Evaluation of Four Subcritical Response Methods for On-Line Prediction of Flutter Onset in Wind Tunnel Tests

Charles L. Ruhlin,* Judith J. Watson,* Rodney H. Ricketts,* and Robert V. Doggett Jr.†
NASA Langley Research Center, Hampton, Virginia

Four subcritical response methods were evaluated for on-line use in transonic wind-tunnel tests where the flutter model is excited solely by airstream turbulence. The methods were: randomdec, power-spectral-density, peak-hold, and cross-spectrum. Subcritical response data were obtained during tests in the Langley Transonic Dynamics Tunnel of a cantilevered flutter model wing. The test procedure was to maintain a constant Mach number M and to increase the dynamic pressure q in incremental steps. The test Mach numbers were 0.65, 0.75, 0.82, 0.90, and 1.15. The four methods provided damping trends by which the flutter mode could be tracked and extrapolated to a flutter-onset q. A "hard" flutter point was obtained at $M=0.82$. The peak-hold and cross-spectrum methods gave reliable results and could be most readily used for on-line testing. At $M=0.82$, a p-k analysis predicted the same flutter mode as the experiment but a 6% lower flutter q. At the subcritical dynamic pressures, calculated damping values were appreciably lower than measured data.

Nomenclature

A = amplitude of spectrum peak (Fig. 2)
f, f_0 = frequency of vibration mode corresponding to peak in spectrum, Hz (Fig. 2)
g = damping coefficient (Fig. 2)
M = Mach number
N = number of wave cycles (Fig. 2)
q = dynamic pressure
q_{CALC} = flutter q calculated at $M=0.82$
q_F = flutter q predicted by damping trend
q_{FA} = average q_F predicted by the four SR methods
q_{LP} = q of last (highest q) point used in damping trend extrapolation
q_M = flutter q measured at $M=0.82$
SR = subcritical response
X_0, X_N = amplitude of randomdec signature at start and after N cycles, respectively (Fig. 2)
$\alpha(t), h(t)$ = time history of model torsion and bending motion response, respectively (Fig. 2)
Δf = frequency bandwidth at half-power level of PSD peak, Hz (Fig. 2)

Introduction

FLUTTER tests in wind tunnels are made to define the flutter characteristics of models of complete aircraft or their components. Such testing necessarily entails the risk of model damage due to the destructive oscillations that can occur at flutter. This risk is reduced if the flutter onset can be predicted from the model behavior in the subcritical region below the flutter boundary. To accomplish this, the vibration modes critical to flutter must be identified and the damping and frequencies of these modes measured and tracked as the test conditions are varied until a damping trend can be reliably extrapolated to a flutter condition of zero damping. Reference 1 describes several methods used in wind-tunnel and airplane flight flutter tests for extracting these modal quantities from subcritical structural responses. The present paper reports the results of an evaluation of four subcritical response (SR) methods for on-line use in transonic wind tunnel flutter tests where the model response is due solely to airstream turbulence.

The four SR methods evaluated were peak-hold, power-spectral-density (PSD), randomdec, and cross-spectrum. The first three of these have been used in previous wind-tunnel tests.[2] The cross-spectrum method is new and attempts to measure quantitatively the coupling between the bending and torsion motions that occur as flutter is approached. The response data used in the evaluation were acquired during a typical flutter test conducted in the Langley Transonic Dynamics Tunnel (TDT). The purpose of this test was to determine the transonic flutter characteristics of a research model wing. The evaluation was made to establish the SR method(s) most applicable during flutter tests of this type and was based primarily on the practical use and capability of each method to provide subcritical damping trends from which the flutter-onset boundary could be accurately estimated.

The flutter research model used in this study represented an aeroelastically tailored wing proposed for a fighter airplane. This model was designed and built by General Dynamics/Fort

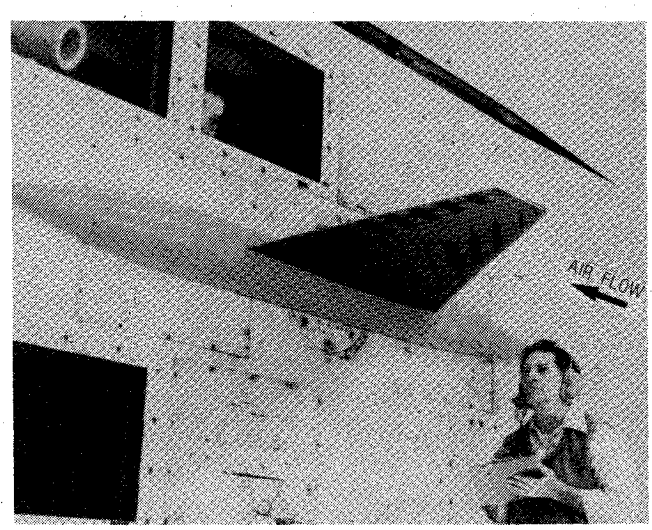


Fig. 1 Model mounted in wind tunnel.

Presented as Paper 82-0644 at the AIAA/ASME/ASCE/AHS 23rd Structures, Structural Dynamics, and Materials Conference, New Orleans, La., May 10-12, 1982; submitted May 28, 1982; revision received March 3, 1983.

*Aero-Space Technologist, Configuration Aeroelasticity Branch, Loads and Aeroelasticity Division. Member AIAA.
†Head, Configuration Aeroelasticity Branch, Loads and Aeroelasticity Division. Member AIAA.

Worth under Air Force contract and tested in cooperation with the National Aeronautics and Space Administration. Details of the design and fabrication of this model are presented in Ref. 3. The semispan wing model was tested cantilever-mounted as shown in Fig. 1. Model subcritical response data were obtained during flutter tests at $M = 0.65$, 0.75, 0.82, 0.90, and 1.15. A "hard" flutter point was obtained purposely at $M = 0.82$.

Post-test analyses of the magnetic tape records of the test model-response data were made using the four SR methods. Procedures were implemented so that the data were reduced and interpreted within time limits consistent with on-line test use. For comparison with experimental data, the model flutter characteristics and flutter-mode damping trend were calculated at $M = 0.82$ using a p-k analysis.[4] Presented herein are the results of this study. An independent flutter analysis of the present model over the complete test Mach number range was made by General Dynamics/Fort Worth under a contract from the U.S. Air Force, and the results are included in Ref. 3.

Description of Methods

An overview of the data reduction procedure for each SR method is presented in Fig. 2. All of these methods could be implemented on the data acquisition system (DAS) of the TDT, which includes a Xerox Sigma 5 digital computer.[5] The TDT DAS was used only with the randomdec method. High-speed frequency analyzers were used with the other three SR methods. All four methods can process the time histories of the model responses on-line, i.e., while the test is in progress, with the present equipment. An arbitrary time limit of about 1.5 min was set to acquire, reduce, and interpret the response data; this permitted a data sampling time of from 30 to 60 s. In near-flutter regions, adequate damping measurements can be obtained in much less time.

The time history of the torsional motion transducer response $\alpha(t)$ was processed in all SR methods (Fig. 2). The cross-spectrum method employed the bending motion transducer response $h(t)$ also. The torsional response was selected as the primary response signal because it gave the best damping trends.

Peak-Hold Method

In the peak-hold method, the response time history is processed and converted to a frequency spectrum by a Spectral Dynamics SD330A Spectroscope-Real Time Analyzer. This analyzer was operated in the peak-hold mode with the spectrum frequency range set from 0 to 100 Hz. For this frequency range, the response time history is processed in time samples of 2.5 s duration, with some overlapping of the samples. Displayed on the analyzer scope was a continuously updated frequency spectrum of the response amplitude.

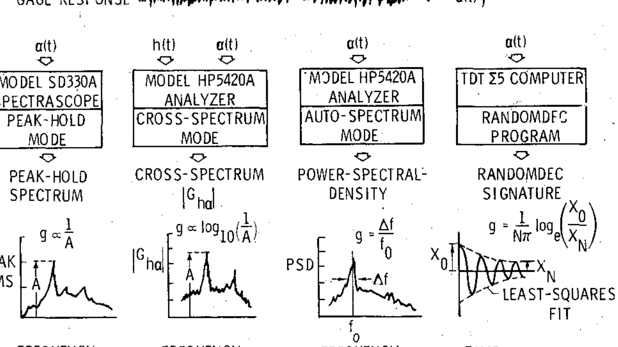


Fig. 2 Implementation of subcritical response methods.

Specifically, the value in each of the 250 frequency windows of the spectrum was the maximum value of the root-mean-square response amplitude measured in any one time sample during the time (typically, 60 s) the analyzer was operated.

In the resulting spectrum, the frequency of each response peak corresponded to that of a vibration mode. It has been found, e.g., in Refs. 6 and 2, that tracking the inverse of the response amplitude value for a given mode gives a good indication of the damping trend to a flutter condition (see Fig. 2).

Cross-Spectrum Method

The cross-spectrum method provides a quantitative measure of the coupling between the torsion and bending motions that occur as flutter is approached. This method is an attempt to quantify what had been regarded in many past tests as an indication of flutter, namely, the regularity and duration of the Lissajous pattern formed from measurements of the wing bending and torsional motions. Time histories of the bending and torsional motions of the model were input separately to a Hewlett-Packard Digital Signal Analyzer, Model HP5420A. The analyzer was set for a cross-spectrum measurement in the frequency range from 9 to 59 Hz. In this setting, the responses are processed in ensembles of time history samples of 5 s duration, with some overlapping of the ensembles. Displayed on the analyzer scope was a continuously updated cross-spectrum which was obtained by stable ensemble-averaging. A 50-s time history of response data was processed during which 60 ensembles were averaged to form the final cross-spectrum.

In a cross-spectrum, each response peak could usually be associated by frequency with a vibration mode. As was done in the peak-hold method, it was assumed that the amplitude of a response peak was indicative of the damping in that mode, i.e., the greater the response, the lower the damping. A logarithmic relationship between the damping and the cross-spectrum amplitude was found to give generally consistent damping trends and was therefore used in this study (see Fig. 2).

PSD Method

The PSD bandwidth method was implemented in a manner similar to the cross-spectrum method except that the HP5420A analyzer was set for an autospectrum measurement. A value of the damping coefficient g was calculated from the response peak bandwidth at the half-power point, as shown in Fig. 2.

Randomdec Method

For the randomdec method,[7] a 30-s time history of the response signal was digitized by the TDT data acquisition system. A fast Fourier transform (FFT) of the time history was performed to acquire a frequency spectrum of the signal. From the frequency spectrum, a peak response was chosen for further analysis of the time history data. The time history was passed through a recursive digital band-pass filter with a center frequency corresponding to the frequency of the chosen peak response. The filtered data were then ensemble-averaged to form a randomdec signature. Damping values of the signature time history were calculated by using a linear least-squares fit of the logarithmic values of the signature peaks (see Fig. 2).

Evaluation Procedure

Evaluation Criteria

Each SR method was evaluated for its capability during on-line testing to provide the following: 1) accurate flutter-onset prediction, 2) consistent damping trend, 3) early flutter-onset prediction as flutter approached, 4) continuous on-line damping indication, 5) actual damping value, 6) ease and simplicity of use.

Model and Wind Tunnel Test

The model (Fig. 1) was a 0.25-size, dynamically and elastically scaled version of a fighter airplane wing which was geometrically similar to an F-16 airplane wing. This wing was aeroelastically tailored for washin aerodynamic characteristics. Some model physical properties, including measured vibration characteristics, are presented in Fig. 3. Strain gages were mounted near the wing root and oriented to measure the bending and torsional motions of the model.

The model was tested in Freon‡ in the Langley Transonic Dynamics Tunnel. The model wing was cantilever-mounted to a turntable on the wind-tunnel sidewall. An aerodynamic fairing, resembling a fuselage half-body, allowed the wing root to be located outside the wall boundary layer (Fig. 1). The model was tested at angles of attack that gave a near minimum aerodynamic load. An attempt was made to define a flutter boundary at Mach numbers of 0.65, 0.75, 0.82, 0.90, and 1.15. In these tests, M was held constant while q was slowly increased in increments until a flutter condition was considered reasonably predicted using the peak-hold and PSD methods. The model was excited solely by the airstream turbulence. Model strain-gage response data were acquired at dwell points of constant q. At $M=0.82$, the model was purposely tested to a "hard" flutter point.

Flutter Analysis

A flutter analysis using the p-k method[4] was conducted for $M=0.82$ to provide subcritical damping data for comparison with the test results. In the analysis, the generalized masses were determined using calculated mass distributions and the measured frequencies and mode shapes of the first five vibration modes. These mass distributions were obtained from a finite element mathematical simulation of the model wing structure and had been checked and corrected (if necessary) to agree with mass measurements of the model component parts and the complete model. The off-diagonal cross-coupling terms in the generalized masses were found to be relatively small (thus indicating the measured mode shapes were reasonably orthogonal) and were neglected in the flutter analysis.

The unsteady aerodynamic terms in the analysis were generated by subsonic lifting-surface (kernel function) theory.[8] For the analysis, 36 aerodynamic collocation points were distributed over the wing surface, with 6 chordwise points located at each of 6 spanwise stations. The analysis provided data at a matched wind-tunnel test velocity.

Presentation of Results

The results of the flutter analysis are presented in Fig. 4. The analysis predicted the model would flutter at $M=0.82$ in the fundamental bending mode (mode 1) at a dynamic pressure of 8.47 kPa (177 psf) and a frequency of 20 Hz. In the test at $M=0.82$, a "hard" flutter point was measured for the model at a dynamic pressure of 9.00 kPa (188 psf) and a frequency of 20.8 Hz (Table 1).

Model response data obtained at the test dwell points were processed using the data reduction procedures previously described for each SR method. With each SR method, a damping indicator value and associated frequency were determined for the 20-Hz flutter mode. Damping indicator values and frequencies were also determined for other identifiable vibration modes, but these data are not presented because they were not the primary indicators of flutter. Plots of the damping values and associated frequencies against dynamic pressure are shown for each test M in Figs. 5-9. A discussion of these figures follow.

A practical problem in using these SR methods is how best to define a damping trend for extrapolation to flutter onset. In this study, all data points that exceed a rough scatter band about an obvious trend were neglected. Also neglected were damping values at the lower dynamic pressures that did not significantly affect the flutter-prediction trend. The neglected damping values are identified by the flagged symbols in Figs. 5-9. To define a damping trend, an attempt was made to fair through the data points a second-order curve using a least-squares fit. However, if an undesirable curve shape resulted such as a concave-up curvature that gave an unconservative flutter dynamic pressure estimate, it was replaced by a linear least-squares fit. Because this curve fitting requires some judgment and considerable time, it is suggested that on-line test damping trends and flutter-onset extrapolations be checked by thorough post-test data reduction.

The dynamic pressures for flutter onset q_F obtained from extrapolating each damping trend to a zero damping value are compiled in Table 1 and plotted in Fig. 10a. For comparison,

‡Registered trademark of E.I. duPont de Nemours & Co., Inc.

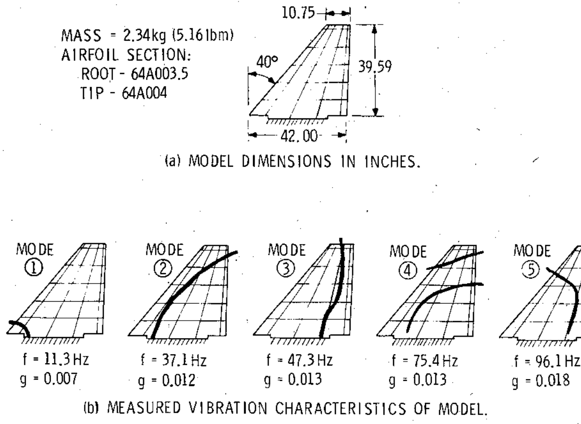


Fig. 3 Model physical properties.

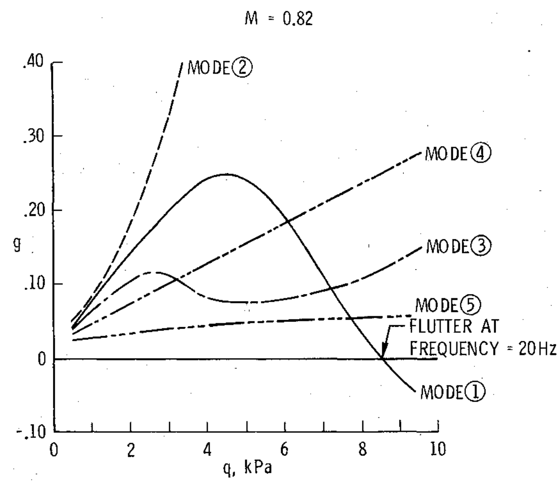


Fig. 4 Damping trends predicted by analysis, $M=0.82$.

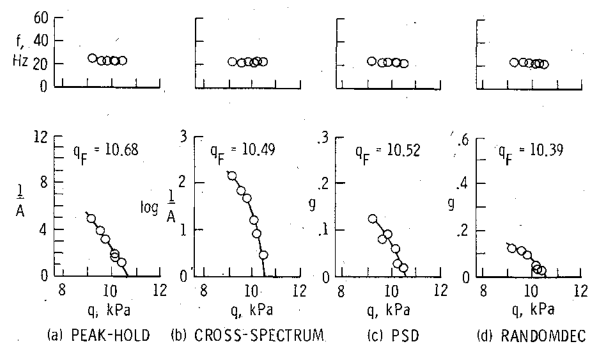


Fig. 5 Damping trends measured by four SR methods, $M=0.65$.

Table 1 Summary of test results

Mach No.	No. of data points	q_{LP}, kPa	q_F predicted by Peak-hold, kPa	q_F predicted by Cross-spectrum, kPa	q_F predicted by PSD, kPa	q_F predicted by Randomdec, kPa	q_{FA}, kPa	q_{LP}/q_{FA}	q_M, kPa
0.65	All	10.43	10.68	10.49	10.52	10.39	10.52	0.99	...
0.75	All	9.00	9.24	10.44	9.20	9.62	9.63	0.93	...
0.82	All	8.86	8.96	8.97	9.24	8.92	9.03	0.98	9.00[b]
	Last 5[a]	8.86	9.10	8.95	9.10	8.95	9.03	0.98	
0.90	All	6.80	9.15	10.05	7.34	7.09	8.41	0.81	...
1.15	All	11.92	13.45	13.45	12.60	12.69	13.04	0.91	...

[a]Extrapolated only five highest q points. [b]"Hard" flutter frequency was 20.8 Hz.

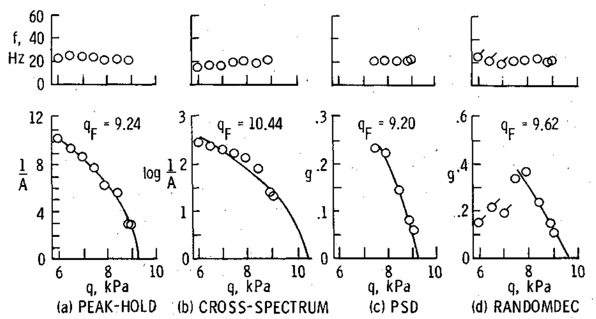


Fig. 6 Damping trends measured by four SR methods, $M = 0.75$.

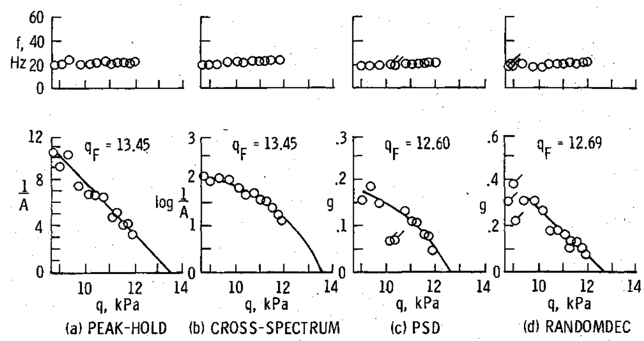


Fig. 9 Damping trends measured by four SR methods, $M = 1.15$.

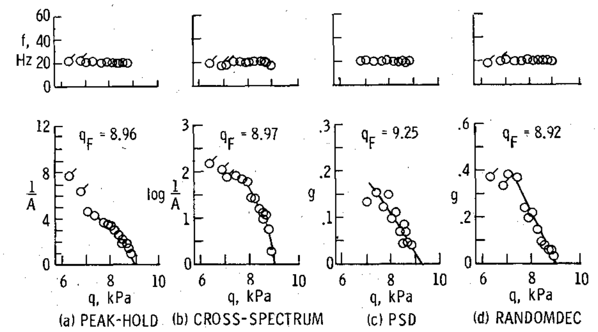


Fig. 7 Damping trends measured by four SR methods, $M = 0.82$.

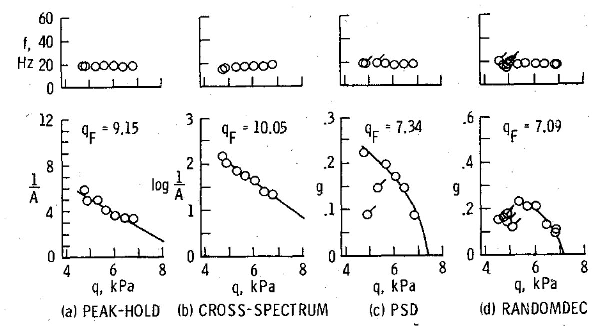
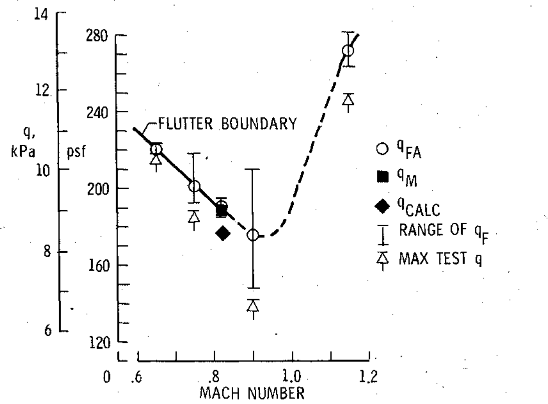
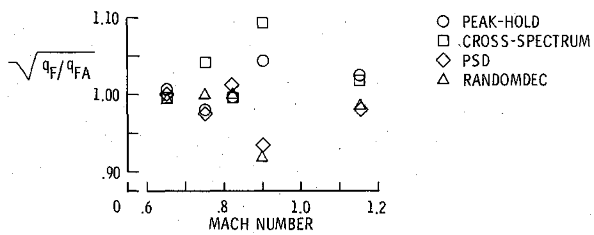


Fig. 8 Damping trends measured by four SR methods, $M = 0.90$.



a) Flutter boundary predicted by SR methods.



b) Variation in flutter speed predictions.

Fig. 10 Predicted flutter boundaries and comparisons.

the calculated and measured flutter dynamic pressures at $M = 0.82$ are indicated in Fig. 10a. A measure of the scatter in q_F values predicted by the different methods from the average q_{FA} is included in Fig. 10b in terms of an equivalent flutter speed ratio $\sqrt{q_F/q_{FA}}$.

The damping (g) values calculated by the p-k analysis at $M = 0.82$ are compared with those measured by the PSD and randomdec methods in Fig. 11. For the comparison, the g values are plotted against dynamic pressures that have been normalized by either the calculated or measured flutter dynamic pressure (q_{CALC} or q_M).

A search was made for trends or procedures which would allow the flutter engineer to know when the flutter onset had been reasonably predicted so that the flutter test could be ended at the lowest possible q. The damping data at $M = 0.82$ were reworked to examine the trend of predicted q_F value against possible end or stop points. From the set of damping data for each SR method, the damping value for the highest-q point was dropped and the curve fitting and extrapolation redone to obtain a new q_F value. This represented the q_F that would be predicted if the test had been stopped at the last, highest-q point (q_{LP}) of the remaining damping data. This

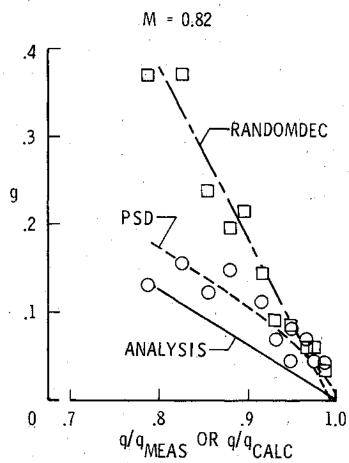


Fig. 11 Comparison of measured and calculated damping values, $M=0.82$.

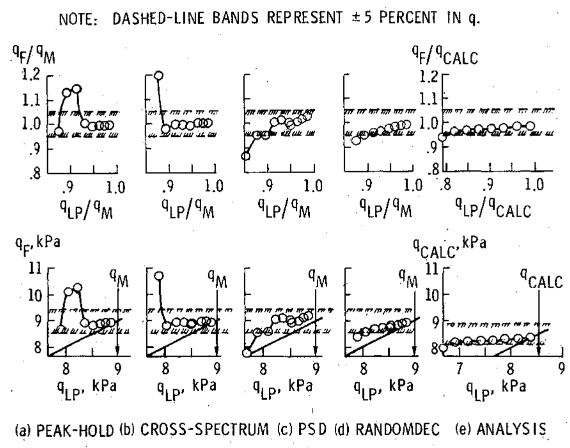


Fig. 12 Flutter onset predictions using different damping-trend endpoints, $M=0.82$.

procedure was repeated until there were only two damping points left for extrapolation. The results are shown in Fig. 12. In a similar manner, flutter-onset predictions using calculated damping values (mode 1 in Fig. 4) were determined and are included in Fig. 12. Lines of equal q values (i.e., $q_F = q_{LP}$) are drawn on these plots. Normalized plots of these data are presented in the upper portion of Fig. 12. The dashed, cross-hatched lines on the plots define a variation of ±5% in q.

Discussion of Results

Analysis-Test Comparison

At $M=0.82$, the calculated and measured flutter point data are in good agreement. The p-k analysis predicted a 6% lower flutter q and a 4% lower flutter frequency than did the experiment. This correlation confirmed that the flutter mode had been correctly identified and tracked in the tests. However, at dynamic pressures near the flutter point (Fig. 11), the calculated g values are appreciably lower than those measured either by the PSD or randomdec methods. The reason for this discrepancy is not known. These data were verified by thorough checks of both the analysis and experimental procedures.

The calculated damping trend with q is approximately linear in the proximity of the flutter point (Figs. 4 and 11). The damping trend for the randomdec method appears linear (Fig. 7), and the trend for the PSD method has only a slight curvature. The damping trends for the peak-hold and cross-spectrum methods have pronounced curvatures. Thus, although the g levels of the PSD and randomdec methods do not agree well with calculated values, they do exhibit roughly similar damping trend shapes.

Accurate Flutter-Onset Prediction

The average (q_{FA}) value is considered to represent the actual flutter-onset q value at each test Mach number except 0.82 and 0.9. At $M=0.82$, the test "hard" flutter point is available for comparison. At $M=0.9$, the model was buffeting considerably and there was concern that the measured damping trends were not truly indicative of flutter proximity; therefore the test was ended at a rather low q for fear of losing the model before the other Mach numbers were explored. Unfortunately, the wind-tunnel schedule did not allow further testing at this M. Consequently, at $M=0.9$ the SR results have by far the greatest scatter and the actual flutter-onset q is least certain. The experimental flutter boundary drawn in Fig. 10a is the best estimate of the boundary shape, with the dashed lines indicating the uncertain portions.

All four SR methods predicted nearly the same q_F at $M=0.65$ and 0.82 (Fig. 10). At the other Mach numbers, there were varying amounts of scatter in the q_F values predicted by the different methods. As might be expected, the closer the model was tested to flutter, the closer grouped were the predictions. At $M=0.82$, comparison with the "hard" flutter q shows that the q_F values predicted by the SR methods (Table 1) range from about 1% low to 2.7% high (PSD method), with the average predicted value (q_{FA}) nearly exactly equal to the measured test point (q_M). At the other Mach numbers, no method appears to be conclusively superior in predicting accurately the q_{FA} value (Fig. 10b).

It was found that a q_F value was dependent on the number of data points used to establish the damping trend. For example, at $M=0.82$, where damping data were obtained very close to the flutter point, the q_F values were slightly different for damping trends that used either all the data points or only the last five highest q points (see Table 1). In the present extrapolations, all the data points that formed a consistent damping trend were used because it was felt that they would give more accurate results.

Consistent Damping Trend

At all test Mach numbers, the damping trends for all four SR methods were fairly consistent over the test dynamic pressure range (Figs. 5-9), with the PSD and randomdec having the most scatter in the damping values. The damping trends for the peak-hold and cross-spectrum methods can usually be identified and tracked at lower dynamic pressures. This could save testing time by allowing the test conditions to be changed more rapidly than when there were no indications of damping levels. It is of interest to note that no SR method had the same damping-trend shape at all test Mach numbers. Nor did all SR methods have the same damping-trend shape at any one Mach number.

Early Flutter Prediction

All four SR methods begin to predict the flutter-onset q with reasonably good accuracy at roughly the same test q level. This is demonstrated in Fig. 12, which shows that to predict the flutter onset at $M=0.82$ within ±5%, the test must be conducted to a dynamic pressure at least within about 7 to 10% of the actual flutter point q_M. Although the peak-hold and cross-spectrum methods provide fairly consistent damping trends at the lower dynamic pressures (Fig. 7), the q_F values predicted from these low-q data are not particularly accurate (Fig. 12). Table 1 shows that at all Mach numbers except 0.90, the tests were conducted to q levels that were within at least 9% of the q_{FA} value. Therefore these q_{FA} values are believed to be reasonably good estimates.

The q_F vs q_{LP} plots of Fig. 12 provide indications of when to terminate a test at a particular M. It can be seen that as flutter is approached, the q_F values tend to converge and approach an intersection with the $q_F = q_{LP}$ line at the actual q_M value. Thus a test could be ended when the q_F values have converged on an acceptably constant value and/or the intersection with the $q_F = q_{LP}$ line is reasonably well defined. Both the peak-hold and cross-spectrum methods appear to do this at lower q levels than the other SR methods. It is suggested that, in using these SR methods, similar plots be made as a routine part of the data reduction.

Continuous Damping Indication

As presently implemented, the peak-hold and cross-spectrum methods can provide nearly continuous damping trend data more readily than the other two methods. This is because the PSD and randomdec methods required more operator involvement in the data reduction process. It is very helpful to have a measure of damping while changing conditions during a test.

Actual Damping Value

Only the PSD and randomdec methods provide actual g values. However, the g values obtained by these two methods do not agree with each other at most of the Mach numbers (Figs. 5-9), nor, as mentioned before, do they agree with the g values calculated by analyses at $M=0.82$. The reason for this discrepancy is not known. In defense of the experimental methods, they do provide consistent damping trends that give good q_F values. The randomdec method can extract damping values at low-q test conditions where the PSD method is inapplicable. The accuracy of a PSD measured damping value becomes poorer as the damping level increases because the response PSD peak shape from which the damping value is determined becomes irregular and less well defined. The randomdec signature is usually well defined over at least several wave cycles (Fig. 2); therefore there is more confidence in the measured damping value. At the low-q, high damping test points, the accuracy of the damping measurements for both of these SR methods would probably be improved if longer than the present 30-60 s of response time history was processed.

Ease/Simplicity of Use

The peak-hold and cross-spectrum methods were the simplest and easiest to use. The randomdec and PSD methods require some judgments and occasional data reworking.

Concluding Remarks

Four subcritical response (SR) methods, namely, the peak-hold, cross-spectrum, power-spectral-density (PSD), and randomdec methods, were evaluated for on-line prediction of flutter onset in a wind-tunnel test where the model was excited solely by the airstream turbulence. The present evaluation was limited to the application of these SR methods in a single but typical flutter test of a cantilevered flutter model wing. The test Mach numbers were 0.65, 0.75, 0.82, 0.90, and 1.15. More experience using these methods with different model configurations and test conditions is needed.

All four SR methods provided flutter-mode damping trends from which the flutter-onset dynamic pressure could be reliably predicted. The peak-hold and cross-spectrum methods are recommended for on-line test use because they provide damping trends more easily and rapidly than the other SR methods.

For $M=0.82$, a p-k flutter analysis was made using lifting surface (kernel-function) theory. Comparisons of the analytical results were made with the experimental data for the "hard" flutter point and SR damping values. The analysis predicted the same flutter mode as the experiment but a 6% lower flutter dynamic pressure. At the subcritical dynamic pressures near flutter, the calculated damping values were appreciably lower than the experimental data.

It was found that to obtain a reliable flutter-onset prediction from SR damping trends, the test must be conducted to within 7 to 10% of the actual flutter dynamic pressure. It is suggested that on-line damping trends and flutter-onset predictions be checked by thorough post-test data reduction.

References

[1] "Flutter Testing Techniques. NASA Symposium on Flutter Testing Techniques," NASA SP-415, Oct. 1975.

[2] Foughner, J.T. Jr., "Some Experience Using Subcritical Response Methods in Wind-Tunnel Flutter Model Studies," Paper 7, NASA SP-415, Oct. 1975.

[3] Murphy, A.C., Rogers, W.A., Shirk, M.H., and Ruhlin, C.L., "Design, Testing and Analysis of Aeroelastically Tailored Transonic Flutter Model Wings," AIAA Paper 83-1027, Lake Tahoe, Nev., May, 1983.

[4] Hassig, H.J., "An Approximate Damping Solution of the Flutter Equation by Determinant Iteration," *Journal of Aircraft,* Vol. 8, Nov. 1971, pp. 885-889.

[5] Cole, P.H., "Wind Tunnel Real-Time Data Acquisition System," NASA TM-80081, 1979.

[6] Sandford, M.C., Abel, I., and Gray, D.L., "Development and Demonstration of a Flutter-Suppression System Using Active Controls," NASA TR R-450, 1975.

[7] Cole, H.A. Jr., "On-Line Failure Detection and Damping Measurement of Aerospace Structures by Random Decrement Signatures," NASA CR-2205, 1973.

[8] Redman, M.C. and Rowe, W.S., "Prediction of Unsteady Aerodynamic Loadings Caused by Leading Edge and Trailing Edge Control Surface Motions in Subsonic Compressible Flow—Computer Program Description," NASA CR-132634, 1975.

NOTICE TO JOURNAL READERS

Because of the recent move of AIAA Headquarters to 1633 Broadway, New York, N.Y. 10019, journal issues have unavoidably fallen behind schedule. The Production Department at the new address was still under construction at the time of the move, and typesetting had to be suspended temporarily. It will be several months before schedules return to normal. In the meanwhile, the Publications Staff requests your patience if your issues arrive three to four weeks late.