the formula for range if range is given). Adding payload, systems weight, and crew weight to all the above weights, one gets the all-up-weight. Iteration is involved to obtain the all-up-weight. Figure 5 gives the flow chart for the WM. In this problem the engine module (EM) consists of the data bank of thrust and sfc for various altitudes and Mach numbers of an existing engine around which the aircraft is designed. Performance module (PM) accepts the values obtained from AM, WM, and EM as input together with mission profile (Fig. 1) and properties of the standard atmosphere and computes the required point performance parameters and radius of action.[2] Figure 6 gives the flow chart of PM. The configuration control module (CCM), which essentially is a multivariable search for optimum of a given cost function, viz. radius of action, under design and operational constraints, adjusts the design parameters in each iteration until the optimum is reached. In the mathematical programming language the above procedure can be expressed as:

Maximize $R(X)$ with $X_L \leq X \leq X_U$, $W \leq 14{,}000$ kg, $TOD \leq 1500$ m and where R = radius of action in n. miles, and

$$X = \begin{bmatrix} AR \\ W/S \\ \Lambda \text{ deg} \\ \lambda \\ t/c \end{bmatrix} \quad X_L = \begin{bmatrix} 2 \\ 250 \\ 45\text{deg} \\ 0.2 \\ 0.04 \end{bmatrix} \quad X_U = \begin{bmatrix} 4 \\ 700 \\ 55 \text{ deg} \\ 0.4 \\ 0.06 \end{bmatrix}$$

In CCM, the program SWIFT (Sequential Weightage Increasing Factor Technique),[3] which is based on flexible polyhedron method for unconstrained optimization, is used. This is essentially a penalty function method which does not need a feasible starting point.

Results and Discussion

Table 1 gives the design parameters of the starting and the optimum wings. Figure 7 shows them superimposed. Figure 8 gives the variation of design parameters with simplex number.[3] It is seen that the optimum configuration is able to increase the radius of action by 5 n. miles without compromising on the constraints. This means that the starting configuration was already near optimum. Hence the marginal increase in radius of action should be viewed in that light. What is significant is that the procedure given in this paper would lead to the optimum regardless of the starting configuration. In this case it is observed that the variation of radius of action near optimum is relatively small over a rather wide range of configuration variables excepting the wing loading. It may be noted that the primary emphasis of the study is the development of the methodology for isolating optimum configurations rather than getting larger radius of action in a quantitative sense. It might also be noted from Fig. 8 that the radius of action is a weak function of thickness ratio and as such for further optimization this variable can be neglected. Also, it is clear from Fig. 7 that the optimum wing is structurally more acceptable than the starting configuration. Floating more variables describing fuselage and empennage and inclusion of more constraints are under study.

Acknowledgment

We thank Dr. C. L. Narayana for providing the program for predicting the aerodynamic characteristics of an aircraft, B. V. Sheela for providing the multivariable search program, "SWIFT" and G. S. Dwarakanath for helping us in troubleshooting and offering constructive criticism. We are grateful to M. Shivakumara Swamy who has consistently helped us with his useful suggestions in this work.

References

[1] Ramamoorthy, P., Narayana, C.L., and Vimala Dutta, "Estimation of Drag Polar," National Aeronautical Laboratory Tech. Memo AE-TM-14-77, Aug. 1977.

[2] Sinha, A.K. and Ramamoorthy, P., "General Purpose Aircraft Performance Estimation Program," National Aeronautical Laboratory Tech. Memo AE-TM-79, April 1979.

[3] Sheela, B.V. and Ramamoorthy, P., "SWIFT—A New Constrained Optimization Technique," *Computer Methods in Applied Mechanics and Engineering*, Vol. 6, No. 9, 1975.

C80-094

Effect of Adding Structural Damping on a Wing/Nacelle Hump Type Flutter Mode

80001
40006

Dave Gimmestad*
Boeing Military Airplane Company, Seattle, Wash.

Introduction

ALTHOUGH it has long been known that adding structural damping suppresses some flutter modes, only recently has the materials technology progressed so that you can easily build structural damping into your airplane. These damping materials include viscoelastomers, silicones, high damping epoxies and enamels, which may be integral to the structure, or may be an add-on to the basic design. In this study the effect of adding damping to nacelle strut side bending on a wing/nacelle hump type flutter mode problem is shown.

Discussion

A twin engine preliminary design was used in this study. The airplane has high bypass fan engines strut mounted on the wing. Damping was added to the nacelle strut in side bending. The nacelle frequency dependent characteristics were mapped with a variation on nacelle side bending stiffness, performed with and without added damping. This "chimney" effect results from the nacelle functioning as a tuned mass damper on the wing. Adding damping to the nacelle strut modifies its behavior from that of a tuned mass damper to a tuned viscoelastic damper. In this study the added damping level selected ($\eta = 0.1$), is typical of the loss factors that may be achieved with add-on damping tape treatments. Higher levels of damping are possible with damping which is designed integral to the structure.

The flutter analysis used in this study was a conventional branch modes analysis. It had 20 deg of freedom; including 6 wing bending modes, 4 wing torsion modes, 2 wing fore and aft bending modes, fore and aft body bending, 3 symmetric rigid body modes, and 3 modes of nacelle motion with respect to the wing. The added damping occurs only in the nacelle side bending generalized coordinate.

Results

The flutter speeds of the chimney are shown as a function of nacelle side bending mode natural frequency on Fig. 1. The

Received May 2, 1979; revision received Sept. 4, 1979.

Index categories: Aeroelasticity and Hydroelasticity; Structural Dynamics.

*Specialist Engineer.

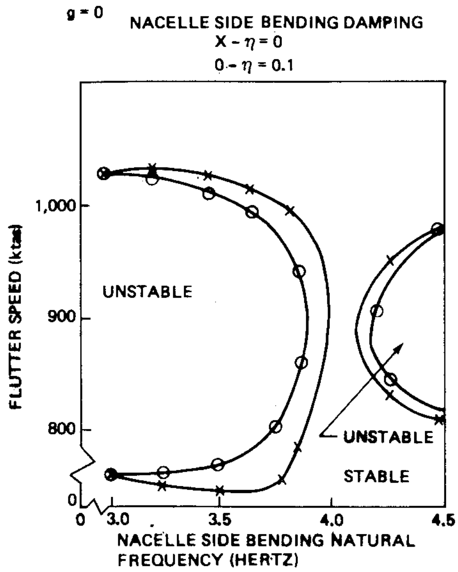

Fig. 1 Nacelle strut damping effect on chimney flutter mode.

flutter boundary is plotted for zero damping and for $\eta = 0.1$ damping added to the nacelle strut in side bending. The addition of damping increases the bandwidth of nacelle side bending frequency in which the nacelle tuning suppresses flutter; the "chimney" becomes wider with the addition of damping. In addition, the flutter speed is increased with the addition of damping at some of the other nacelle side bending natural frequencies studied but not at all of them.

Conclusion

The addition of damping to the nacelle strut in this study improved the airplane flutter characteristics. This addition of damping to nacelle struts has become practical with the recent development of materials such as 3M's ISD 113. An application of these materials is documented on an F-15 application in Ref. 1. Their durability in a harsh environment has been demonstrated on the TF-30 inlet guide vane treatment discussed in Ref. 2. A large selection of damping materials is currently available for the designer to choose from.

Recommendations

1) The addition of structural damping should be considered on designs requiring the suppression of "chimney" type flutter modes.

2) The effects of any damping added to the structure should be included in dynamic gust and fatigue calculations.

3) When damping has been added to a structure for other reasons (e.g., noise control, sonic fatigue), its effect should be included in flutter calculations. This could include transport aircraft aft body damping affecting wing/body coupled flutter modes and affecting empennage flutter.

4) The possibility of adding damping to combat airplanes with external store hump mode flutter problems should be investigated.

References

[1] Share, J.D. and Drake, M.L., "Elimination of a Resonant Fatigue Problem for Major Maintenance Benefits," ASME Paper 77-DET-135.

[2] "Vibration Damping Short Course," Course Notes, University of Dayton, Oct. 1978.

Technical Comments

C 80-095

Comment on "Prediction of Performance of Low-Pressure-Ratio Thrust-Augmentor Ejectors"

~~C80-09~~

Peter R. Payne*
Payne, Inc., Annapolis, Md.

IN Ref. 1 Kentfield has presented a one-dimensional incompressible flow model of ejector performance which seems to show good agreement with experimental data generated by the U.S. Air Force Aerospace Research Laboratories. In the writer's view, Kentfield's paper is open to criticism on two grounds: the work presented is not original, and the experimental "agreement" is apparently obtained by arbitrarily "adjusting" the diffuser efficiency η_D to get the correct answer. Since η_D is, as his paper shows, the single most powerful coefficient, (it has a large effect on augmentation ratio) such a procedure is hardly meaningful. It is also misleading not to state clearly that such a procedure was employed.

On the first count, the writer thinks he has noticed in recent years a trend toward inadequate citation of prior references†; a trend, incidentally, also suggested by writers in at least one other discipline.[2,3] In the case of Kentfield's paper, a newcomer to the field might think that he was reading the first incompressible flow analysis of this type. In fact, many have preceeded it (one[4] carries the illustrious name of von Karman‡), and Flugel[5] refers to a number of analyses prior to 1930 including one by Lorenz[6] in 1910. [Even earlier, Timothy Hackworth and George Stevenson (circa 1830) employed ejectors to obtain a forced draft in the stacks of their boilers. This led to boiler feed-water ejector pumps, and thence to the extensive employment of ejectors by engineers for a wide variety of applications.]

Perhaps understandably, the writer is most taken with the similarities between Kentfield's analysis and his own of fourteen years ago. (An AIAA paper[7] was presented at a joint CASI/AIAA meeting in Ottawa, and later expanded into Ref. 8.) The writer took the entrained mass flow ratio as the independent variable. Kentfield uses the area ratio—a trivial difference. The writer also used a now outmoded definition for diffuser efficiency which is slightly different from Kentfield's.

Not to be too parochial, it is fair to point out that both Quinn[9] and Salter[10] (both referenced by Kentfield) can make the same complaint and validly ask in what meaningful way Kentfield's theory differs from theirs. As can other, earlier authors, not referenced by any of these three. As a matter of fact, it is arguable that almost no original contributions have been made since Flugel's in 1939, the writer's papers included.

One of the most satisfying things about eductors is that one almost never knows what value to ascribe to the "diffuser

Received Jan. 18, 1979.

Index categories: Powerplant Design; Jets, Wakes, and Viscid-Inviscid Flow Interactions; Airbreathing Propulsion.

*President.

†The writer is not claiming to be guiltless himself, especially when young. But he *tries* to do better.

‡Who also omitted any reference to prior work.