PRESSURE MEASUREMENTS ON AN F/A-18 TWIN VERTICAL TAIL IN BUFFETING FLOW

VOLUME 3- BUFFET POWER SPECTRAL DENSITIES

AD-A281 444

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This technical report has been reviewed and is approved for publication.

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Buffeting pressure measurements were made on the vertical tail surface of a full scale F/A-18 aircraft model in the National Full Scale Aerodynamics Complex at NASA Ames Research Center. Test variables included aircraft angle-of-attack, aircraft sideslip angle, and dynamic pressure. Accelerometers were used to obtain vertical tail accelerations. Pressure transducers were mounted on the starboard vertical tail. Steady and unsteady pressures were obtained. Unsteady pressure data were reduced to PSD and CSD forms. Both steady and unsteady RMS pressure coefficients are also presented.

Volume 1 contains the general description of the model, the test program, and highlights of the reduced data. Volume 2 contains steady and unsteady RMS data. Volume 3 contains unsteady PSD results. Volume 4 contains unsteady CSD results.
Foreword

This report was prepared by the Structural Dynamics Branch, Structures Division, Flight Dynamics Directorate, Wright Laboratory, Wright Patterson Air Force Base, Ohio. The wind tunnel test program described in this report was conducted during a joint NASA, Navy, and Air Force F/A-18 test program conducted at the NASA Ames Research Center. The wind tunnel data taken by Wright Laboratory engineers during the F/A-18 wind tunnel test was acquired in support of Project 2401, "Structural Mechanics", Task 240104, "Vibration Prediction and Control, Measurement, and Analysis" and Work Unit 24010446, F-18 Twin Vertical Tail Buffet. The project engineers for this effort were Mr. Ed Pendleton and Mr. Chris Pettit. Mr. Dansen Brown, a mathematician, provided engineering analysis support for reduction of the test data. Mr. Mike Banford was the lead technician responsible for instrumentation and data collection.

The authors wish to thank the NASA Ames F/A-18 Wind Tunnel Test Team for their cooperation during testing of the F/A-18, especially Mr. Gavin Botha, Ms. Wendy Lanser, Mr. Kevin James, Mr. Roger Stewart, and Mr. Roy Arakaki. The authors also wish to thank Dr. Holt Ashley of RANN Corporation, Dr. Marty Ferman formerly of McDonnell Douglas Corporation, and Dr. James Olsen for their technical advice and suggestions during the preparation of this report. The authors further thank Mr. Larry Dukate for his assistance in reducing test data, and Mr. Scott Harris and Mr. Dick Talmadge for their technical assistance during the instrumentation phase of the test program.

This manuscript was released in August 1994 for publication as a Technical Memorandum. This report covers technical work conducted from March 1993 through August 1994.
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Introduction

Contemporary twin-tail fighter aircraft may encounter high frequency empennage vibrations caused by flow emanating from the forebody or wings during high angle-of-attack maneuvering. This turbulent flow occurs when the air flow on the forebody or upper wing surfaces becomes detached at high angles of attack. Air flow in the detached region becomes turbulent, giving rise to fluctuating pressures on the wing and induced oscillating pressures on surfaces which are in the flow path.

The induced unsteady pressures, commonly referred to as buffet, are broad-band random fluctuations having predominant frequencies associated with the primary air flow characteristics of the aircraft. These primary airflow properties may include, but are not limited to, vortex flow from engine inlets, sharp corners, and highly swept lifting surfaces. The turbulent air flow excites the tail surfaces embedded in the flow and large oscillatory structural responses result at the resonant frequencies of the tail. After prolonged exposure to this flow environment, the tail structure can begin to fatigue and repairs must be initiated. The maintenance costs and aircraft down time associated with these repairs are often quite high. To reduce these costs, the tail structure and associated equipment must be designed to both minimize and tolerate these oscillatory responses.

One twin-tail fighter aircraft that often encounters tail buffet when conducting air combat maneuvers at high angles-of-attack is the F/A-18. In an effort to quantify the F/A-18 tail buffet loads and to provide data for use in the development of potential solutions to counter the twin tail buffet problem, wind tunnel tests were conducted to measure the aerodynamic pressures on the twin tails of an F/A-18. Buffet pressures and the resulting structural vibrations of the vertical fins were obtained over a range of angle of attack and sideslip conditions.
Volume III of this technical report presents the Power Spectral Densities (PSD) from the measured aerodynamic pressures and accelerations obtained from the F/A-18's starboard vertical tail during wind tunnel testing. Volume I of this report presents a general description of the full scale aircraft model and the test program. Volume II presents results from both steady and unsteady pressures, obtained during high buffet flow conditions. Volume IV of this report presents the unsteady pressures reduced to Cross Spectral Density (CSD) form.
Dynamic Data

The wind tunnel buffet tests were conducted during a ten day period in August 1993 at the NASA Ames NAFC 80 by 120 foot tunnel in Mountain View, California. Unsteady pressure measurements, as well as acceleration data, were obtained for sixty-three (63) test conditions. Four of the test conditions were at a dynamic pressure of 20 lb/ft², and fifty nine of the conditions were at the maximum tunnel dynamic pressure of 33 lb/ft². During the tests, pressure measurements were collected as the static angle-of-attack, $\alpha$, was varied through a range from 20 to 40 degrees at zero sideslip. Measurements were also obtained as the static aircraft sideslip angle, $\beta$, was varied from -16 to 16 degrees at angles-of-attack of both 30 degrees and 35 degrees. Measurements were taken with the LEX fence both deployed and undeployed.

Figure 1 shows the Kulite microphone pressure transducer locations along the F/A-18's twin vertical starboard tail. The station number for each pair of inside and outside transducers is equivalent to the number for each outboard transducer. Accelerometers were located on both starboard and port tails at the tails' tips close to the leading and trailing edges.

At each test condition, unsteady pressure data were recorded for 30 seconds with the data acquisition system's multiplexers operating in the alternating current (AC) mode. Seventy two channels of pressure data and four channels of acceleration data were recorded.

Pressure differential time histories were computed for each pressure transducer pair at each location by subtracting the outer time history from the inner time history. These data and the acceleration data were converted to the frequency domain using Fast Fourier Transform techniques. A transform size of 2048 resulted in a frequency resolution of approximately $\Delta f = 0.8$ Hz. A Hanning window was applied to reduce the bandwidth leakage, and an average of 22 transforms with a 50% overlap was used to increase statistical confidence. Power Spectral Densities were then computed from the Fourier transforms and the results were plotted from 2 Hz to 120 Hz. The total record time of $T = 15$ seconds was determined to be an adequate record time with a sample time of $\Delta t = 611.77 \mu$seconds.
The pressure power spectral densities computed for the pressures at the various locations are shown in Figures 2 through 601. The PSDs are plotted versus amplitude squared per Hertz and also in non-dimensional form as discussed in Volume I. The "LEX fence on" were overlaid on the corresponding "LEX fence off" plots for easier comparison.

Following the wind tunnel test, a post-test inspection of the instrumentation was conducted to evaluate the condition of each pressure transducer. The inspection revealed that the wire from transducer #26 had severed. All remaining transducers appeared functional, but some were slightly fouled with residue from test fogging mixture.

Reduction of the raw signals from data also revealed clues about transducer condition. Steady and unsteady data plots reduction confirmed that transducer #26 had been inoperative during the entire wind tunnel test. These pressure plots also indicated that transducer #22 had been functional for only a portion of the test and was inoperative for data records 66-79.

Steady pressure differences across the fin determined using transducer pairs #20 and #53 and #29 and #44 appeared to be inconsistent with the steady data from the other stations' transducers. Unsteady RMS pressure differences across the fin determined using transducer pairs #29 and #44 also appeared to be inconsistent with the unsteady RMS data from the other stations' transducers. Further inspection of the raw signals from these transducer pairs indicated that the signals from transducers #20, #53 and #44 were inconsistent with the signals from the other transducers.

Overall, the conclusion from evidence gathered during the post test inspections and steady and unsteady data reduction is that transducers #26 was nonfunctional for all records, transducers #20, #44 and #53 were functioning improperly for all records and #22 was nonfunctional for data records 66-79.
Acceleration Power Spectral Densities

Test Variable - Angle of Attack (AoA)
AoA = 20, 24, 26, 28, 30, 32, 36, 40 degrees

Test Variable - Dynamic Pressure
q = 20 psf, 33 psf

LEX Fence Off and LEX Fence On
Pressure Coefficient Differential
Power Spectral Densities

(In dimensional form)

Pressure Transducer Stations 1-36

Test Variable - Angle of Attack (AoA)
AoA = 20, 24, 26, 28, 30, 32, 36, 40 degrees

Test Variable - Dynamic Pressure
q = 20 psf, 33 psf

LEX Fence Off and LEX Fence On
Pressure Coefficient Differential
Power Spectral Densities

(Nondimensional form)

Pressure Transducer Stations 1-36

Test Variable - Angle of Attack (AoA)
AoA = 20, 24, 26, 28, 30, 32, 36, 40 degrees

Test Variable - Dynamic Pressure
q = 20 psf, 33 psf

LEX Fence Off and LEX Fence On
Acceleration Power Spectral Densities

Angle of Attack = 30 degrees

Test Variable - Aircraft Sidetlip Angle
Sidetlip Angle = -16, -10, -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
\( q = 33 \text{ psf} \)

LEX Fence Off and LEX Fence On
Pressure Coefficient Differential
Power Spectral Densities

(In dimensional form)

Pressure Transducer Stations 1-36

Angle of Attack = 30 degrees

Test Variable - Aircraft Sideslip Angle
Sideslip Angle = -16, -10, -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
q = 33 psf

LEX Fence Off and LEX Fence On
F-18 Tail Buffet Test
LOC 6 RMS = 0.122  Record 49: 0=33 Alpha=30 Beta=-2 FENCE OFF
LOC 9 RMS = 0.0846  Record 148: 0=33 Alpha=30 Beta=-2 FENCE ON

F-18 Tail Buffet Test
LOC 6 RMS = 0.0474  Record 49: 0=33 Alpha=30 Beta=-2 FENCE OFF
LOC 9 RMS = 0.0366  Record 148: 0=33 Alpha=30 Beta=-2 FENCE ON

F-18 Tail Buffet Test
LOC 7 RMS = 0.0408  Record 49: 0=33 Alpha=30 Beta=-2 FENCE OFF
LOC 9 RMS = 0.0333  Record 148: 0=33 Alpha=30 Beta=-2 FENCE ON

F-18 Tail Buffet Test
LOC 7 RMS = 0.0804  Record 49: 0=33 Alpha=30 Beta=-2 FENCE OFF
LOC 9 RMS = 0.0618  Record 148: 0=33 Alpha=30 Beta=-2 FENCE ON
PRESSURE MEASUREMENTS ON AN F/A-18 THIN VERTICAL TAIL IN 4/8 BUFFETING FLOW VOLUME 3 BUFFET POWER SPECTRAL DENSITIES (U) WRIGHT LAB WRIGHT-PATTERSON AFB OH C PETTIT ET AL. UNCLASSIFIED AUG 94 WL*-TM-94-3066
Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.
Pressure Coefficient Differential
Power Spectral Densities

(Nondimensional form)

Pressure Transducer Stations 1-36

Angle of Attack = 30 degrees

Test Variable - Aircraft Sideslip Angle
Sideslip Angle = -16, -10, -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
q = 33 psf

LEX Fence Off and LEX Fence On
F-18 Tail Buffet Test: Q=33 Alpha=30 Beta=+10 LOC 2

F-18 Tail Buffet Test: Q=33 Alpha=30 Beta=+10 LOC 4

F-18 Tail Buffet Test: Q=33 Alpha=30 Beta=+10 LOC 1

F-18 Tail Buffet Test: Q=33 Alpha=30 Beta=+10 LOC 3
Acceleration Power Spectral Densities

Angle of Attack = 35 degrees

Test Variable - Aircraft Sideslip Angle
Sideslip Angle = -16, -10 -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
q = 33 psf

LEX Fence Off and LEX Fence On
Pressure Coefficient Differential
Power Spectral Densities

(In dimensional form)

Pressure Transducer Stations 1-36

Angle of Attack = 35 degrees

Test Variable - Aircraft Sideslip Angle
Sideslip Angle = -16, -10, -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
$ q = 20 \text{ psf, } 33 \text{ psf} $
PRESSURE MEASUREMENTS ON AN F/A-18 THIN VERTICAL TAIL IN 7/8
BUFFETING FLOW VOLUME 3 BUFFET POWER SPECTRAL DENSITIES
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Pressure Coefficient Differential
Power Spectral Densities

(Nondimensional form)

Pressure Transducer Stations 1-36

Angle of Attack = 35 degrees

Test Variable - Aircraft Sideslip Angle
Sideslip Angle = -16, -10, -6, 4, -2, 0, 2, 4, 6, 10, 16 degrees

Test Variable - Dynamic Pressure
q = 20 psf, 33 psf

LEX Fence Off and LEX Fence On
InIt

\[
\text{F-18 Tail Buffet Test: } Q=33 \text{ Alpha}=35 \text{ Beta}=+2 \quad \text{LOC 18}
\]

\[
\text{F-18 Tail Buffet Test: } Q=33 \text{ Alpha}=35 \text{ Beta}=+2 \quad \text{LOC 20}
\]

\[
\text{F-18 Tail Buffet Test: } Q=33 \text{ Alpha}=35 \text{ Beta}=+2 \quad \text{LOC 17}
\]

\[
\text{F-18 Tail Buffet Test: } Q=33 \text{ Alpha}=35 \text{ Beta}=+2 \quad \text{LOC 19}
\]
Graphs showing data for different conditions.

Graph 1: F-18 Tail Buff Test: Q=33 Alpha=35 Beta=+4 LOC 16
Graph 2: F-18 Tail Buff Test: Q=33 Alpha=35 Beta=+4 LOC 15
Graph 3: F-18 Tail Buff Test: Q=33 Alpha=35 Beta=+4 LOC 14
Graph 4: F-18 Tail Buff Test: Q=33 Alpha=35 Beta=+4 LOC 13
F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+10 LOC 2

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+10 LOC 4

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+10 LOC 1

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+10 LOC 3
I. F
I-I
0 0
In 0
1
Cv
*0
-
-
1
II
Ro
SM4me(M1)

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+16 LOC 8

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+16 LOC 7

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+16 LOC 6

F-18 Tail Buffet Test: Q=33 Alpha=35 Beta=+16 LOC 5