



NUMERICAL EVALUATION OF THE CONTRIBUTION OF THE STICK MODEL-INDUCED ELASTIC STREAMWISE CAMBER DEFORMATION TO THE FLUTTER SPEED OF A SWEEPED WING

Emil Suci Precision Conversions, Escondido, CA 92025

Jose Luis Panza Structural Analysis Group Manager, General Atomic Aeronautical Systems Inc., Rancho Bernardo, CA 92127



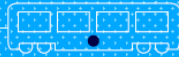
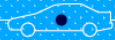
OR

THE STICK MODEL REVISITED (but only a little)



ABSTRACT

- When the aerodynamic derivatives factoring method is used with the DLM, the elastic streamwise camber deformation at the aerodynamic surface is automatically separated from other types of motion.
- For a highly swept wing with structure modeled as a swept beam, the difference in the flutter speed calculated with/without streamwise camber terms included in the generalized aerodynamics can be large.



The stick model has enjoyed a long and successful period of use with applications to flutter and dynamic analyses for aircraft of all types and sizes and categories, except perhaps delta-winged aircraft.



It is well known that unswept or swept stick models do not contain sufficient structural detail to represent the actual structural dynamic camber deformation of lifting surfaces; further, the actual structural dynamic camber deformation cannot be imparted to the aerodynamic surface by either a swept or by an unswept stick model.



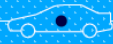
It will be shown here that the swept stick model induces an artificial dynamic camber at the aerodynamic surface.

The effect which this artificial elastic streamwise camber deformation at the aerodynamic surface has on the calculated flutter speed of a swept wing with structure modeled as a swept beam will be isolated and quantified



Motion transfer from structure to the aerodynamic surface is through the use of beam splines with rigid arms (the SPLINE2 card) for all cases discussed.

Another way of stating this is that we perform linear extrapolations of the motions from the beam to the aerodynamic points in planes normal to the elastic axis.



If the elastic axis of the stick model has zero sweep angle, there is no elastic streamwise camber deformation (dynamic camber) arising at the aerodynamic surface for any mode of vibration.

This does not mean that there is no dynamic camber at the actual structure; it only means that we cannot model dynamic camber with the unswept stick model and transfer it to the aerodynamic surface using beam splines with rigid arms.



If the sweep angle of the stick model is different from zero, an artificial dynamic camber deformation at the aerodynamic surface appears for all elastic modes; this dynamic camber is dependent on the mode shape.

For a swept lifting surface, as for an unswept one, there is no structural detail between the elastic axis and the leading and trailing edges of the wing to define any kind of dynamic camber deformation anywhere.

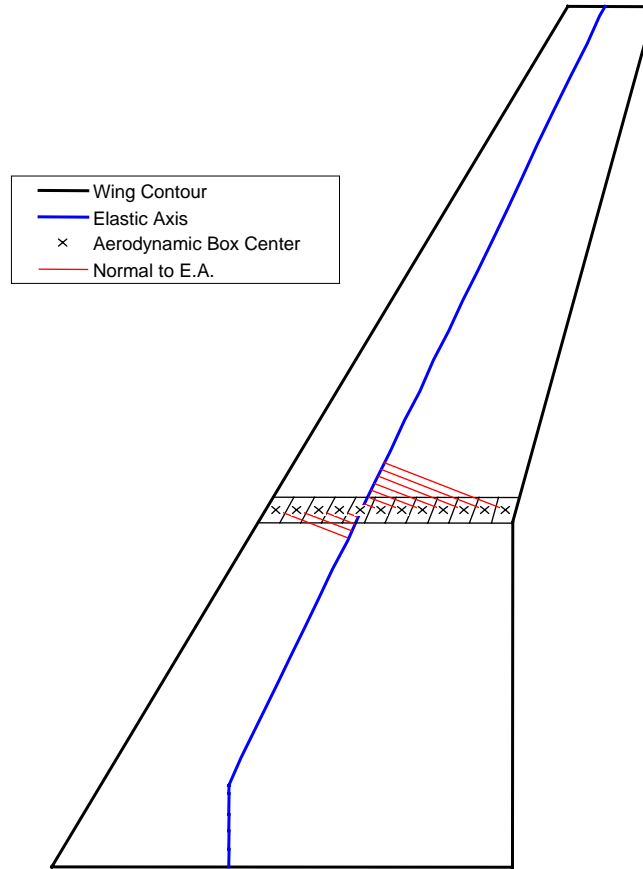
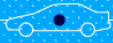


Figure 1. Swept Wing Platform With Aerodynamic Box Centers for Typical Strip. Structural Displacements are Enforced from the Swept Elastic Axis to the Aerodynamic Boxes Using the SPLINE2 Card.



The structural motion defined at the beam is **linearly extrapolated** to the aerodynamic surface, with the perils associated with extrapolation of any kind.

The results of linear extrapolation are not as dramatic as the results from other types of extrapolation; see for example the cubic or surface splines rambling outside the region of constraint (the potato chip effect).



For this reason, the dynamic camber deformation at the aerodynamic surface arising as a result of the use of swept stick models as discussed above is considered to be artificial.

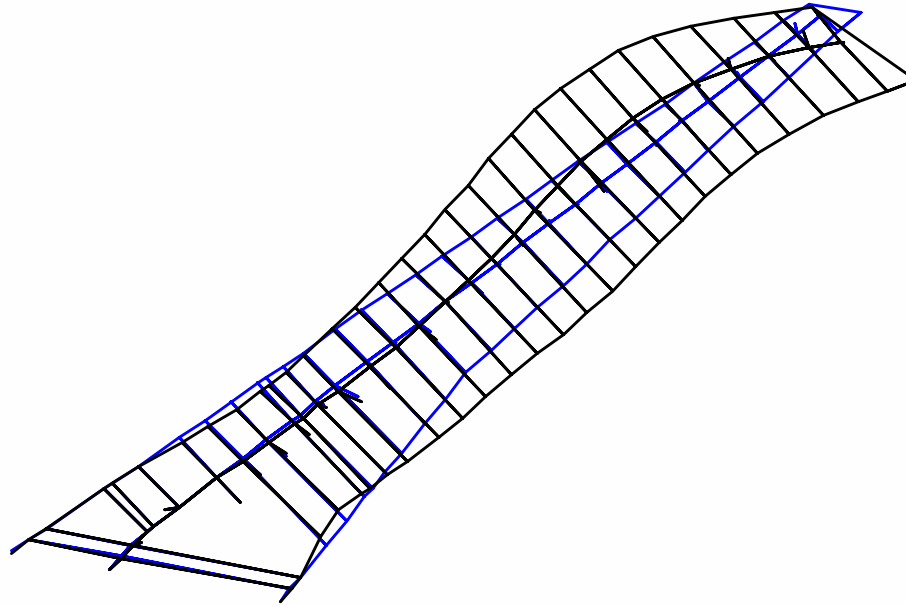
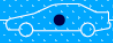


Figure 2. Wing Second Torsional Mode; Transverse Lines are Normal to the Elastic Axis.

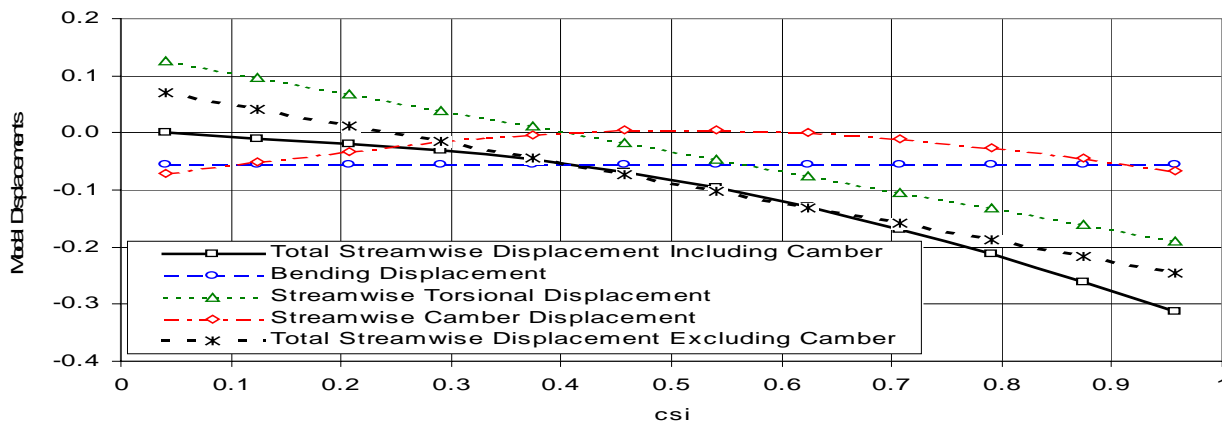


Figure 3a. Descrambled and Total Streamwise Modal Displacements at Centers of Aerodynamic Boxes of Wing Strip Shown in Figure 1 (Spanwise Strip No. 12) for the Second Wing Torsional Mode.

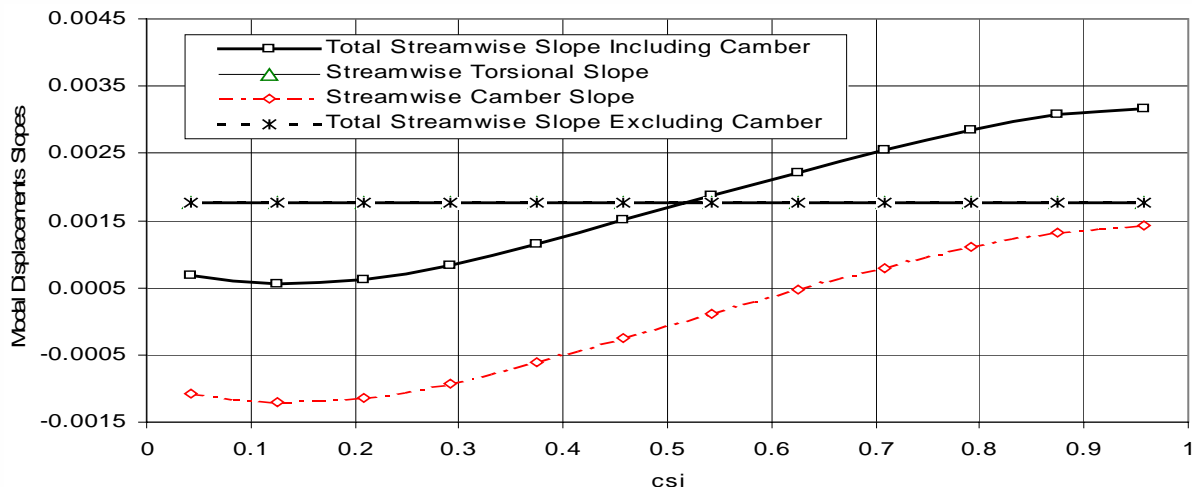


Figure 3b. Descrambled and Total Streamwise Slopes of Modal Displacements at Centers of Aerodynamic Boxes of Wing Strip Shown in Figure 1 (Spanwise Strip No. 12) for the Second Wing Torsional Mode

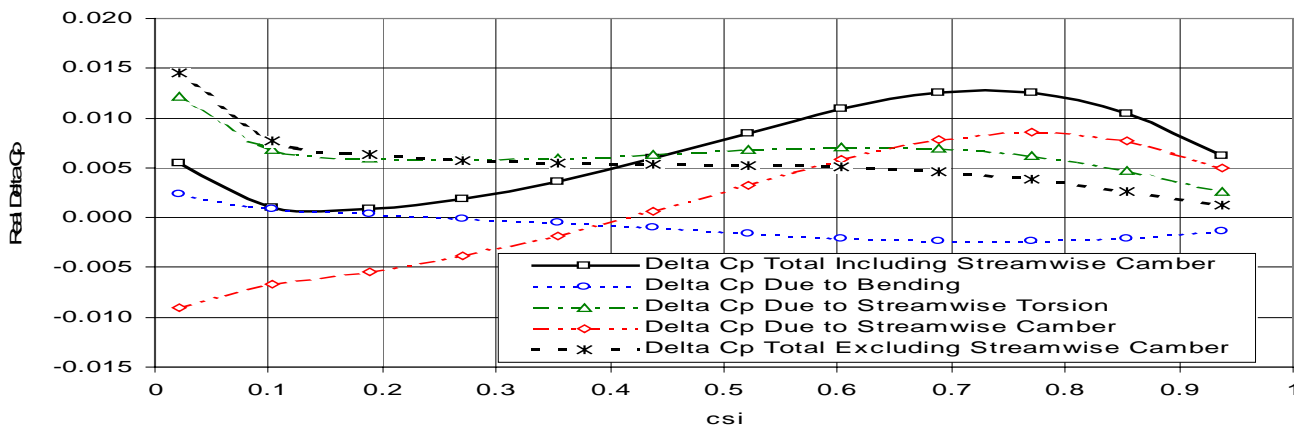


Figure 4.a. Descrambled and Total Real Chordwise Pressures at Box ¼ Chord for Wing Second Torsional Mode for Aerodynamic Strip of Figure 1 (Spanwise Strip No. 12); $k=0.35$

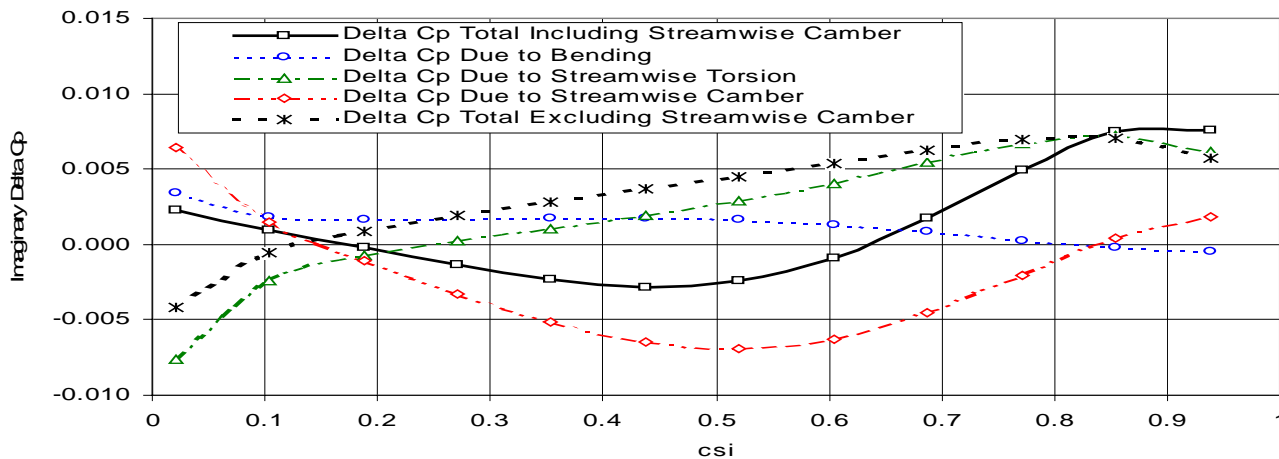


Figure 4.b. Descrambled and Total Imaginary Chordwise Pressures at Box ¼ Chord for Wing Second Torsional Mode for Aerodynamic Strip of Figure 1 (Spanwise Strip No. 12); $k=0.35$

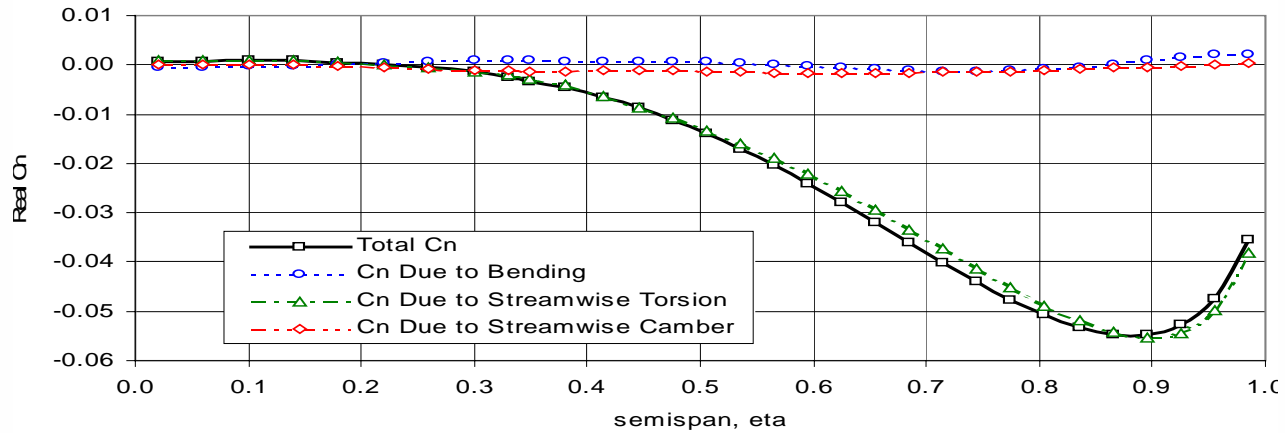


Figure 5.a. Descrambled and Total Real Spanwise Cn Distributions for Second Torsional Mode for Wing of Figure 1; k=0.35

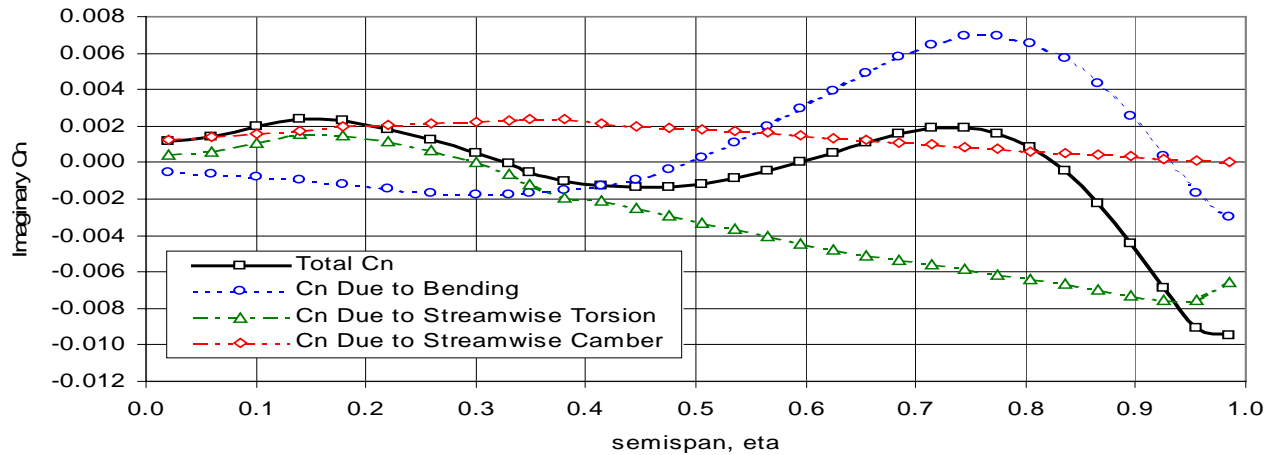


Figure 5.b. Descrambled and Total Imaginary Spanwise Cn Distributions for Second Torsional Mode for Wing of Figure 1; k=0.35

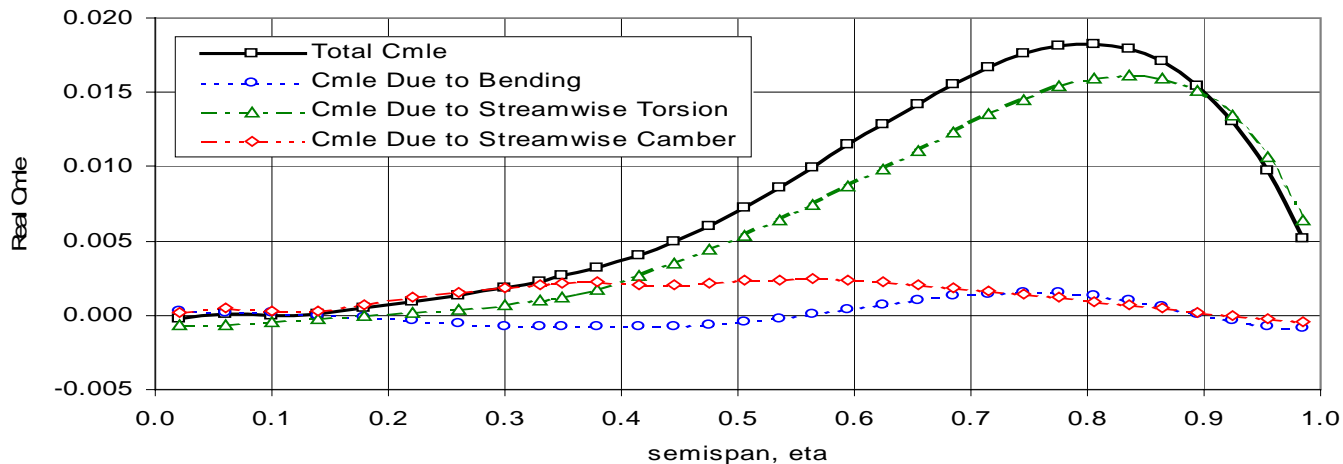
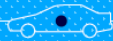


Figure 6.a. Descrambled and Total Real Spanwise Moment Distributions About the Leading Edge for Second Torsional Mode for Wing of Figure 1; $k=0.35$

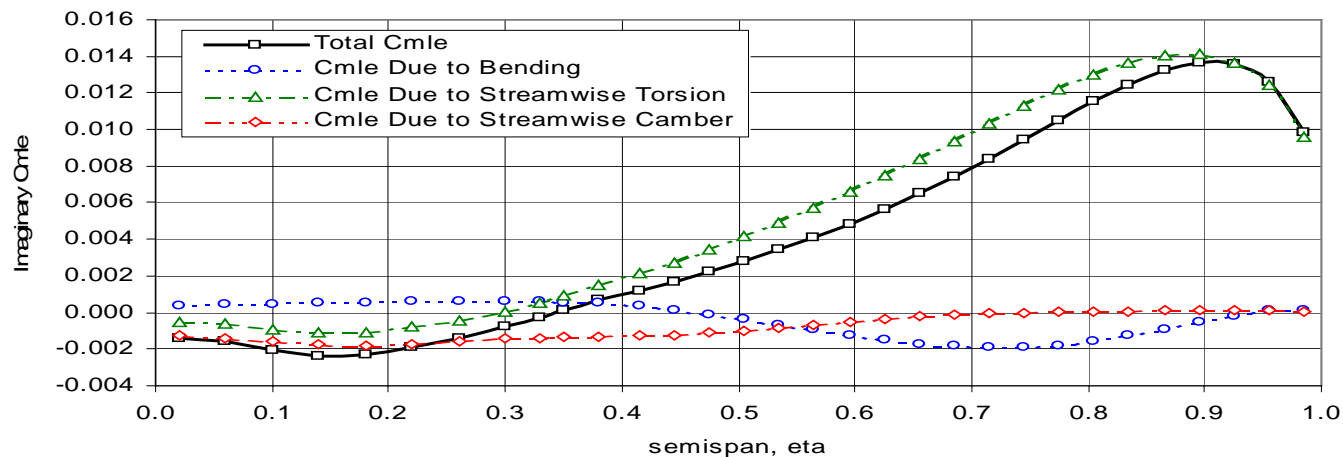


Figure 6.b. Descrambled and Total Imaginary Spanwise Moment Distributions About the Leading Edge for Second Torsional Mode for Wing of Figure 1; $k=0.35$

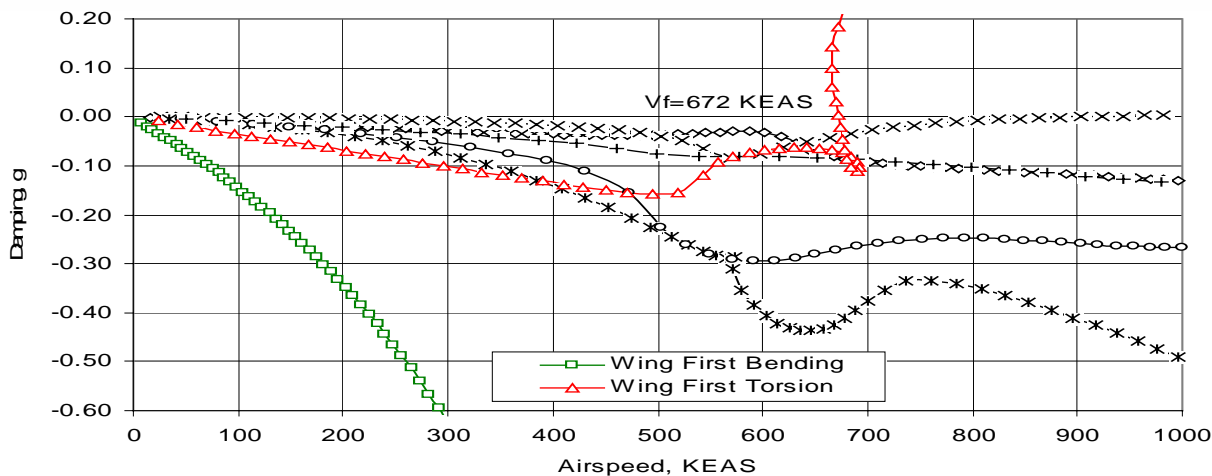


Figure 7. V-g Plot for Symmetric Flutter Analysis of Swept Wing of Figure 1; Streamwise Camber Deformation Terms Are Included in the Generalized Aerodynamics Matrix.

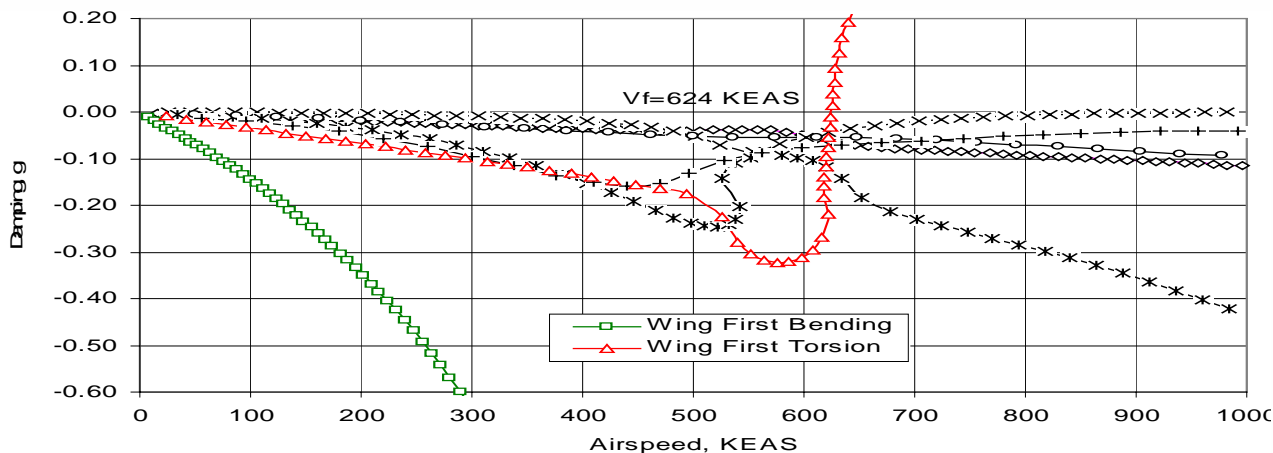


Figure 8. V-g Plot for Symmetric Flutter Analysis of Swept Wing of Figure 1; Streamwise Camber Deformation Terms Have Been Removed from the Generalized Aerodynamics Matrix.

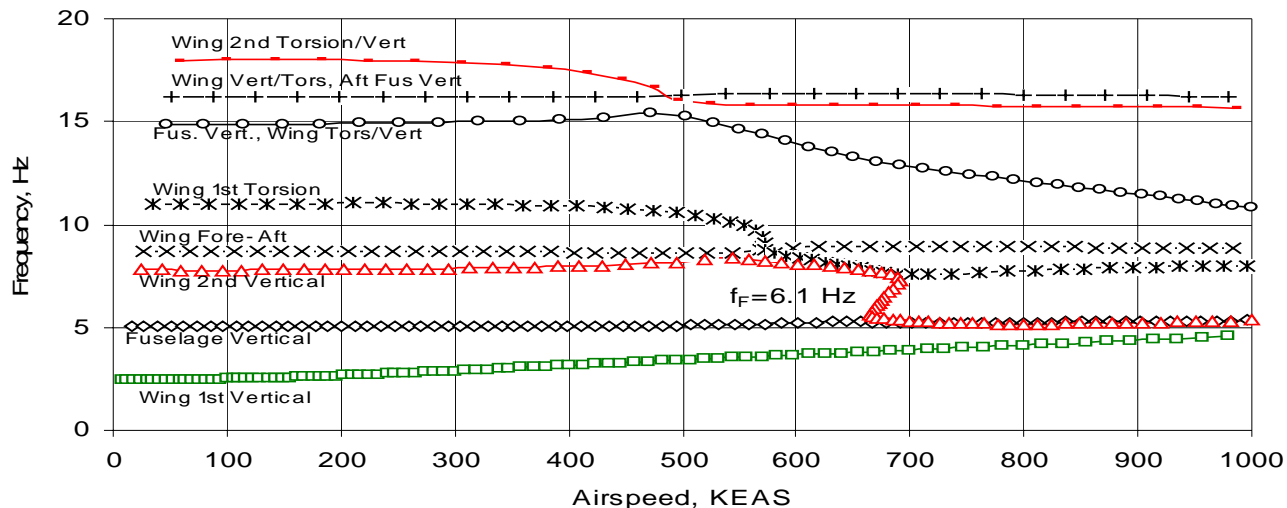


Figure 9. V-f Plot for Symmetric Flutter Analysis of Swept Wing of Figure 1; Streamwise Camber Deformation Terms Are Included in the Generalized Aerodynamics Matrix.

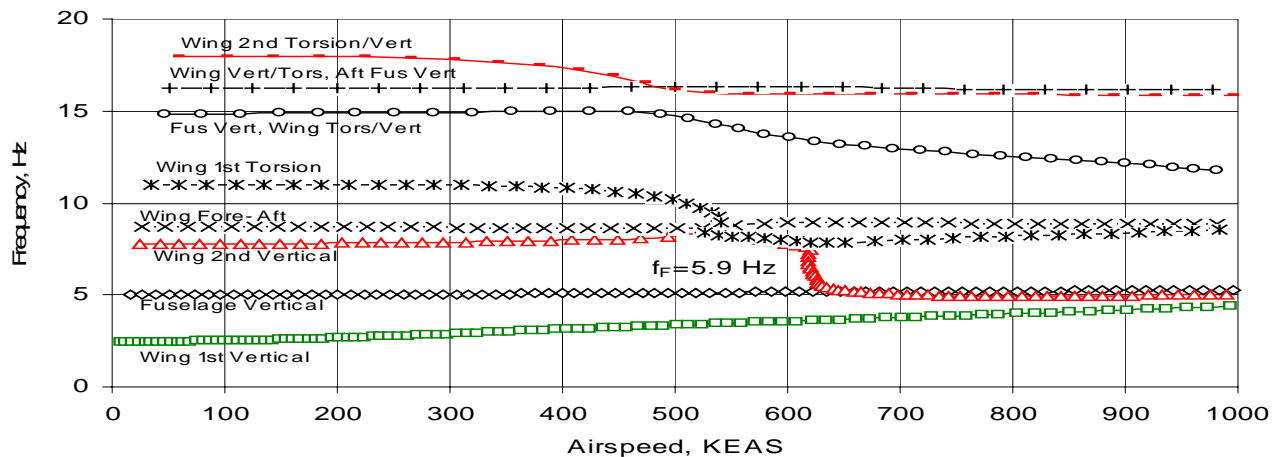
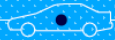


Figure 10. V-f Plot for Symmetric Flutter Analysis of Swept Wing of Figure 1; Streamwise Camber Deformation Terms Have Been Removed from the Generalized Aerodynamics Matrix.



The results presented in this paper were obtained with the use of computer program LSP3 (Lifting Surface Program 3) which implements the aerodynamic derivatives factoring method through automatic descrambling of the modal motion and the calculation of associated descrambled forces and moments which are then available for factoring.



CONCLUSIONS

It has been shown numerically that the contribution ΔV_c of the artificial dynamic camber deformation to the flutter speed of a swept wing can be large.

The calculated contribution ΔV_c is configuration-dependent and it can be either positive or negative.



CONCLUSIONS, continued

Such large calculated flutter speed changes can usually be seen after the application of large factors on some aerodynamic parameters.

At least for this problem, the calculated flutter frequency change due to discarding dynamic camber deformation at the aerodynamic surface is not as large as the change in airspeed.



CONCLUSIONS, continued

For a complete aircraft modeled structurally with swept beams, even in the absence of a large database of cases to support the assertion, it is suggested here that the artificial dynamic camber is responsible for contributions of anywhere between $\Delta V_c = \pm 10$ KEAS to $\Delta V_c = \pm 50$ KEAS to the calculated flutter speed of each swept lifting surface.



CONCLUSIONS, continued

Static aeroelastic analyses will also have a contribution from the artificial elastic streamwise camber deformation at the aerodynamic surface arising from the use of a swept stick model.



CONCLUSIONS, continued

It is suggested that flutter analyses of a swept wing represented as a stick model and then as a full finite element model (correlated to the same baseline data as the stick model) be performed in order to compare and to quantify the real and the artificial dynamic camber deformation effects with the aid of the aerodynamic derivatives factoring method



CONCLUSIONS, the end

Experimental aerodynamic forces resulting from arbitrary elastic modes actual or artificial dynamic camber deformation are not likely to be available any time soon, so obviously correcting these forces with anything other than unit factors is just automatic and unintended guesswork.

This raises another question about the use of factoring methods which do not separate dynamic camber deformation from the other structural displacements.