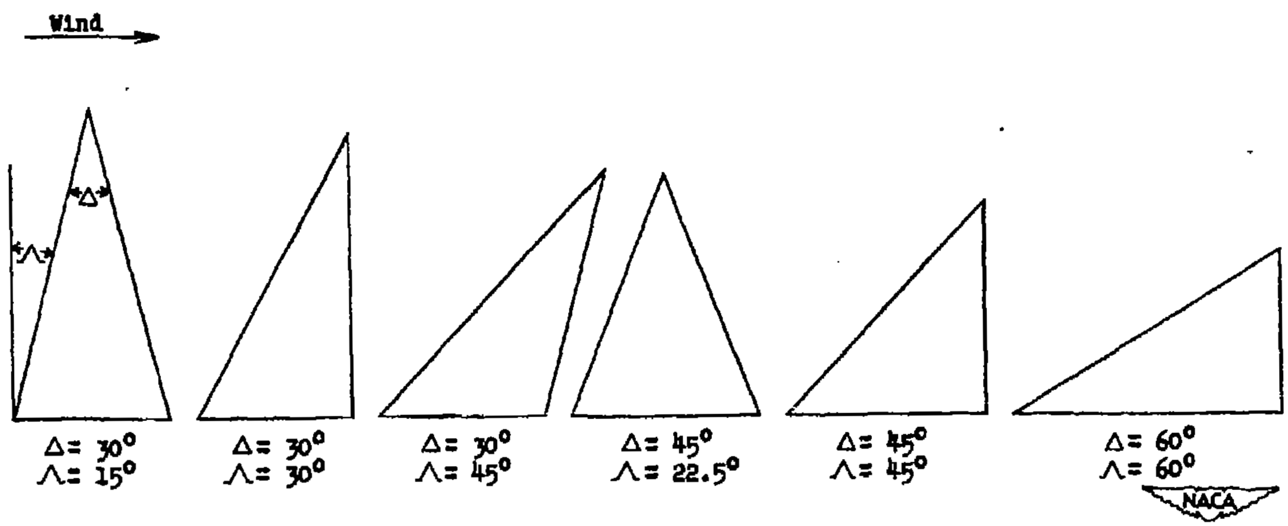


(a) Untapered swept-wing models.



(b) Arrowhead-type-wing models.

Figure 1.- Plan forms of wing models tested.

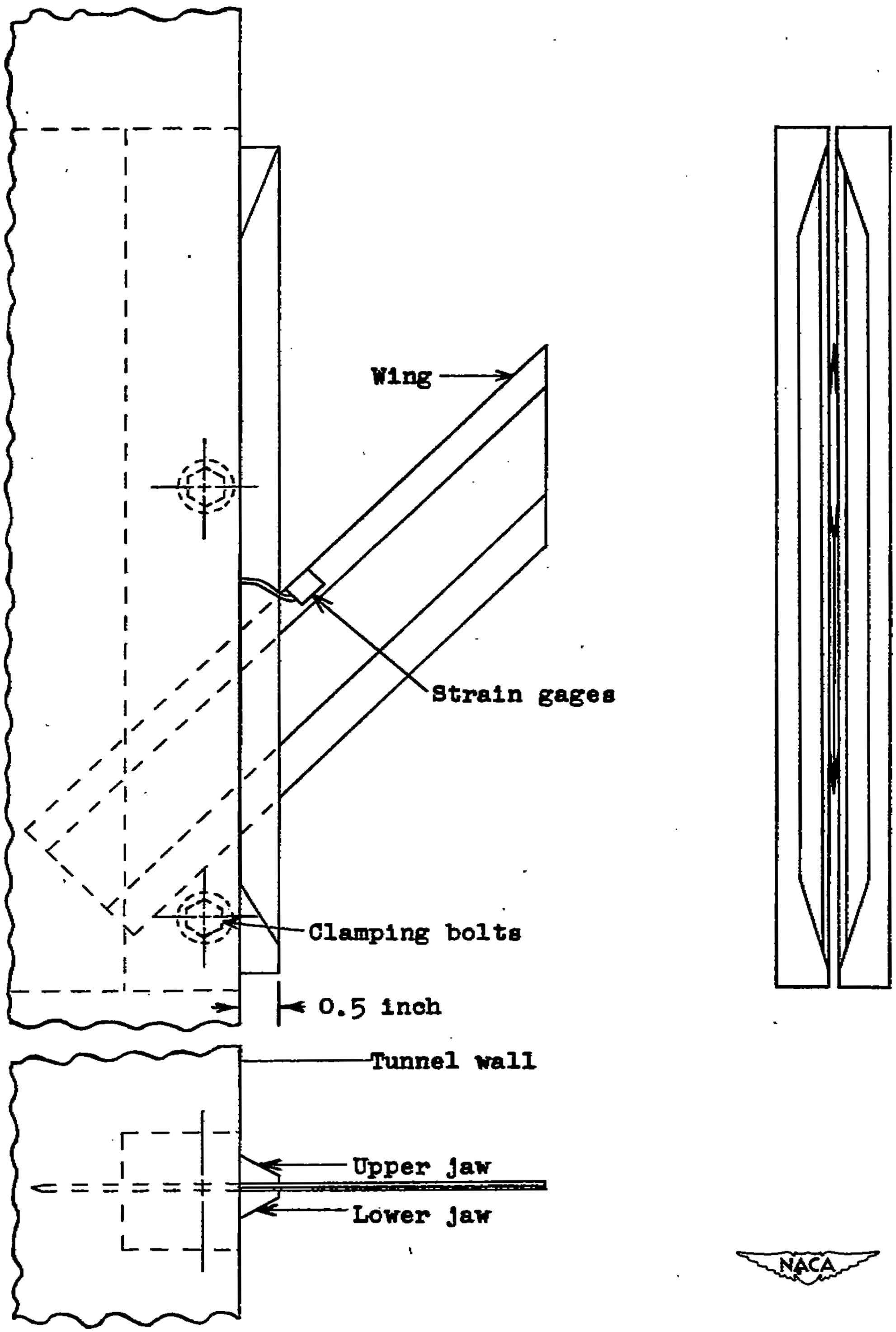


Figure 2.- Sketch of model mount.

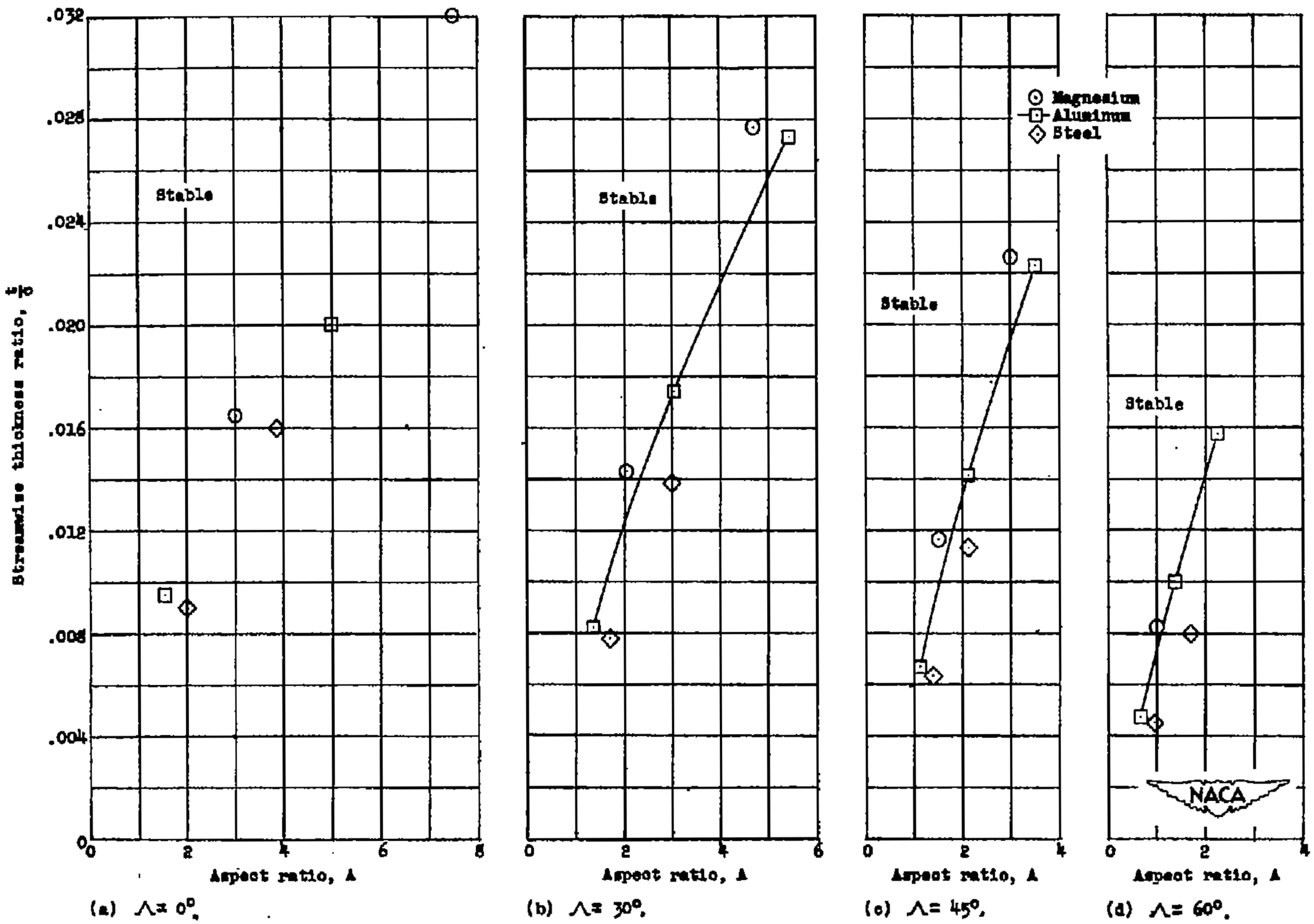


Figure 3.- Aspect ratio and thickness ratio required to attain flutter boundary at Mach number 1.3 for wings of solid magnesium, aluminum, and steel at various sweep angles.

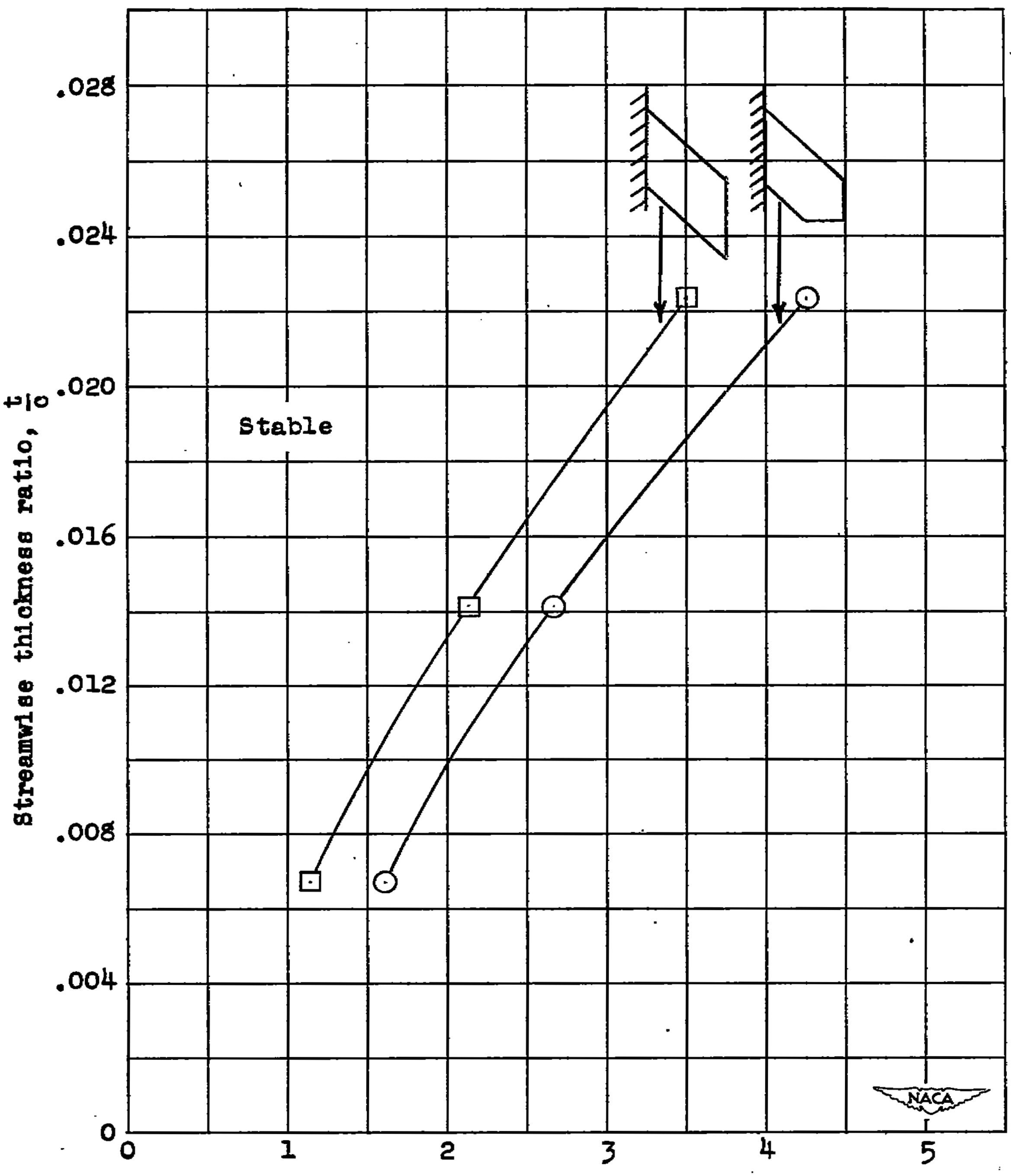


Figure 4.- Effect of different tip configuration on the aspect ratio and thickness ratio required to attain flutter boundary at Mach number 1.3 for 45° sweptback aluminum wings.

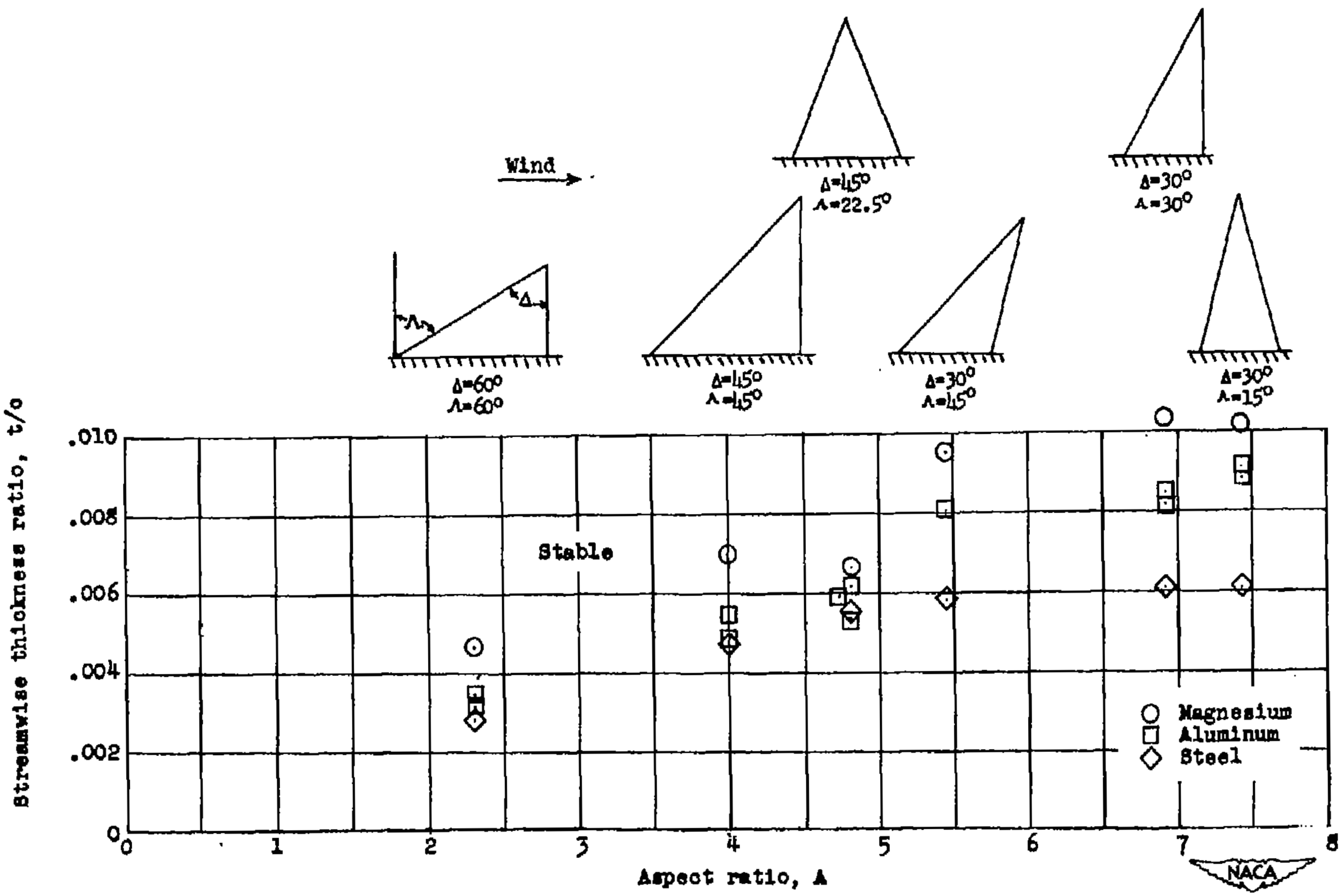


Figure 5.- Aspect ratio and thickness ratio required to attain flutter boundary at Mach number 1.3 for triangular wings of solid magnesium, aluminum, and steel.

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