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RESEARCH MEMORANDUM

SOME LOW-SPEED STUDIES OF THE EFFECTS OF WING LOCATION ON WING-DEFORMATION—BODY-FREEDOM FLUTTER

By E. Widmayer, Jr.

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NATIONAL ADVISORY COMMITTEE
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SOME LOW-SPEED STUDIES OF THE EFFECTS OF WING LOCATION ON WING-DEFORMATION—BODY-FREEDOM FLUTTER

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SUMMARY

An investigation of flutter of wings mounted on the after portion of a body free to pitch was made in the Langley 4.5-foot flutter research tunnel. The purpose of the investigation was to explore the effect of wing location on a low-frequency flutter which had occurred in some rocket tests. Uniform wings of 0° and 45° sweep were tested at various positions rearward of the pitch axis. All experiments were performed in air at atmospheric pressure and at low speeds.

A low-frequency flutter involving primarily wing deformation and body pitching was obtained on the unswept wings. The flutter frequencies were in the order of the "short period" stability frequencies, being considerably below the lowest natural deformation frequencies of the wing. The reduced frequencies at flutter were in range of 0.01 to 0.03, representing a wave length of from 210 to 500 semichords. No low-frequency flutter was obtained with the 45° swept wings for the few cases considered.

A comparison of the experiment has been made with theory, with various assumptions regarding the air forces being used. The experimental trend of the flutter-speed coefficient to increase as the unswept wings were moved rearward was also obtained from the analysis. It was found that taking account of finite span effects gave better agreement between experiment and theory than did the use of two-dimensional air forces. The experimental and calculated frequencies of flutter when referred to the natural deformation frequencies of the wing were of the same order of magnitude.

INTRODUCTION

During some previous flutter tests made with rocket models having the wings rearward of the configuration center of gravity, a low-frequency flutter involving wing deformation and rigid-body freedoms was encountered on unswept wings (ref. 1). An analysis of this type of flutter indicates that the mode of flutter is strongly influenced by the wing location with

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respect to the configuration center of gravity. The problem of the effect of rigid-body freedoms (fuselage mobility) on flutter has been of interest for some time (refs. 2 to 4). The early investigations for the most part dealt with conventional locations of unswept wings, the system center of gravity being close to the wing quarter chord. Interest in the subject has increased with the use of swept wings, tailless configurations, and wing locations remote from the system center of gravity (refs. 5 to 8). References 6, 7, and 8 treat experimentally flutter of swept, cranked, and delta wings having root freedoms in pitch and translation.

In some recent wind-tunnel experiments on the flutter of wing and horizontal-tail combinations, a low-frequency flutter involving wing deformation and body pitching was observed when the tail was absent. Since flutter of this kind may have a bearing on the stability of missiles and tailless designs and since there seems to be a lack of data on this type of flutter, these experiments on a tailless model are being reported. These experiments, made at low speeds, were performed for some uniform wings having 0° and 45° sweep in which the wing was located rearward of the pitching axis. A comparison is made of all results of the experiments with some analytical results in which aerodynamic forces based on various approximations were used. The flutter involved low reduced frequencies, and it might be expected that the effects of aspect ratio would be important. The calculations were based on the following air forces: (a) the unsteady two-dimensional theory of reference 9, (b) the unsteady two-dimensional theory of reference 9 modified to include finite-span effects as derived in reference 10, (c) the air forces of reference 9 for the case of $C(k) = 1$, (d) the air forces of (c) modified by the correction $A/(A + 2)$.

SYMBOLS

A	aerodynamic aspect ratio, for rectangular plan-form wings, l/c
a	nondimensional distance (in wing semichords) from wing midchord line to location of the elastic axis, positive when elastic axis is behind wing midchord line
l	wing span
$C(k)$	Theodorsen's function $F(k) + iG(k)$ (ref. 9)
c	wing chord
d_{ij}	expressions appearing in determinant (defined in appendix)

f_h first bending natural frequency, cps

f_t first torsion natural frequency, cps

g, g_h, g_α damping coefficients as defined in reference 11

h the bending deflection of wing at span station y given in terms of reference deflection (at tip) and normalized mode, $h_o f_h(y)$

I_p mass moment of inertia of fuselage and wings about the pitch axis

I_w mass moment of inertia of wing per unit length about wing elastic axis

k reduced frequency parameter, $\omega c/2V$

m mass of wing per unit length

θ angle of pitch of fuselage center line, positive when nose up

q dynamic pressure

r_α nondimensional radius of gyration of wing section about wing section elastic axis, $r^2 = 4 \frac{I_w}{mc^2}$

s nondimensional distance (in wing semichords) from wing midchord line to fuselage pitch axis measured parallel to fuselage center line, positive when pitch axis is behind wing midchord line

V flutter speed

$2V/\omega_h c$ nondimensional flutter speed coefficient

x_α nondimensional position of wing-section center of gravity in wing semichords relative to the wing section elastic axis, positive when center of gravity is behind elastic axis

y coordinate of span station measured from fuselage center line

α torsional deflection of wing at span station y in terms of reference deflection α_o (at tip) and normalized mode, $\alpha_o f_\alpha(y)$

μ ratio of mass of wing to the mass of a cylinder of air of a diameter equal to the chord of wing, both taken for equal length along the span, $\mu = \frac{4m}{\pi \rho c^2}$

ρ mass density per unit volume of air

$\sigma_\alpha, \sigma_h, \sigma_\theta$ correction factors to $C(k)$ which vary with span station as given in reference 10

Ω parameter defined by $\Omega = (\omega_h/\omega)^2 (1 + ig)$

ω circular frequency of flutter

ω_h circular frequency of natural bending deformation

ω_α circular frequency of natural torsional deformation

APPARATUS AND METHOD

Tunnel.- The experiments were conducted in air at atmospheric pressure in the Langley 4.5-foot flutter research tunnel which is a closed-throat single-return type having a cylindrical test section. The highest velocity reported in these tests is 338 feet per second, corresponding to a Mach number of 0.32. The Reynolds number was greater than 1×10^6.

Model.- The model used in these experiments was intentionally simplified and is shown in figure 1. The model consisted of a fuselage with vertical tail and the aerodynamic surfaces to be examined. The fuselage, of 1-inch-square aluminum stock, was 31.75 inches in length. The fuselage was mounted on a ball-bearing pivot and had no spring restraint in the pitching degree of freedom. Provision was made for this bearing to be located at various positions on the forward 13 inches of the fuselage. Lead counter weights were employed to maintain, as near as possible, static balance of the entire model about the bearing support. No provision was made for maintaining a constant mass moment of inertia about the pitch axis. Consequently, this inertia varied with the position of the wings and with the counter weighting used for each pitch axis. The wings could be attached to the fuselage at six different stations.

The model was mounted in the tunnel by use of taut wires connected to the stationary bearing support; thus, although the bearing housing was held firm, the fuselage could pitch about the bearing axis and had some freedom in yaw. A rigid (as compared with the wings) vertical tail of $2.8 \times 9.5 \times 0.125$ aluminum plate effectively restrained the freedom of yaw when under the influence of the air stream.

Wings.- The different sets of wings were mounted in base blocks to facilitate the variation in their location relative to the pitching axis. Experiments were conducted on two sets of wood wings, designated wings I and wings II. These wings had an airfoil section of NACA 16-006 and were made of solid maple. It was necessary to cut slots perpendicular to the plane of the wing in the chordwise direction to reduce the structural stiffnesses so that the desired flutter might be obtained at the desired speeds. The structural properties are presented in table I(a).

The 45° swept wings used in the experiment were $\frac{1}{16}$-inch aluminum-alloy sheet. These wings had the same tip-to-tip distance as wings I and II and had a sheared tip plan. The structural properties are presented in table I(b).

Instrumentation.- The instrumentation consisted of resistance-type strain gages mounted at the root of each wing so as to indicate the bending or torsion deformation or both. The strain-gage output was recorded on an oscillograph. The action of both the fuselage and the wings could be qualitatively determined from this record, since from observation it was noted that the pitching of the fuselage was accompanied by the bending of the wings. Although this instrumentation yields frequencies of oscillation, the phase between bending and torsion, and relative amplitudes of the wing deformations, it does not give the phase between the pitching of the fuselage and the wing deformation or the amplitude of the pitching oscillation.

Test procedure.- In order to obtain the flutter of the model for a given wing location, the airspeed was increased slowly until flutter was observed. The strain-gage outputs and the tunnel conditions were then noted.

ANALYTICAL CONSIDERATIONS

The analytical procedures are indicated in this section in order to provide a background before presenting the results of the experiments. In previous investigations, involving cases where the values of reduced frequency are fairly high, it has been found that the flutter calculations based on two-dimensional oscillating air forces usually give good agreement with experiment. In these tests, however, the values of the reduced frequency parameter were low, bordering on those encountered in certain stability phenomena. It was felt, therefore, that the two-dimensional theory would have to be modified to account for aspect-ratio effects and possibly other factors. Accordingly, computations of the flutter were made using several different concepts of the air forces and moments involved. These concepts are designated as follows:

A air forces of two dimensional incompressible flow as in reference 9

B air forces of concept A modified by the aspect ratio correction of Reissner as in reference 10

C air forces of concept A with the circulation function $C(k) = 1$

D air forces of concept C reduced by the aspect ratio correction factor $\frac{A}{A + 2}$

In A to D only the aerodynamic terms in the equations of equilibrium are altered, the structural terms remaining unchanged.

The model was treated as having three degrees of freedom, pitching about the bearing pivot, and two wing-deformation degrees of freedom which are approximated by the first uncoupled bending and first uncoupled torsion modal shapes of an ideal uniform cantilever beam. In order to determine if the structural representation was adequate, a differential-equation type of flutter analysis as presented in reference 12 was performed on one case. The results of this analysis are shown in figure 2 and indicate that the representation was adequate.

The wings were treated as though they extended through the fuselage, and no attempt was made to approximate the air forces arising from the fuselage. The aerodynamic forces at each span station were assumed to be proportional to the displacement and motion of the wing section at that station (strip analysis).

Since the pitching degree of freedom has zero natural frequency, the equations of motion for the model undergoing harmonic motion are of the following form:

$$\left.\begin{aligned}
&\left(d_{11} - \mu\Omega\right)\frac{2h_o}{c} + d_{12}\alpha_o + d_{13}\theta_o = 0 \\
&d_{21}\frac{2h_o}{c} + \left(d_{22} - \mu r_a{}^2\Omega\right)\alpha_o + d_{23}\theta_o = 0 \\
&d_{31}\frac{2h_o}{c} + d_{32}\alpha_o + d_{33}\theta_o = 0
\end{aligned}\right\} \qquad (1)$$

The equations and the definitions of the quantities d_{ij} are given in the appendix. The border condition of stability or flutter is given for the determinant of the coefficients equal to zero.

RESULTS AND DISCUSSION

The results of the experiments and of the computations are presented in table II and illustrated in figures 2 and 3. Computations A, C, and D (see appendix) were performed for each experimental point for unswept wings involving the low-frequency wing-deformation—body-pitching flutter while computation B was performed for two cases. In the experiments using 45° swept wings no low-frequency flutter was obtained and no calculations were performed. The conditions for these experiments are given in table III.

Unswept wings.- In table II it may be seen that the experimental value of $2V/c\omega$ decreases as the distance from the root midchord to pitch axis is decreased. A similar trend is also noted for all the analytical results. It is seen that the order of magnitude of the analytical coefficients for B and D are in agreement with the experimental values; whereas, considerable differences are noted between the results of A and C and the experimental $2V/c\omega_h$ coefficients. The significance of correcting the air forces for some effects of aspect ratio may be evidenced by the improvement in the results with the experiment when some correction is made.

It is of interest to note that calculation A indicated that flutter of this type was unobtainable for $s = -2.4$ while calculations C and D predicted flutter. As indicated in figures 2 and 3 the nature of the flutter as discerned from analysis is changing to a different type of instability. An attempt was made to obtain wing deformation—body-pitching flutter experimentally when s lay in the region described as single degree of freedom instability, but no instability was noted (see table II).

In order to determine the bending-torsion-flutter characteristics of wings I, some tests were made with the fuselage restrained in pitch. An instability of destructive violence was encountered which resulted in the loss of the wings. The loss of the wings came without warning and, unfortunately, only the air velocity at destruction was obtained. From calculations for wing bending-torsion flutter using the forces of reference 9 a theoretical flutter speed was obtained that was 17.4 percent lower than the experimental velocity. The torsional divergence speed, as calculated by the method of reference 11, is 9 percent lower than the experimental velocity. These data are given in table II and figure 2. No tests of this kind were made for wings II for they had been damaged in previous testing.

The correlation of the calculated frequencies to the experimental frequencies may be seen by referring to table II. Calculated frequencies of B, C, and D appear to be consistently higher than those of the experiment, while the calculated frequencies of A appear to be consistently lower than the experimental values. However, the trend of the experimental frequency to increase as the wings are moved rearward is predicted by the results of the analysis. Furthermore, if both experimental and computed frequencies are referred to the natural deformation frequencies of the wing (f_h = 26.9 cps, f_α = 106 cps), it is seen that the calculated frequencies are of the same order as the experimental frequencies.

Swept wings.- In the experiments involving the 45° swept wings, no low-frequency flutter was obtained for the range of wing locations examined. The wing-root-midchord location was varied from $s = 0$ to $s = 5.88$, where the reference semichord is taken normal to the wing leading edge. The data for these experiments are presented in table III. In references 6, 7, and 8 wing flutter involving body freedoms in both pitch and translation has been reported for the swept wing. In those tests, conditions of small body inertias and the mass center location within the root chord of the wing were used. In the present simple experiments, these conditions were not obtained and could possibly account for the absence of flutter.

CONCLUDING REMARKS

A low-frequency flutter involving interaction between rigid-body pitching and wing deformation was obtained experimentally on an unswept wing. The flutter-speed coefficient increased as the wing was moved rearward along the fuselage away from the pitch axis. This trend was also indicated by theoretical calculations based on various assumptions regarding the air forces. No flutter was obtained for a similar wing-body combination with 45° swept wings for the few cases considered.

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APPENDIX

DETERMINATION OF THE FLUTTER DETERMINANT

The equations of motion for a system having a body freedom in pitch and wing deformation freedoms in twisting and bending are obtained from Lagrange's equations. The kinetic energy of the system is as follows:

$$T = \frac{1}{2} I_p \dot{\theta}^2 + \int_0^{l/2} I_w\left(\dot{\alpha}^2 + 2\dot{\alpha}\dot{\theta}\right) dy +$$

$$\int_0^{l/2} m\left[\dot{h}^2 + 2(-s + a + x_\alpha)\frac{c}{2}\,\dot{h}\dot{\theta} + 2x_\alpha\,\frac{c}{2}\,\dot{h}\dot{\alpha} + 2(-s + a)x_\alpha\,\frac{c^2}{4}\,\dot{\theta}\dot{\alpha}\right] dy$$

The potential energy is given by

$$U = \omega_h^{\,2} \int_0^{l/2} m h^2 dy + \omega_\alpha^{\,2} \int_0^{l/2} I_w \alpha^2 dy$$

The generalized work is given by

$$Q_h\ dh = -2\pi\rho\,\frac{c^3}{8}\,\omega^2 \int_0^{l/2} \left[\frac{2h}{c} A_{ch} + \theta A_{c\theta} + \alpha A_{c\alpha}\right] dh\ dy$$

$$Q_\alpha\ d\alpha = -2\pi\rho\,\frac{c^4}{16}\,\omega^2 \int_0^{l/2} \left[\frac{2h}{c} A_{ah} + \theta A_{a\theta} + \alpha A_{a\alpha}\right] d\alpha\ dy$$

$$Q_\theta\ d\theta = -2\pi\rho\,\frac{c^4}{16}\,\omega^2 \int_0^{l/2} \left[\frac{2h}{c} A_{dh} + \theta A_{d\theta} + \alpha A_{d\alpha}\right] d\theta\ dy$$

From Lagrange's equation the following equations are obtained:

$$\left(d_{11} - \mu\Omega\right)\frac{2h_o}{c} + d_{12}\alpha_o + d_{13}\theta_o = 0$$

$$d_{12}\,\frac{2h_o}{c} + \left(d_{22} - \mu r_\alpha{}^2\Omega\right)\alpha_o + d_{23}\theta_o = 0$$

$$d_{13}\,\frac{2h_o}{c} + d_{32}\alpha_o + d_{33}\theta_o = 0$$

In these equations $\Omega = \left(\frac{\omega_h}{\omega}\right)^2(1 + ig)$ where g has the properties of a damping coefficient. The quantities d_{ij} are

$$d_{11} = \mu - A_{ch}$$

$$d_{12} = \left(\mu x_\alpha - A_{c\alpha}\right)I_1$$

$$d_{13} = \left[\mu(-s + a + x_\alpha) - A_{c\theta}\right]I_2$$

$$d_{21} = \left(\mu r_\alpha{}^2 - A_{ah}\right)\left(\frac{\omega_h}{\omega_\alpha}\right)^2 I_3$$

$$d_{22} = \left[\mu\left(r_\alpha{}^2\right) - A_{a\alpha}\right]\left(\frac{\omega_h}{\omega_\alpha}\right)^2$$

$$d_{23} = \left\{\mu\left[r_\alpha{}^2 + (-s + a)x_\alpha\right] - A_{a\theta}\right\}\left(\frac{\omega_h}{\omega_\alpha}\right)^2 I_4$$

$$d_{31} = \left[\mu(-s + a + x_\alpha) - A_{dh}\right]\frac{1}{\mu r_\theta{}^2}\,I_5$$

$$d_{32} = \left\{\mu\left[r_\alpha{}^2 + (-s + a)x_\alpha\right] - A_{d\alpha}\right\}\frac{1}{\mu r_\theta{}^2}\,I_6$$

$$d_{33} = \left(1 - \frac{1}{\mu r_\theta{}^2}\,A_{d\theta}\right)$$

where $\mu r_\theta{}^2 = \dfrac{\text{mass moment of fuselage about pitch axis}}{(\text{span})\pi\rho(c/2)^4}$

The I_n are, for modal shapes considered,

$$I_1 = \frac{\int_0^1 f_h f_\alpha \, dy}{\int_0^1 f_h{}^2 dy} = 1.3558 \qquad I_4 = \frac{\int_0^1 f_\alpha f_\theta \, dy}{\int_0^1 f_\alpha{}^2 dy} = 1.7273$$

$$I_2 = \frac{\int_0^1 f_h f_\theta \, dy}{\int_0^1 f_h{}^2 dy} = 1.5662 \qquad I_5 = \frac{\int_0^1 f_h f_\theta \, dy}{\int_0^1 f_\theta{}^2 dy} = 0.39153$$

$$I_3 = \frac{\int_0^1 f_\alpha f_h \, dy}{\int_0^1 f_\alpha{}^2 dy} = 0.67780 \qquad I_6 = \frac{\int_0^1 f_\alpha f_\theta \, dy}{\int_0^1 f_\theta{}^2 dy} = 0.63662$$

The A_{ij} are the aerodynamic expressions which are modified in various ways as depicted in the section entitled "Analytical Considerations" and are given as follows:

Analysis A.-

$$A_{ch}(k) = -1 - \frac{2G}{k} + i\,\frac{2F}{k}$$

$$A_{c\alpha}(k,a) = a + \frac{2F}{k^2} - \left(\frac{1}{2} - a\right)\frac{2G}{k} + i\left[\frac{1}{k} + \frac{2G}{k^2} + \left(\frac{1}{2} - a\right)\frac{2F}{k}\right]$$

$$A_{ah}(k,a) = -A_{ch}\left(\frac{1}{2} + a\right) - \frac{1}{2}$$

$$A_{a\alpha}(k,a) = -\frac{1}{8} - a^2 - \left(\frac{1}{2} + a\right)\frac{2F}{k^2} + \left(\frac{1}{4} - a^2\right)\left(\frac{2G}{k}\right) + i\left[\left(\frac{1}{2} - a\right)\frac{1}{k} - \left(\frac{1}{4} - a^2\right)\frac{2F}{k} - \left(\frac{1}{2} + a\right)\frac{2G}{k^2}\right]$$

$$A_{c\theta} = A_{c\alpha}(k,s)$$

$$A_{a\theta} = A_{a\theta}(k,a,s) = A_{a\alpha} - (s - a)A_{ah}$$

$$A_{dh} = A_{ah}(k,s)$$

$$A_{d\alpha} = A_{d\alpha}(k,a,s) = A_{a\alpha} - (s - a)A_{c\alpha}$$

$$A_{d\theta} = A_{a\alpha}(k,s)$$

Analysis B.-

$$\overline{A_{ch}} = A_{ch} + \sigma_h(y)\left(\frac{2i}{k}\right)$$

$$\overline{A_{c\alpha}} = A_{c\alpha} + \sigma_\alpha(y)\frac{2i}{k}\left(\frac{1}{2} + a\right)$$

$$\overline{A_{ah}} = A_{ah} - \sigma_h(y)\frac{2i}{k}\left(\frac{1}{2} + a\right)$$

$$\overline{A_{a\alpha}} = A_{a\alpha} + \sigma_\alpha(y)\left[-\frac{2}{k^2}\left(\frac{1}{2} + a\right) - i\left(\frac{1}{4} - a^2\right)\frac{2}{k}\right]$$

$$\overline{A_{c\theta}} = A_{c\theta} + \sigma_\theta(y)\left[\frac{2}{k^2} + \frac{2i}{k}\left(\frac{1}{2} - s\right)\right]$$

$$\overline{A_{dh}} = A_{dh} + \sigma_h(y)\left(-\frac{2i}{k}\right)\left(\frac{1}{2} + s\right)$$

$$\overline{A_{d\theta}} = A_{d\theta} - \sigma_\theta(y)\left[\frac{2}{k^2}\left(\frac{1}{2} + s\right) + \frac{2i}{k}\left(\frac{1}{4} - s^2\right)\right]$$

$$\overline{A_{a\theta}} = A_{a\alpha} - \sigma_\theta(y)\left[\frac{2}{k^2}\left(\frac{1}{2} + a\right) + \frac{2i}{k}\left(\frac{1}{4} - a^2\right)\right] - (s - a)A_{ah} +$$

$$(s - a)\sigma_\theta(y)\frac{2i}{k}\left(\frac{1}{2} + a\right)$$

$$\overline{A_{d\alpha}} = A_{a\alpha} - \sigma_{\alpha}(y)\left[\frac{2}{k^2}\left(\frac{1}{2} + a\right) + \frac{2i}{k}\left(\frac{1}{4} - a^2\right)\right] - (s - a)A_{c\alpha} -$$

$$(s - a)\sigma_{\alpha}(y)\left[\frac{2}{k^2} + \frac{2i}{k}\left(\frac{1}{2} - a\right)\right]$$

Analysis C.- Evaluated as for analysis A for $F = 1$, $G = 0$.

Analysis D.- $\left(\frac{A}{A + 2}\right)A_{ij}$ of analysis C.

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TABLE I.- WING PARAMETERS

(a) Unswept Wing

	Wing I		Wing II	
	Right	Left	Right	Left
Section	NACA 16-006	NACA 16-006	NACA 16-006	NACA 16-006
Material	Maple	Maple	Maple	Maple
Semispan length (Center line of fuselage to tip)	1.298 ft	1.298 ft	1.298 ft	1.298 ft
Density	0.0216 lb/in.^{3}	0.0216 lb/in.^{3}	0.0216 lb/in.^{3}	0.0216 lb/in.^{3}
c	0.333 ft	0.333 ft	0.333 ft	0.333 ft
Elastic axis	43.35 percent c	38.0 percent c	45.4 percent c	40.6 percent c
Section center of gravity	46.8 percent c	46.8 percent c	46.8 percent c	46.8 percent c
a	-0.133	-0.24	-0.092	-0.188
x_α	0.069	0.176	0.028	0.124
${r_\alpha}^2$	0.234	0.261	0.230	0.245
g	0.03	0.03	0.03	0.03
f_h	29.9 cps	29.9 cps	27.0 cps	27.0 cps
f_α	106 cps	106 cps	105 cps	105 cps
A	7.25		7.25	

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TABLE I.- WING PARAMETERS - Concluded

(b) 45° Swept Wings

Section	0.064-inch-thick flat plate
Material	aluminum
Semispan length (center line of fuselage to tip) ft	1.298
Chord perpendicular to leading edge, ft	0.333
Density, lb/in.^{3}	0.101
Elastic axis, percent chord	50
Center of gravity, percent chord	50
f_h, cps	6.1
f_a, cps	33.3

TABLE II.- FLUTTER DATA

(a) Wings I, fuselage free

V ft/sec	q lb/ft^2	I	s	2V/cω Experimental	2V/cω$_h$ Experimental	Analytical 2V/cω$_h$ A	B	C	D	f$_{cps}$ Experimental	Analytical f$_{cps}$ A	B	C	D
248.1	73.7	0.2725	-2.412	79.60	8.86	(a)	(b)	6.85	7.72	2.98	(a)	(b)	3.09	3.08
259.3	30.6	.1800	-4.68	42.20	9.21	5.17	(b)	7.85	8.84	5.88	3.95	(b)	6.91	6.88
282.1	95.1	.2180	-6.43	40.65	10.09	6.55	8.95	8.40	9.45	6.64	5.67	9.5	8.38	8.41
282.3	95.1	.2950	-7.50	39.00	10.10	7.30	(b)	8.67	9.90	6.93	6.77	(b)	8.20	9.17
292.6	101.9	.2650	-8.26	34.25	10.45	7.34	(b)	8.38	9.90	8.16	6.89	(b)	9.71	9.60
289.6	99.8	.2790	-8.26	33.45	10.34	7.30	(b)	8.81	10.30	8.28	6.82	(b)	9.39	10.22
297.1	104.7	.3067	-8.26	39.00	10.61	7.26	(b)	8.70	9.74	7.28	6.22	(b)	8.66	9.06
295.6	103.8	.3560	-8.26	39.70	10.56	7.20	(b)	8.80	9.87	7.12	5.92	(b)	8.31	8.23
297.7	105.2	.3425	-9.32	38.80	10.63	7.65	9.65	9.03	10.15	7.33	6.97	10.2	9.55	9.59
Fuselage Fixed														
338.1	137.1	(d)	(d)	(c)	12.08	10.00	(b)	(b)	(b)	(c)	56.4	(b)	(b)	(b)
(b) Wings II, fuselage free														
283.1	93.45	0.4513	-11.25	36.40	10.19	8.15	(b)	9.35	10.48	7.49	7.54	(b)	9.88	9.83
271.7	85.8	.3522	-9.42	35.05	9.71	7.72	(b)	9.1	10.15	7.41	7.16	(b)	9.68	9.43
259.0	77.5	.2927	-7.65	38.65	9.26	7.05	(b)	8.68	9.75	6.41	6.02	(b)	8.41	8.57
228.7	57.4	.2041	-3.51	56.10	8.18	3.54	(b)	7.64	8.36	3.53	1.98	(b)	5.02	4.87
221.7	57.1	.1964	-2.38	70.8	7.91	(a)	(b)	6.83	7.80	2.99	(a)	(b)	3.61	3.69

[a]No solution obtained.

[b]No solution attempted.

[c]Data not obtained, model destroyed.

[d]Not defined.

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TABLE III.- TEST CONDITIONS FOR 45° SWEPT WING

s (a)	I	V	q	f	Comments
------	------	214.3	55.2	25.3	Spar locked
0	0.1092	217.2	56.2	23.0	Flutter was bending-torsion type
-1.16	.1774	-----	----	----	Low-reduced-frequency flutter not obtained and data for bending-torsion flutter were not recorded
-4.098	.2160	-----	----	----	
-5.88	.2800	-----	----	----	

[a] s is nondimensional in semichords which are normal to leading edge.

[redacted]

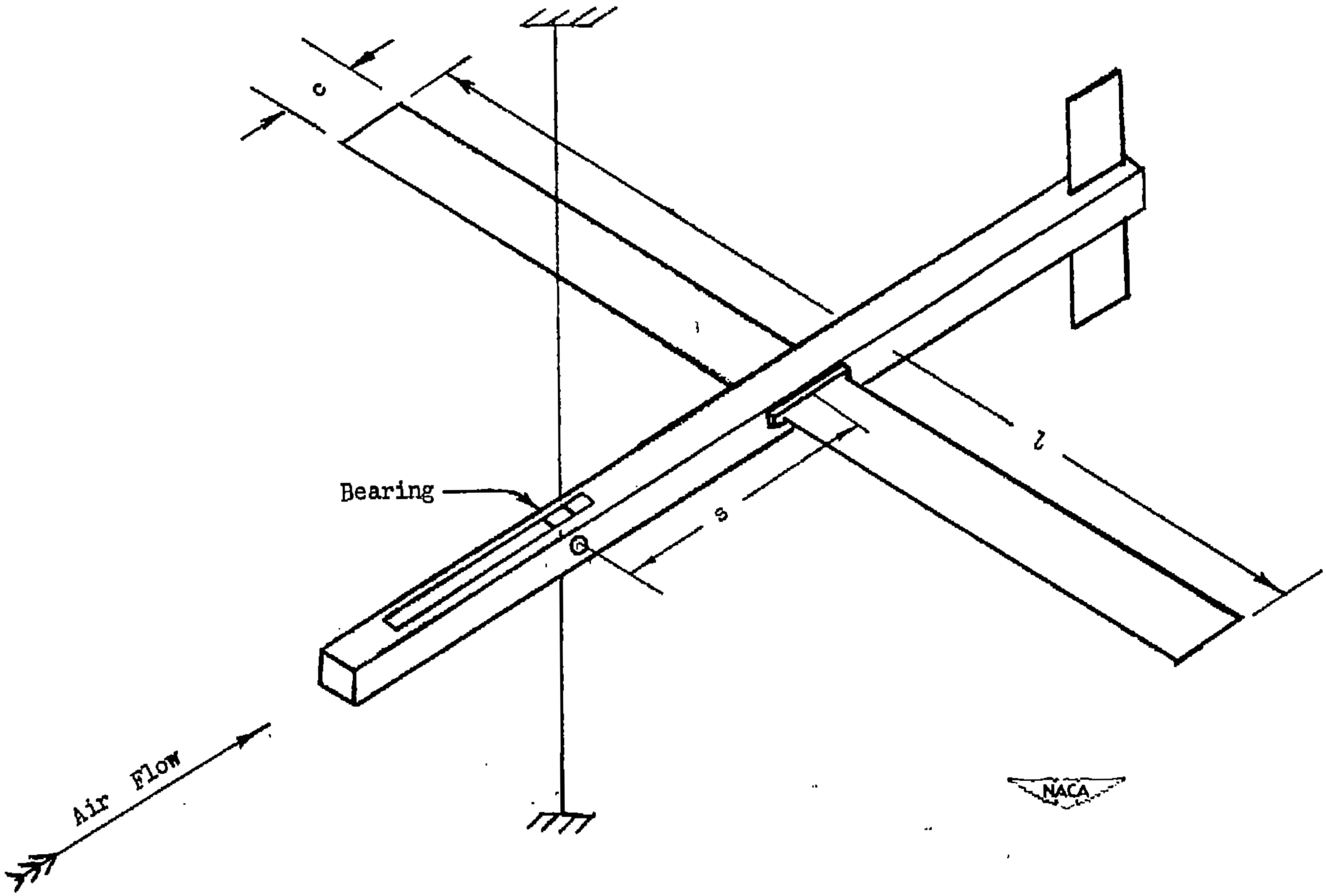

Figure 1.- Sketch of model.

[redacted]

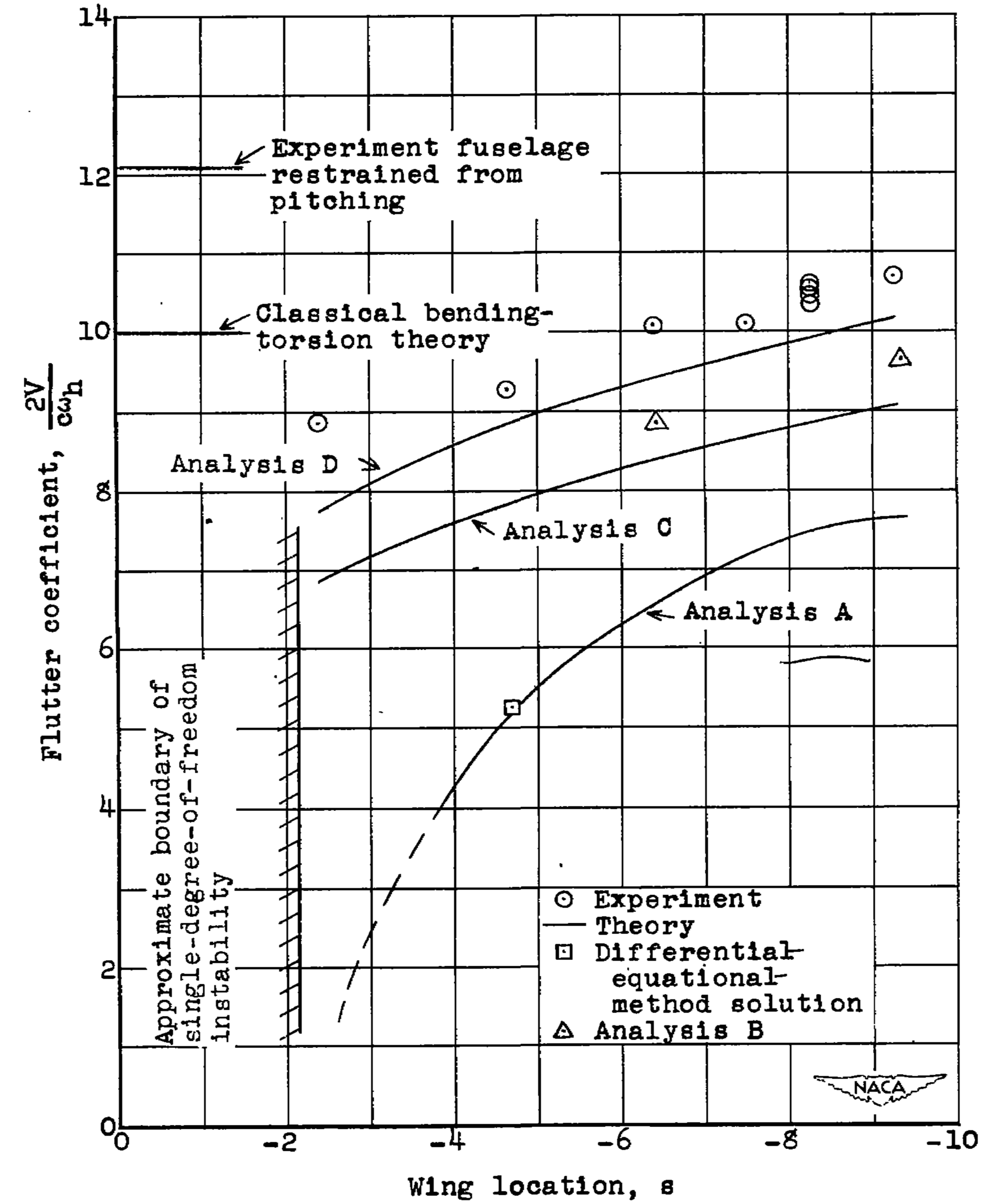

Figure 2.- Flutter coefficient against wing location for wood wings I.

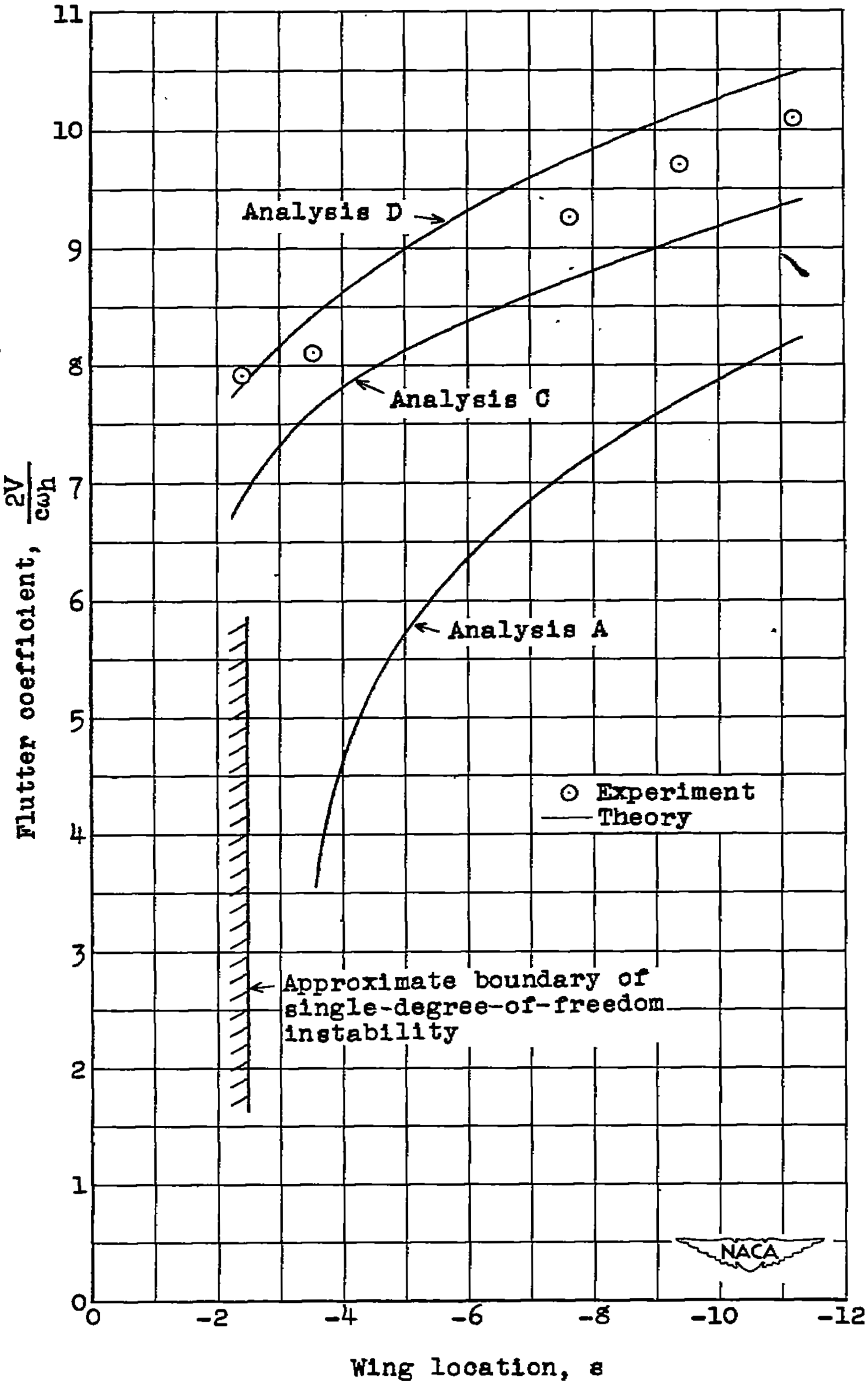

Figure 3.- Flutter coefficient against wing location for wood wings II.

SECURITY INFORMATION

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