vortex shedding contributions to acoustic stability analyses of rocket motors and ramjet engines.

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Advanced Design Propeller Noise Testing in an Anechoic Chamber

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THE rising interest in advanced design propellers (ADP) together with the availability of a Boeing cold air turbine drive (CATD) resulted in a cooperative program between NASA and the Boeing Company to test the NASA-owned SR-6 propeller. The experimental work reported here was accomplished in a large anechoic chamber with relative velocity provided by a freejet.

Test goals included combining the CATD propeller system with the freejet operation, acquiring high-quality noise data delineating transition from near to far field, and describing acoustic directivity for ADP. Test results were subsequently confirmed by testing in a wind tunnel.[1]

The Boeing-developed CATD is a single-rotation, two-stage turbine providing 800 hp at 10,000 rpm.[2] The freejet is a large ejector system which produces low velocity flow at a 4-ft diam exit nozzle. Mach numbers up to 0.25 were achieved, with $M = 0.15$ the typical operating condition.

Figure 1 shows the CATD mounted on a pedestal (monopod) in the Boeing Large Anechoic Test Chamber (LTC), which has a volume of 150,000 ft^3. This test arrangement allowed the propeller to operate in a nearly anechoic, or free-field, environment. Test parameters included propeller pitch angle, rpm, and relative velocity.

Multiple fixed microphones were located at various distances from the source (in and out of flow), and traversing microphones continuously sampled the noise. Three different traverse systems employed a total of seven microphones: three sideline traverse microphones at 3, 4, and 5 ft; three polar traverse centerline-high microphones at 4, 8, and 16 ft, moving from 45 to 145 deg as measured from the propeller rotation axis; and one 90-deg radial traverse microphone from 2 to 26 ft at centerline height. (Distances given are relative to the propeller shaft centerline).

During testing, on-line data were available by tracking the SPL level of the blade passage frequency and the next four harmonics. The tracking procedure produced directivity plots for evaluation of smoothness, shape, and expected values. Also, narrowband spectra could be produced by use of an FFT analyzer. These data supplement the harmonic data and serve to widen the frequency range.

Results

A primary test goal was to determine the distance of near-to far-field transition. If this distance were shown to be small enough, measurements could be made in a restricted area such as a wind tunnel without resorting to flight tests or ultralarge test facilities. Further, this distance becomes very important when ADPs are installed on aircraft.

Propeller noise measurements produce a huge volume of complex data. The plots shown are representative of the many available. For example, one way of examining the data is represented by Fig. 2. For a radially traversing microphone with each data sample normalized to a reference distance

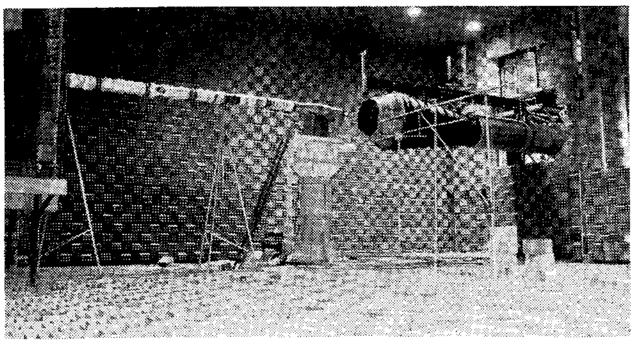

Fig. 1 ADP installation in Boeing large anechoic test chamber with freejet.

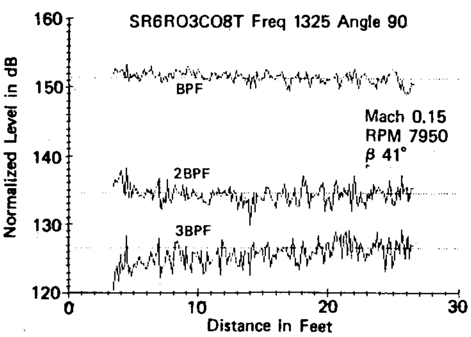

Fig. 2 Normalized SPL vs distance for ADP with freejet.

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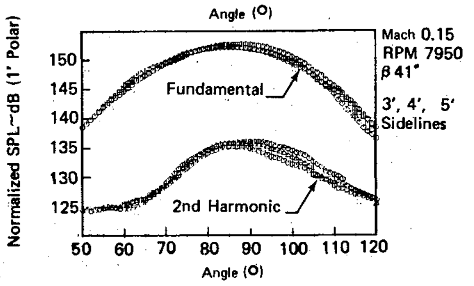

Fig. 3 Directivity of ADP with freejet.

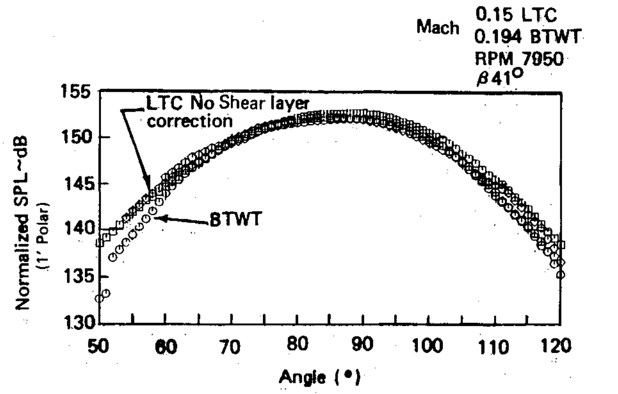

Fig. 4 Comparison of SR-6 ADP in anechoic chamber with freejet and in Boeing Transonic Wind Tunnel.

under true far-field conditions in an anechoic environment, the results would be a flat line. Deviations from a flat line indicate near-field effects or the presence of reflections.

Figure 2 shows typical results. Note that the far-field zone has already occurred at approximately 3 to 4 ft from propeller centerline (1½ to 2 propeller diameters) and that some reflections are present even in a large anechoic chamber.

These SPL vs distance plots were supplemented by directivity plots. Comparisons were made with data from microphones located at different distances, looking at peak SPL, angle of maximum noise, and general shapes of the directivity curves. Normalized data collapse as shown by the sample plot of Fig. 3. This indicates near-field or reflection effects are minimal. These typical data agree with the radial traverse.

Figure 4 compares anechoic chamber results with data taken in the acoustically treated Boeing Transonic Wind Tunnel. Good agreement exists between two tests, even though no shear layer corrections were applied to the LTC data. Doubtless, there are shear layer effects; however, they seem insignificant for these angles and conditions.

Summary

ADP noise data can be obtained in freejet anechoic facilities and are similar to those measured in a wind tunnel. Farfield assumptions appear valid for measurements taken only 1½ to 2 diam away from the SR-6 propeller. Traversing microphones are useful tools in such evaluations.

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