VOL. 14, NO. 7, JULY 1977 J. AIRCRAFT 611

Core Noise Measurements on a YF-102 Turbofan Engine

Meyer Reshotko,* Allen Karchmer,† Paul F. Penko,† and Jack G. McArdle†
NASA Lewis Research Center, Cleveland, Ohio

Theme

IN the past several years considerable prograss has been made in reducing the noise generated by jet aircraft engines. The two largest sources of engine noise, the fan and the jet exhaust, have been reduced significantly. Further treatment of these sources may not reduce the overall engine noise because an acoustic threshold may have been reached. This threshold consists of noise generated by heretofore poorly understood sources within the engine core. One of the most likely sources of far-field noise originating from the engine core is the combustion process, during which large amounts of chemical energy are released.

At the NASA Lewis Research Center, tests have been conducted to determine the characteristics of combustion and other core noises and their propagation through the engine core to the far-field using an AVCO-Lycoming YF-102 high-bypass-ratio turbofan engine. The overall objective of the program was to measure the noise in the combustor at various engine operating speeds and to determine its propagation 1) upstream to the compressor exit, 2) downstream through the turbine and core nozzle, 3) to the near field, and 4) to the far field. The results indicate the range of engine operating conditions where the combustor or other core engine noises influence or dominate the far-field acoustic signal.

Contents

The AVCO-Lycoming YF-102 engine is a two-spool turbofan engine with a bypass ratio of 6, and a rated thrust of 33 kN. The engine core consists of an eight-stage compressor, a reverse-flow annular combustor, and a four-stage turbine. Dynamic pressure probes (acoustic waveguides in conjunction with pressure response condenser microphones) were placed in the engine core at seven different locations (Fig. 1) as follows: two just downstream of the compressor exit about 2-cm apart; one at the combustor entrance; two within the combustor at the same axial location but separated 90° circumferentially; and two within the core nozzle, one just downstream of the turbine at the turbine exit and one close to the nozzle exit plane. Measurements were made at eight fan speeds between 30% and 95% of maximum speed (7600 rpm).

Typical one-third octave band dynamic pressure level spectra measured internally and in the far field for an engine fan speed of 43% are presented in Fig. 2. The internally measured spectra exhibit the broadband nature of the signal below 6000 Hz and the tonal content due to rotating machinery above 6000 Hz. The far-field spectrum is broadband below 2000 Hz and tonal above. Except for the far-field signal, which is definitely acoustic in nature, these data by themselves do not indicate the origin or the propagation characteristics of the broadband signals and the tones, nor do they indicate whether the probes are measuring acoustic pressure, hydrostatic pressure fluctuations, or some combination of the two. The subsequent discussion examines these issues.

At the compressor exit, fluctuating pressure measurements indicated broadband low-frequency signals (below 2000 Hz), and high-frequency tones (above 8000 Hz) which were attenuated greatly as they passed through the combustor. These tones are the fundamentals and harmonics of the blade passage frequencies of the various compressor stages. For signals below 2000 Hz, the time delay from a normalized cross-correlation of pressure fluctuation between two probes near the compressor exit (Fig. 1) was measured. Considering the distance between the probes, the time delay for an acoustic signal to travel between them is calculated to be one-fourth the observed time delay. From this it is concluded that the low-frequency signal is not the result of acoustic pressure fluctuation, but is caused by some convection phenomenon, possibly turbulence.

In the combustor, tone-free low-frequency signals were measured at all speeds except at ground idle (30% speed) where a 380-Hz tone was detected (Fig. 3). From cross-correlation and coherence techniques,[1] it was determined that the signals from combustor and far field are not related by simple time delay which would be characteristic of pure acoustic propagation, but rather, that the combustor is a source region for far-field low-frequency noise.

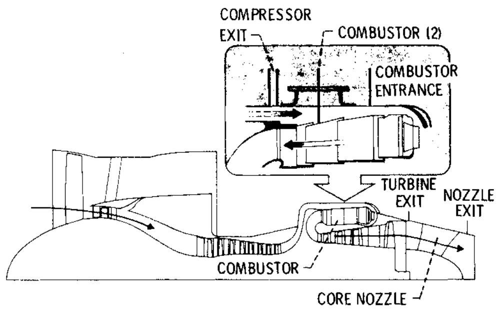

Fig. 1 Core pressure probe locations.

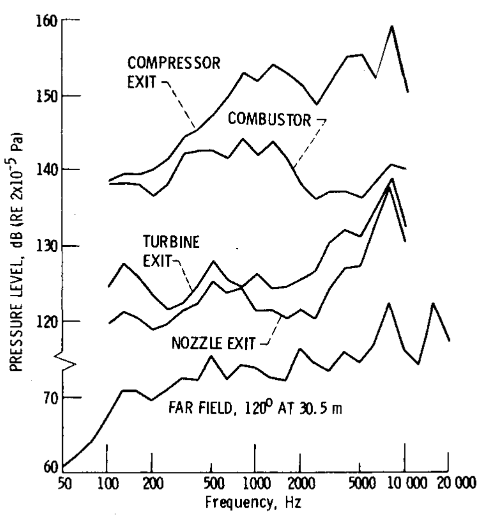

Fig. 2 YF-102 internal and far-field pressure level spectra – engine speed, 43%.

Presented as Paper 77-21 at the AIAA 15th Aerospace Sciences Meeting, Los Angeles, Calif., Jan. 24-26, 1977; synoptic received March 17, 1977. Full paper available from AIAA Library, 750 Third Avenue, New York, N.Y. 10017. Price: Microfiche, $2.00; hard copy, $5.00. **Order must be accompanied by remittance.**

Index categories: Noise; Aeroacoustics; Airbreathing Propulsion.

*Aerospace Engineer, V/STOL and Noise Division. Member AIAA.

†Aerospace Engineer, V/STOL and Noise Division.

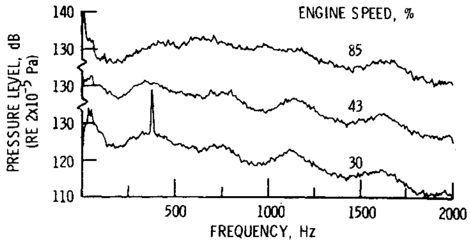

Fig. 3 Combustor pressure spectra – filter bandwidth, 6 Hz.

In the core nozzle, tone-free low-frequency signals were measured at all speeds except at 85% of maximum (where tones corresponding to the shaft rotational speed appeared) and high-frequency tones corresponding to the blade passage frequencies of the various turbine stages were detected at all speeds. Computation of a cross-correlation between signals in the core nozzle and far field indicate that pure acoustic propagation is taking place.

The variation of low-frequency acoustic power as a function of effective jet exhaust velocity (a conveniently chosen velocity weighted by the mass flow rates of the two streams) is shown in Fig. 4. The acoustic power level was computed from signals below 2000 Hz only, the main region of interest for core engine noise. The far-field acoustic power was computed in the usual manner from the microphone data. The acoustic power at the core nozzle exit was computed, on the assumption of an acoustic plane wave, as the product of the acoustic intensity and the area of the duct at the probe location.

It is seen in Fig. 4 that in the low-velocity region (up to 150 m/sec), the power level calculated at the core engine exit is in close agreement with the power level calculated in the far field at 30.5 m. However, above 150 m/sec, the power level in the far field becomes considerably greater (10 dB at 250 m/sec) than the level in the nozzle exit region. Also, above a jet velocity of 150 m/sec, the far-field acoustic power behaves as velocity to the eighth power which is indicative of jet mixing noise. This suggests strongly that below certain engine operating conditions (60% maximum speed in this case) where the jet noise is not significant, noise emanating from the engine core makes a significant contribution to the far-field noise.

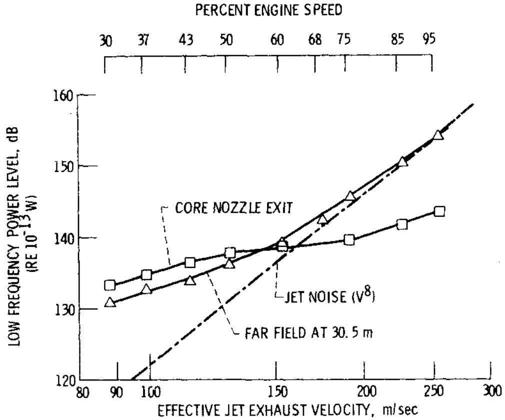

Fig. 4 YF-102 low-frequency acoustic power – frequency range 50-2000 Hz.

References

[1] Karchmer, A. and Reshotko, M., "Core Noise Source Diagnostics on a Turbofan Engine Using Correlation and Coherence Techniques," NASA TM X-73535, Nov. 1976.