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Wind Tunnel Tests on Antisymmetric Flutter of a Delta Wing with Rolling Body Freedom

By

D. R. Gaukroger and D. Nixon

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SUMMARY

Wind tunnel tests on a half span model to determine the antisymmetric flutter characteristics of a delta wing are described. The model had a leading edge sweepback of 45° and a tip chord 1/16th of the root chord. The effect of fuselage rolling moment of inertia on critical flutter speed and frequency was investigated. The results show that body freedom flutter is obtained under conditions of fuselage rolling moment of inertia that are representative of full scale, and that the flutter speeds are considerably higher and the frequencies lower than with the root fixed. With large values of fuselage rolling moment of inertia disturbed root flutter occurs, the speeds again being higher than with the root fixed.

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1 Introduction

Experimental and theoretical investigations of antisymmetric wing flutter by Frazer and Duncan[1], Houbolt[2] and Gaukroger[3] have shown that with swept and unswept wings, flutter speeds greater than the fixed root flutter speeds are obtained when the wings are allowed a body freedom in roll. The present report describes a wind tunnel investigation of antisymmetric flutter on a wing of delta planform. The model is similar to that used in an investigation of symmetric flutter with body freedoms in normal translation and pitch[4], thus enabling a direct comparison to be made of the symmetric and antisymmetric flutter characteristics of this particular delta planform.

The test results show that two forms of flutter occur, corresponding to the 'body freedom' and 'disturbed root' forms of antisymmetric flutter on a sweptback wing[3]. The flutter speeds in both forms of flutter are considerably higher than that of the wing with the root fixed. The value of the fuselage rolling moment of inertia at which the transition occurs from one form of flutter to the other is much greater than the corresponding value for a sweptback wing. Values of fuselage rolling moment of inertia that are likely to occur in practice are shown to be associated with the body freedom form of flutter.

2 Model details

2.1 Wing

The wing was of delta planform with 45° sweepback of the leading edge (Fig.1). A half span model was used having a span of 45 inches, root chord 48 inches and tip chord 3 inches. A single spar of spruce at 35% chord formed the main structural member, and composite spruce and balsa ribs were glued to the spar at 1 inch spacing. The ribs, which were 5/16 inch thick, were of symmetrical aerofoil section, (RAE 101), and had a thickness/chord ratio of 0.10. The leading and trailing edges of the wing were stiffened with cartridge paper glued to the ribs, but a small unstiffened section was left between each rib. The structure was covered with silk, doped with a solution of Vaseline in chloroform. Lead weights were built into the ribs to give an overall inertia axis for the wing at 50% chord. Each weight was proportional to the square of the local rib chord. The weight of the wing, including the root fixing block, was 16.12 lb. The rolling moment of inertia was measured by timing oscillations in still air about the axis of rolling body freedom. The resulting moment of inertia - effectively the rolling moment of inertia of the wing about the centre line of the aircraft - was 4,123 lb in^2.

2.2 Body

The wing was attached to a rig that allowed body freedom in roll about the root; the rig is shown diagrammatically in Figure 2. The wing, which was mounted vertically in the wind tunnel, was attached at its root end to a rigid framework. The framework was supported by two ball races, fore and aft of the wing root giving the wing freedom to roll about an axis parallel to the airflow, and corresponding to the centre line of an aircraft. A lever arm extended vertically downward from the framework, and at the end of this arm a tube was fitted which projected horizontally to a point outside the tunnel working section, where it was supported by a long vertical cord. A ball bearing joint formed the junction of the tube and the lever arm. From Figure 2 it may be seen that by attaching weights to the tube, the rolling moment of inertia of the rig (or fuselage) could be varied. For stabilizing the model a pair of springs was attached to the lever arm to provide a restoring moment when the wing was displaced in roll. The frequency of oscillation was obtained from a make-and-break contact on the lever arm which operated an electrical counting device.

3 Wind tunnel tests

The tests were made in the R.A.E. 5 foot open jet wind tunnel, and the rolling axis of the wing coincided with the edge of the tunnel nozzle.

The rolling moment of inertia of the fuselage was varied from a large positive value down to zero, and by using stabilizing springs of high stiffness, (acting as large negative masses under oscillatory conditions), some negative values of fuselage rolling moment of inertia were obtained. At each flutter condition, the critical flutter speed and frequency were measured.

4 Test results and discussion

The results of the tests are shown in Fig.3 in which flutter speed and frequency are plotted against fuselage rolling moment of inertia. It will be seen that two forms of flutter, represented by two branches of the flutter speed and frequency curves, are obtained. With negative values of the fuselage rolling moment of inertia the flutter is of the body freedom form. The characteristic of this flutter is the large amplitude of the wing in roll relative to the wing flexural and torsional displacements. The flutter speed is above and the frequency below the corresponding fixed root values. As the fuselage rolling moment of inertia is increased through zero into the positive range the flutter speed increases and the frequency falls slightly, the mode remaining essentially the same. At a critical value of the fuselage rolling moment of inertia (1110 lb in^2. for the wing tested) a transition occurs; for any value of moment of inertia greater than that at the transition the flutter is of the "disturbed root" form. The mode of oscillation in this flutter closely resembles the fixed root flutter mode, but there is a small rolling amplitude compared with the amplitudes in wing flexure and torsion. The flutter speed reaches a maximum at transition, which is approximately 1.75 times the fixed root flutter speed. The flutter frequency in the disturbed root form is higher than that of the fixed root value, giving a discontinuity in the frequency curve at transition.

If the fuselage rolling moment of inertia is increased beyond the value at transition the flutter speed falls rapidly at first and then less rapidly; it may be assumed that it becomes asymptotic to the fixed root flutter speed as in the case of the sweptback wing[3]. The flutter frequency remains practically constant for disturbed root flutter over the range tested, although Figure 3 indicates some increase in frequency for the maximum value of rolling moment of inertia that was tested. However, with very large values of rolling moment of inertia (approximating to fixed root conditions) the flutter speed and frequency will both tend to the fixed root values.

The results of the tests indicate that in the practical range of values of rolling moment of inertia of the fuselage, the flutter speeds are likely to be considerably higher than the fixed root speed. As in the case of aircraft with sweptback wings the value of the fuselage rolling moment of inertia of the delta wing aircraft is unlikely to exceed a fifth of the rolling moment of inertia of the wings. In Figure 3 this value has been indicated in the diagrams, and it may be seen that the practical range of values of fuselage rolling moment of inertia, from zero to a fifth of the wing rolling moment of inertia, falls entirely within the body freedom flutter region.

Two interesting points may be noted from a comparison of the present test results and of similar tests on a sweptback wing[3]. First, the flutter speeds occurring with the delta wing are considerably higher in relation to the fixed root speed than are those of the sweptback wing. Secondly, the transition from body freedom to disturbed root flutter occurs at a much higher value of fuselage rolling moment of inertia for the delta than for the sweptback wing.

5 Comparison of symmetric and antisymmetric characteristics

The model used in the present tests was basically similar to that used in an earlier investigation of symmetric flutter of a delta wing[4]. The only structural difference was that the cartridge paper along the leading and trailing edges of the present wing was discontinuous whereas in the earlier tests it had been continuous. Apart from this the two wings were made to the same design. In comparing the two sets of results fluttor speeds are considered relative to the fixed root speeds, as the latter were not the same for both wings.

In comparing the symmetric and antisymmetric flutter characteristics there is a striking similarity between the conclusions to be drawn from the tests on the sweptback and delta wings. The following paragraph, which is taken from the report on the antisymmetric flutter of sweptback wings[3], may be quoted here since it applies equally to the delta wing.

"In the antisymmetric case, whichever form of flutter occurs flutter speeds are never less than the fixed root flutter speed. In the symmetric case[4] disturbed root flutter gives flutter speeds above the fixed root flutter speeds, but body freedom flutter can give speeds below it. It may therefore be concluded that both symmetric and antisymmetric flutter must be considered except for those conditions in which symmetric body freedom flutter occurs at speeds below the fixed root flutter speed and in which symmetric flutter will therefore occur before antisymmetric flutter."

In the case of the sweptback wing it is possible that symmetric body freedom flutter will occur under certain sweepback and fuselage inertia conditions[3,5], but for the delta wing this form of flutter is unlikely to occur in practice[4], and it may be concluded that the fixed root flutter speed for the delta wing is always likely to be lower than any of the symmetric or antisymmetric forms of flutter that may occur in practice.

6 Conclusions

6.1 Two forms of antisymmetric flutter may be obtained for the delta, "body freedom" or "disturbed root". The occurrence of either form is dependent upon the fuselage rolling moment of inertia.

6.2 The body freedom form of flutter occurs over a wide range of values of fuselage rolling moment of inertia. This range includes the values that are likely to be found in practical designs.

6.3 The body freedom flutter speeds are above, and the frequencies below, the fixed root values.

6.4 The disturbed root form of flutter occurs with large values of fuselage rolling moment of inertia. Both flutter speed and frequency are higher than the corresponding fixed root values. The flutter speed falls as the fuselage rolling moment of inertia is increased.

6.5 Flutter tests on similar delta wings with symmetric and antisymmetric body freedoms indicate that for any practical design either case may be the more critical, but flutter speeds below that with the root fixed are unlikely to occur.

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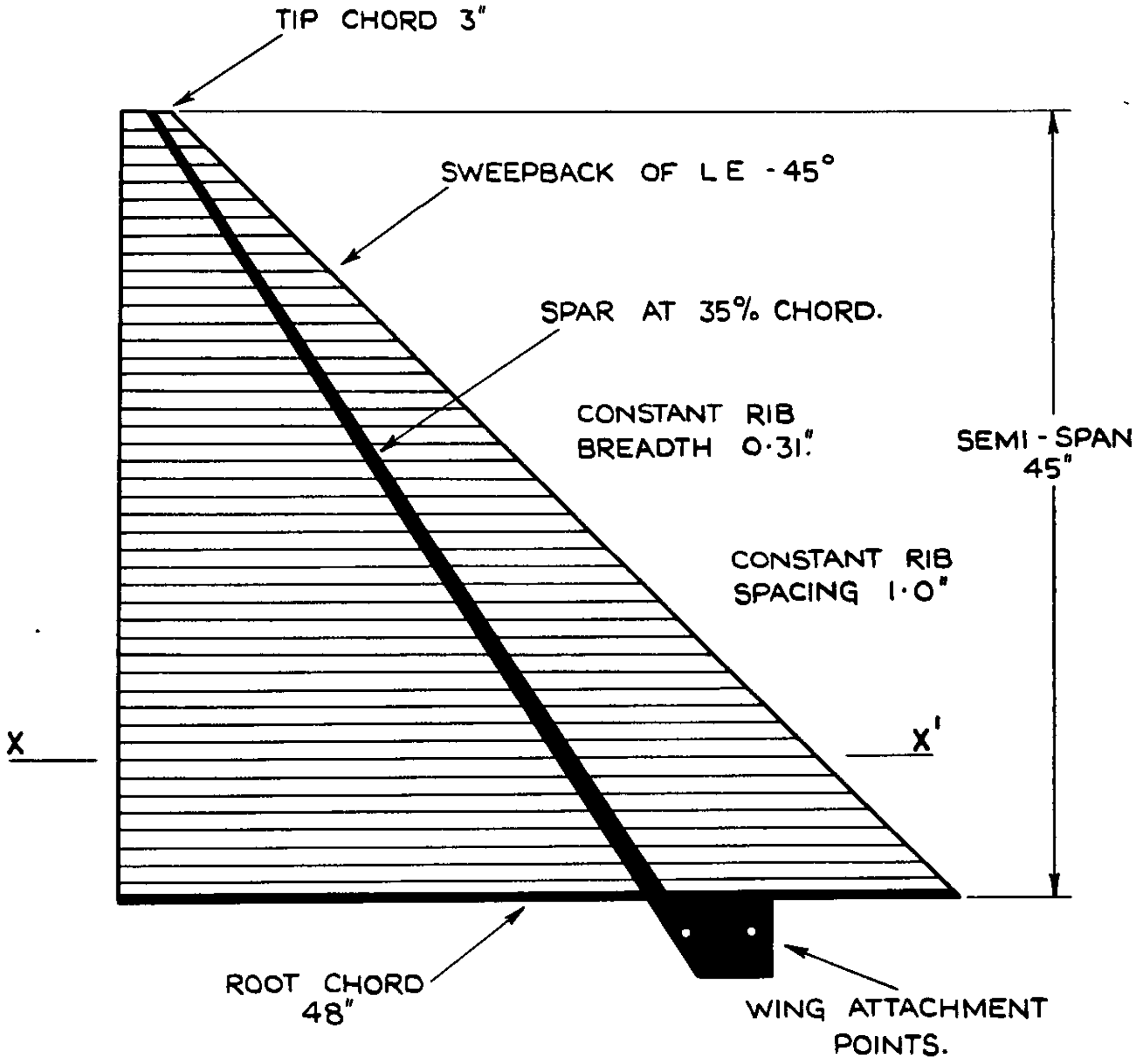

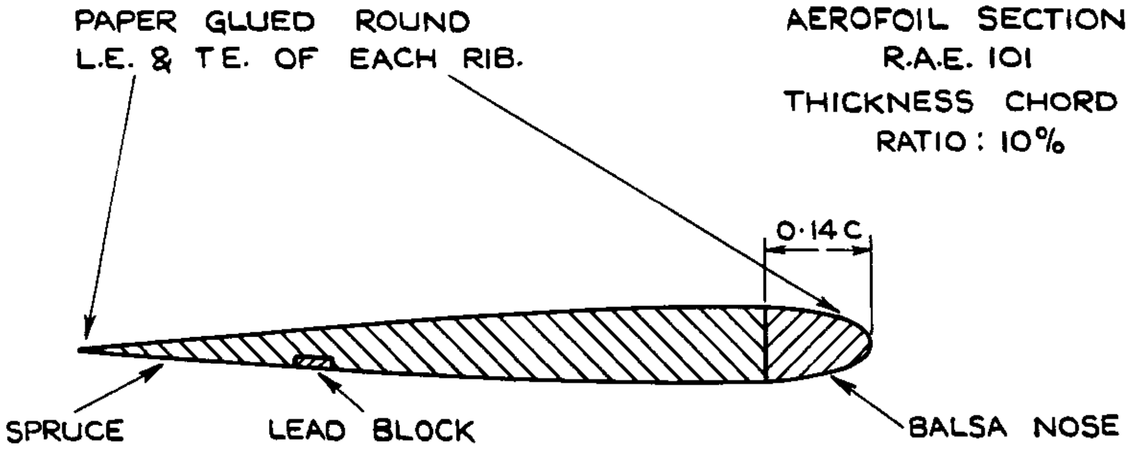

SECTION THROUGH XX'

FIG. I. WING DETAILS.

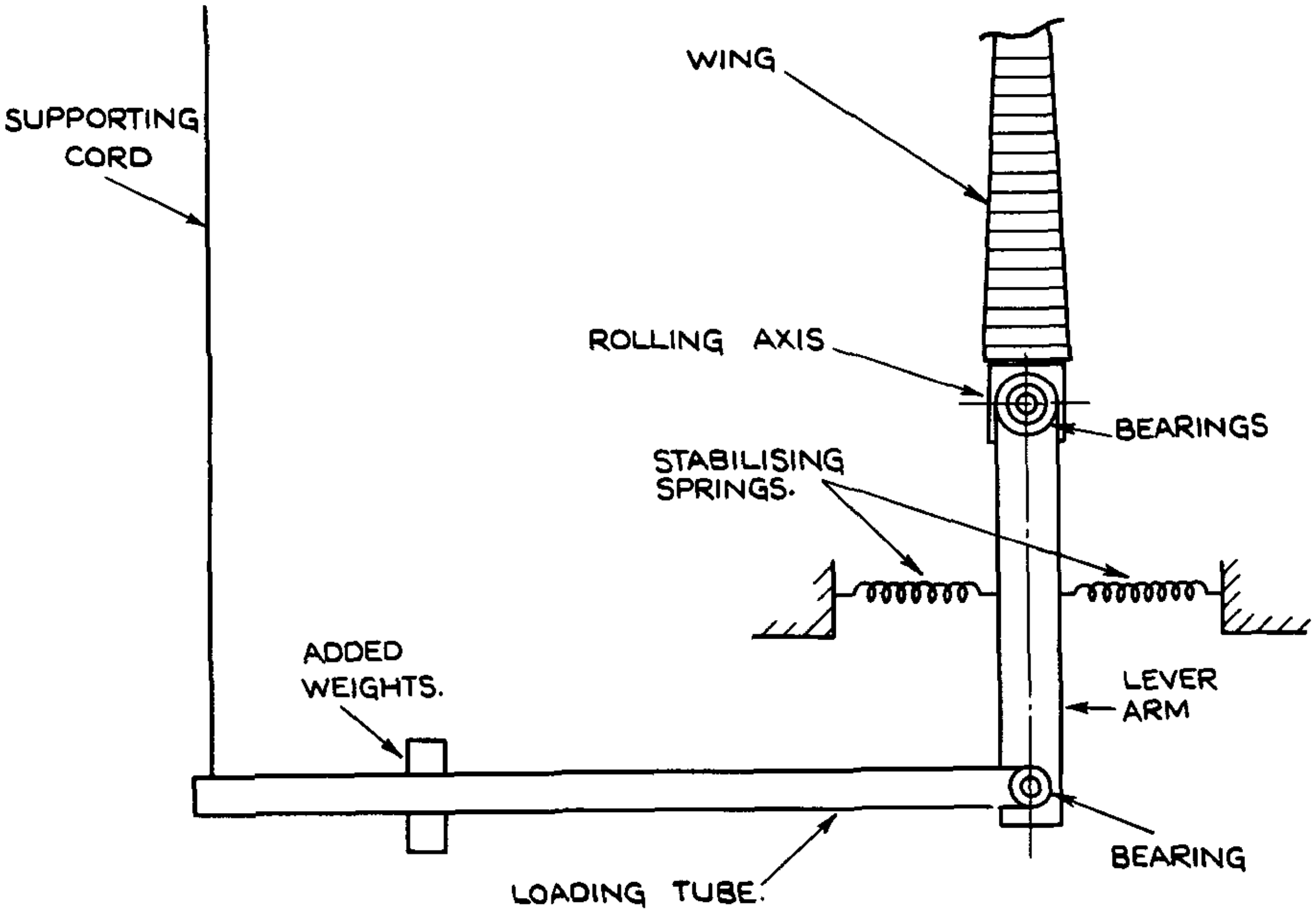

FIG. 2. ARRANGEMENT OF ROLLING FREEDOM.

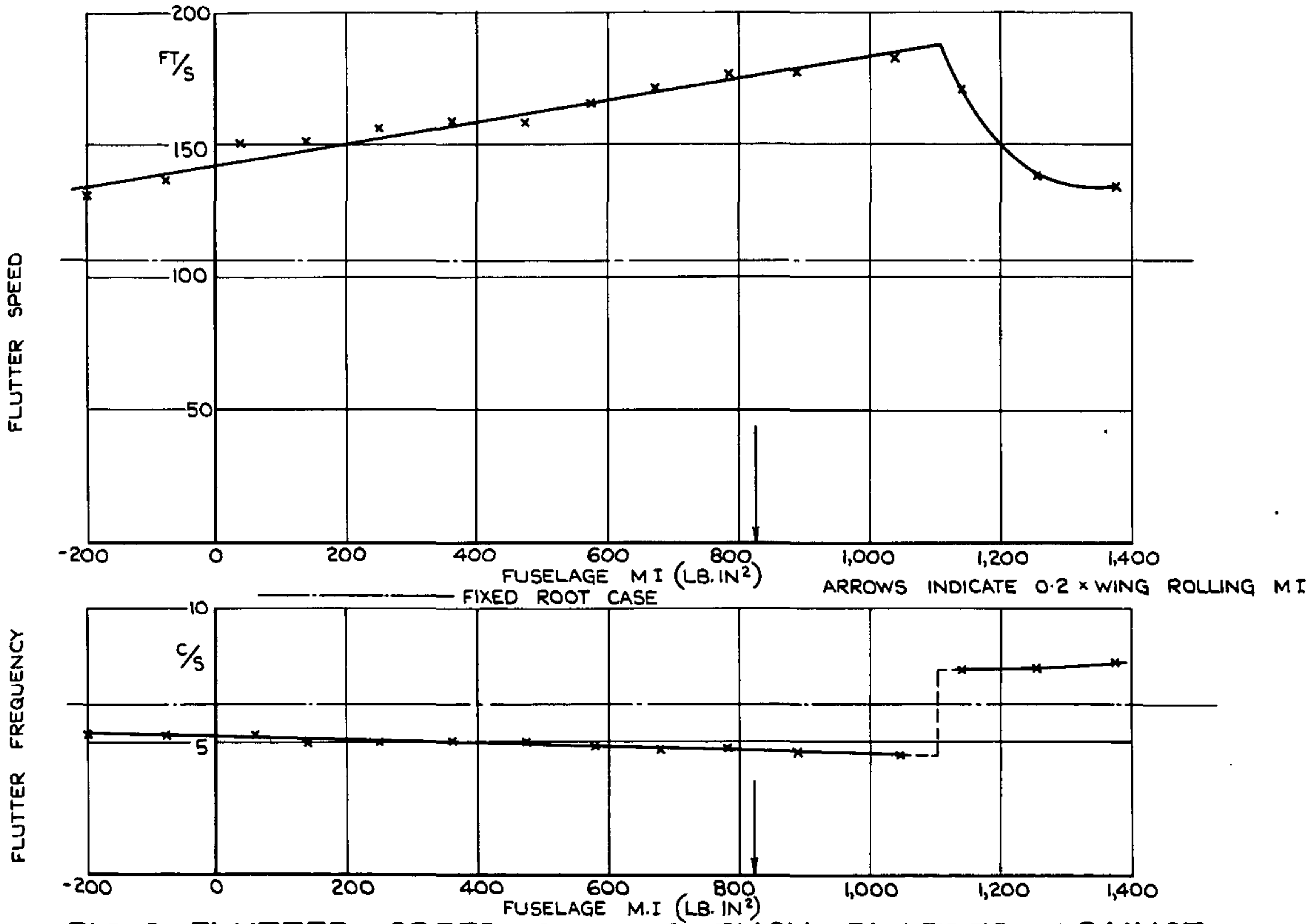

FIG. 3. FLUTTER SPEED & FREQUENCY PLOTTED AGAINST FUSELAGE ROLLING MOMENT OF INERTIA.

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