(4)

ARL-STRUC-TM-495 AR-005-544

AD-A209 244

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Aircraft Structures Technical Memorandum 495

FLUTTER CALCULATIONS FOR A MODEL WING USING THE MSC NASTRAN STRUCTURAL ANALYSIS PROGRAM

by

Betty Emslie

Approved for Public Release

NOVEMBER 1988

AR-005-544

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORY

Aircraft Structures Technical Memorandum 495

FLUTTER CALCULATIONS FOR A MODEL WING USING THE MSC NASTRAN STRUCTURAL ANALYSIS PROGRAM

by

Betty Emslie

SUMMARY

Flutter calculations for a semispan model wing with a trailing edge control surface have been carried out using MSC NASTRAN. In order to alter the critical flutter speeds of the model wing, provision was made to allow rods or other masses to be attached at the wing tip. In these calculations aluminium and steel rods were used to modify the flutter characteristics of the model. Eleven configurations of the model wing were considered. For each of the 11 configurations, flutter calculations were carried out for a number of different aileron rotational stiffnesses.

DSTO ARL
MELBOURNE

POSTAL ADDRESS: Director, Aeronautical Research Laboratory,
P.O. Box 4331, Melbourne, Victoria, 3001, Australia

CONTENTS

Page No.

1. INTRODUCTION

A semispan model wing has been used to carry out wind tunnel tests on active flutter control laws.

At the time when the model wing was being designed and fabricated, the Structural Analysis Program, MSC NASTRAN became available at ARL. It was decided to use NASTRAN to predict the vibration modes and frequencies of the model wing and subsequently to use the aeroelastic capabilities of NASTRAN to carry out flutter analyses of the model wing.

This paper describes the calculations carried out using the MSC NASTRAN Structural Analysis Program.

2. MODEL WING

The model wing is a cantilever with a span of 894 millimetres and a chord of 300 millimetres. The airfoil section is symmetrical with a maximum thickness of 50 millimetres. There is a single trailing edge control surface, which will be referred to as the aileron throughout this paper. The main dimensions of the model wing and a sketch of the airfoil section are shown in Fig. 1.

The main structure of the model wing consists of four aluminium spar rods, each with a circular cross-section five millimetres in diameter. The distance between the front and rear spar rods is 125 millimetres and the distance between the top and bottom spar rods is 20 millimetres. To ensure that the natural frequencies of the model wing would be sufficiently low, the remainder of the wing was constructed as five separate sub-assemblies. Each sub-assembly consisted of supporting ribs covered by a thin plastic wing skin and was attached to the four aluminium spar rods at one intermediate rib.

In order to alter the critical flutter speeds of the model, provision was made to allow rods or other masses to be attached at the wing tip.

3. NASTRAN FLUTTER ANALYSIS PROCEDURE

The first step in carrying out flutter analyses using NASTRAN is to develop and verify a finite element structural model which allows prediction of the normal vibration modes and frequencies by means of real eigenvalue analysis. After confirming that the calculated normal modes (eigenvectors) and frequencies (eigenvalues) accurately represent the modes and frequencies of the model wing, the next step in setting up the flutter equations of motion is the calculation of the matrices of generalized aerodynamic forces.

Both linear and surface splining techniques are available to generate the transformation matrix between structural and aerodynamic grid point deflections. Then there is a choice of two subsonic aerodynamic theories for calculating the generalized aerodynamic force matrices. These two theories are Strip Theory and the Doublet-Lattice Method.

Three methods of flutter solution are available in NASTRAN. These are the PK-method, the K-method and the KE-method.

A concise introduction to NASTRAN static and normal modes analysis can be found in [1] and further details of NASTRAN'S aeroelastic capabilities are provided in [2].

4. NORMAL MODES

As soon as the drawings of the model wing became available a finite element structural model was set up using NASTRAN; see Fig. 2. This finite element model was used to calculate the first four normal modes and corresponding frequencies.

When the model wing was constructed, a ground vibration test was carried out. Comparison of the experimental frequencies and mode shapes with the calculated values revealed some differences . The calculated and experimental mode shapes were similar, but the calculated frequencies were too high. After some trial and error, reasonably good agreement was achieved with a model in which the structure was represented by the four aluminium rods, two boxes near the wing tip made up of membrane elements and a steel rod simulating the aileron drive motor and other masses near the aileron hinge line; see Fig. 3. This NASTRAN structural model represents the model wing with the aileron clamped.

The four lowest modal frequencies calculated for this model were 6.73, 7.88, 14.16 and 44.22 Hertz. The 6.73 Hertz mode is essentially a bending mode, the 7.88 Hertz mode is a fore and aft mode, the 14.16 Hertz mode is a torsion mode and the 44.22 Hertz mode is an overtone bending mode.

This model was designated the STANDARD CONFIGURATION, Configuration 1.

5. CONFIGURATIONS USED IN THE FLUTTER CALCULATIONS

Aluminium and steel rods were used to modify the flutter characteristics of the model. These rods have the same five millimetre diameter circular cross-section as the aluminium spar rods. The location of structural grid points 27 and 28, referred to below, can be seen in *Fig. 3*.

Flutter calculations were carried out for the following configurations.

Configuration 1 - The STANDARD CONFIGURATION, described in Section 4

Configuration 2 - The STANDARD CONFIGURATION plus an aluminium tip rod connecting structural grid points 27 and 28

Configuration 3 - The STANDARD CONFIGURATION plus a steel tip rod connecting structural grid points 27 and 28

Configuration 4 - The STANDARD CONFIGURATION plus an aluminium tip rod connecting structural grid points 27 and 28 and extending backward a further 100 millimetres

Configuration 5 - The STANDARD CONFIGURATION plus a steel tip rod connecting structural grid points 27 and 28 and extending backward a further 100 millimetres

Configuration 6 - The STANDARD CONFIGURATION plus an aluminium tip rod connecting structural grid points 27 and 28 and extending backward a further 200 millimetres

Configuration 7 - The STANDARD CONFIGURATION plus a steel tip rod connecting structural grid points 27 and 28 and extending backward a further 200 millimetres

Configuration 8 - The STANDARD CONFIGURATION plus an aluminium tip rod connecting structural grid points 27 and 28 and extending forward a further 100 millimetres

Configuration 9 - The STANDARD CONFIGURATION plus a steel tip rod connecting structural grid points 27 and 28 and extending forward a further 100 millimetres

Configuration 10 - The STANDARD CONFIGURATION plus an aluminium tip rod connecting structural grid points 27 and 28 and extending forward a further 200 millimetres

Configuration 11 - The STANDARD CONFIGURATION plus a steel tip rod connecting structural grid points 27 and 28 and extending forward a further 200 millimetres

The four lowest modal frequencies calculated for each of these configurations are listed in Table 1.

6. FLUTTER CALCULATIONS WITH THE AILERON CLAMPED

At first, flutter calculations were carried out with the aileron clamped.Flutter calculations were carried out for Configuration 1, the STANDARD CONFIGURATION, using the three lowest modal frequencies. Both the PK and the KE flutter solution methods were used. The flutter speeds and flutter frequencies calculated by each of these methods are in close agreement; see Table 2. These flutter calculations were repeated, using the four lowest modal frequencies. As expected, the addition of the fourth mode with a frequency much higher than the first three frequencies, did not alter the critical flutter speed. Therefore, only the three lowest modal frequencies were used in all further calculations.

Three degree of freedom flutter calculations, using the three lowest modal frequencies, were carried out for Configurations 2 - 11. For these calculations, the PK method of flutter solution was used. The calculated flutter speeds and corresponding flutter frequencies for all the configurations are listed in Table 3. The influence of the tip rods in modifying the critical flutter speed of the model wing can be clearly seen. The flutter speed for Configuration 7, in which a steel rod connecting structural grid points 27 and 28 extends backward a further 200 millimetres, has been reduced to 9.95 metres per second. On the other hand, if the same steel rod is attached to grid points 27 and 28 and allowed to extend forward 200 millimetres, Configuration 11, the flutter speed is increased to 19.99 metres per second. The shorter rods modify the flutter speed to a lesser extent.

7. FLUTTER CALCULATIONS WITH THE AILERON UNCLAMPED

All of these flutter calculations were carried out with four degrees of freedom. The modes used were the normal modes with the three lowest frequencies and the fourth mode was aileron rotation about its hinge. In all these calculations the aileron is assumed to be statically balanced.

7.1 Flutter Calculations with the Aileron Hinge Moment of Inertia Equal to 0.000168 kilogram metre squared

An estimate of the aileron moment of inertia about its hinge yielded a value of 0.000168 kilogram metre squared. Five values of aileron rotational frequency were chosen. These values are 20, 14, 12, 8 and 2 Hertz. The frequency 20 Hertz was chosen to represent an aileron with high rotational stiffness and the frequency 2 Hertz represents an aileron with low rotational stiffness. The other three frequencies were chosen so that coupling could take place between the aileron rotation mode and the torsion and bending modes of the model wing. Table 10 lists the aileron rotational frequencies and the corresponding aileron rotational stiffnesses.

At first, the PK method of flutter solution was used. The calculated flutter speeds and corresponding flutter frequencies are presented in Table 4. The KE method of flutter solution was used to calculate flutter speeds and flutter frequencies for a number of configurations. These results are presented in Table 5. Flutter speeds and flutter frequencies for configurations 3, 6, 10 and 11 were calculated using both the PK and KE methods of flutter solution. Comparison of these results shows good agreement in the calculated flutter speeds and flutter frequencies.

7.2 Flutter Calculations with the Aileron Hinge Moment of Inertia Equal to 0.000336 kilogram metre squared

To test the sensitivity of the flutter calculations to the value of the aileron hinge moment of inertia, the original estimate was doubled. At first, the same five values of aileron frequency were chosen. These were 20, 14, 12, 8 and 2 Hertz. The aileron rotational stiffnesses corresponding to these frequencies, when the aileron hinge moment of inertia is 0.000336 kilogram metre squared, are listed in Table 10.

As before, four degree of freedom flutter calculations were carried out. Most calculations were done using the PK method of flutter solution. These results are listed in Table 6. A few flutter calculations were carried out using the KE method of flutter solution. These results are presented in Table 7.

Subsequently, some further calculations were carried out with the aileron hinge moment of inertia equal to 0.000336 kilogram metre squared. In this case the values of the aileron rotational frequency were 14.14, 9.90, 8.49, 5.65 and 1.41 Hertz. These values were obtained by keeping the aileron rotational stiffnesses constant when the estimate of the aileron hinge moment of inertia was doubled; see Table 10. Four degree of freedom flutter calculations, using the PK method of flutter solution, were carried out for configurations 6, 7, 10 and 11. The results of these calculations are presented in Table 8. Besides providing information on the sensitivity of the flutter speeds and frequencies to changes in the aileron hinge moment of inertia, the results listed in Table 8 can be combined with results from Table 6 to present extra data on the variation of flutter speeds and frequencies with variation in the aileron rotational frequency. This combination of results from Tables 6 and 8 is presented in Table 9.

7.3 Flutter Calculations using the K Method of Flutter Solution

The K method of flutter solution calculates the complex eigenvalues, from which the velocity, damping and frequency are determined, and all the corresponding complex eigenvectors; see [2]. From these complex eigenvectors the complex displacements at all the structural grid points are determined. In other words, the relative displacement amplitudes and phase relationships are available at all the structural grid points. Therefore, if it is assumed that the response at some reference point i is given by

$$z_i(t) = \bar{z}_i \sin(\omega t)$$

then the response at each structural grid point can be written

$$z_g(t) = \bar{z}_g \sin(\omega t + \phi_g) \ .$$

This may be expanded to

$$\begin{aligned} z_g(t) &= \bar{z}_g(\sin \omega t \ \cos \phi_g + \cos \omega t \ \sin \phi_g) \\ &= (\bar{z}_g \cos \phi_g) \ \sin \omega t + (\bar{z}_g \sin \phi_g) \ \cos \omega t \\ &= \bar{x}_g \sin \omega t + \bar{y}_g \cos \omega t \end{aligned}$$

where $\bar{x}_g$ is the response in phase with the reference point and $\bar{y}_g$ is the response in quadrature with the reference point.

Thus, graphs of the vector response can be plotted for each of the cases studied.

Since more computer time is required for the K method of flutter solution, only three cases were studied. The configuration chosen was configuration 11 with the aileron hinge moment of inertia equal to 0.000168 kilogram metre squared. The three values of aileron rotational frequency chosen were 12, 8 and 2 Hertz. The flutter speeds and flutter frequencies calculated for these three cases, using the K method of flutter solution, are presented in Table 11. These values of flutter speed and flutter frequency are identical to the values calculated for the same cases using the KE method of flutter solution; compare Tables 5 and 11.

The graphs of the vector response for each of these three cases are shown in Figs. 4 - 6. In these graphs, the vector response at the structural grid points along the front and rear top spars are plotted. The vector response at structural grid points 1252 and 1501 are also shown in Figs. 4 - 6. Structural grid point 1252 is the forward tip of the steel rod and structural grid point 1501 is the inboard trailing edge of the aileron. Inspection of Figs. 4 - 6 shows that, in all three cases, the phase relationship between the front and rear spars and the forward tip of the steel rod, while not the same, are similar. However, there are differences in phase relationship when structural grid point 1501, the inboard trailing edge of the aileron is considered. In Figs. 4 and 5 the response of the inboard trailing edge of the aileron has a phase lag when compared with responses along the rear spar. On the other hand, in Fig. 6, the response of the inboard trailing edge of the aileron has a phase lead when compared with responses along the rear spar. This all seems reasonable as the only difference between the three cases considered is the change in aileron rotational frequency. In Figs. 4 - 6 the orientations of the vector response graphs are not all the same. This occurs because of the way in which the complex eigenvectors have been normalized during the K method solution process.

If it is desired to view the deformation mode shape of the model wing, at the flutter condition, probably the best method would be to use a graphics program that displays the periodic motion on a visual display unit. This approach was not followed in the present work.

8. DISCUSSION OF THE FLUTTER CALCULATIONS

8.1 General Comments

The main references used to produce the NASTRAN code for the above flutter calculations were [1], [3] and [4].

The Structural Analysis Program, MSC NASTRAN was available at ARL for a limited period. The opportunity was taken to study as many relevant parameter variations as possible for the model wing and also to gain as much experience as possible in the use of NASTRAN's aeroelastic capabilities. As the calculations for the various configurations proceeded, preliminary studies of the results showed that the calculated flutter speeds were consistent with expected trends. However, when more detailed analysis of the calculated flutter speeds was undertaken a few results seemed inconsistent. It was not possible to investigate these cases further using NASTRAN because the licence agreement had been terminated.

8.2 Comments on the Aerodynamics

As mentioned in Section 2, there is a choice of two subsonic aerodynamic theories for calculating the generalized aerodynamic force matrices. The Doublet-Lattice Method was used for most of the calculations presented in this paper; see Fig. 7 for the distribution of Doublet-Lattice panel boxes.

A few calculations for configurations with the aileron clamped were carried out using Strip Theory. The rectangular wing with an aspect ratio of approximately three was suitable for the use of Strip Theory and, as expected, the flutter speeds and frequencies calculated using this aerodynamic theory were almost identical with those calculated using the Doublet-Lattice Method.

8.3 Discussion of the Calculated Flutter Speeds

In general, there is good agreement between the flutter speeds and flutter frequencies calculated using the PK and KE flutter solution methods.

At first, flutter calculations were carried out with the aileron clamped. In Section 7, it was pointed out that in all the flutter calculations with the aileron unclamped, the aileron was assumed to be statically balanced. This assumption was made, because the main example of an aeroelastic response problem with the capability of including control systems (Section 3.5, [3]) included a sample data deck with the code for a wing with a statically balanced trailing edge control surface. It was intended to repeat at least some of the flutter calculations with an unbalanced aileron. However, in the time available, it was not possible to produce the code and carry out these calculations.

Flutter calculations were carried out for two values of aileron hinge moment of inertia, 0.000168 and 0.000336 kilogram metre squared. Flutter speeds calculated for the model wing with the aileron clamped can be compared with those for the model wing with the aileron unclamped, but with a high aileron rotational stiffness; see Table 12. For all configurations except 7 and 11 the flutter speeds for the unclamped aileron with high rotational stiffness are higher than those for the clamped aileron. The maximum increase is 9 per cent. For both Configurations 7 and 11 the flutter speeds for the unclamped aileron are lower than those for the clamped aileron. The maximum decrease for Configuration 7 is 3 per cent and for Configuration 11 it is 10 per cent.

Table 12 also allows the sensitivity of the calculated flutter speeds to variations in the aileron hinge moment of inertia to be easily seen. The information in Table 12 is for the case where the aileron rotational stiffness is high. Similar information for those cases where the aileron rotational stiffness is lower can be obtained from Tables 4 - 9.

In each of Tables 4 - 9, the aileron hinge moment of inertia is held constant and hence the variation of flutter speed and corresponding flutter frequency with variation in aileron rotational stiffness can be seen. In general, as the aileron rotational stiffness is reduced from a high value to a low value, the calculated flutter speed decreases to a minimum and then increases again. This behaviour was expected, as the aileron rotational frequencies and hence the aileron rotational stiffnesses were chosen so that the intermediate values were likely to couple with the wing bending or wing torsion modes. Configuration 7 is an exception to this behaviour.

The difference in flutter behaviour between Configuration 7 and all the other configurations analysed can be clearly seen by examining the velocity-damping and velocity-frequency graphs which are part of the output of each NASTRAN flutter calculation. It is important to be aware that the damping in these velocity-damping graphs is the amount of damping that would be required to make the system neutrally stable. In other words, a point with positive damping indicates instability. Further details of the equations used in NASTRAN flutter calculations are provided in [2].

First of all, consider the flutter calculations that were carried out with the aileron clamped; see Table 3. The velocity-damping and velocity- frequency graphs for Configurations 6, 7 and 11 are presented in Figs. 8 - 10. For both Configurations 6 and 11, (Figs. 8 and 10), there is a clearly defined stable region, below the zero damping axis. This is typical of all the configurations studied with the exception of Configuration 7. For Configuration 7, which is the configuration with the lowest critical flutter speed, the stable region is very much reduced; see Fig. 9.

Now consider the flutter calculations that were carried out with the aileron unclamped. The examples illustrated are drawn from Table 4. Consider Configuration 5. In this case, as discussed above, when the aileron rotational frequency is reduced from 20 Hertz to 2 Hertz the flutter speed decreases to a minimum and then increases again. The velocity-damping and velocity-frequency graphs for Configuration 5 with aileron rotational frequencies equal to 20, 12 and 2 Hertz are presented in Figs. 11-13 respectively. In Fig. 12, where the aileron rotational frequency couples with the wing torsion frequency, the flutter speed is reduced and the region of stability is considerably reduced. The behaviour illustrated in Figs. 11-13 is typical for all the configurations considered with the exception of Configuration 7. The velocity-damping and velocity- frequency graphs for Configuration 7 with aileron rotational frequencies equal to 20, 12 and 2 Hertz are presented in Figs. 14-16 respectively. In each of these figures, the points on the critical velocity-damping curve for low values of velocity lie very close to the zero damping axis. When the velocity reaches approximately 10 metres per second the points then indicate increasing instability. In other words the flutter calculations show that for Configuration 7 there is almost no stable region.

8.4 Comparison of the Flutter Calculations with Wind Tunnel Results

Wind tunnel measurements of flutter speed and flutter frequency are available for the following three cases.

1. The model wing was in the STANDARD CONFIGURATION, Configuration 1. Wind tunnel measurements were made with the aileron clamped.

2. The model wing had an aluminium tube attached to the wing tip. The model wing, in this case, was the STANDARD CONFIGURATION plus an aluminium tube connecting grid points 27 and 28 and extending backward 350 millimetres. This tube also extended forward 20 millimetres. The mass of the tube was 126.5 grams. This configuration is designated Configuration 12. Wind tunnel measurements were made with the aileron clamped.

3. The model wing was in Configuration 12. Wind tunnel measurements were

made with the aileron unclamped. The aileron was unbalanced and the aileron rotational stiffness was approximately zero.

Comparison of calculated and experimental results for case one, showed good agreement for the flutter frequency, but the calculated flutter speed was very much lower than the experimental value. In an attempt to discover why the calculated flutter speed is so much lower than the experimental value, the bending and torsion frequencies of the model wing in the STANDARD CONFIGURATION were again measured. These measurements showed that, during the wind tunnel tests, the bending frequency had reduced from 6.05 to 4.65 Hertz; similarly the torsion frequency had reduced from 13.12 to 12.2 Hertz. It is not possible to determine at what stage of the tests, the reduction in stiffness of the model wing occurred. However, the wind tunnel measurements for case one were carried out near the beginning of the series of tests, and are likely to provide results applicable to the model wing in its original condition.

In order to gain some idea of the sensitivity of the calculated flutter speeds and frequencies to changes in the structural model, consider Configurations 1, 5 and 6; see Table 3. Each of these configurations provides a reasonable representation of the model wing in its test condition. For these three configurations, the calculated bending and torsion frequencies are all within 11 per cent of the original measured values. These values give a torsion / bending ratio of 2.17 compared with calculated ratios of 2.1, 2.29 and 2.16 for Configurations 1, 5 and 6 respectively. The calculated mass of Configuration 1 is 269 grams. The mass of the steel rod that has been added to Configuration 5 is 34 grams. The mass of the aluminium rod that has been added to Configuration 6 is 17 grams.

The calculated flutter frequencies for Configurations 1, 5 and 6 are 10.57, 10.33 and 10.77 Hertz respectively. All three frequencies are close to the flutter frequency, 10.89 Hertz that was measured in the wind tunnel. The calculated flutter speeds for Configurations 1, 5 and 6 are 12.25, 13.69 and 12.45 metres per second. All three speeds are much lower than the flutter speed, 22.13 metres per second that was measured in the wind tunnel. However, consideration of the flutter speeds and frequencies calculated for Configurations 1, 5 and 6 does indicate that the flutter calculations are not too sensitive to small changes in the structural model. This suggests that the aerodynamic forces are not well represented. In all the calculations, the model wing is assumed to have zero structural damping. This assumption would also contribute to a lower calculated flutter speed.

In section 2, the main features of the model wing are described. It was pointed out that the model wing was constructed as five separate sub-assemblies. Each sub-assembly consisted of supporting ribs covered by a thin plastic wing skin and was attached to the four aluminium spar rods at one intermediate rib. The vibration test results for the model wing indicate that there is differential movement between the sub-assemblies. Possibly it is difficult to predict the aerodynamic forces on the model wing when the theory assumes that the lifting surface is a thin continuous plate. Furthermore, the thickness to chord ratio for the model wing is 0.17 and thickness effects have not been taken into account in the calculations.

The flutter speed and flutter frequency measured in the wind tunnel for case two are 23.56 metres per second and 5.83 Hertz. When these values are compared with those measured for case one, it can be seen that there has been a marked reduction in flutter frequency. It is difficult to determine whether this reduction in flutter frequency occurred solely as a result of attaching the aluminium tube to the model wing tip, or whether some reduction in stiffness of the model wing, as discussed above, had already occurred before the wind tunnel measurements for case two were made. The frequencies measured for this configuration, Configuration 12, are 4.15 Hertz (bending) and 9.8 Hertz (torsion). Therefore, attaching the 126.5 gram aluminium tube to the model wing has reduced the bending frequency by 11 - 31 per cent and the torsion frequency by 20 - 25 per cent. This reduction is similar to that for Configuration 7 in which the attachment of a 50 gram steel rod reduced the bending frequency by 14 per cent and the torsion frequency by 17 per cent.

In the NASTRAN calculations, Configuration 7 showed a 19 per cent reduction in flutter speed and a 6 per cent reduction in flutter frequency compared with the wind tunnel model for case two which showed a reduction of 46 per cent in flutter frequency but a small increase in flutter speed. It is not surprising that the flutter frequency, measured in the wind tunnel for case two, is substantially lower than that measured for case one. It is surprising that the flutter speed, measured for case two, is not substantially lower than that measured for case one.

The only case in which the NASTRAN calculations can be directly compared with the wind tunnel measurements is case one. In this case, the NASTRAN calculations and the wind tunnel results showed good agreement for the flutter frequency, but the calculated flutter speed was much lower than the flutter speed measured in the wind tunnel.

9. CONCLUDING REMARKS

The MSC NASTRAN Structural Analysis Program has been used to carry out flutter calculations for a model wing. In order to alter the critical flutter speeds of the model wing, provision was made to allow rods or other masses to be attached at the wing tip. In these calculations aluminium and steel rods were used to modify the flutter characteristics of the model. Eleven configurations of the model wing were considered and the calculated critical flutter speeds ranged from approximately 10 metres per second to 20 metres per second. The trends of the calculated flutter speeds are as expected with the minimum flutter speed being achieved when a steel rod is attached to to the model wing tip and allowed to extend backward a further 200 millimetres. The maximum flutter speed is achieved when the same steel rod is attached to the model wing tip and allowed to extend forward a further 200 millimetres. Shorter steel rods and aluminium rods modify the flutter speed to a lesser extent.

For each of the 11 configurations, flutter calculations were carried out for a number of different aileron rotational stiffnesses. The aileron rotational frequencies and hence the aileron rotational stiffnesses were chosen so that the intermediate values were likely to couple with the wing bending or wing torsion modes. For ten of the configurations analysed, when coupling took place both the critical flutter speed and the region of stability were reduced. For Configuration 7, the configuration with the lowest critical flutter speed, the calculations indicate that there is almost no stable region.

Although the trends of the calculated flutter speeds are as expected, limited comparison with wind tunnel data showed that the calculated flutter speeds are far too low. A number of factors may contribute to this result, but the main one is thought to be a poor representation of the aerodynamic forces.

The Structural Analysis Program, MSC NASTRAN was available at ARL for a limited period. The opportunity was taken to use several of the aeroelastic options provided. While the Doublet-Lattice aerodynamic theory was used in most of the calculations, a few calculations were carried out using aerodynamic Strip Theory. The three methods of flutter solution available in NASTRAN are the

PK-method, the K-method and the KE-method. All three methods were used in the calculations.

REFERENCES

[1]	Schaeffer, H. G.	MSC/NASTRAN Primer Static and Normal Modes Analysis Schaeffer Analysis, Inc 3rd. Printing 1982.
[2]	Rodden, W. P. Harder, R. L. and Bellinger, E. D.	Aeroelastic Addition to NASTRAN NASA CR 3094,1979
[3]	Bellinger, E. D. Editor	MSC/NASTRAN Aeroelastic Supplement MacNeal-Schwendler Corporation,1980
[4]	Bellinger, E. D.	Aeroelasticity in MSC/NASTRAN (Seminar Notes) MacNeal-Schwendler Corporation,1985

TABLE I

Calculated Modal Frequencies

Config.	Modal Frequencies Hz			
	$f1$	$f2$	$f3$	$f4$
1	6.73	7.88	14.16	44.22
2	6.74	7.75	15.51	43.60
3	6.55	7.51	14.91	42.37
4	6.61	7.64	15.25	42.56
5	6.22	7.25	14.26	40.11
6	6.43	7.55	13.87	39.96
7	5.78	7.02	11.75	37.27
8	6.69	7.64	14.39	43.38
9	6.40	7.25	12.51	41.87
10	6.66	7.55	12.08	43.25
11	6.27	7.01	9.17	41.62

TABLE 2

Calculated Flutter Speeds and Flutter Frequencies
Both PK and KE Methods of Flutter Solution
Aileron Clamped

Config.	Modal Frequencies Hz			Flutter Freq Hz	Flutter Speed m/s	Method
	$f1$	$f2$	$f3$	ff	vf	
1	6.73	7.88	14.16	10.57	12.25	PK
1	6.73	7.88	14.16	10.56	12.26	KE

TABLE 3

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Clamped

Config.	Modal Frequencies Hz			Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	ff	vf
1	6.73	7.88	14.16	10.57	12.25
2	6.74	7.75	15.51	10.98	14.68
3	6.55	7.51	14.91	10.50	14.84
4	6.61	7.64	15.25	10.91	14.23
5	6.22	7.25	14.26	10.33	13.69
6	6.43	7.55	13.87	10.77	12.45
7	5.78	7.02	11.75	9.90	9.95
8	6.69	7.64	14.39	10.47	14.67
9	6.40	7.25	12.51	9.36	15.22
10	6.66	7.55	12.08	9.57	14.10
11	6.27	7.01	9.17	7.79	19.99

TABLE 4

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Moment of Inertia = 0.000168 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
1	6.73	7.88	14.16	20.00	20.00	11.10	13.11
1	6.73	7.88	14.00	14.16	14.00	11.27	12.68
1	6.73	7.88	12.00	14.16	12.00	11.44	12.08
1	6.73	7.88	8.00	14.16	8.00	10.38	14.02
1	2.00	6.73	7.88	14.16	2.00	10.70	13.95
3	6.55	7.51	14.91	20.00	20.00	11.12	16.02
3	6.55	7.51	14.00	14.91	14.00	11.38	15.38
3	6.55	7.51	12.00	14.91	12.00	11.63	14.52
3	6.55	7.51	8.00	14.91	8.00	9.70	17.45
3	2.00	6.55	7.51	14.91	2.00	10.18	17.52
4	6.61	7.64	15.25	20.00	20.00	11.65	15.13
4	6.61	7.64	14.00	15.25	14.00	11.91	14.53
4	6.61	7.64	12.00	15.25	12.00	11.98	14.03
4	6.61	7.64	8.00	15.25	8.00	9.81	17.33
4	2.00	6.61	7.64	15.25	2.00	10.95	16.40
5	6.22	7.25	14.26	20.00	20.00	11.03	14.59
5	6.22	7.25	14.00	14.26	14.00	11.15	14.30
5	6.22	7.25	12.00	14.26	12.00	11.12	14.01
5	6.22	7.25	8.00	14.26	8.00	10.59	14.85
5	2.00	6.22	7.25	14.26	2.00	10.53	15.56
6	6.43	7.55	13.87	20.00	20.00	11.35	13.13
6	6.43	7.55	13.87	14.00	14.00	11.43	12.87
6	6.43	7.55	12.00	13.87	12.00	11.52	12.51
7	5.78	7.02	11.75	20.00	20.00	10.45	9.73
7	5.78	7.02	11.75	14.00	14.00	10.39	9.98
7	5.78	7.02	11.75	12.00	12.00	10.29	10.30
7	5.78	7.02	8.00	11.75	8.00	10.48	9.79
7	2.00	5.78	7.02	11.75	2.00	10.51	9.55
8	6.69	7.64	14.39	20.00	20.00	11.03	15.72
8	6.69	7.64	14.00	14.39	14.00	11.25	15.09
8	6.69	7.64	12.00	14.39	12.00	11.51	14.16
8	6.69	7.64	8.00	14.39	8.00	10.44	15.63
8	2.00	6.69	7.64	14.39	2.00	10.04	17.50

TABLE 4 (Continued)

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Moment of Inertia = 0.000168 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
9	6.40	7.25	12.51	20.00	20.00	9.74	16.38
9	6.40	7.25	12.51	14.00	14.00	9.90	15.76
9	6.40	7.25	12.00	12.51	12.00	10.05	15.13
9	6.40	7.25	8.00	12.51	8.00	9.69	14.48
9	2.00	6.40	7.25	12.51	2.00	8.66	17.55
10	6.66	7.55	12.08	20.00	20.00	9.93	14.99
10	6.66	7.55	12.08	14.00	14.00	10.07	14.38
10	6.66	7.55	12.00	12.08	12.00	10.20	13.72
10	6.66	7.55	8.00	12.08	8.00	9.71	13.89
10	2.00	6.66	7.55	12.08	2.00	8.99	17.01
11	6.27	7.01	9.17	20.00	20.00	7.89	18.34
11	6.27	7.01	9.17	14.00	14.00	7.97	17.06
11	6.27	7.01	9.17	12.00	12.00	8.02	16.26
11	6.27	7.01	8.00	9.17	8.00	8.23	12.27
11	2.00	6.27	7.01	9.17	2.00	7.21	16.28

TABLE 5

Calculated Flutter Speeds and Flutter Frequencies
KE Method of Flutter Solution
Aileron Moment of Inertia = 0.000168 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
2	6.74	7.75	15.51	20.00	20.00	11.65	15.75
2	6.74	7.75	14.00	15.51	14.00	11.92	15.06
2	6.74	7.75	12.00	15.51	12.00	12.09	14.28
2	6.74	7.75	8.00	15.51	8.00	10.81	16.26
2	2.00	6.74	7.75	15.51	2.00	10.83	17.19
3	6.55	7.51	14.91	20.00	20.00	11.12	16.01
3	6.55	7.51	14.00	14.91	14.00	11.36	15.41
3	6.55	7.51	12.00	14.91	12.00	11.60	14.61
3	6.55	7.51	8.00	14.91	8.00	10.50	15.98
3	2.00	6.55	7.51	14.91	2.00	10.16	17.58
6	6.43	7.55	13.87	20.00	20.00	11.35	13.15
6	6.43	7.55	13.87	14.00	14.00	11.42	12.89
6	6.43	7.55	12.00	13.87	12.00	11.48	12.64
6	6.43	7.55	8.00	13.87	8.00	10.83	14.31
10	6.66	7.55	12.08	20.00	20.00	9.93	14.98
10	6.66	7.55	12.08	14.00	14.00	10.06	14.39
10	6.66	7.55	12.00	12.08	12.00	10.20	13.75
10	6.66	7.55	8.00	12.08	8.00	9.71	13.90
11	6.27	7.01	9.17	20.00	20.00	7.89	18.36
11	6.27	7.01	9.17	14.00	14.00	7.97	17.09
11	6.27	7.01	9.17	12.00	12.00	8.03	16.28
11	6.27	7.01	8.00	9.17	8.00	8.23	12.30
11	2.00	6.27	7.01	9.17	2.00	7.21	16.27

TABLE 6

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Moment of Inertia = 0.000336 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	f1	f2	f3	f4	fa	ff	vf
4	6.61	7.64	15.25	20.00	20.00	11.54	15.37
4	6.61	7.64	14.00	15.25	14.00	11.68	15.03
4	6.61	7.64	12.00	15.25	12.00	11.97	14.04
4	6.61	7.64	8.00	15.25	8.00	10.92	16.44
4	2.00	6.61	7.64	15.25	2.00	11.27	15.91
5	6.22	7.25	14.26	20.00	20.00	10.93	14.79
5	6.22	7.25	14.00	14.26	14.00	11.03	14.57
5	6.22	7.25	12.00	14.26	12.00	11.18	14.15
5	6.22	7.25	8.00	14.26	8.00	10.42	15.73
5	2.00	6.22	7.25	14.26	2.00	10.75	15.20
6	6.43	7.55	13.87	20.00	20.00	11.33	13.18
6	6.43	7.55	13.87	14.00	14.00	11.38	13.04
6	6.43	7.55	12.00	13.87	12.00	11.52	12.57
6	6.43	7.55	8.00	13.87	8.00	11.14	13.72
7	5.78	7.02	11.75	20.00	20.00	10.22	9.69
7	5.78	7.02	11.75	14.00	14.00	10.43	9.79
7	5.78	7.02	11.75	12.00	12.00	10.37	10.04
7	5.78	7.02	8.00	11.75	8.00	10.51	9.55
7	2.00	5.78	7.02	11.75	2.00	10.50	9.57
8	6.69	7.64	14.39	20.00	20.00	10.96	15.90
8	6.69	7.64	14.00	14.39	14.00	11.13	15.47
8	6.69	7.64	12.00	14.39	14.00	11.46	14.42
8	6.69	7.64	8.00	14.39	8.00	9.63	17.60
8	2.00	6.69	7.64	14.39	2.00	10.61	16.71
9	6.40	7.25	12.51	20.00	20.00	9.68	16.59
9	6.40	7.25	12.51	14.00	14.00	9.78	16.20
9	6.40	7.25	12.00	12.51	12.00	9.92	15.71
9	6.40	7.25	8.00	12.51	8.00	9.15	15.90
9	2.00	6.40	7.25	12.51	2.00	9.07	18.43
10	6.66	7.55	12.08	20.00	20.00	9.91	15.10
10	6.66	7.55	12.08	14.00	14.00	10.00	14.74
10	6.66	7.55	12.00	12.08	12.00	10.10	14.28
10	6.66	7.55	8.00	12.08	8.00	9.08	15.56
10	2.00	6.66	7.55	12.08	2.00	9.53	16.48
11	6.27	7.01	9.17	20.00	20.00	7.84	19.03
11	6.27	7.01	9.17	14.00	14.00	7.91	18.05
11	6.27	7.01	9.17	12.00	12.00	7.95	17.36
11	6.27	7.01	8.00	9.17	8.00	8.21	12.07
11	2.00	6.27	7.01	9.17	2.00	6.53	20.94

TABLE 7

Calculated Flutter Speeds and Flutter Frequencies
KE Method of Flutter Solution
Aileron Moment of Inertia = 0.000336 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
2	6.74	7.75	15.51	20.00	20.00	11.58	15.91
2	6.74	7.75	14.00	15.51	14.00	11.78	15.45
2	6.74	7.75	12.00	15.51	12.00	12.08	14.27
2	6.74	7.75	8.00	15.51	8.00	10.73	17.25
2	2.00	6.74	7.75	15.51	2.00	11.26	16.54
3	6.55	7.51	14.91	20.00	20.00	11.06	16.16
3	6.55	7.51	14.00	14.91	14.00	11.22	15.77
3	6.55	7.51	12.00	14.91	12.00	11.55	14.83
3	6.55	7.51	8.00	14.91	8.00	10.05	17.30
3	2.00	6.55	7.51	14.91	2.00	10.70	16.88

TABLE 8

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Moment of Inertia = 0.000336 $kg\ m^2$

Config.	Modal Frequencies *Hz*				Aileron Freq *Hz*	Flutter Freq *Hz*	Flutter Speed *m/s*
	f1	*f2*	*f3*	*f4*	*fa*	*ff*	*vf*
6	6.43	7.55	13.87	14.14	14.14	11.38	13.05
6	6.43	7.55	9.90	13.87	9.90	10.24	15.13
6	6.43	7.55	8.49	13.87	8.49	11.09	13.83
6	5.65	6.43	7.55	13.87	5.65	11.22	13.51
6	1.41	6.43	7.55	13.87	1.41	11.25	13.43
7	5.78	7.02	11.75	14.14	14.14	10.44	9.79
7	5.78	7.02	9.90	11.75	9.90	9.79	11.96
7	5.78	7.02	8.49	11.75	8.49	10.51	9.57
7	5.65	5.78	7.02	11.75	5.65	10.50	9.56
7	1.41	5.78	7.02	11.75	1.41	10.52	9.46
10	6.66	7.55	12.08	14.14	14.14	9.99	14.75
10	6.66	7.55	9.90	12.08	9.90	9.97	13.80
10	6.66	7.55	8.49	12.08	8.49	9.28	15.49
10	5.65	6.66	7.55	12.08	5.65	9.06	17.61
10	1.41	6.66	7.55	12.08	1.41	9.54	16.44
11	6.27	7.01	9.17	14.14	14.14	7.90	18.09
11	6.27	7.01	9.17	9.90	9.90	8.05	15.97
11	6.27	7.01	8.49	9.17	8.49	8.22	13.31
11	5.65	6.27	7.01	9.17	5.65	7.25	17.67
11	1.41	6.27	7.01	9.17	1.41	6.47	21.07

TABLE 9

Calculated Flutter Speeds and Flutter Frequencies
PK Method of Flutter Solution
Aileron Moment of Inertia = 0.000336 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
6	6.43	7.55	13.87	20.00	20.00	11.33	13.18
6	6.43	7.55	13.87	14.14	14.14	11.38	13.05
6	6.43	7.55	13.87	14.00	14.00	11.38	13.04
6	6.43	7.55	12.00	13.87	12.00	11.52	12.57
6	6.43	7.55	9.90	13.87	9.90	10.24	15.13
6	6.43	7.55	8.49	13.87	8.49	11.09	13.83
6	6.43	7.55	8.00	13.87	8.00	11.14	13.72
6	5.65	6.43	7.55	13.87	5.65	11.22	13.51
6	1.41	6.43	7.55	13.87	1.41	11.25	13.43
7	5.78	7.02	11.75	20.00	20.00	10.22	9.69
7	5.78	7.02	11.75	14.14	14.14	10.44	9.79
7	5.78	7.02	11.75	14.00	14.00	10.43	9.79
7	5.78	7.02	11.75	12.00	12.00	10.37	10.04
7	5.78	7.02	9.90	11.75	9.90	9.79	11.96
7	5.78	7.02	8.49	11.75	8.49	10.51	9.57
7	5.78	7.02	8.00	11.75	8.00	10.51	9.55
7	5.65	5.78	7.02	11.75	5.65	10.50	9.56
7	2.00	5.78	7.02	11.75	2.00	10.50	9.57
7	1.41	5.78	7.02	11.75	1.41	10.52	9.46
10	6.66	7.55	12.08	20.00	20.00	9.91	15.10
10	6.66	7.55	12.08	14.14	14.14	9.99	14.75
10	6.66	7.55	12.08	14.00	14.00	10.00	14.74
10	6.66	7.55	12.00	12.08	12.00	10.10	14.28
10	6.66	7.55	9.90	12.08	9.90	9.97	13.80
10	6.66	7.55	8.49	12.08	8.49	9.28	15.49
10	6.66	7.55	8.00	12.08	8.00	9.08	15.56
10	2.00	6.66	7.55	12.08	2.00	9.53	16.48
10	1.41	6.66	7.55	12.08	1.41	9.54	16.44
11	6.27	7.01	9.17	20.00	20.00	7.84	19.03
11	6.27	7.01	9.17	14.14	14.14	7.90	18.09
11	6.27	7.01	9.17	14.00	14.00	7.91	18.05
11	6.27	7.01	9.17	12.00	12.00	7.95	17.36
11	6.27	7.01	9.17	9.90	9.90	8.05	15.97
11	6.27	7.01	8.49	9.17	8.49	8.22	13.31
11	6.27	7.01	8.00	9.17	8.00	8.21	12.07
11	5.65	6.27	7.01	9.17	5.65	7.25	17.67
11	2.00	6.27	7.01	9.17	2.00	6.53	20.94
11	1.41	6.27	7.01	9.17	1.41	6.47	21.07

TABLE 10

Aileron Properties

Aileron Moment of Inertia $kg\ m^2$	Aileron Frequency Hz	Aileron Rotational Stiffness Nm/rad
I	fa	$k = I\ \omega^2$
0.000168	20.00	2.653
	14.00	1.300
	12.00	0.955
	8.00	0.424
	2.00	0.0265
0.000336	20.00	5.306
	14.00	2.600
	12.00	1.910
	8.00	0.848
	2.00	0.05306
0.000336	14.14	2.653
	9.90	1.300
	8.49	0.955
	5.65	0.424
	1.41	0.0265

TABLE 11

Calculated Flutter Speeds and Flutter Frequencies
K Method of Flutter Solution
Aileron Moment of Inertia = 0.000168 $kg\ m^2$

Config.	Modal Frequencies Hz				Aileron Freq Hz	Flutter Freq Hz	Flutter Speed m/s
	$f1$	$f2$	$f3$	$f4$	fa	ff	vf
11	6.27	7.01	9.17	12.00	12.00	8.03	16.28
11	6.27	7.01	8.00	9.17	8.00	8.23	12.30
11	2.00	6.27	7.01	9.17	2.00	7.21	16.27

TABLE 12

Calculated Flutter Speeds

Config.	Aileron Clamped	Aileron Freq 20 Hz $I = 0.000168$	Aileron Freq 20 Hz $I = 0.000336$	Aileron Freq 14.14 Hz $I = 0.000336$
	vf m/s	vf m/s	vf m/s	vf m/s
1	12.25	13.11		
2	14.68	15.75	15.91	
3	14.84	16.02	16.16	
4	14.23	15.13	15.37	
5	13.69	14.59	14.79	
6	12.45	13.13	13.18	13.05
7	9.95	9.73	9.69	9.69
8	14.67	15.72	15.90	
9	15.22	16.38	16.59	
10	14.10	14.99	15.10	14.75
11	19.99	18.34	19.03	18.09

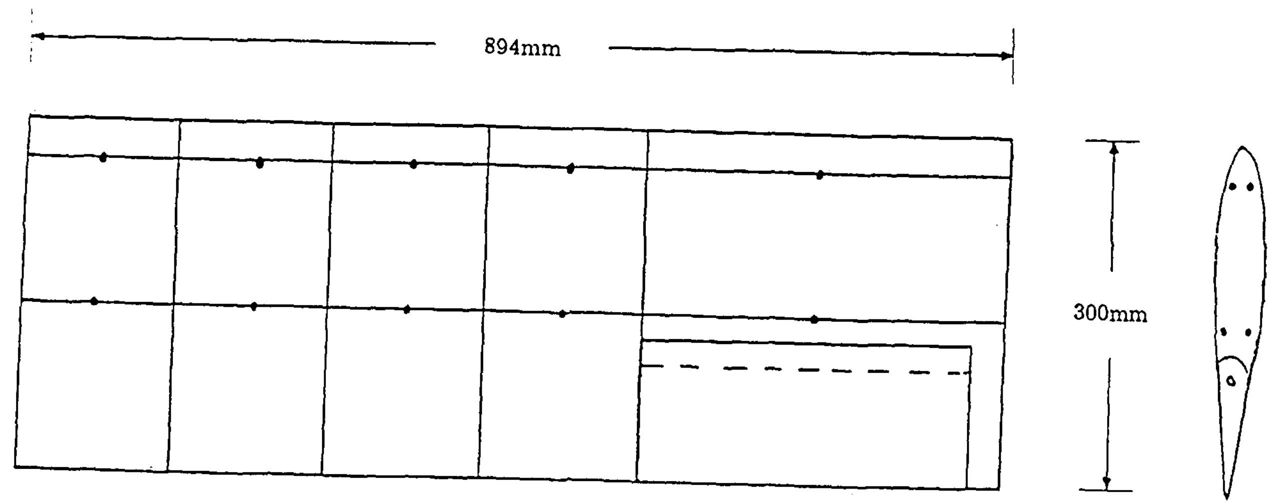

Fig.1 Plan View Of Model Wing With A Sketch Of The Airfoil Section

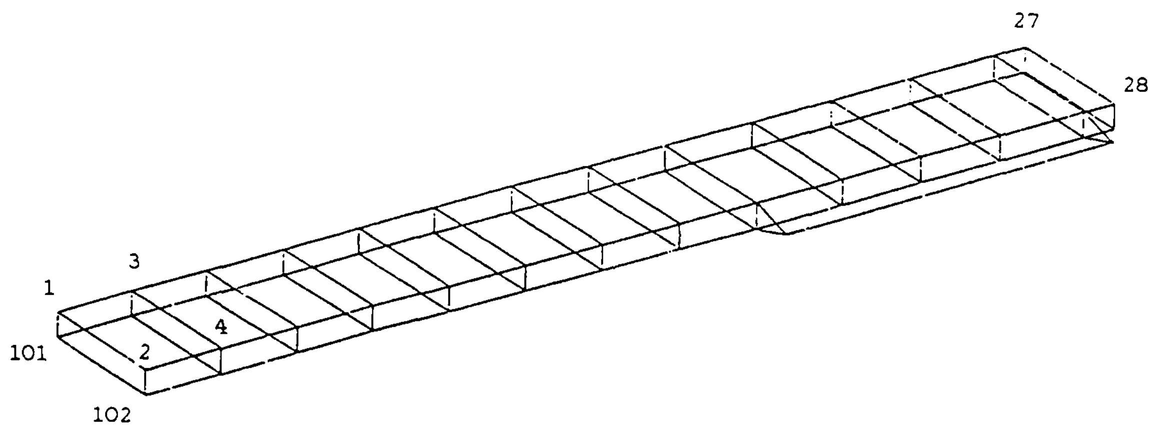

Fig.2 First Finite Element Structural Model

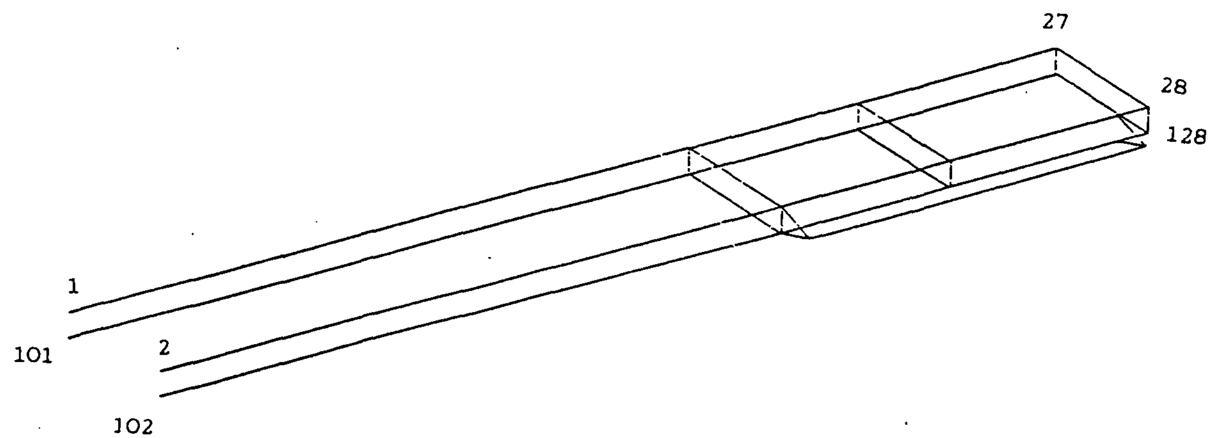

Fig.3 Finite Element Structural Model For The Standard Configuration

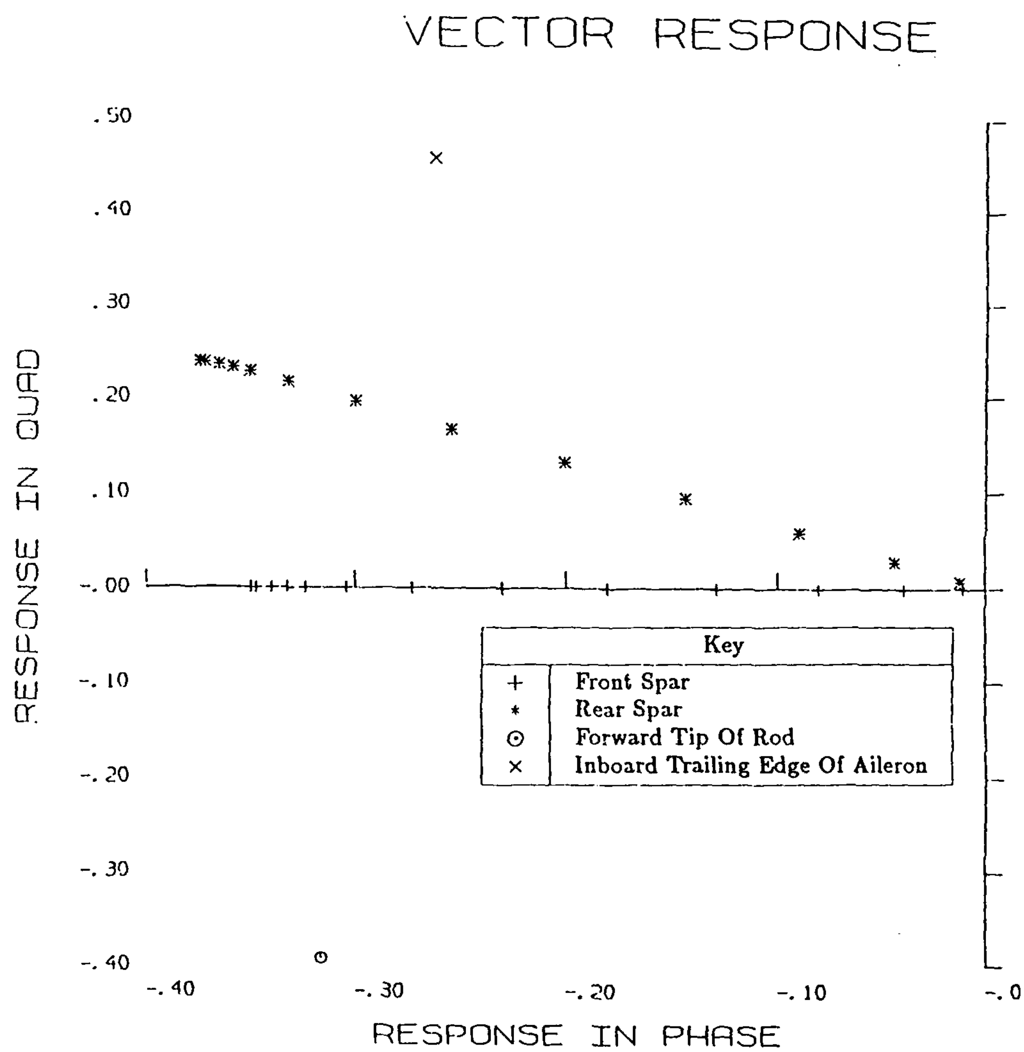

Fig.4 Flutter Mode Vector Response
Configuration 11
Aileron Hinge Moment Of Inertia = 0.000168 $kg\ m^2$
Aileron Rotational Frequency = 12 Hz

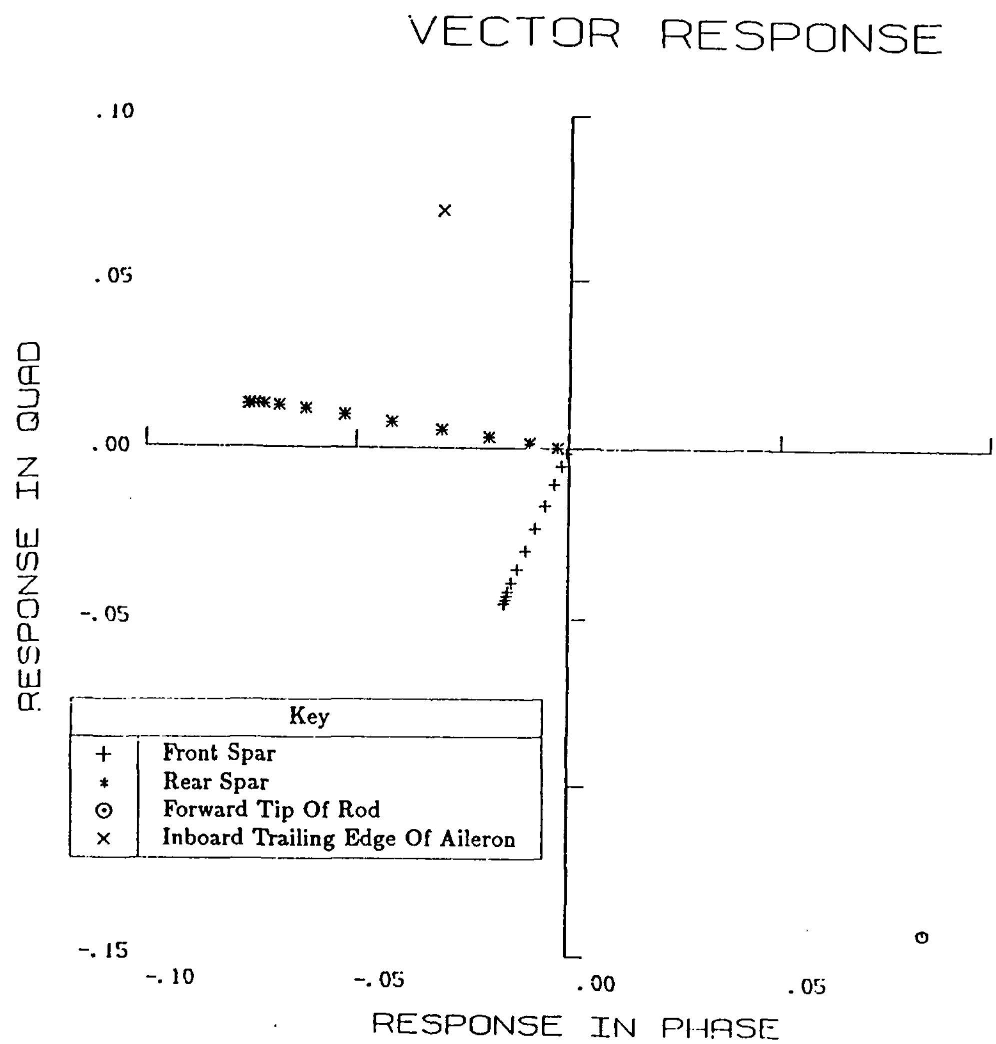

Fig.5 Flutter Mode Vector Response
Configuration 11
Aileron Hinge Moment Of Inertia = 0.000168 $kg\ m^2$
Aileron Rotational Frequency = 8 Hz

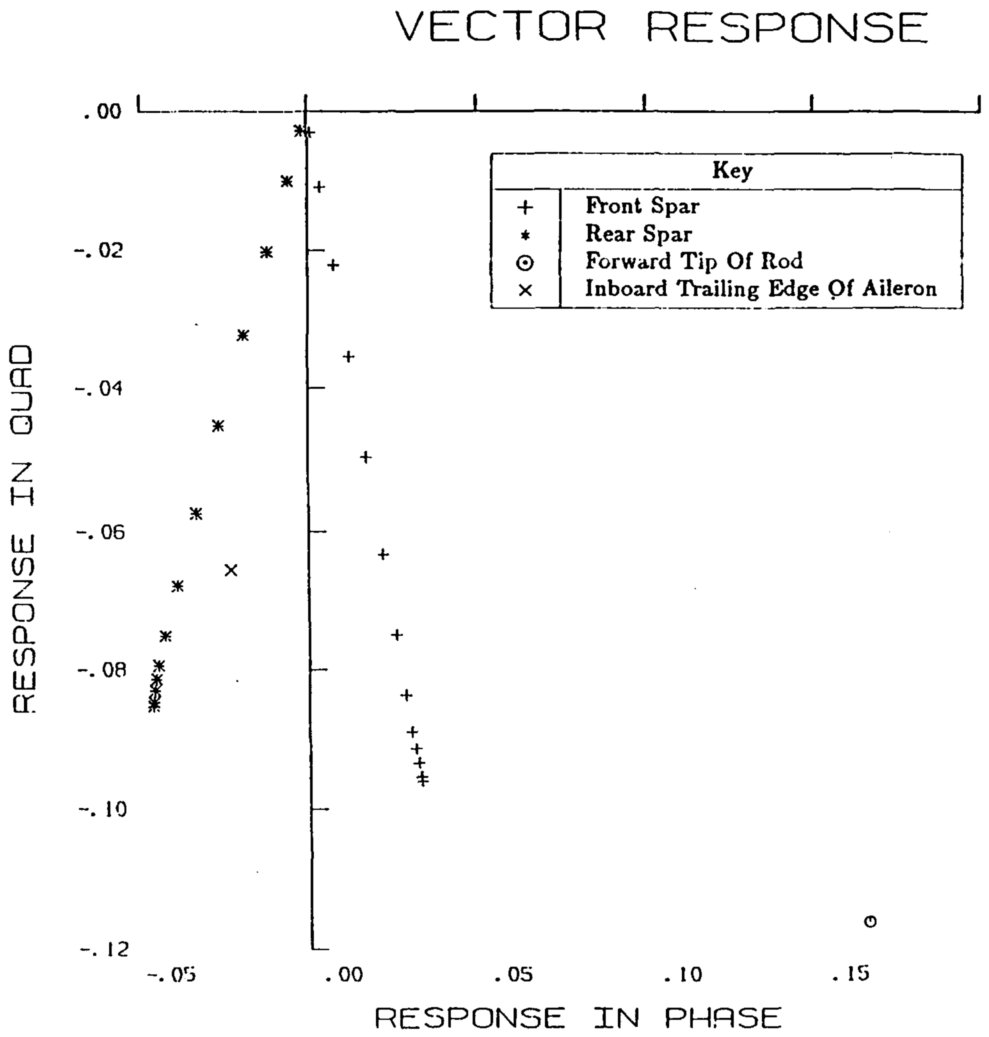

Fig.6 Flutter Mode Vector Response
Configuration 11
Aileron Hinge Moment Of Inertia = 0.000168 $kg\ m^2$
Aileron Rotational Frequency = 2 Hz

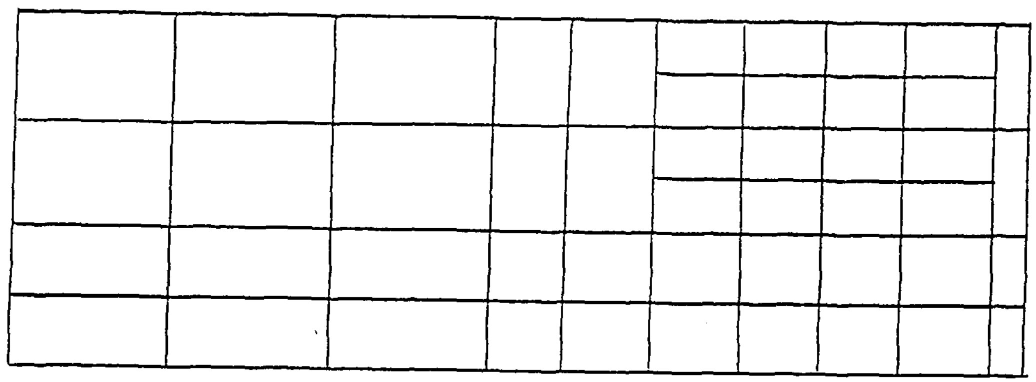

Fig.7 Distribution Of Doublet-Lattice Panel Boxes

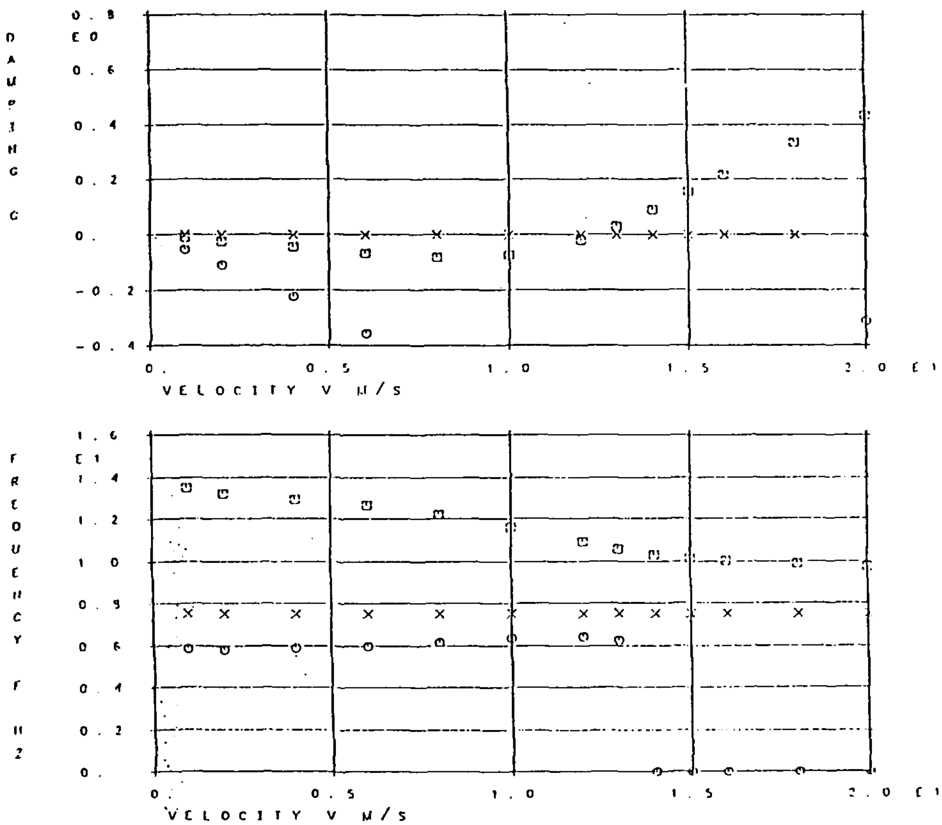

Fig.8 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 6
Aileron Clamped

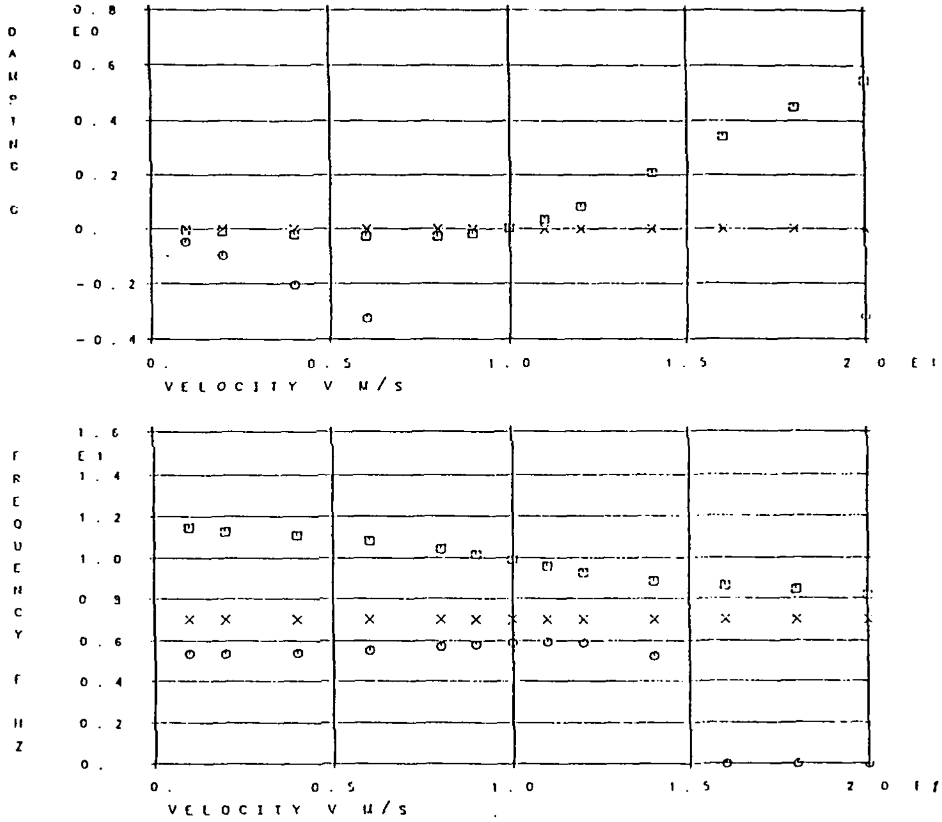

Fig.9 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 7
Aileron Clamped

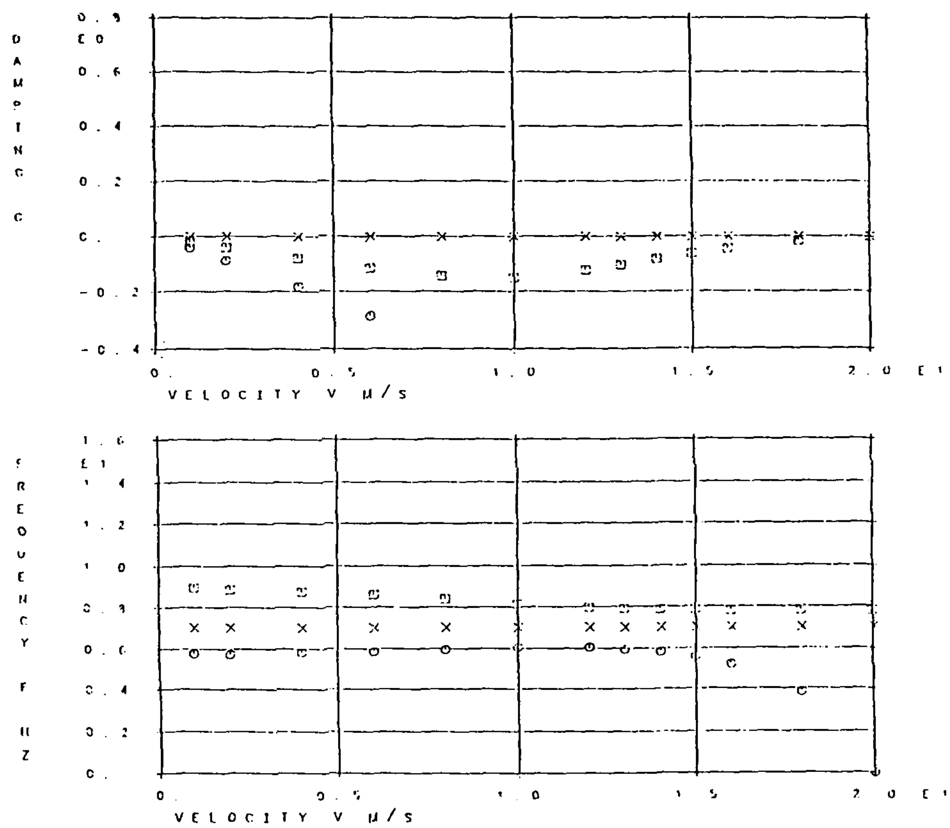

Fig.10 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 11
Aileron Clamped

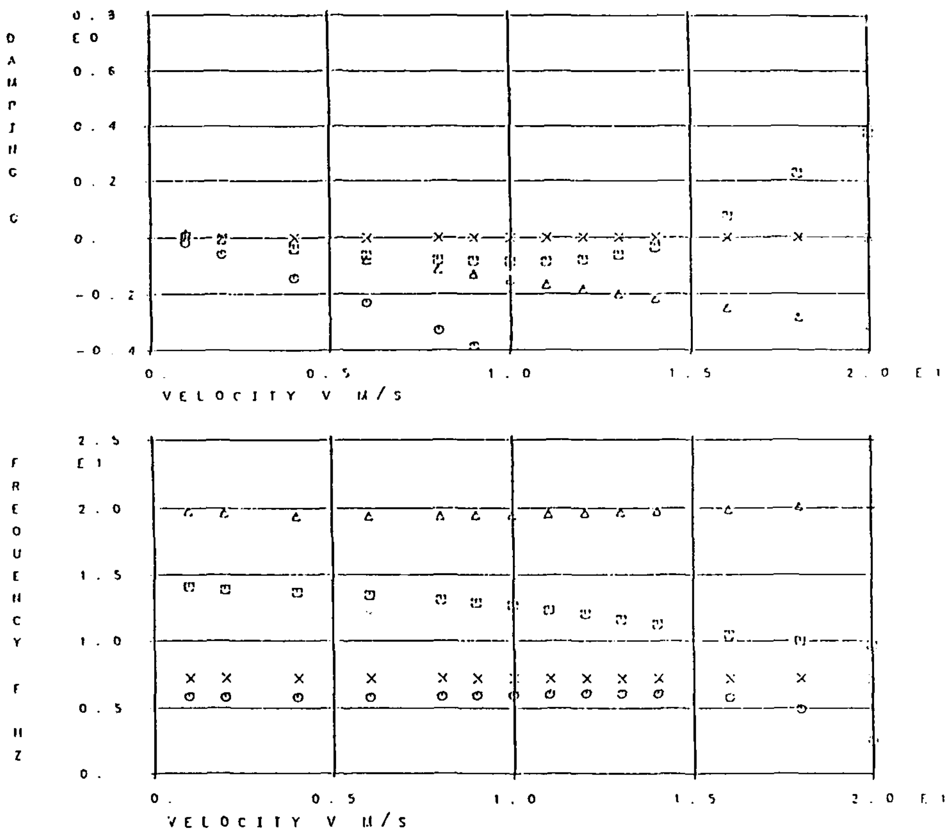

Fig.11 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 5
Aileron Unclamped
Aileron Rotational Frequency = 20 Hz

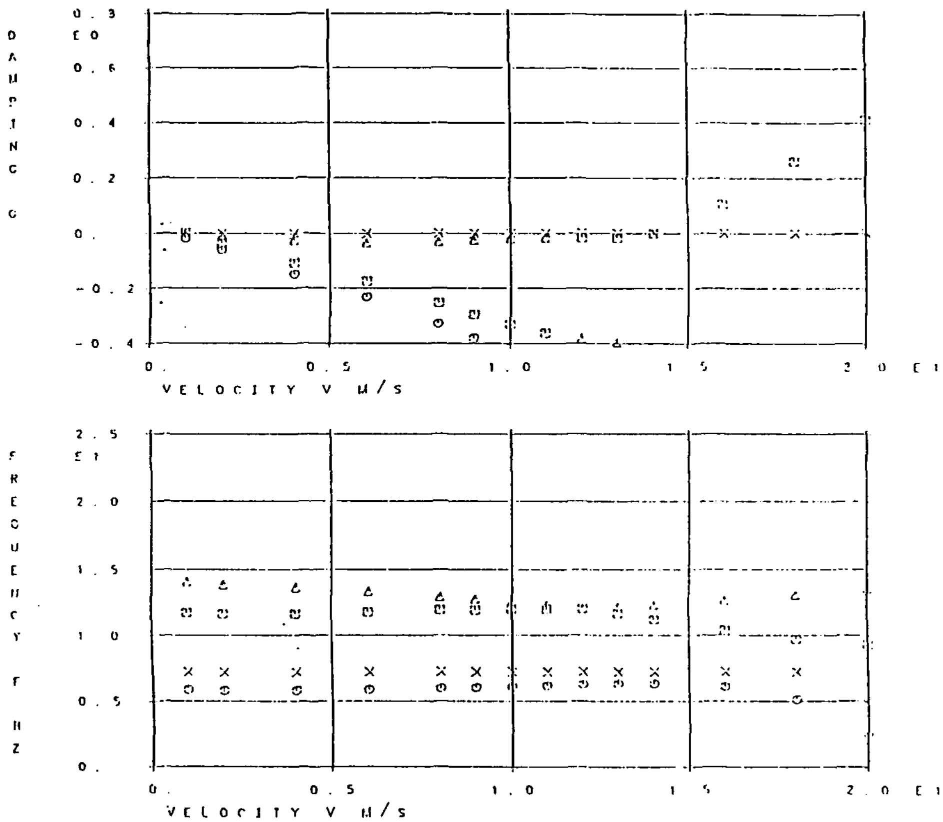

Fig.12 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 5
Aileron Unclamped
Aileron Rotational Frequency = 12 *Hz*

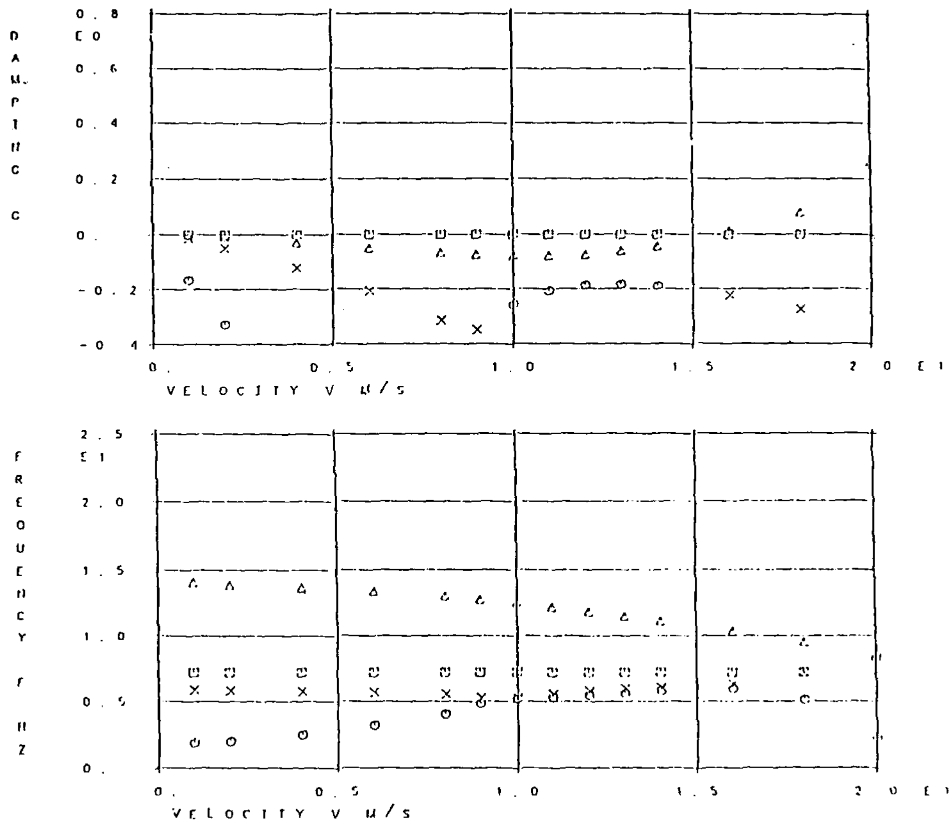

Fig.13 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 5
Aileron Unclamped
Aileron Rotational Frequency = 2 Hz

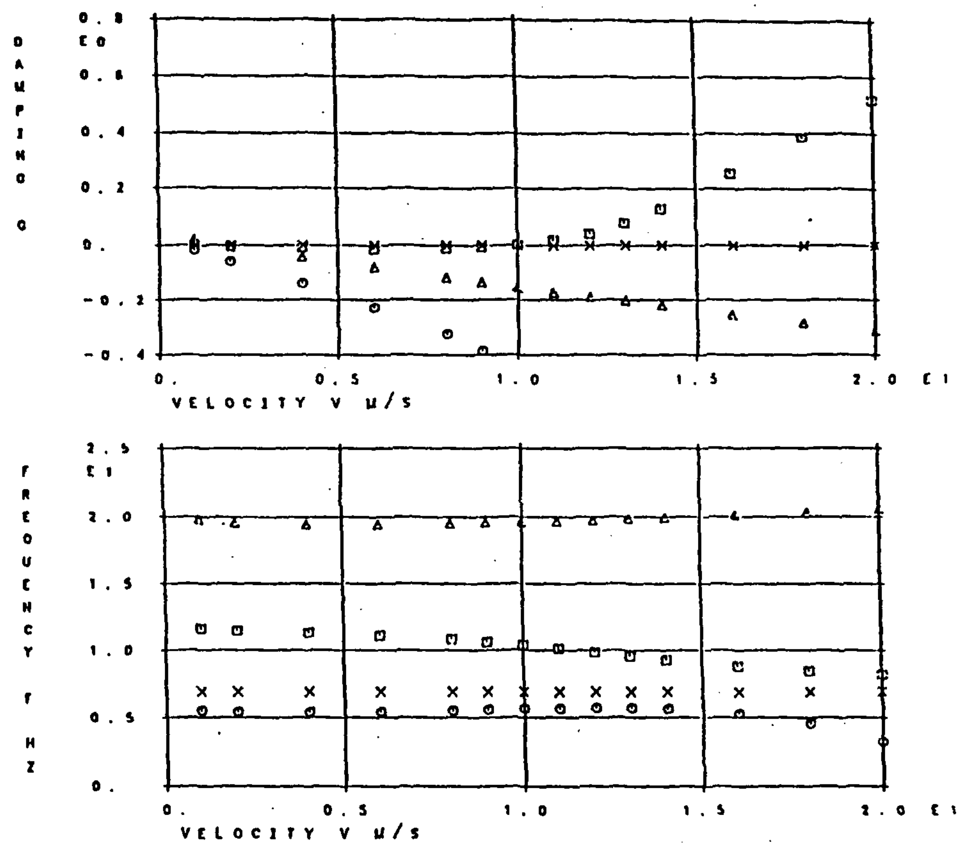

Fig.14 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 7
Aileron Unclamped
Aileron Rotational Frequency = 20 Hz

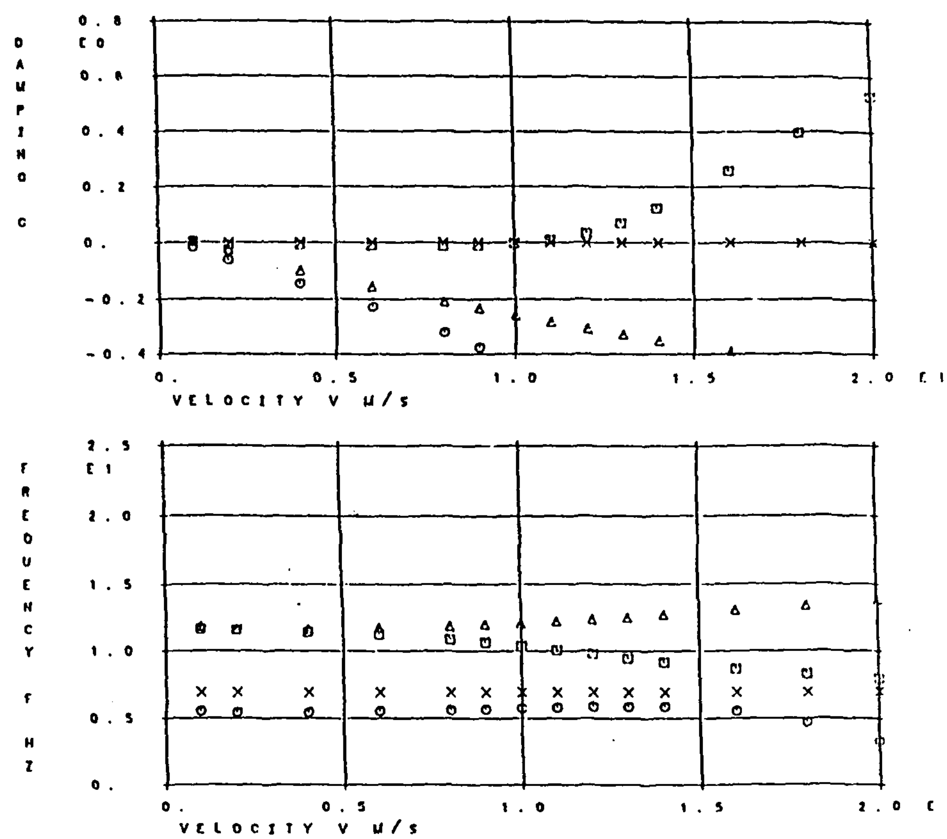

Fig.15 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 7
Aileron Unclamped
Aileron Rotational Frequency = 12 Hz

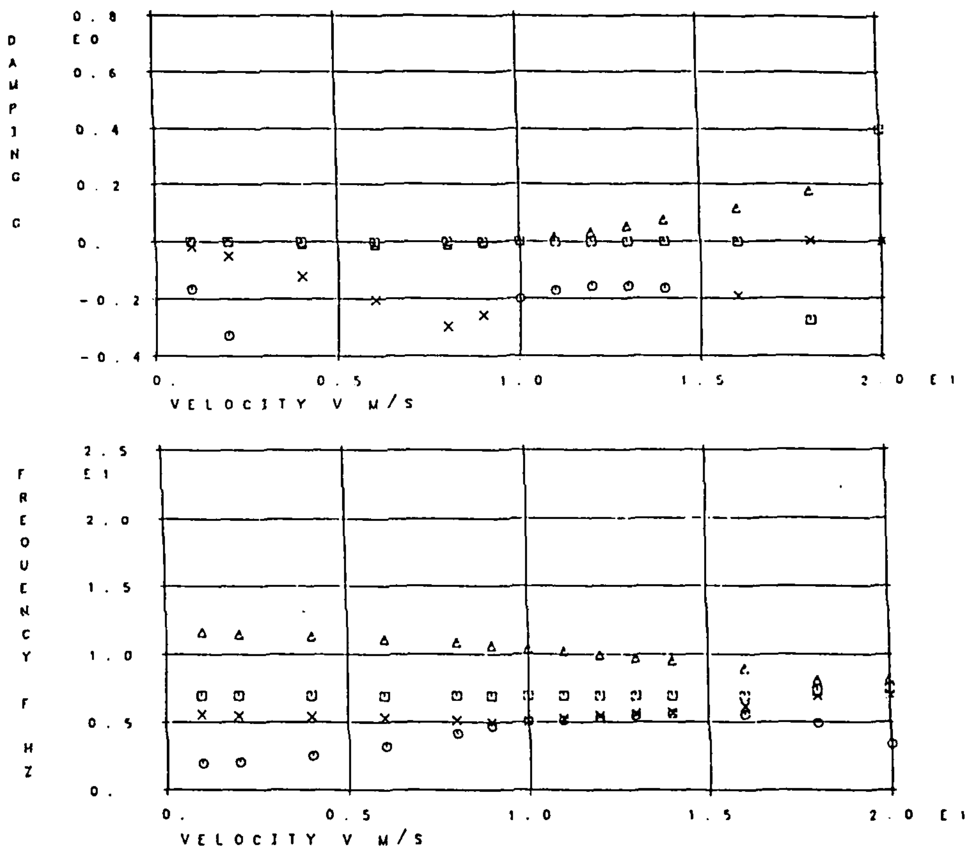

Fig.16 Nastran Velocity-Damping And Velocity-Frequency Graphs
Configuration 7
Aileron Unclamped
Aileron Rotational Frequency = 2 Hz

DISTRIBUTION

AUSTRALIA

Department of Defence

Defence Central
Chief Defence Scientist
FAS Science Corporate Management (shared copy)
FAS Science Policy (shared copy)
Director, Departmental Publications
Counsellor, Defence Science, London (Doc Data Sheet Only)
Counsellor, Defence Science, Washington (Doc Data Sheet Only)
S.A. to Thailand MRD (Doc Data Sheet Only)
S.A. to the DRC (Kuala Lumpur) (Doc Data Sheet Only)
OIC TRS, Defence Central Library
Document Exchange Centre, DISB (18 copies)
Joint Intelligence Organisation
Librarian H Block, Victoria Barracks, Melbourne
Director General - Army Development (NSO) (4 copies)

Aeronautical Research Laboratory
Director
Library
Chief - Aircraft Structures
Divisional File - Aircraft Structures
Author: Betty Emslie
T.G. Ryall
P.A. Farrell
A. Goldman
I. Grundy

Materials Research Laboratory
Director/Library

Defence Science & Technology Organisation - Salisbury
Library

Navy Office
Navy Scientific Adviser (3 copies Doc Data sheet)

Army Office
Scientific Adviser - Army (Doc Data sheet only)

Air Force Office
Air Force Scientific Adviser (Doc Data sheet only)
Aircraft Research and Development Unit
Scientific Flight Group
Library
Engineering Division Library

Department of Transport & Communication
Library

Statutory and State Authorities and Industry

Aero-Space Technologies Australia, Manager/Librarian (2 copies)
Hawker de Havilland Aust Pty Ltd, Victoria, Library
Hawker de Havilland Aust Pty Ltd, Bankstown, Library

Universities and Colleges

Adelaide
Barr Smith Library

Flinders
Library

LaTrobe
Library

Melbourne
Engineering Library

Monash
Hargrave Library

Newcastle
Library

New England
Library

Sydney
Engineering Library

NSW
Physical Sciences Library
Library, Australian Defence Force Academy

Queensland
Library

Tasmania
Engineering Library

Western Australia
Library

RMIT
Library

University College of the Northern Territory
Library

SPARES (10 copies)
TOTAL (71 copies)

AL 149 DEPARTMENT OF DEFENCE

DOCUMENT CONTROL DATA

PAGE CLASSIFICATION
UNCLASSIFIED
PRIVACY MARKING

1a. AR NUMBER	1b. ESTABLISHMENT NUMBER	2. DOCUMENT DATE	3. TASK NUMBER
AR-005-544	ARL-STRUC-TM-495	NOVEMBER 1988	DST 86/019

4. TITLE
FLUTTER CALCULATIONS FOR A MODEL WING USING THE MSC NASTRAN STRUCTURAL ANALYSIS PROGRAM

5. SECURITY CLASSIFICATION (PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF.(C) RESTRICTED (R), UNCLASSIFIED (U)).

DOCUMENT	TITLE	ABSTRACT
U	U	U

6. NO. PAGES 39

7. NO. REFS. 4

8. AUTHOR(S)
Betty Emslie

9. DOWNGRADING/DELIMITING INSTRUCTIONS
Not applicable

10. CORPORATE AUTHOR AND ADDRESS
AERONAUTICAL RESEARCH LABORATORY
P.O. BOX 4331, MELBOURNE VIC 3001

11. OFFICE/POSITION RESPONSIBLE FOR:
SPONSOR DSTO
SECURITY
DOWNGRADING
APPROVAL CSTD

12. SECONDARY DISTRIBUTION (OF THIS DOCUMENT) Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE CENTRE, DEFENCE INFORMATION SERVICES BRANCH, DEPARTMENT OF DEFENCE, CAMPBELL PARK, CANBERRA, ACT 2601

13a. THIS DOCUMENT MAY BE ANNOUNCED IN CATALOGUES AND AWARENESS SERVICES AVAILABLE TO....

No limitations

13b. CITATION FOR OTHER PURPOSES (IE. CASUAL ANNOUNCEMENT) MAY BE [X] UNRESTRICTED OR [ ] AS FOR 13a.

14. DESCRIPTORS
Flutter
Wings;
Aircraft models;
Wind tunnel models. Australia, (edc)
NASTRAN (computer program)

15. DRDA SUBJECT CATEGORIES
0051F

16. ABSTRACT Flutter calculations for a semispan model wing with a trailing edge control surface have been carried out using MSC NASTRAN. In order to alter the critical flutter speeds of the model wing, provision was made to allow rods or other masses to be attached at the wing tip. In these calculations aluminium and steel rods were used to modify the flutter characteristics of the model. Eleven configurations of the model wing were considered. For each of the 11 configurations, flutter calculations were carried out for a number of different aileron rotational stiffnesses. Keywords:

PAGE CLASSIFICATION
UNCLASSIFIED
PRIVACY MARKING

THIS PAGE IS TO BE USED TO RECORD INFORMATION WHICH IS REQUIRED BY THE ESTABLISHMENT FOR ITS OWN USE BUT WHICH WILL NOT BE ADDED TO THE DISTIS DATA UNLESS SPECIFICALLY REQUESTED.

16. ABSTRACT (CONT.)

17. IMPRINT

AERONAUTICAL RESEARCH LABORATORY, MELBOURNE

18. DOCUMENT SERIES AND NUMBER	19. COST CODE	20. TYPE OF REPORT AND PERIOD COVERED
AIRCRAFT STRUCTURES TECHNICAL MEMORANDUM 495	231090	

21. COMPUTER PROGRAMS USED

MSC NASTRAN

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)