NASA Technical Memorandum 81865

Passive Control of Wing/Store Flutter

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DECEMBER 1980

NASA

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**Scientific and Technical
Information Branch**

1980

SUMMARY

Modern fighter airplanes must carry many types and combinations of external wing-mounted stores to satisfy multimission requirements. The carriage of such stores can reduce the flutter speed and thereby degrade the operational and mission effectiveness of combat airplanes. Because of the importance of flutter avoidance, considerable research has been conducted to develop and assess the capabilities of various flutter suppression concepts. In recent years, promising results have been demonstrated by analyses and wind-tunnel tests for both active and passive flutter suppression concepts.

This paper presents results for a passive flutter suppression approach known as the decoupler pylon. The decoupler pylon dynamically isolates the wing from the store pitch inertia effects by means of soft-spring/damper elements assisted by a low-frequency feedback-control system which minimizes static pitch deflections of the store because of maneuvers and changing flight conditions. Wind-tunnel tests and analyses show that this relatively simple pylon suspension system provides substantial increases in flutter speed and reduces the sensitivity of flutter to changes in store inertia and center of gravity. Flutter characteristics of F-16 and YF-17 flutter models equipped with decoupler-pylon-mounted stores are presented and compared with results obtained on the same model configurations with active flutter suppression systems. These studies show both passive and active concepts to be effective in suppressing wing/store flutter. Also presented are data showing the influence of pylon stiffness nonlinearities on wing/store flutter.

INTRODUCTION

High-speed tactical airplanes must carry many types and combinations of wing-mounted external stores. Out of this vast array of possible store loadings it is highly probable that some will cause significant reductions in flutter speed with consequent penalties in airplane performance and mission effectiveness. Because of the importance of avoiding flutter and/or flutter-related airplane performance restrictions, considerable research effort is being devoted to investigation of various flutter suppression concepts.

One promising concept involves the application of active control technology. (See, for example, refs. 1 to 4.) With this concept, electrical signals from vibration response sensors on the structure are fed back through appropriate control laws and filters to drive aerodynamic control surfaces in a manner to counteract flutter. Active flutter suppression systems (FSS) have the potential to be integrated into the flight control systems of advanced airplanes with minimal mass increase and to accommodate readily changes in store configuration by changing the control law. However, because theories for predicting unsteady aerodynamic control forces are inadequate in the transonic speed range, extensive wind-tunnel and/or flight testing is required to establish the proper control law for various store configurations and flight conditions.

An alternate approach under investigation is based on a passive means of controlling wing/store flutter known as the decoupler pylon. Rather than attempting to modify the unsteady aerodynamic forces associated with flutter, as with active flutter suppression concepts, the idea behind this passive approach is to eliminate a major underlying cause of wing/store flutter, namely, the adverse coupling of flutter-critical modes associated with pitch inertia of the store. The decoupler pylon dynamically isolates the wing from store pitch inertia by means of passive soft-spring/damper elements. Static pitch deflection of the soft-mounted store due to maneuvers and changing aerodynamic drag forces is minimized through the use of a low-frequency feedback-control system. The decoupler pylon concept is described in reference 5 and illustrated schematically in figure 1.

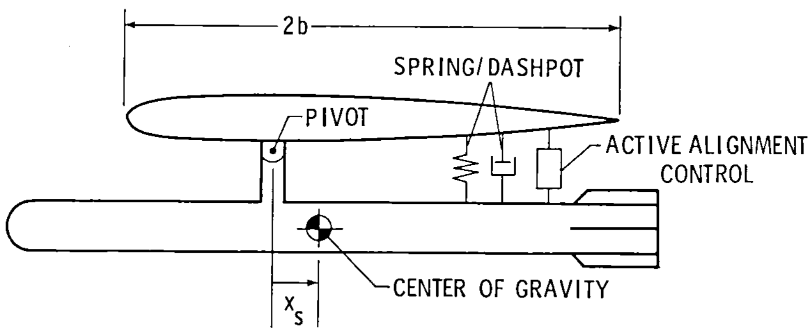

Figure 1.- Schematic diagram of decoupler pylon system.

Wind-tunnel tests were conducted at low subsonic speeds by using a cantilevered, rectangular-wing model with a decoupler-pylon-mounted store. The experimental results in reference 5 agreed well with analytical predictions and showed that, for all cases studied, the flutter speed of the wing with a decoupler-pylon-mounted store was greater than the flutter speed of the wing with no store at all. Equally important, the decoupler pylon made flutter relatively insensitive to changes in the store inertia and center of gravity.

On the basis of the encouraging results indicated from these low-speed model tests, it was desired to evaluate the concept on an advanced fighter configuration at transonic speeds. During 1979, advantage was taken of two opportunities to fulfill this need. As a part of a long-range study of the feasibility of active wing/store FSS for advanced fighters, highly sophisticated flutter models of the F-16 and YF-17 equipped with active control surfaces and multiple feedback sensors are being utilized in a series of research investigations in the Langley Transonic Dynamics Tunnel. Since 1977, these models have shared approximately 1000 hours of occupancy time in the Transonic Dynamics Tunnel undergoing evaluation tests of various active FSS. Results from the most recent (1979) of these entries are presented in reference 2 for the F-16 and in references 3 and 4 for the YF-17. As an adjunct to the 1979 test programs, the models also were equipped with decoupler pylons so that the flutter suppression characteristics of both systems could be evaluated and compared for selected flutter-critical store configurations. Cooperative assistance in testing the decoupler pylon on these models was provided by the Air Force Flight Dynamics Laboratory; General Dynamics Corporation, Fort Worth Division; and Northrop Corporation.

This paper presents a brief summary of major results from evaluation tests of the decoupler pylon flutter suppressor on high-speed flutter models of the F-16 and YF-17. Also presented for completeness are some key findings from parametric studies in reference 5 of the decoupler pylon on a low-speed, rectangular-wing flutter model.

SYMBOLS AND ABBREVIATIONS

b	wing semichord
c.g.	center of gravity
FSS	flutter suppression system
I	moment of inertia of store and pylon about pylon pitch axis
k_θ	pylon pitch spring constant about pylon pitch axis
LE	leading edge
M	Mach number
P	pitching moment of store about decoupler pylon pivot
P_o	static pitching moment required to deflect decoupler pylon against mechanical stop
q	dynamic pressure
q_{nom}	flutter dynamic pressure with nominally stiff pylon
r_s	store radius of gyration about pivot
TE	trailing edge
V	velocity
V_{nom}	flutter velocity with nominally stiff pylon
x_s	distance between store center-of-gravity and pivot, positive aft
θ	store pitch deflection
θ_o	store pitch deflection at which pylon contacts mechanical stop
ω_h	fundamental bending frequency of wing with rigidly mounted store
ω_θ	uncoupled store pitch frequency, $\sqrt{k_\theta/I}$

WIND-TUNNEL MODELS

The three wing/store flutter models which have been used in studies in the Langley Transonic Dynamics Tunnel are shown in figure 2.

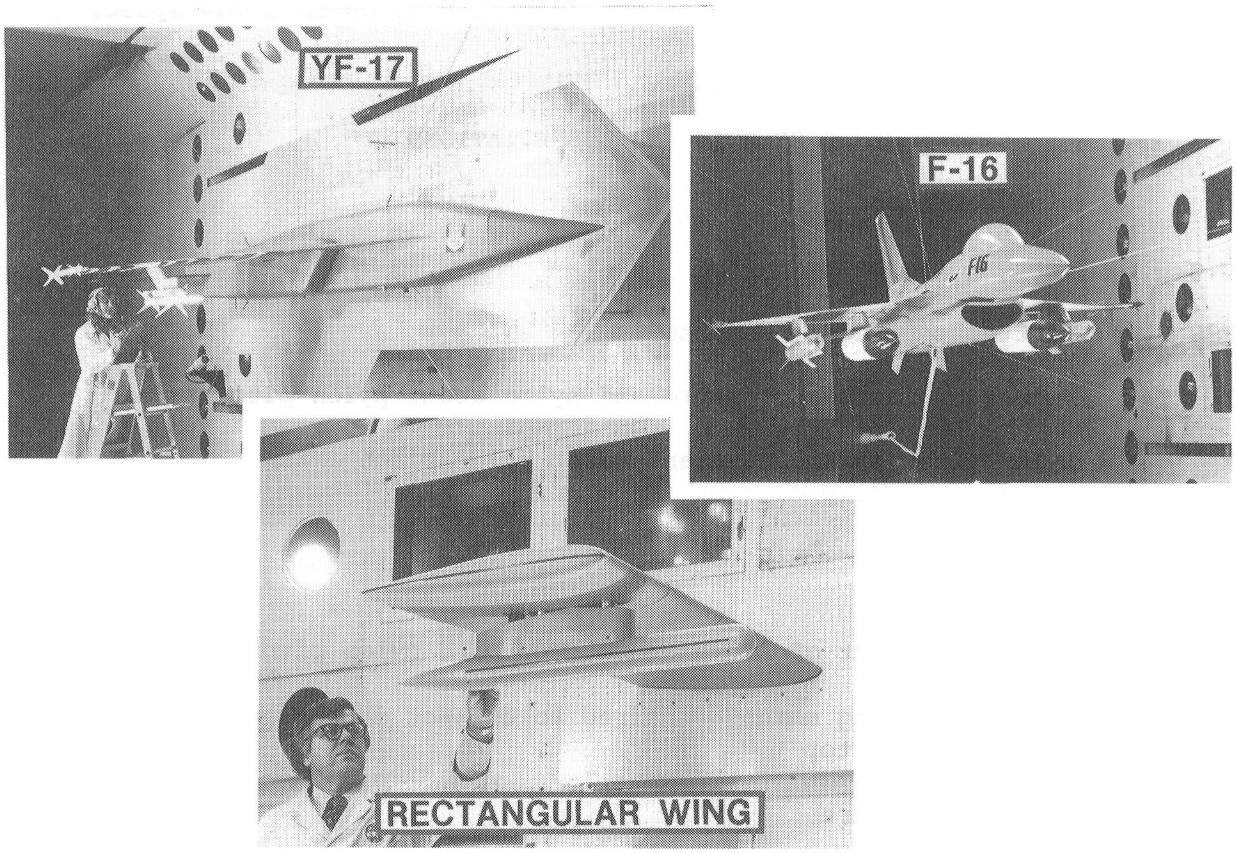

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Figure 2.- Wing/store flutter suppression studies in Langley Transonic Dynamics Tunnel.

Rectangular-Wing Model

The rectangular-wing model, designed for tests in air at low subsonic speeds, was used in initial exploratory research studies of the decoupler pylon concept. This cantilever-mounted, aspect-ratio-5 wing carries a single store at the 81.5-percent span. The store mass, inertia, and center of gravity could be changed readily by means of two movable masses within the store.

The soft pylon pitch spring was implemented on the model by means of a pneumatic system. Air springs were connected between the wing and the store on either side of the pitch axis. Store pitch frequency was controlled by the average pressure in the air springs and pitch alignment by the pressure difference. Pitch deflections of the store caused by aerodynamic drag loads were compensated for by feedback control of pressure in the air springs. Also, a dashpot damper was used to provide additional damping to the system. Further details on this rectangular-wing model and the decoupler pylon system are given in reference 5.

F-16 Model

A 1/4-scale F-16 flutter model, which had been used extensively for flutter clearance testing in the airplane development program (ref. 6), was modified and used to investigate the feasibility of employing active controls on the F-16 to suppress wing/store flutter. Major changes to the model consisted of a new set of wings, a hydraulic power supply installed in the fuselage, and a set of high-frequency actuators to power flaperons on each wing. Six accelerometers located on each wing were available to provide feedback signals for flutter suppression purposes.

The model was "flown" on a cable-mount system which simulated free-flight rigid-body motions; thus, tests of both symmetric and unsymmetric store loadings were possible. A symmetric store loading configuration is considered in the present report. Designated Configuration 33 in reference 2, it consists of the following symmetric store loading: AIM-9J missile mounted on wing-tip launcher, GBU-8B heavy bomb mounted at the 61-percent semispan, and half-filled fuel tank mounted at the 36-percent semispan. Additional details on the F-16 model with active controls are given in reference 2.

The decoupler pylon used on the F-16 model was manually controlled and, therefore, somewhat simpler than the system previously described for the rectangular-wing model. For this model, the spring function was provided by a single mechanical leaf spring connected between the store and the wing aft of the pivot. Two small pneumatic dashpot dampers were connected in parallel between the wing and store, aft of the pivot. The closed ends of the damper cylinders were connected to a pressurized air supply. Alignment of the store, therefore, could be controlled manually by adjusting the pressure as needed to counteract aerodynamic drag loads on the store.

YF-17 Model

The 0.30-scale, half-span YF-17 model was used in a series of wing/store active FSS studies by the Northrop Corporation under an Air Force Flight Dynamics Laboratory contract and by several European organizations (refs. 3 and 4). Symmetric flutter modes were simulated by a sidewall model mount system which provided rigid-body pitch and plunge degrees of freedom. A large splitter plate was installed to remove the model from tunnel-wall boundary-layer effects. The store loading configuration consisted of an AIM-7S missile mounted on an outboard wing pylon and an empty tip launcher rail. The violent nature of flutter for this configuration had been established in prior tests of the model. Thus, it represented a challenging test case for evaluating the effectiveness of store flutter suppression systems. Active leading-edge and trailing-edge control surfaces on the model were driven by miniature hydraulic actuators. Four accelerometers in the wing were available for use as flutter suppression feedback signals. The decoupler pylon for the YF-17 was the same design as that used in the F-16 test except a spacer member was added to make the decoupler pylon height match that of the basic pylon. Further details on the YF-17 active FSS model are given in references 3 and 4.

FLUTTER TESTS

Rectangular-Wing Model

With the aid of selected results from reference 5, some basic characteristics of the decoupler pylon concept are discussed in this section.

Pylon pitch stiffness.- Consider first the effect of pylon pitch stiffness on flutter. Because wing flutter usually results from coupling between bending and torsion modes of the wing, it is generally desirable to maintain good frequency separation between these flutter-critical modes. When a store with large pitch inertia is attached rigidly to the wing, this frequency separation is reduced because of the lowered torsion frequency. Consequently, flutter often occurs at a much lower speed than for the wing with no store. The idea behind the use of a pylon that is soft in pitch is to isolate dynamically the wing first torsion mode from the influence of store pitch inertia. In this way, the torsion frequency of a wing carrying a soft-mounted store becomes about the same as for the wing with no store or substantially higher than it would be had the store been mounted rigidly. The wing-bending frequency is reduced due to added store mass. Intuitively then, the flutter speed should increase because of the increase in frequency separation of flutter-critical modes caused by the decoupling of the wing from store pitch inertia effects.

Results presented in figure 3 support these observations. This figure indicates the manner in which the flutter speed of the rectangular-wing model varies with store pitch frequency. Note the excellent agreement between the experimental flutter points and the theoretical curve which was developed in reference 7. The flutter speed in figure 3 has been normalized with respect to V_{nom}, the flutter velocity for a nominally rigid pylon, which in this case is about 20 percent below the bare-wing flutter speed; the uncoupled store pitch frequency ω_θ has been divided by ω_h, the fundamental wing-bending frequency with the store rigidly attached. This figure can be discussed in terms of three pylon frequency (or stiffness) regions: "stiff" ($\omega_\theta/\omega_h \geqq 1.5$), "tuned" ($0.8 < \omega_\theta/\omega_h < 1.5$) and "soft" ($\omega_\theta/\omega_h \leqq 0.8$). In the stiff region, which is representative of current airplane design practice, the flutter speed is equal to or less than V_{nom}. In the tuned region the flutter speed becomes very high but tends to be sensitive to changes in store inertia and center of gravity. In the soft (decoupler pylon) region, the flutter velocity is well above V_{nom} and, as shown later, is also relatively insensitive to variations in store inertia and center of gravity. In practical applications, the decoupler-pylon stiffness should be above some minimum value defined on the basis of controlling store pitch deflection within allowable limits, yet soft enough to isolate dynamically the store from the wing. For example, pylon stiffness values suggested by the data in figure 3 give frequency ratios within the range $0.5 \leqq \omega_\theta/\omega_h \leqq 0.8$.

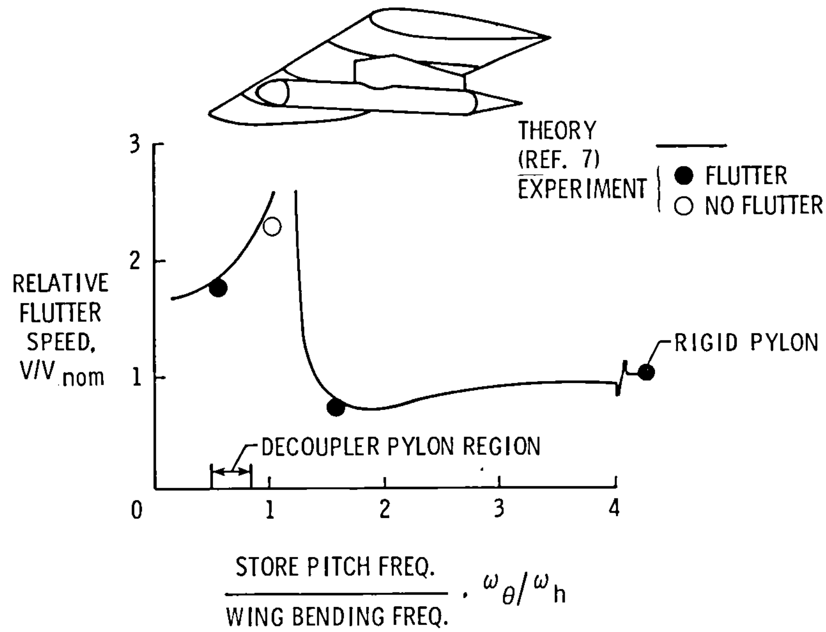

Figure 3.- Effect of store pitch frequency on flutter speed of rectangular-wing model.

Store pitch inertia and center of gravity.- The sensitivity of flutter speed to radius of gyration (store pitch inertia) and center of gravity is illustrated in figure 4 for both a rigid pylon and decoupler pylon. Variations

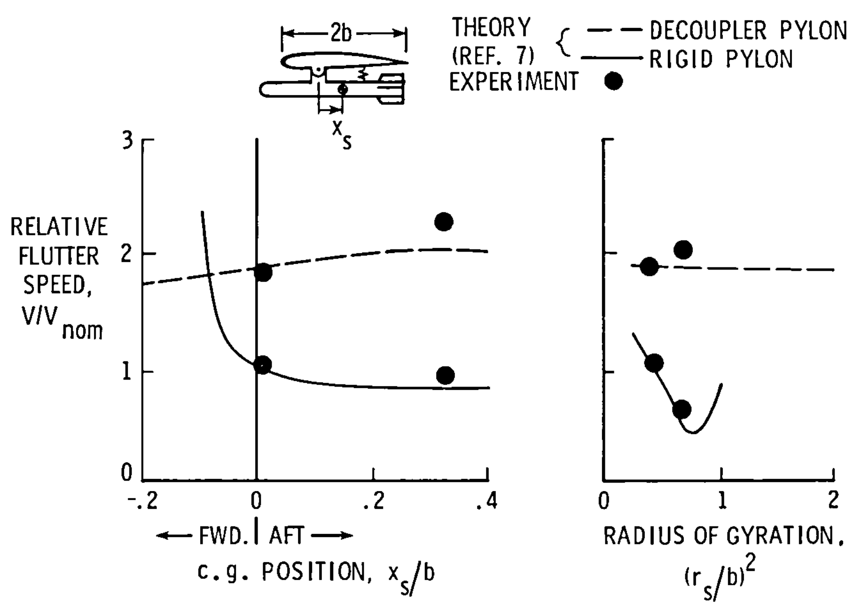

Figure 4.- Sensitivity of flutter to store inertia and c.g. on rectangular-wing model.

in the store c.g. and inertia parameters were achieved by changing the position of masses in the store while holding store total mass and pylon stiffness constant. The flutter velocity used for normalizing these results correspond to the rigid-pylon store configuration with minimum pitch inertia and no c.g. offset. The important point to be made about the figure is that for the decoupler pylon the flutter speed is uniformly high over a considerable range of variation in store pitch inertia and c.g. travel, whereas flutter speed for the rigid pylon is reduced and is much more sensitive to variations in these parameters. As might be expected, when the store c.g. for the rigid pylon case is sufficiently forward, the store mass has a stabilizing influence and flutter no longer occurs.

F-16 Model

Decoupler pylon FSS.- Figure 5 shows the implementation of the decoupler pylon on the F-16 flutter model. This particular store loading configuration was selected for flutter suppression evaluation tests because of the low flutter speed it exhibited in earlier wind-tunnel tests. Because the "culprit" stores which made this configuration flutter critical were GBU-8B's, only these (one

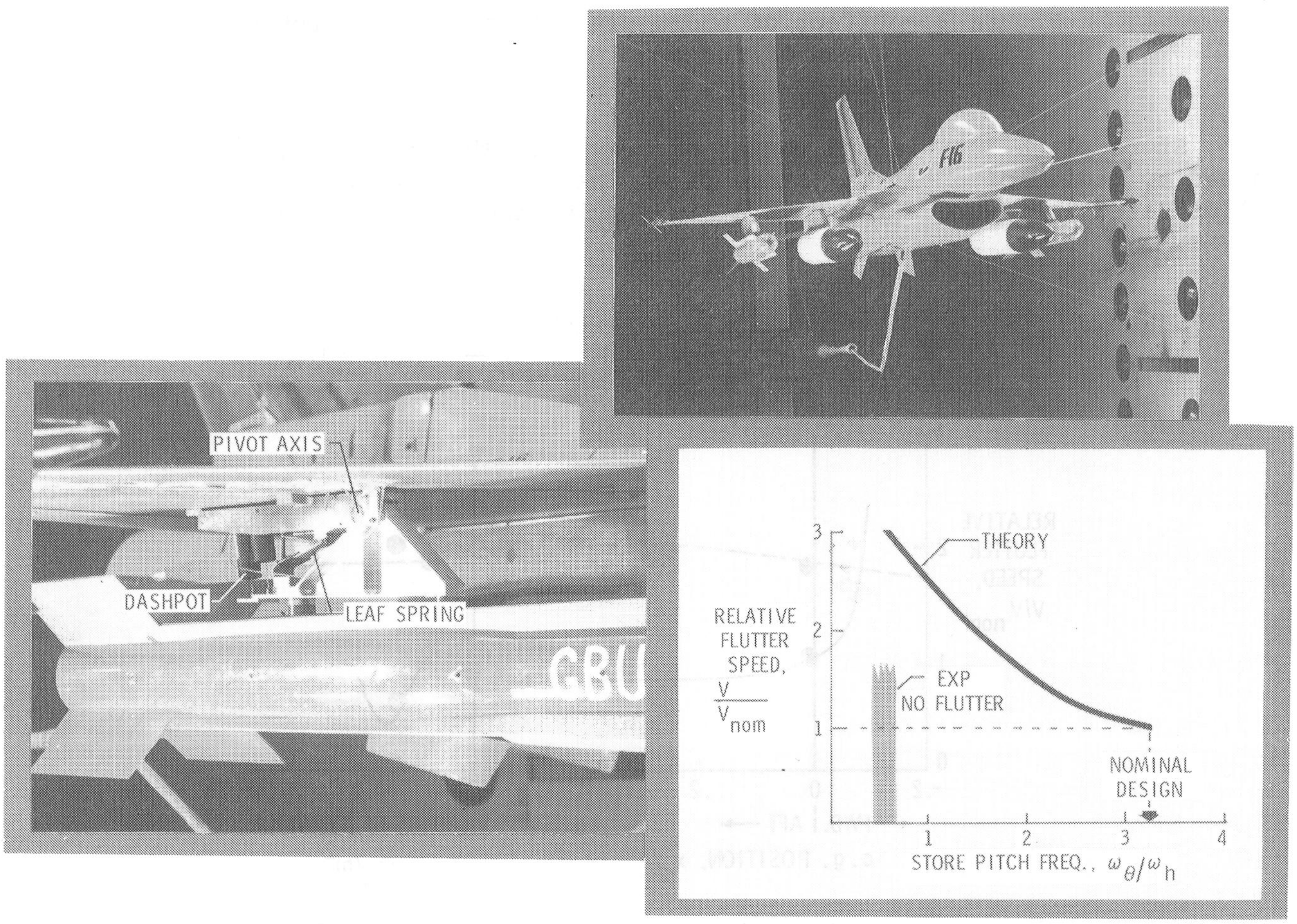

Figure 5.- Flutter studies of F-16 model with decoupler pylon.

on each wing) were mounted on decoupler pylons. The photograph of the decoupler pylon system shown in figure 5 with the pylon cover removed reveals such features as the pivot axis, leaf spring, and the dashpot dampers that also served as pneumatic actuators for control of store deflection due to changing drag loads.

The pylon stiffness was selected to give an uncoupled store pitch frequency of 6.1 Hz on the model (4.0 Hz on the airplane) which is about 70 percent of the first antisymmetric bending frequency of the wing with nominal-design pylon stiffness. (The antisymmetric modes are flutter critical for this configuration.)

Flutter analyses for Configuration 33 were performed by General Dynamics, Fort Worth, to determine the effect of reducing the pitch stiffness of the GBU-8B pylons. Results of the analysis for antisymmetrical flutter at Mach 0.90 are shown by the plot in figure 5. These results indicate an up to threefold increase in flutter speed as the pylon pitch stiffness is reduced from its nominal design value. In the wind-tunnel tests of the configuration with the nominal pylon, flutter onset occurred at $M = 0.59$ and $q = 4.40$ kPa (92 lbf/ft^2); the flutter mode was antisymmetric at 8.6 Hz (ref. 2). With decoupler pylons, the model was tested at constant tunnel stagnation pressure up to $M = 0.85$ and $q = 8.62$ kPa (180 lbf/ft^2). Although there was no indication of flutter up to $M = 0.85$, the model became difficult to fly due to a low-frequency dutch roll type of motion; therefore, the tests were terminated.

Decoupler pylon/active FSS comparison.- Configuration 33 was also tested with an active FSS over the same Mach number and dynamic pressure range. This active FSS, designated control law 44 in reference 2, utilized an accelerometer on each wing, as indicated by the sketch in figure 6, to measure wing response

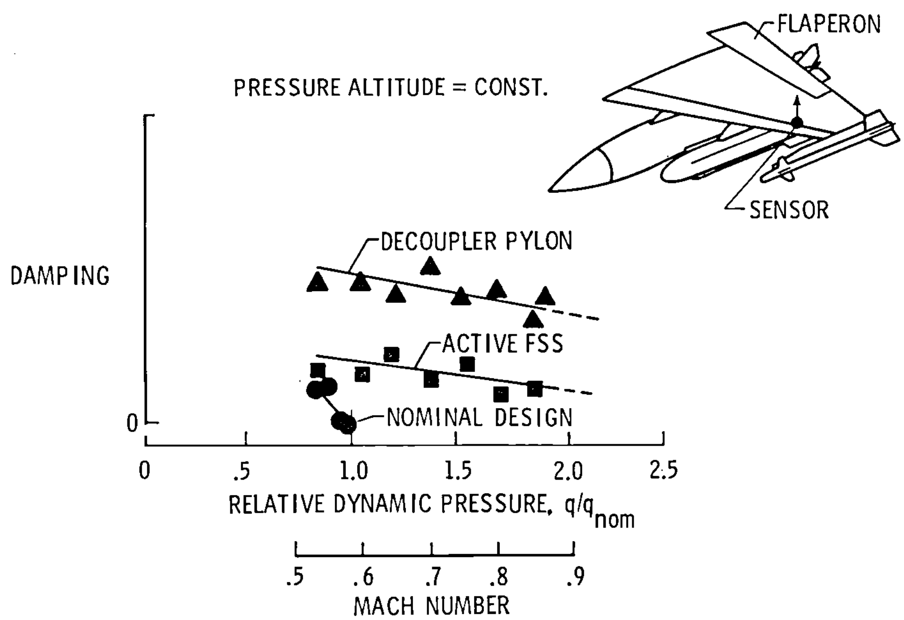

Figure 6.- Measured damping trends of F-16 model with active FSS and decoupler pylon.

for feedback to the flaperon control surfaces. Again, there were no signs of impending flutter, but the model flying difficulties precluded going to more severe test conditions.

Although the onset of flutter for the decoupler pylon and the active FSS could not be determined during these tests, damping of the flutter-critical mode was measured at several tunnel test conditions. These damping values were estimated by a subcritical flutter testing technique called the peak-hold spectrum method wherein the damping of the flutter mode is assumed to be proportional to the inverse of the peak amplitude of a measured spectrum of model response. Damping trends established from these measurements are presented in figure 6 for the three previously described cases. These damping trends were obtained by analyzing the output of a wing bending-moment strain gage located near the wing root. The major point to be made from figure 6 is that both the decoupler pylon and the active FSS effectively eliminated the flutter condition exhibited by the unaugmented model. The damping level indicated for the decoupler pylon is substantially higher than for the active FSS, but because both are high, it is difficult to project to a flutter point for either system.

YF-17 Model

Pylon pitch stiffness.- The decoupler pylon pitch stiffness for the model with an AIM-7S missile was selected on the basis of calculations performed by the Northrop Corporation. As in the previous examples, results of the analysis are presented as the variation of flutter velocity ratio with uncoupled store pitch frequency ratio. The velocity is normalized by the measured flutter velocity for the unmodified model which fluttered at $q = 3.54$ kPa (74 lbf/ft^2). The results in figure 7 show that, as the uncoupled-store pitch frequency is reduced below the fundamental wing-bending frequency with store rigidly attached, the flutter speed increases rapidly, peaks at about twice the nominal flutter velocity, and then decreases to about 1.5 times the nominal velocity. When the store pitch frequency is slightly greater than the wing-bending frequency, the flutter velocity dips to a minimum which is 40 percent

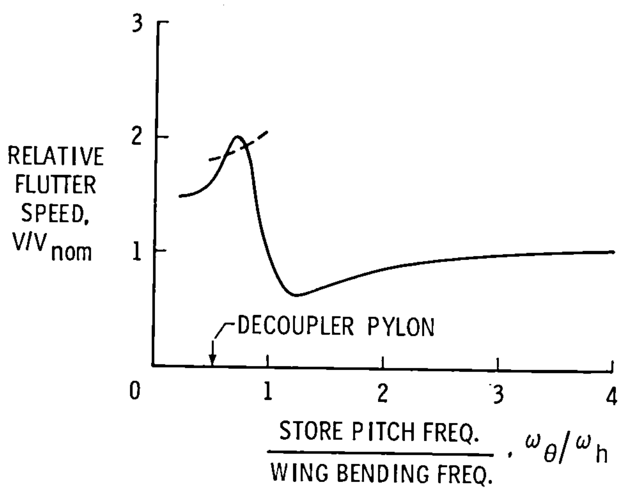

Figure 7.- Effect of store pitch frequency on flutter speed of YF-17 model.

below the nominal value. (It is shown later that this dip in the flutter boundary led to an unexpected flutter encounter during an investigation of nonlinear pylon-stiffness effects.) The dashed-line segment which intersects the continuous flutter boundary in the vicinity of the peak in figure 7 represents a higher frequency flutter-mode boundary. The decoupler pylon stiffness that was implemented and tested on the model corresponded to $\omega_\theta/\omega_h = 0.54$ which, based on the calculations, would increase the flutter speed by about 70 percent.

Decoupler pylon/active FSS comparison.- During the test, model damping was monitored by means of the peak-hold spectrum plots based on signals from a wing torsion strain gage. Figure 8 shows some typical damping trends observed for the decoupler pylon and an active FSS with leading-edge and trailing-edge control surfaces. The tunnel dynamic pressure was increased while holding Mach number constant at 0.80. Projection of these damping trends to the point of flutter indicates that both the active and passive approaches to wing/store flutter suppression are effective and offer approximately 100-percent improvement in flutter dynamic pressure above that of the nominal configuration.

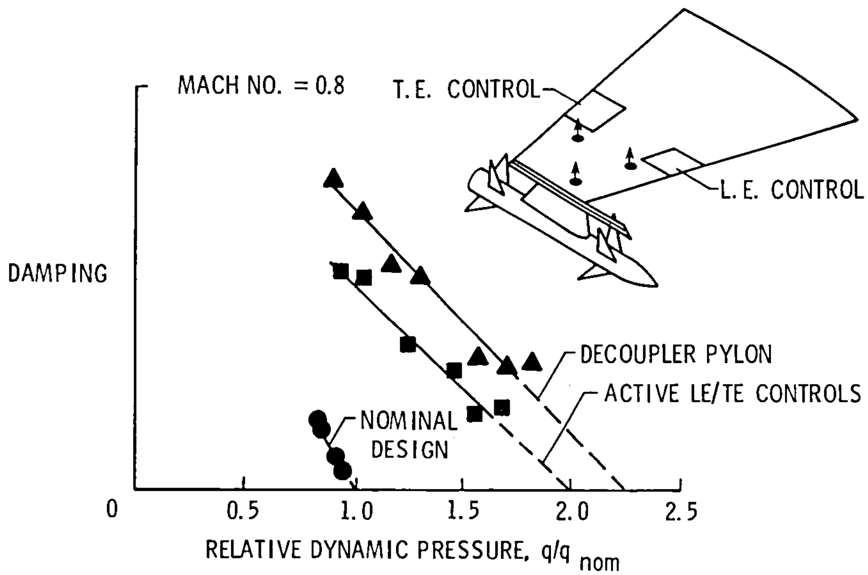

Figure 8.- Measured damping trends of YF-17 flutter suppression model. Control law N3P (ref 3).

Store vibration environment.- Because, in principle, the decoupler pylon functions as a form of vibration isolator, it is of interest to examine a potential side benefit, namely, isolation of the store from shock and vibration response transmitted from the airframe. Vibration response associated with airplane buffeting, for example, can create a severe and hazardous environment for missile guidance and control components. To evaluate vibration isolation characteristics of the decoupler pylon, power spectral density measurements were made of the vertical acceleration at a point near the aft end of the AIM-7S missile. Data were obtained at $M = 0.80$ with the decoupler pylon and with an active FFS for a dynamic pressure 35 percent above the flutter dynamic pressure of the unaugmented model. Figure 9 shows a comparison of the two cases over the

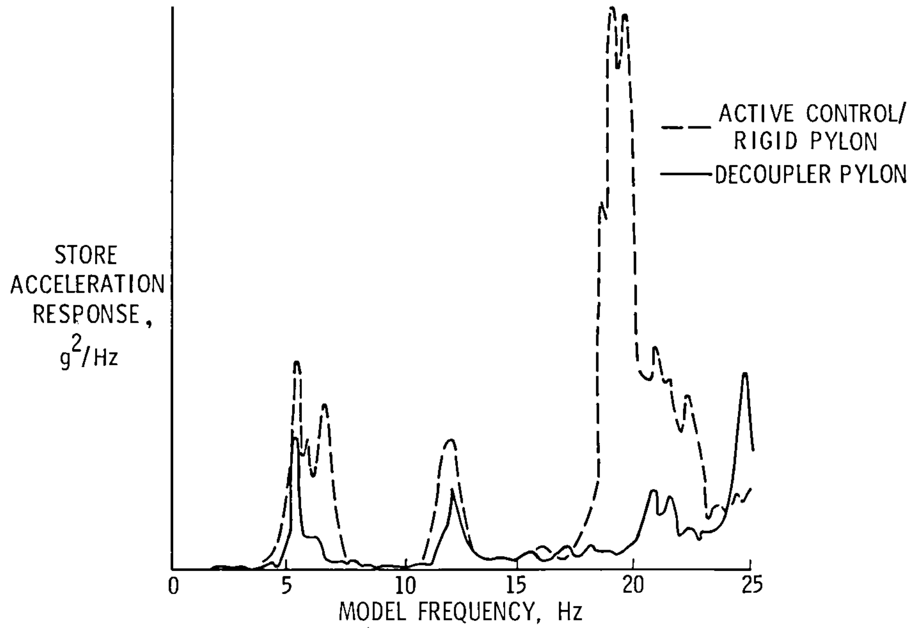

Figure 9.- Power spectra of YF-17 store acceleration response in pitch plane with active LE control and decoupler pylon. Control law N1 (ref. 3); $M = 0.8$; $q/q_{nom} = 1.35$.

frequency interval from 0 to 25 Hz. There is substantially greater response in all modes for the active FSS (with a nominally stiff pylon) than for the decoupler pylon. The root-mean-square level over this frequency range is 70 percent higher for the active system than for the passive system.

Nonlinear Pylon Stiffness

The analytical and experimental results presented thus far have been for structures with assumed linear characteristics, that is, structures having stiffness and damping properties that are essentially independent of amplitude of static and dynamic deflections. Over certain regions of operation, however, airplane structural components typically exhibit nonlinear characteristics. Some common examples are backlash, hysteresis, and mechanical deflection limits of control surfaces and pylon mounts. Pressure and flow rate limits for hydraulic control systems are other forms of nonlinearity that must be considered in active FSS. Such nonlinearities can have significant influence on flutter characteristics.

In reference 8, the effects of pylon stiffness nonlinearity on wing/store flutter were investigated for the decoupler pylon. The specific nonlinearity treated was the kind encountered when the pylon pitch spring exceeds its linear range of deflection and "bottoms" against a relatively stiff back-up structure as a result of excessive static and/or dynamic deflections of the store. The flutter characteristics associated with such nonlinearities were studied by means of the "describing function" analysis technique. The specific configurations chosen for illustration of the analysis method were the rectangular-wing model and the 1/4-scale F-16 model, but no experimental data were available for comparison with the analysis.

Wind-tunnel tests in October 1979 of the YF-17 model with the decoupler pylon afforded an opportunity to obtain experimental flutter data on nonlinear pylon stiffness effects for correlation with analysis. Therefore, as a peripheral part of the decoupler pylon investigation, an attempt was made to investigate nonlinear flutter effects as well.

In application of the describing function method to flutter calculations, the actual nonlinear spring characteristics are represented by an equivalent linear spring whose stiffness varies with static deflection and oscillation amplitude of the store. The flutter speed is computed as a function of this equivalent linear pylon using any standard flutter analysis technique.

At the time of the YF-17 wind-tunnel tests, flutter calculations had been made only for the nominally rigid pylon and for the decoupler pylon. It was assumed, therefore, that the YF-17 model would exhibit roughly the same type of nonlinear flutter behavior as predicted for the F-16 model in reference 8. This analysis indicated that when the pylon is forced by static preload against a hard stop, flutter onset would occur at the same speed as for a linear system having stiffness matching that of the hard spring. However, in contrast to linear system behavior, where flutter oscillation amplitude grows without bound, predictions for the nonlinear system showed flutter to be in the form of limit-cycle oscillations. The amplitude of oscillation increases as the velocity exceeds the flutter onset velocity associated with the linear, hard-spring system.

In order to investigate the nonlinear flutter behavior of the YF-17 model, a static nose-up preload was applied to the store by means of air pressure to the store-alignment actuator. This preload was several times greater than the load required to contact the stop. During the test, the model fluttered unexpectedly with divergent oscillations at $q = 2.68$ kPa (56 lbf/ft^2) which is 75 percent of the flutter dynamic pressure of the basic unaugmented model with the rigid pylon. Fortunately, the model was undamaged, and the remainder of the decoupler pylon investigation was successfully completed.

After the model test had been completed, additional flutter calculations were performed by Northrop to define in greater detail the linear-system flutter boundary as a function of pylon stiffness. The differences in this calculated flutter boundary for the YF-17 model (fig. 7) and the one assumed for the model prior to test (similar to the F-16 results shown in fig. 5) are significant and can be used to explain the unexpected flutter encountered during the model test. The describing function analysis method of reference 8 was applied by using the linear-analysis flutter boundary for the YF-17 model together with measured stiffness properties of the soft-pylon pitch spring and of the hard stop. The resulting flutter dynamic pressure for the nonlinear system is plotted as a function of store pitch oscillation amplitude in figure 10. The static preload moment was about $2.5P_o$ where P_o is the pitch-up moment about the pylon pivot axis needed to make contact against the stop. For flutter to occur at the

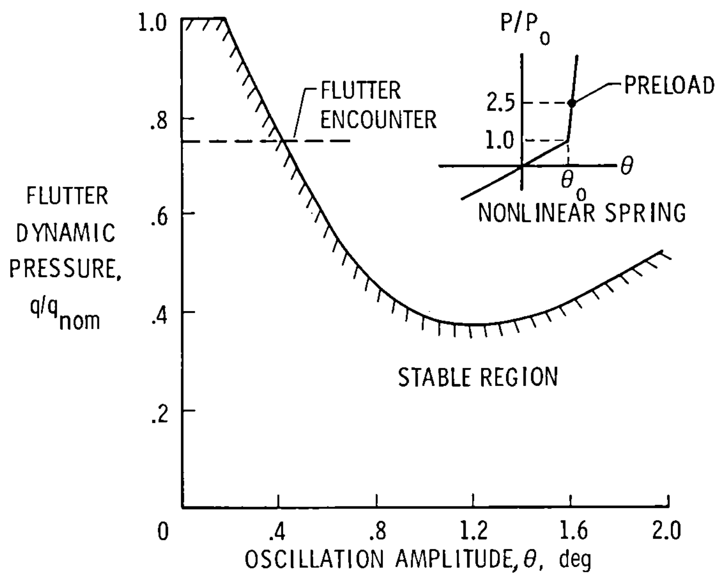

Figure 10.- Effect of nonlinear pylon stiffness of flutter of YF-17 model.

dynamic pressure observed during the test ($q = 0.75q_{nom}$), the analysis indicates that the store must be disturbed above a threshold oscillation amplitude of about 0.4°. Because oscillations of this magnitude were not unusual, this nonlinear flutter analysis appears to be in reasonable quantitative agreement with experiment.

A conclusion to be drawn from these results, as well as those presented in reference 8, is that the limits set on store pitch deflection are an important design consideration for the decoupler pylon, just as the limits set on control surface deflection are important in active FSS design. As pointed out earlier, the function of the automatic alignment control system is to compensate for the deflections of the store due to changing mean loads such as those arising from aerodynamic drag, maneuvers, and gusts. Of these, the most significant from the standpoint of store deflections about the pylon pivot axis appears to be drag loads. Calculations were made by General Dynamics of the effect of high-g pitch-up maneuvers on deflections of the decoupler pylon system for the configuration tested on the 1/4-scale F-16. The military specification of reference 9 gives the limit inertia flight loads for design. All possible combinations of the limiting normal accelerations of +11.5g and -6.5g, longitudinal accelerations of ±1.5g, and pitch rotational accelerations of ±4 rad/sec^2 were considered for a GBU-8 store with a forward longitudinal store c.g. offset of 0.089 m (3.5 in.). Although these represent rather severe conditions, the maximum store pitch deflections were determine to be less than $\pm 1.7^{\circ}$.

FLIGHT DEMONSTRATION PROGRAM

Although the decoupler pylon was shown to be effective in suppressing wing/store flutter, there are other issues not related to flutter, however, that must be investigated prior to installing a decoupler pylon on an actual airplane. (See ref. 10.) These issues concern such areas as flight loads and response of soft-mounted stores, dynamic response requirements for the store alignment control system, and dynamic coupling between the low-frequency store pitch mode and the airplane flight control system. General Dynamics Corporation, Fort Worth Division, under contract with Langley Research Center, is investigating these and other issues in a study of the feasibility of applying the decoupler pylon to the F-16 as a means of suppressing wing/store flutter. This study includes an assessment and comparison of the passive decoupler pylon with active controls as flutter suppression approaches for the F-16.

CONCLUSIONS

The purpose of this report has been to describe and summarize some recent studies relating to a passive means for suppressing aircraft wing/store flutter as an alternative to concepts based on use of active controls. The approach, known as the decoupler pylon, utilizes soft-spring/damper elements to isolate the wing from store pitch inertia effects and a low-frequency feedback-control system to reduce static pitch deflections of the soft spring because of changing mean loads on the store. A summary of major results from wind-tunnel investigations of the decoupler pylon system has been presented for three wind-tunnel model configurations: rectangular wing, F-16, and YF-17. Comparisons were made between results obtained for the decoupler pylon and active flutter suppression systems. On the basis of promising results indicated by wind-tunnel tests, a feasibility study for a flight demonstration of the decoupler pylon on the F-16 has been initiated.

Some major conclusions from results presented herein are as follows:

1. Both passive and active types of flutter suppression systems provided substantial increases in flutter speed.

2. The performance of the decoupler pylon was equal to or somewhat better than that of the active FSS tested on the F-16 and YF-17 models.

3. Dynamic isolation of the store by means of a soft-pitch spring reduced the sensitivity of flutter to changes in pitch inertia and center of gravity of the store and alleviated airframe-induced vibrations of the store.

4. Bottoming of the soft pylon-pitch spring against a hard stop resulted in significant reduction in the flutter speed.

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October 30, 1980

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1. Report No. NASA TM-81865	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PASSIVE CONTROL OF WING/STORE FLUTTER		5. Report Date December 1980
		6. Performing Organization Code 505-33-53-01
7. Author(s) Wilmer H. Reed III; F. W. Cazier, Jr.; and Jerome T. Foughner, Jr.		8. Performing Organization Report No. L-14010
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

This report is based on a paper presented at the Fifth Joint Technical Coordinating Group Aircraft/Stores Compatibility Symposium, St. Louis, MO, September 9-11, 1980.

16. Abstract

Results are presented for a passive flutter suppression approach known as the decoupler pylon. The decoupler pylon dynamically isolates the wing from store pitch inertia effects by means of soft-spring/damper elements assisted by a low-frequency feedback-control system which minimizes static pitch deflections of the store because of maneuvers and changing flight conditions. Wind-tunnel tests and analyses show that this relatively simple pylon suspension system provides substantial increases in flutter speed and reduces the sensitivity of flutter to changes in store inertia and center of gravity. Flutter characteristics of F-16 and YF-17 flutter models equipped with decoupler-pylon-mounted stores are presented and compared with results obtained on the same model configurations with active flutter suppression systems. These studies show both passive and active concepts to be effective in suppressing wing/store flutter. Also presented are data showing the influence of pylon stiffness nonlinearities on wing/store flutter.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Aeroelasticity Flutter Active flutter suppression Stores Decoupler pylon	Unclassified - Unlimited Subject Category 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	16	A02

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