Spectrum of rotor noise caused by atmospheric turbulence

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11:45

A10. Experimental analysis of the motion of a vibrating surface by speckle interferometery and optical spatial filtering. A. V. Mehta (Acoustics Group, The Catholic University of America, Washington, D.C. 20017)

Optical spatial filtering [J. A. Clark and A. V. Mehta, J. Acoust. Soc. Amer. 54, 291 (1973)] and speckle interferometric techniques are employed to analyze the motion of vibrating surfaces for many cases (e.g., rectangular bar, circular disk, etc.). Data, which is displayed in real time as contours of equal displacements over the image of vibrating surface, are recorded by time average, real time, and stroboscopic photographic methods using ordinary camera equipment. Calibration procedures are also described along with advantages and limitations of the method. The analysis compares well with the theoretical solutions.

TUESDAY, 23 APRIL 1974 GOLD ROOM, 9:00 A.M.

Session B. Noise I: Inlet Flow Effects on Turbomachinery Noise

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Invited Papers

9:00

B1. Introductory remarks. D. B. Hanson (Hamilton Standard, Division of United Aircraft Corporation, Windsor Locks, Connecticut 06096)

9:05

B2. Sources of unsteady flow in subsonic aircraft inlets. L. T. Clark (Commercial Airplane Division, The Boeing Company, Seattle, Washington 98124)

The paper presents the results of a study of turbulent flow typically found in subsonic inlets. Space—time correlations measured at the inlet-engine interface plane were used to represent the structure of the turbulent flow. The results have application in the analysis of rotor noise and performance. It was observed that turbulence which originated outside and was convected through the inlet had elongated shapes with stream correlation lengths much longer than those in transverse directions. However, when inlet originated turbulence was measured, the lengths were about the same in each direction. Thus, the contraction effect on the flow through the inlet strongly affects the shape of the turbulent eddies. The basis for the observations were high-frequency response total pressure transducers mounted on rakes in the inlet near the fan plane. The inlets used were representative of current technology in subsonic aircraft. 15-in.-diameter models were used in a 9×9-ft wind tunnel. Flow through the inlets was established using a downstream engine. Mach numbers studied were representative of the full-scale inlet. Conditions represented in the results are static, crosswind, and angle of attack.

9:35

B3. Spectrum of rotor noise caused by atmospheric turbulence. D. B. Hanson (Hamilton Standard, Division of United Aircraft Corporation, Windsor Locks, Connecticut 06096)

The spectrum of blade loading and the associated noise caused by interference of a propeller, helicopter rotor, or fan rotor with inlet turbulence are studied experimentally and theoretically. One test with hot-wire anemometers in a static inlet and another test with pressure transducers on the blades of a fan rotor reveal inlet turbulence to be highly anisotropic. The intensity of the transverse velocity component was found to be 2.5% of the mean flow and the streamwise component was 0.9%, with ambient winds of about 2 mph. The transverse integral scale of the turbulence is a fraction of an inlet diameter, while the streamwise integral scale is over 100 diameters. Evidence indicates the source of these disturbances is atmospheric turbulence. The associated noise is partially coherent with spectrum peaks which are so narrow as to be difficult to distinguish from true harmonics. A novel blade loading model is developed using concepts from random pulse modulation theory. Theoretical spectrum predictions indicate for the test fan that the peak at blade passing frequency and the high-frequency broad-band noise are due to inflow turbulence. It appears that this narrow-band random mechanism explains spectrum peaks which have previously been described as harmonic noise due to fixed inflow distortion.

10:05

B4. Inlet turbulence—rotor noise. R. Mani (Corporate Research and Development, General Electric Company, Schenectady, New York 12301)

The present contribution is concerned with aerodynamic noise from isolated, subsonic tip rotors. With large axial spacing between blade rows and elimination of inlet guide vanes, at least the forward radiated noise from modern single-stage aero-engine fans is dominated by isolated rotor noise. In an early study, Sharland described three agencies by which such a rotor would produce noise, namely, vortex shedding, turbulent boundary layer noise, and noise due to inflow distortion or inlet turbulence. The present study develops means of computing inlet and discharge PWL spectra due to impingement of inlet distortion or inlet turbulence on an isolated rotor. Both dipole and quadrupole mechanisms are analyzed as only the latter afford a good explanation of why fan noise is pressure ratio dependent at constant wheel rpm. The input parameters needed are a description of the inlet distortion far upstream of the rotor and of the inlet turbulence and steady-state design parameters of the isolated rotor. Preliminary ideas of the author have been expanded in several directions by the author's colleagues at GE, especially in the direction of experimental verification of the analysis. This study will emphasize such comparisons.

10:35

B5. Effects of nonuniform inflow on fan noise. G. F. Pickett (Pratt and Whitney Aircraft, East Hartford, Connecticut 06108)

A prominant source of turbomachinery noise is due to high-speed unsteady flows interacting with blades and vanes. In particular, atmospheric turbulence, cross-wind effects, and the "ground vortex" apparent during most static test conditions can interact with the fan on turbofan engines to produce significant levels of noise. An analysis is presented that models this noise-generating mechanism and is capable of predicting propagating noise, accepting as input various inlet turbulence structures, temperature fluctuations, and flow distortions. Because of the random nature of most inflow disturbances, a statistical approach was used to develop the model which is a modification and extension of a previous analysis presented by Mani ["Noise Due to Interaction of Inlet Turbulence with Isolated Stators and Rotors," J. S. V. **19** (1971)]. The analysis shows that the level of fan blade passing tone and harmonics and their relative forward and rearward radiated intensities are critically dependent on both the inlet turbulence intensity and correlation length scales in the axial, circumferential, and spanwise directions. This analysis is used in conjunction with measured fan noise data to infer the turbulence properties that would be required to account for levels of observed blade passage tone noise.

11:05

B6. Quiet airplane paradox and its theoretical explanation. E. D. Griffith and J. D. Revell (Acoustics Division, Lockheed California Company, Burbank, California 91520)

Farfield noise radiated from low-tip-speed propellers on the YO-3A quiet observation aircraft and measured in flyover tests exhibited unexpected levels and trends that have been called the "quiet airplane paradox." Levels of rotational propeller noise were found to be higher than predicted by conventional axisymmetric theory, and as propeller tip speed was decreased below a given value, at constant thrust, both harmonic and broad-band noise levels actually increased. Thus a "bucket" was formed in the SPL vs tip speed curve. In addition, the harmonic character of the flyover propeller noise was markedly different than that observed in static propeller tests. These data were declassified in 1973, and a program was conducted to investigate the paradoxical experimental results and to develop a theoretical explanation. The theoretical study considered propeller blade aerodynamics, nonuniform inflow through the propeller, chordwise blade loading, and, finally, propeller blade wake/wing interaction. It was concluded that the principal explanation of the paradox lies with the nonuniformity of inflow through the propeller disk causing circumferential variations of blade loads. The blade wake/wing interaction rated second in important. [Original experiments with the YO-3A aircraft were supported by the Army and this research program was supported by the Air Force.]

11:35

B7. Open discussion on the forecasting of flyover noise from static test data. Discussion Moderator: D. B. Hanson (Hamilton Standard, Division of United Aircraft Corporation, Windsor Locks, Connecticut 06096)

Aircraft noise specialists are becoming aware that aircraft static and flyover noise signatures can be quite different. Most aircraft engine and propeller noise research is carried out on static test stands; however, the forward flight condition is most critical for annoyance and certification. This is discussed in light of the invited papers.