Evaluation of F-15 Inlet Dynamic Distortion

A. Pike Farr*
McDonnell Aircraft Company, St. Louis, Mo.

An instrumentation and data acquisition system for evaluating inlet dynamic distortion has been developed and used successfully during the full-scale inlet/engine test in the wind tunnel at AEDC and in the F-15 flight test program. The system consists of the following: high-and low-response pressure transducers mounted in an inlet rake; data acquisition systems for both high-and low-response measurements; and an analog computer for economical evaluation of dynamic distortion data. The rake incorporates 48 low-response and 48 high-response total pressure probes, arranged in an 8-leg, 6-ring configuration. A set of matched filters removes the high-frequency components from the low-response signals, and the low-frequency components from the high-response signals. After filtering, separate data acquisition systems record the low-and the high-response data. Because cost prohibits digital reduction of all recorded data, an analog computer is used to monitor the data and mark the data tape in the regions of peak distortion. The design of the inlet rake and instrumentation has been closely coordinated with the F-15 engine manufacturer and is used for distortion measurement by both the air-frame and engine contractors. Inlet distortion data obtained from the full-scale wind-tunnel test and flight test using this measurement system are in close agreement for both subsonic and supersonic flight conditions.

Introduction

THE high maneuvering capability of the F-15 aircraft results in operation at high angles of attack and sideslip in both the subsonic and supersonic flight regimes. These conditions can cause adverse steady-state and dynamic inlet distortion at the engine face. Experience has shown that turbofan engines, including the F-15 engine, are sensitive to dynamic distortion levels which exist for only a few milliseconds-approximately the time for one revolution of the rotor. In developing a propulsion system that will operate without engine stalls during these aircraft maneuvers, it is, therefore, necessary to evaluate both steady-state and dynamic inlet distortion.

The system used to measure dynamic distortion must be able to respond to high-frequency pressure oscillations over the temperature and pressure ranges which are consistent with the aircraft flight envelope. Several types of high-response systems have been used successfully for subscale wind-tunnel testing. In general, the pressure and temperature range requirements for these systems have been quite small. However, during flight testing the instrumentation is exposed to ranges of temperatures and pressures much greater than are experienced in subscale wind-tunnel testing. In addition, inlet distortion must be evaluated during aircraft transients, which can include rapid changes in both pressure and temperature levels. The measurement system must be able to provide accurate steady-state and dynamic data for these maneuvers throughout the aircraft operating envelope.

An inlet rake design which can be used by both the airframe and engine contractors is highly desirable since commonality in instrumentation design and location eliminates several significant unknowns from inlet/engine compatibility data analysis. Close coordination with the engine manufacturer is required to provide an evaluation system which can be used by the airframe contractor for wind-tunnel and flight tests, and by the engine contractor for ground and wind-tunnel tests using either screens or other distortion-generating devices.

An imposing data handling problem is encountered because of the massive quantity of data recorded during dynamic distortion testing. The data acquisition system must record and time correlate both steady-state and high-response data. Frequency response and recording capacity must be consistent with data requirements. All of the recorded data must then be analyzed and edited for post-test data reduction. Digital data reduction is required to provide accurate waveforms and levels of dynamic distortion. However, since both cost and time prohibit digital reduction of all acquired data, a device is required to select the peak distortion points in the recorded data for post-test digital reduction.

A description of the F-15 inlet distortion measurement system developed to meet these requirements is given in this paper. The instrumentation system and the data acquisition systems used to acquire both low-and high-response data are described. The analog recording device used to select peak dynamic distortion data for digital data reduction is also discussed. Inlet distortion data were obtained using this measurement system during the full-scale wind-tunnel test at AEDC and during the flight test program. Dynamic distortion levels are presented from these tests for subsonic and supersonic flight conditions.

Design Criteria

The instrumentation and data system designs for evaluating dynamic distortion were based on both operational and physical requirements as defined by the intended use of the system. These design criteria include the following: installation considerations, sensor characteristics, and data recording and data evaluation system requirements.

Installation Considerations

These criteria were based on requirements of the inlet/engine interface and the test programs that were to use this measurement system. The criteria are as follows: a) engine/airframe interface-inlet rake mounted on the engine with a minimum mechanical interface; b) plane of instrumentation-located within 4.5 in. of the engine face; c) inlet-flow blockage-constrained to about 5%; d) maintainability-transducers easily accessible and replaceable without engine removal; no external pneumatic connections; and e) use-measurement system used for both wind-tunnel and flight testing; same system design used by engine and airframe contractors.

Sensor Characteristic

The transducers used in the system must provide accurate data, both steady state and dynamic, over a wide range of en-

Presented as Paper 73-784 at the AIAA 5th Aircraft Design, Flight Test and Operations Meeting, St. Louis, Missouri, August 6-8, 1973; submitted August 6, 1973; revision received April 24, 1975. This work was conducted under U.S. Air Force Contract F33657-70-C-0300.

Index category: Aircraft Testing (including Componet Wind Tunnel Testing).

*Senior Group Engineer, F-15 Propulsion. Member AIAA

vironmental conditions. The transducer design criteria, based on the aircraft operational envelope and the dynamic distortion sensitivity of the F-15 engine, are: a) number of probes-a minimum of 40 probes to define both circumferential and radial distortion; b) pressure range - 2-4 psia; c) temperature range- −65°F to greater than 400°F; d) frequency response- 0 to 100 Hz; and e) accuracy - maximum of 4% error at minimum absolute pressure.

Data System Requirements

These criteria minimize errors in data recording and provide rapid and economical post-test data processing. The data system requirements are: a) accurate low-response data at 10 samples per sec; b) high-frequency data continuously recorded and time correlated; c) rapid, low-cost data handling procedures; and d) similar systems for both ground and flight testing.

Instrumentation

The design of the inlet rake and instrumentation system has a large impact on the quality of the data, both steady-state and dynamic, obtained during testing. To ensure that satisfactory data could be obtained, the following areas were considered in the development of the F-15 measurement system; inlet rake design, probe location, and low-and high-response sensor design. Because accurate steady-state and dynamic data are required during aircraft transient maneuvers, special consideration was given to the transient environment in which the measurement system would operate.

Inlet Rake Design

The inlet rake and probe locations were chosen to meet both the distortion measurement and the operational requirements of the F-15 test program. An 8-leg rake (shown in Fig. 1) is located just ahead of the engine face to measure the inlet dynamic distortion. Rake legs are spaced at 45° intervals; each leg has six probe positions, providing a total of 48 locations. The rake legs have an airfoil shape to minimize flow disturbances from the rake, and the leading edge fairings of the rake legs are removable for transducer replacement. A ninth leg is included for routing of electrical wiring.

The rake assembly has no external pneumatic connections with the engine or the airframe, and the mechanical interface with the engine is minimal. Five electrical plug-in units connect the instrumentation to the airframe-mounted data acquisition system. No mechanical attachments to the airframe are necessary; the rake is bolted to the engine hub and outer flange, permitting the rake to be easily moved from one engine to another.

The plane of instrumentation is located in a region of constant annular area approximately 4.5 in. ahead of the engine face (as shown in Fig. 2). Both a low-response and a high-response probe are provided at each of the 48 instrumentation locations. The low-response probes are located at the exact centroids of six equal, annular areas. Each high-response probe is located 0.304 in. (center-to-center) away from its corresponding low-response probe. The plane of instrumentation in located 5.8 chord thicknesses upstream of the maximum cross section of the strut to minimize the effects of the rake on the measured data. Flow angularity is minimized by locating the probes in a region of constant annular area, and by using internal chamfers in both low-and high-response probes. Figure 3 shows that the probe errors are small for flow angles of 15° or less.

The instrumentation is designed to meet the required frequency response over the aircraft pressure and temperature operating ranges. Frequency-response requirements dictate that the transducers be mounted on the rake so high-frequency oscillations are not damped. However, the temperature extremes to which the rake is exposed can cause errors in the high-response transducer signals. The largest

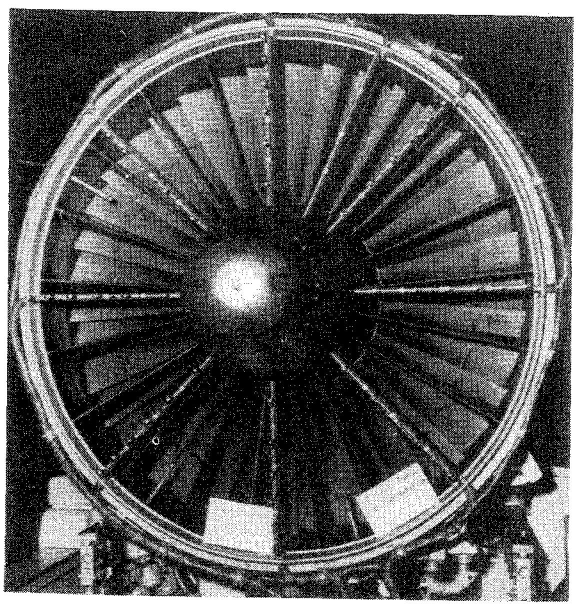

Fig. 1 Inlet rake.

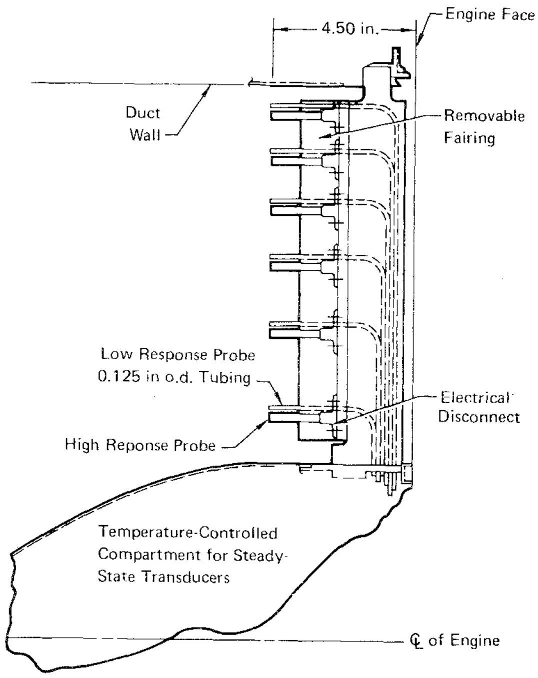

Fig. 2 Rake instrumentation configuration.

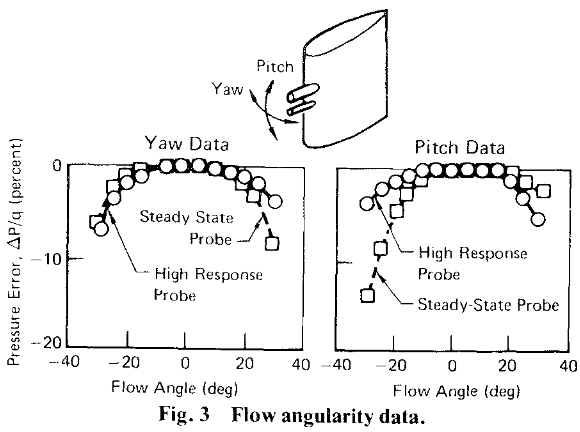

Fig. 3 Flow angularity data.

portion of the temperature-induced error is transducer zero shift with temperature, which is a steady-state offset error. Continuous monitoring of transducer temperature could eliminate this error; however, measuring transducer temperature during rapid transients becomes very difficult with a multi-probe configuration. This problem was eliminated by using separate low-response and high-response pressure transducers in the rake. Only the high-response, or fluctuating, portions of the pressure are measured by the rake-mounted transducers. Zero shift error is eliminated from high-response transducer measurements using high-pass filters. Because the zero shift errors in the high-response transducers can be ignored, the sensors are designed for minimum variation in sensitivity throughout the temperature range. The low-response transducers, placed in a temperature-controlled environment to eliminate temperature-related errors, provide an accurate measurement of steady-state pressures.

Low-Frequency-Response Pressure Transducer System

The low-response (0-0.25 Hz) pressure instrumentation used 48 transducers mounted in a temperature-controlled compartment in the engine nose dome. The pressure at each location on the rake is sensed through a 0.125-in. o.d. tube located at the centroid of an equal annual area. Each tube is routed through the rake leg to an absolute pressure transducer located inside the engine nose dome cover, which is an integral part of the rake. A single pneumatic connection exists between each low-response probe and its corresponding transducer; disconnect is necessary only for transducer replacement. No pneumatic connections are affected during engine or rake removal.

Transducer Location

The location of the transducers in the engine nose dome provides easy access and permits use of short (19 in.) tubes from the probes. These short tubes ensure satisfactory amplitude and phase response in the low-frequency range. Figure 4 shows that any errors induced by the 19-in. length used in the low-response system can be considered negligible in the 0-0.25-Hz range.

Transducer Type

Primary considerations in selection of the low-response transducer were size, reliability, and temperature characteristics. The Statham PA856 absolute pressure transducer selected for this application is a thin-film, flush-diaphragm, strain-gage transducer.

Two separate sets of low response Statham transducers are used to minimize errors throughout the required pressure range. Sensors having a 50 psia full-scale range are used for all inlet distortion investigations where the inlet total pressures are greater that 15 psia. During investigations at low inlet total pressures, 15 psia (full-scale) units are used for improved accuracy.

Temperature Control System

Nose dome temperature is controlled by thermostatically controlled electrical heater elements bonded to the inner surface of the nose dome. Convection and radiation maintain a uniform temperature for the transducers and mounting blocks.

Because both a rapid warm up and accurate temperature control are required, the heater system has two circuits. An ac-powered, thermostatically controlled circuit produces 500 W for warmup. A dc-powered, proportionally controlled 100-W heater circuit controls the temperature to 300°F ± 25°F after warmup.

High-Frequency Response Pressure Transducer System

The high-response transducer system consists of 48 rake-mounted probe assemblies, located side by side with the low-response probes, to measure fluctuating pressures in the 0.25-1000-Hz frequency range. The side-by-side configuration is used for the low-and high-response probes to simplify attachment and disconnect. Use of separate high-response probes permits easy probe replacement and positive contact for transducer excitation power and signal leads.

Transducer Location

The high-response transducers are located in rake-mounted probes to satisfy the system frequency response requirements. Each transducer is attached to the rake with two fasteners. Probe assemblies are attached to the rake beneath the removable forward fairings on each rake strut.

Transducer Type

The high-response transducer is a semiconductor strain-gage type and is designed as an integral part of a replaceable probe assembly. This probe contains an absolute pressure sensor and has only electrical connections to the rake. No pneumatic connections are required.

A protective screen is located ahead of the transducer because wind-tunnel experience has shown that the diaphragms of miniature transducers are extremely susceptible to particle damage. The screen is placed to prevent resonances in the frequency range of interest. Transducer sensitivity to temperature transients is reduced by designing the probe to maximize the thermal time lag. The design uses as much mass as possible around the transducer and in front of the diaphragm.

The complete probe and transducer assembly (shown in Fig. 5) is manufactured by Kulite Semiconductor Products, Inc. Qualification and acceptance testing indicates that the probes are insensitive to thermal transients and have flat frequency response from 0-1000 Hz.

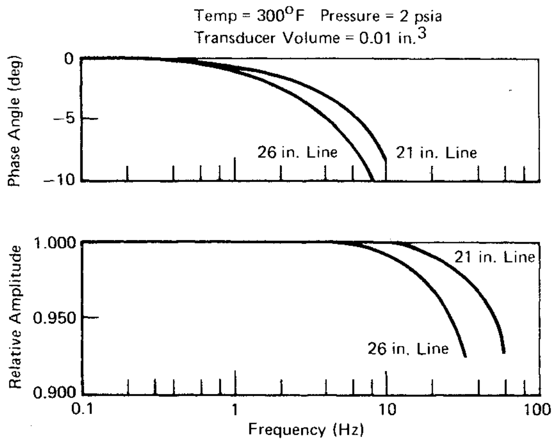

Fig. 4 Frequency response of pressure transmission line.

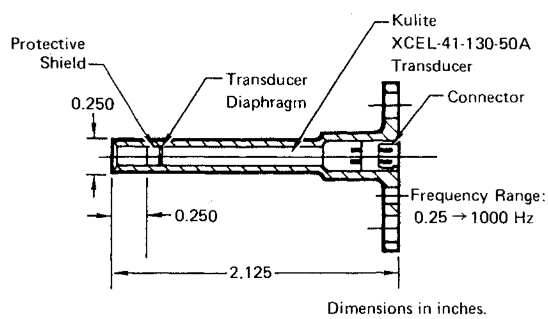

Fig. 5 High-response probe configuration.

Data Acquisition System

The data acquisitiion system used to evaluate F-15 inlet distortion consists of three parts: a set of matched prerecording filters, a low-response recording system, and a high-response recording system.

A block diagram of the data acquisition system is shown in Fig. 6. Signals from both the low-and high-response transducers are filtered using a set of matched low-and high-pass filters. The 40 low-response signals are each sampled 10 times per sec, digitized, and recorded on tape. High-frequency data are tape recorded in analog form.

Low-Response and High-Response Signal Filters

Signals from both the low-response and high response transducers are filtered in the extreme low-frequency region prior to recording. These low-pass and high-pass filters are first-order-type filters and have a cutoff frequency of 0.25 Hz. A separate low-pass/high-pass filter set is used for each of the 48 low-and high-response transducer outputs.

Filtering the data in the extreme low-frequency region prior to recording offers the following advantages: 1) The large thermal zero shifts of the high-response pressure transducers are removed from the transducer output to avoid introducing steady-state errors. 2) The low-response transducer outputs are filtered to eliminate the higher-frequency components of pressure that are distorted by pneumatic line attenuation and phase shifts, and to prevent aliasing errors in the sampled data. 3) Accurate and straightforward recombination of the two outputs can be accomplished because the low-and high-pass filters are matched to one another ot provide a flat frequency response with extremely low amplitude errors.

The effects of the filters on the combined pressure signal are shown in Fig. 7. A very small error in amplitude occurs at the 0.25 Hz crossover frequency, attenuating rapidly to zero on either side of this frequency.

Low-Response Data Acquisition

The low-response data acquisition system consists of an on-board sampling and digitizing unit which supplies data to the tape recorder. The general-purpose low-response data acquisition rate is 10 samples per sec, which is the base rate of the on-board digital acquisition system. Because the data are filtered through 0.25-Hz first-order filters prior to sampling, this rate is sufficient to define the wave forms and levels of the low-response pressure data accurately.

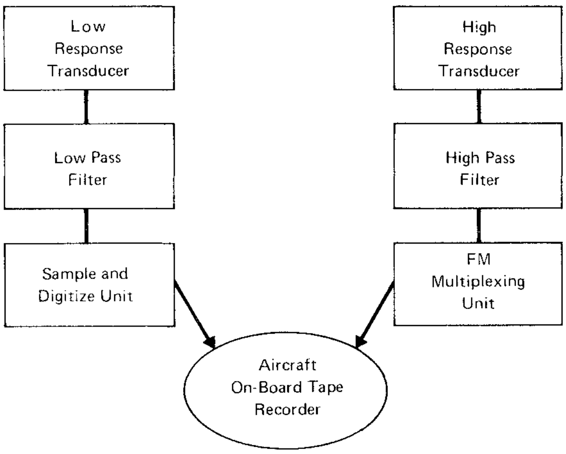

Fig. 6 Pressure measurement system.

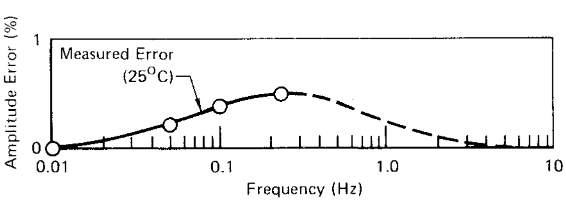

Fig. 7 Amplitude error due to filter mismatch.

High-Response Data Acquisition

The high-response data acquisition system is a signal multiplexing system which provides data to the on-board tape recorder in FM-multiplex form. The F-15 Frequency Division Multiplex System (FDMS) utilizes constant bandwidth (± 2 kHz) FM-multiplex recording conforming to IRIG standards. Channel center frequencies are spaced 8 kHz apart, beginning at 16 kHz. This system is used to record data containing frequencies from 0.25-1000 Hz. Twelve channels of data plus a 120 kHz reference frequency can be recorded on each tape track.

The 120 kHz reference frequency is also used as a translation frequency (to obtain channels 7 through 12, lower-frequency subcarriers are translated up) and for tape speed compensation during data playback. The high-response distortion data are recorded on four tape tracks, all of which use the same recording head stack.

Dynamic Distortion Editing

Because of the vast quantity of data recorded during tests involving dynamic distortion, a method is required to select only small portions of the recorded data for further reduction. For example, during the full-scale wind-tunnel test, dynamic data were recorded for approximately 340 points, resulting in approximately 35 miles of FM-multiplexed tape to be analyzed. Both time and cost considerations preclude a digital reduction of all the recorded data to determine peak distortion levels.

The reduction of inlet dynamic distortion data using statistical, random sampling techniques does not provide an accurate representation of peak distortion levels because studies have shows that the parameters used for F-15 distortion analysis have non-Gaussian distributions. Figure 8 shows that the distribution of peak dynamic distortion is non-uniform, resulting in peak distortion levels which are higher than would be statistically predicted. Further, this distribution of peak distortion levels changes with flight conditions and is not predictable using statistical techniques.

Because the random sampling technique for dynamic distortion is not adequate, it became evident early in the inlet development program that a means of positively identifying peak distortion in a dynamic data record was required. An analog computer was developed to compute dynamic distortion on-line and to mark the tape in the region of peak distortion. Reference 1 discusses an early version of the analog device used for dynamic distortion editing.

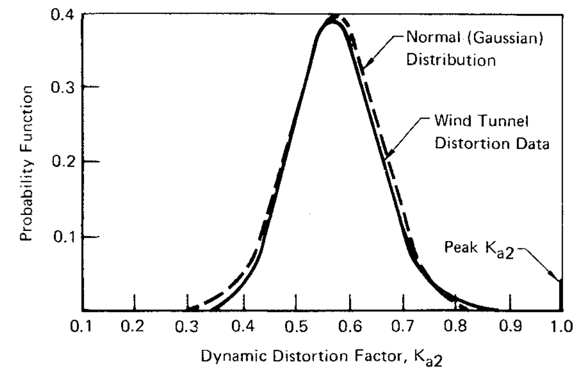

Fig. 8 Distortion probability distribution.

Consistency between the airframe and engine contractors is also maintained for dynamic distortion editing. Both contractors use similar analog distortion computers for on-line data screening and for selection of peak distortion levels for post-test analysis.

System Configuration

The analog device shown in Fig. 9 uses the inputs from both the low-and high-response transducers after these data are filtered by the matched crossover networks. The high-response data are then filtered using 48 three-pole, linear-phase, 170-Hz filters, which are required for the distortion factor computation.

Peak dynamic distortion levels are computed and displayed on digital panel meters which are integral to the computer. All of the dynamic distortion parameters used for F-15 inlet/engine compatibility assessment are displayed and recorded in analog form on tape. The parameters computed are: K_{a2} - fan total distortion parameter; K_θ - fan circumferential distortion component; K_{ra} - fan radial distortion component; K_{c2} - compressor total distortion parameter; and $K_{\theta splitter}$ - compressor circumferential distortion component. In addition, the analog device is used to compute the ratio of instantaneous to steady-state inlet recovery at the engine face, *Pi/Ps*. This parameter shows any in-phase pressure oscillations which might be present.

Editing Procedure

The analog computer is used to process the dynamic data after the on-board tape has been returned. Using the on-board tape, which contains both the low-and high-response pressure data, the dynamic distortion levels are continuously computed and separately recorded; the peak distortion levels are detected and corresponding tape locations are identified.

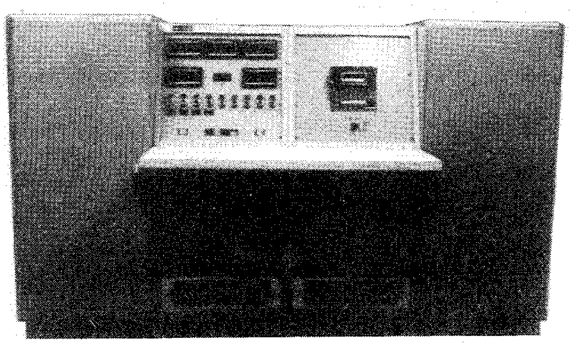

Fig. 9 Analog computer used for on-line distortion editing.

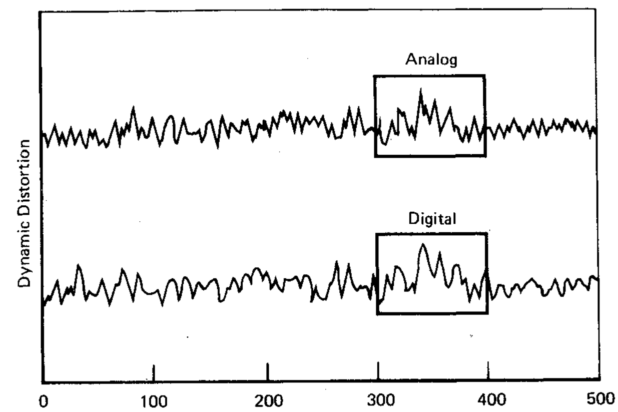

Fig. 10 Waveform comparison of analog and digitally computed distortion.

Electrical marker pulses are provided for both K_{a2} and K_{c2} distortion parameters since both parameters are required to determine which engine component is critical from the inlet/engine compatibility standpoint. The analog computer places time-correlated marker pulses on the tape when peaks in dynamic distortion occur that exceed the previously detected peaks. During post-test data reduction, the last marker pulses on the record are located for both maximum K_{a2} and K_{c2}, and the dynamic data are digitized only in these regions.

If analog-computed distortion levels are low and no inlet or engine problems occur during the flight, post-flight digitization of the dynamic data is probably not required, resulting in a significant cost saving.

A number of comparisons between the analog and digitally computed distortion data have been made. Figure 10 shows good agreement, for both waveform and distortion level.

Test Results

The instrumentation and data system designs described in this paper have been used successfully in the full-scale inlet/engine test in the propulsion wind-tunnel facilities at AEDC and during F-15 flight testing at Edwards Air Force Base, Calif. The inlet rake was instrumented with 15-psia low-response transducers for both the transonic and supersonic tunnel tests at AEDC. Both the 15- and the 50-psia range transducers have been used during flight test, depending on the flight regime investigated. Inlet dynamic distortion data from these tests are in close agreement.

The inlet rake has proved to be reliable and easily maintained during both the full-scale wind-tunnel test and flight test. In addition, the rake has been moved from one engine to another during flight testing; about three hours is required for this change. The rake has been used in F-15 aircraft No. 2 for more than 80 flight-hr during the first 5 months of flight testing. During this period only eight high-response and five low-response probes required replacement.

The analog distortion computer has been successfully used during both the wind-tunnel test and flight test. Distortion levels are in close agreement with digital results.

Inlet Distortion Data

Inlet distortion data have been evaluated over a wide range of flight speeds, at various altitudes, and for both straight and level flight and aircraft maneuvers. Table 1 presents typical data in terms of the F-15 distortion parameters K_{a2} and K_{c2}, which were developed by Pratt & Whitney Aircraft. The inlet distortion data obtained during flight test are compared with the distortion levels obtained during the full-scale inlet/engine test conducted at AEDC. Wind-tunnel test results demonstrated stable, stall-free operation for both subsonic and supersonic flight conditions.

Inlet dynamic distortion obtained during flight has been evaluated over a wide Mach range. Figure 11 shows a com-

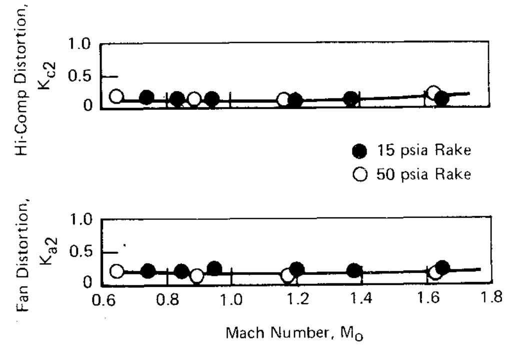

Fig. 11 F-15 inlet dynamic distortion (flight test data). Stabilized level flight at high altitude.

parison between peak distortion levels measured by 15-psia and 50-psia range transducers. These flight test data, obtained from high-altitude level flight accelerations, show close agreement between the two transducer types. Consistent distortion levels were obtained from flight test data with fairly large variations in pressure and temperature. Steady-state and transient data also show consistent results.

The distortion data obtained during aircraft flight test are compared with the full-scale wind-tunnel results in Figs. 12-14. These data show that peak dynamic distortion levels are in close agreement for both subsonic and supersonic flight conditions. The range of angle of attack in these comparisons is limited to the range in the full-scale inlet test which was constrained by the tunnel/test article interface. The wind-tunnel and flight test data show similar levels and trends. The distortion levels shown in Fig. 11 appear slightly higher than the flight data for Figs. 12 and 13. This increase is caused by the higher engine corrected airflow demand at the high-altitude conditions.

Digital To Analog Comparison

The analog-processed and the digitally processed inlet distortion levels, computed using flight test data, are compared in Fig. 15. Close agreement with digital results indicates that the analog computer provides an accurate assessment of peak inlet distortion for screening purposes. This agreement also permits the amount of digital distortion reduction to be minimized, resulting in cost savings.

Conclusions

To evaluate F-15 inlet dynamic distortion accurately, a system was developed to provide low-and high-response pressures during both aircraft steady-state conditions and raped maneuvering transients. Both steady-state and high response pressure data are provided throughout the aircraft operational pressure and temperature ranges to establish the inlet dynamic distortion levels. The inlet rake system meets all design criteria; unique features include minimal interface with the engine and provisions for transducer replacement without engine removal. This system has been successfully used during a full-scale inlet/engine wind-tunnel test at AEDC and for F-15 flight testing.

It is desirable to coordinate both the rake design and instrumentation between the engine and the airframe contractors. Potential error sources are eliminated if both the engine and the airframe contractors use the same distortion

Table 1 Inlet dynamic distortion factors

FAN DISTORTION FACTOR, $K_{a2} = K_\theta + b\,K_{ra2}$

FAN CIRCUMFERENTIAL DISTORTION FACTOR, K_θ

$$K_\theta = \frac{\displaystyle\sum_{ring=1}^{J}\left[\left(\frac{A_N}{N^2}\right)_{max}\right]_{ring} \times \frac{1}{D_{ring}}}{\displaystyle\left(q/P_{t2}\right)_{ref}\sum_{ring=1}^{J}\frac{1}{D_{ring}}}$$

where:

J = Number of rings (probes per leg)

D = Ring diameter

$\left(\frac{q}{P_{t2}}\right)_{ref}$ = Reference value of engine face dynamic pressure head, function of engine face Mach number

$$A_N = \sqrt{a_N^2 + b_N^2},\ N = 1, 2, 3, 4$$

where

$$a_N = \frac{\Delta\theta}{180}\sum_{k=1}^{K}\frac{P_{t2}/P_{to}\,(k\Delta\theta)}{(P_{\overline{t2}}/P_{to})}\cos(Nk\Delta\theta)$$

$$b_N = \frac{\Delta\theta}{180}\sum_{k=1}^{K}\frac{P_{t2}/P_{t}\,(k\Delta\theta)}{(P_{\overline{t2}}/P_{to})}\sin(Nk\Delta\theta)$$

and

$P_{t2}/P_{to}(k\,\Delta\theta)$ = Local recovery at angle, $k\Delta\theta$

$(P_{\overline{t2}}/P_{to})$ = Face average recovery

K = number of rake legs

$\Delta\theta$ = angular distance between rake legs, degrees

$\left(\frac{A_N}{N^2}\right)_{max}$ = maximum value for the four Fourier coefficients calculated; normally turns out to be A_1.

FAN RADIAL DISTORTION FACTOR, $b\,K_{ra2}$

$$K_{ra2} = \frac{\displaystyle\sum_{ring=1}^{J}\left(\frac{\Delta P_{t2}}{P_{\overline{t2}}}\right)_{ring}\frac{1}{D_{ring}^{2.8}}}{\displaystyle\left(q/P_{t2}\right)_{ref}\sum\frac{1}{D_{ring}^{2.8}}}$$

with:

$$\left(\frac{\Delta P_{t2}}{P_{\overline{t2}}}\right)_{ring} = \left|\frac{(P^*_{t2}/P_{to})}{P_{\overline{t2}}/P_{to}} - \frac{P^*_{t2_{base}}}{P_{\overline{t2}}}\right|\frac{P_{\overline{t2}}}{P^*_{t2_{base}}}$$

where

P^*_{t2}/P_{to} = ring average recovery

$\frac{P^*_{t2_{base}}}{P_{\overline{t2}}}$ = reference radial profile, function of $(q/P_{t2})_{ref}$,

b = radial distortion weighting factor,

P_{to} = Freestream total pressure

HIGH COMPRESSOR DISTORTION FACTOR, K_{c2}

$$K_{c2} = K_{\theta splitter}\frac{180}{\theta^-}$$

where:

$K_{\theta splitter}$ is calculated in the same way as K_θ, but using values only for rings having diameters less than or equal to the splitter diameter, $D_{splitter}$, as defined below:

$$D_{splitter} = \sqrt{\alpha_s(OD^2 - ID^2) + ID^2}$$

OD = Outside diameter

ID = Inside diameter

α_s = splitter streamtube area ratio, function of $(q/P_{t2})_{ref}$,

θ^- = the greatest angular extent where $P_{t2}/P^*_{t2} < 1.0$. If there are two regions of low P_{t2}/P^*_{t2} separated by 25^o or less they are to be treated as one low pressure region. The lower limit of θ^- is to be 90^o.

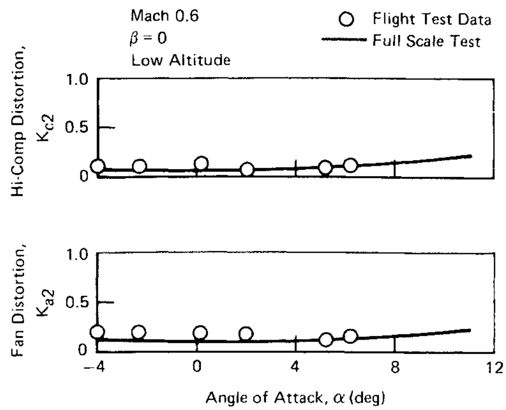

Fig. 12 F-15 inlet dynamic distortion comparison of full-scale and flight data.

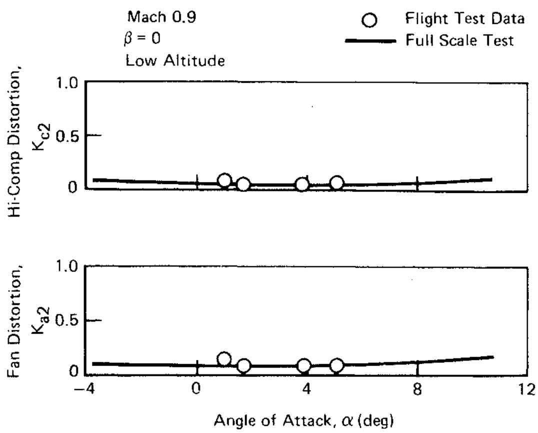

Fig. 13 F-15 inlet dynamic distortion comparison of full-scale and flight data.

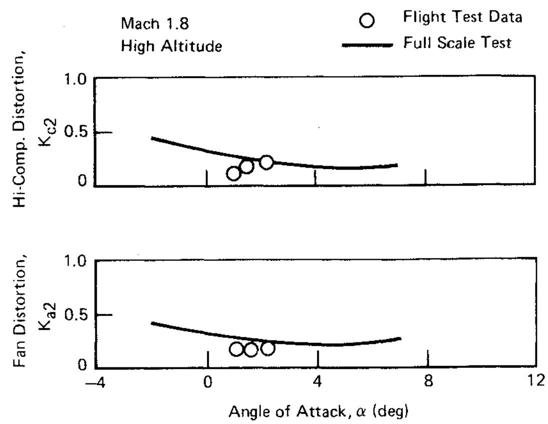

Fig. 14 F-15 inlet dynamic distortion comparison of full-scale and flight data.

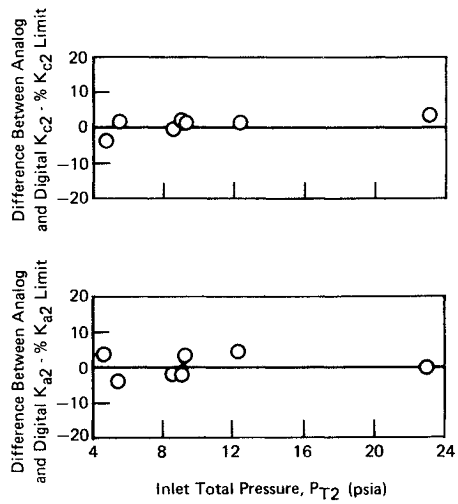

Fig. 15 Comparison of analog and digital computed distortion factors.

measurement system and the same editing device. Consistent data are then obtained on the distortion tolerance of the engine and on the distortion produced by the inlet.

Because of the massive amount of data recorded during dynamic distortion testing, a specialized monitoring and editing device was developed to select specific regions in the recorded data for post-test reduction. An analog computer is used to compute the inlet distortion factors continuously from the dynamic pressure data, and to mark regions of peak distortion.

The inlet distortion levels obtained from flight testing are in agreement with the data from the full-scale wind-tunnel test. Flight test data using both the 15-and 50-psia low-response transducers are in close agreement. In addition, the analog and digital distortion data correlate very closely; thus, data reduction using digital techniques is required for only a small portion of the flight test inlet distortion data.

Reference

[1] Crites, R.C. "The Philosophy of Analog Techniques Applied to the Analysis and High-Speed Screening of Dynamic Data," AIAA Paper 70-595, Tullahoma, Tenn. 1970.