Fan Stage Broadband Noise Benchmarking Program

Specification of Realistic Test Case 2 (RC2)
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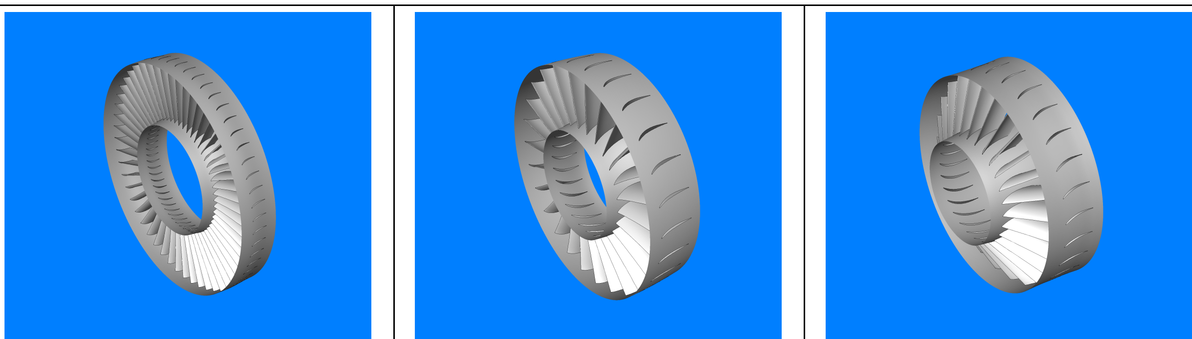
Test Case Coordinator: Ed Envia
Acoustics Branch, M/S 54-3
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, OH 44135, U.S.A.
E-mail: edmane.envia-1@nasa.gov

Program Website: *http://www.oai.org/aeroacoustics/FBNWorkshop*
Information on all the test cases are available at this website.

Introduction

The purpose of this test case is to benchmark calculation methods for the prediction of the broadband noise generated by a realistic fan stage. Predictions are sought for the fan stage configured with three different outlet guide vane packs (see Figure 1) at the five operating conditions listed in the table below.

Op. Condition	RPM	% Design Speed
Approach	7808	61.7
—	9493	75.0
Cutback	11075	87.5
—	11771	93.0
Sideline	12657	100.0



Baseline OGV (54 Radial Vanes)	Low Count OGV (26 Radial Vanes)	Low Noise OGV (26 Swept Vanes)

Figure 1. Benchmark OGV packs.

The geometric and aerodynamic input description of the benchmark problem will be provided by the test coordinator.

The participants interested in solving this benchmark problem must provide, at the minimum, the narrowband spectrum of in-duct acoustic power level (PWL) downstream of the OGV. The PWL spectrum should be expressed in dB relative to 10^{-12} Watt reference level. The range of frequencies to be considered is 0 to 50 kHz.

Additional information of interest include one or more of the following:

- The narrowband spectrum of in-duct acoustic PWL upstream of the fan rotor. (Assuming stage acoustic calculations are performed.)
- Spectrum of acoustic PWL radiating through a sphere centered on the fan origin, i.e., location $(x,y,z) = (0,0,0)$ and with a radius of 39.4 inches (1 m). (Assuming external acoustic calculations are performed.)
- Sideline sound pressure level spectra (expressed in dB relative to 2×10^{-6} Pascal) on a lateral line (i.e., blue line in Figure 2) parallel to the axis of the fan and lying in the horizontal plane $z = 0$, at a distance of 88.6 inches (2.25 m) from the fan axis. The SPL spectra is to be provided at one or more of the following five locations on the lateral line: $\theta = 30^{o}$, 60^{o}, 90^{o}, 120^{o}, 137^{o}. The range of frequencies to be considered is 0 to 50 kHz. (Assuming external acoustic calculations are performed.)

Methods expected to be benchmarked for this test case include, but are not limited to:

- Hybrid analytical-CFD/CAA
- High-Fidelity URANS
- CAA
- Large Eddy Simulation

Submission of results using other relevant methods is also welcomed.

Test Rig Description

This test case is based on the aerodynamic and acoustic data acquired for the NASA 22-inch fan rig simulator called the Source Diagnostic Test (SDT) Fan. The data was acquired at the NASA 9-foot by 15-foot Low-Speed Acoustic Wind Tunnel. A photograph and a cut-away sketch of the fan rig along with the test layout in the 9’ x 15’ tunnel are shown in Figure 2. For additional details regarding the 9’ x 15’ facility and the SDT test program consult references (1-5).

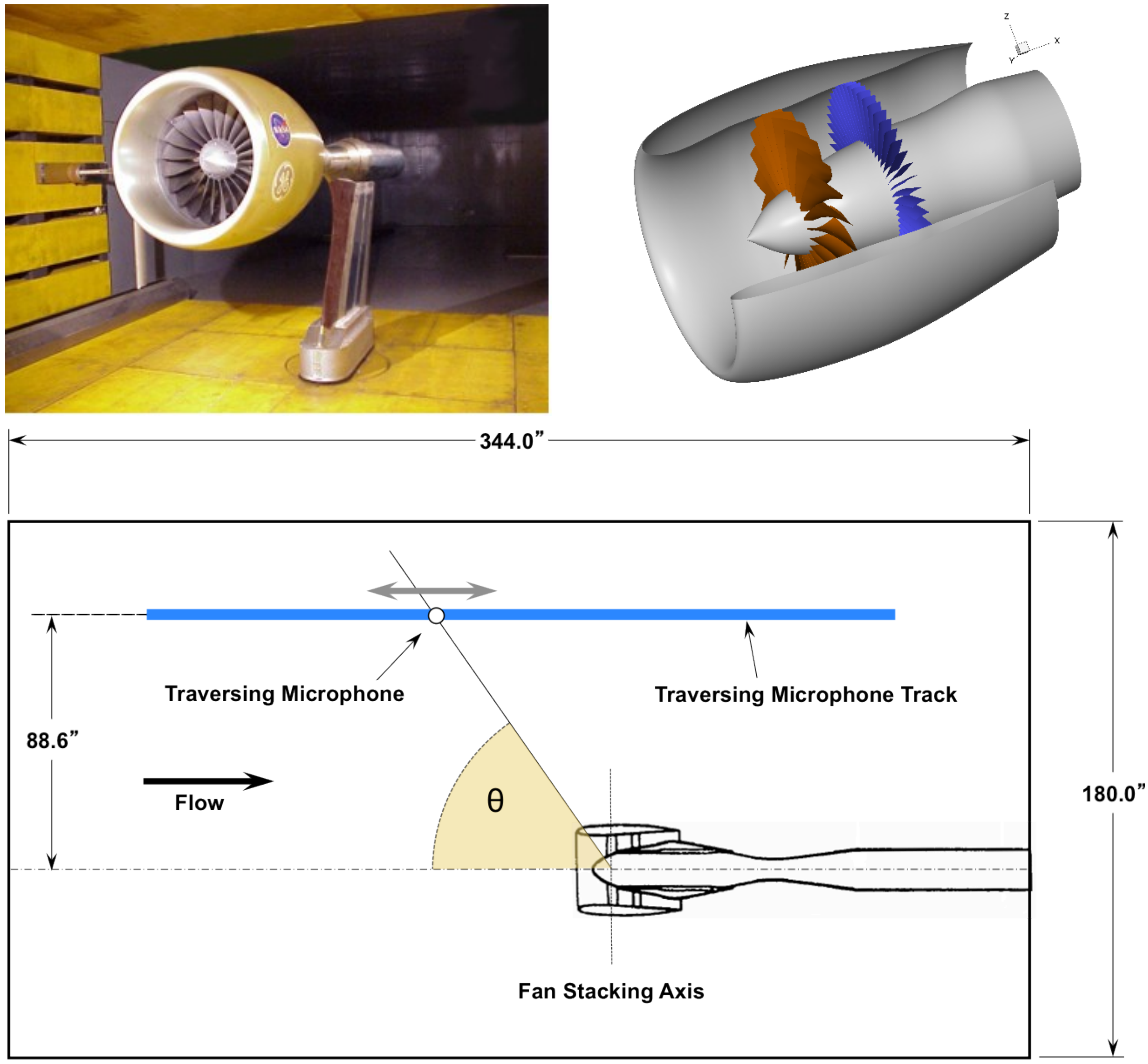


Figure 2. The Source Diagnostic Test (SDT) Fan Rig (top). Top view of the test layout in the 9-foot by 15-foot Acoustic Wind Tunnel (bottom). Dimensions are in inches.

The input data that will be provided are as follows:

Fan Stage Geometry: The geometric definition of the fan stage including the internal flowpath, rotor & stator airfoil sections, and nacelle. This information is available in two formats from which the participants can choose. A Cartesian coordinate system based definition and a CAD based definition in IGES format.

Aerodynamic input information:

1- The CFD-based description of the axisymmetric flow inside and outside of the fan nacelle, but not including the 3D flow regions associated with the rotor and stator (see Figure 3). Data provided at all five speeds of interest.

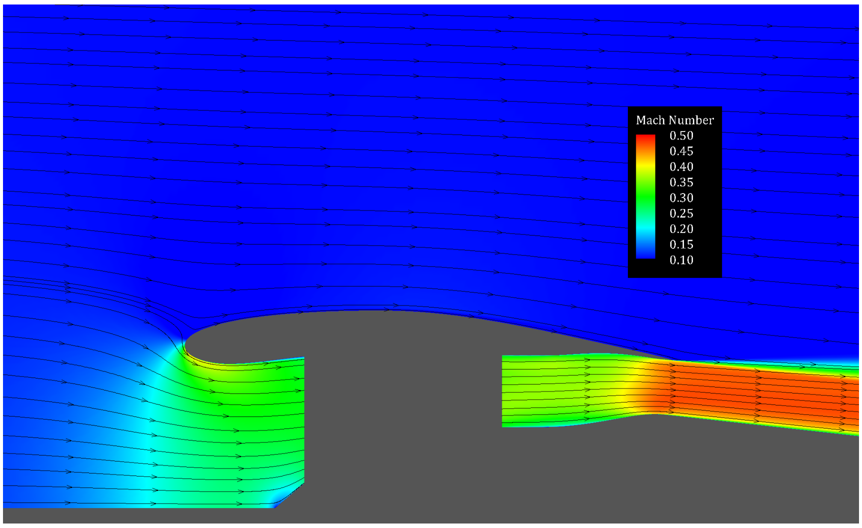


Figure 2. Axisymmetric flow inside and outside of the fan duct (Source: CFD). Mach number contours are shown. The flowfield in the vicinity of the fan stage is not shown.

2- The measured and turbulence velocity components as a function of the spanwise and pitchwise locations at two axial stations indicated in Figure 3. Measurements were obtained using hot wire anemometry. Data is available only at the approach speed.

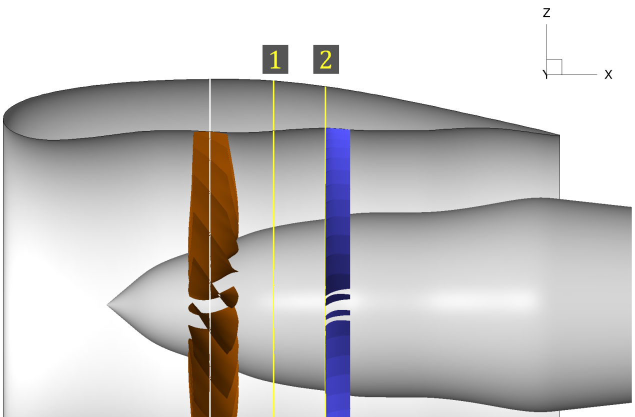


Figure 4. Measured mean flow and turbulent velocities are given at the axial station 1 (*x* = 4.00 inches) and axial station 2 (*x* = 7.26 inches). All coordinates are referenced to the axial location of the fan stacking axis (*x* = 0.00 inches).

References

1. Yuska, Joseph A.; Diedrich, James H.; and Clough, Nestor: Lewis 9- by 15-Foot V/STOL Wind Tunnel. NASA TM X–2305, 1971.

2. Arrington, E. Allen; and Gonsalez, Jose C.: Flow Quality Improvements in the NASA Lewis Research Center 9- by 15-Foot Low Speed Wind Tunnel; Final Report. NASA CR–195439, 1995. Available from the NASA Center for Aerospace Information.

3. Woodward, Richard P., et al.: Background Noise Levels Measured in the NASA Lewis 9- by 15-Foot Low-Speed Wind Tunnel. NASA TM–106817 (AIAA–95–0720), 1995.

4. Hughes, C.E.: Aerodynamic Performance of Scale-Model Turbofan Outlet Guide Vanes Designed for Low Noise. AIAA–2002–374, 2002.

5. Woodward, Richard, et al.: Fan Noise Source Diagnostic Test—Far-Field Acoustic Results. AIAA–2002–2427, 2002.