AFC Sweeping Jet Aeroacoustic Measurements and Phased Microphone Array Development

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Topics

• Active Flow Control (AFC) sweeping jet acoustic and flow measurements (AATT High Aspect Ratio Wing) – paper submitted to 22\textsuperscript{nd} AIAA/CEAS Aeroacoustics Conf

• Array fairing, windscreen optimization (TTT Advanced Sensors)

• ARC/GRC/LaRC common reference phased microphone array and calibration sources (AATT ANR FY16 OGL task)
AFC Sweeping Jet Acoustic Study in ARC anechoic chamber

- Single full- and dual half-scale actuators relative to 2013 757 rudder test with 37 actuators
- Actuators on wall plate, exits ~13” downstream of 4”x10” nozzle
- $0 < M_{\text{NOZZLE}} < 0.19, 5 < P_{\text{IN}} < 33 \text{ psig}, \Rightarrow 24 < W < 88 \text{ scfm(FS)}$
Half-scale actuator configurations

Single sweeping, steady jets measured independently

Dual sweeping jets, independent and synchronized in-, out-of-phase (shown)
Sweeping jet visualization, computation

Instantaneous Schlieren image of sweeping jet actuator

Time-avg. Schlieren image of sweeping jet actuator

Mach No. profiles on sweeping jet nozzle exit plane at 8 intervals within one oscillation cycle. Overflow computation (Childs)

Sweeping Jet Sound Power Spectral Density

Red: M=0, Blue: M=0.15

Broadside to wall
Emission angle $\theta = 90^\circ$
Azimuth angle $\phi = 0^\circ$

Sideline to wall
Emission angle $\theta = 90^\circ$
Azimuth angle $\phi = 90^\circ$
Half-scale single, dual actuator tone directivities

**Fundamental F0 = 420 Hz**
- 12th oct., M=0, 10 scfm, phi at theta = 90°, F0 = 420 Hz

**1st harmonic F1 = 840 Hz**
- 12th oct., M=0, 10 scfm, phi at theta = 90°, H1 = 841 Hz

\[ \theta = 90° \text{ (cross-flow plane)} \]

\[ \phi = 0° \text{ (symmetry plane)} \]
Compare sweeping vs steady jet at similar pressure, flow rate

Pressure vs flow rate characteristics for sweeping jet (red) vs steady jet (blue)

At same supply pressure, sweeping jet broadband level ~3 dB higher than steady jet. At same flow rate, sweeping jet bb. Level is ~10 dB higher
Steady Jet: Flow Rate Scaling (low freq)

Half-scale non-sweeping jet PSD’s, $R = 48''$, $\theta = 90°$, $\phi = 45°$, $M = 0$, unscaled (left) and scaled with 4th power of flow rate, $7.1 < W < 23.4$ SCFM. $(+40 \log(W/W_{REF})$)
Sweeping Jet: Flow rate scaling (low freq)

Half-scale sweeping jet PSD’s, $R = 48''$, $\theta = 90^\circ$, $\phi = 45^\circ$, $M = 0$, unscaled (left) and scaled with 2nd power of flow rate, $8.2 < W < 19.4$ SCFM ($+20 \log (W/W_{\text{REF}})$)
Velocity Profiles from Total Pressure Surveys

Velocity scaled by avg exit value for the configuration, max at $x/W_J = 2$
Spatial scale increases linearly with downstream distance
Dual actuator profiles in progress: indep, in-/out-of-phase

(Single Sweep Jet)

(Single Steady Jet)

(Plot size scale grows with downstream distance)
TTT: Assess New Windscreen Design, Microphone Mounting on Array Background Noise/Response

ARC 1.5 oz Kevlar screen, 15 cgs Rayl, 2-6 dB reverb + 20kHz noise

ARC 200x600 s.st. windscreen, 15 cgs Rayl, 2-6 dB reverb, no HF noise

Windscreen DP vs normal flow vel
Slope is \( \frac{d\Delta P(Pa)}{dVn(m/s)} \) or MKS Rayls

2nd Small array at GRC(Podboy) with 2 cgs Rayl s.st. windscreen. No HF noise, reverberation seen
TTT: Assess small array fairing flow quality, deeper recess mods

- Mount existing array in floor of FML LSWT, speaker in ceiling
- +/- 3° pitch, 0-30° yaw
- Look for separation (tufts) variation in background noise
- Add lower dummy fairing and assess flow quality (tufts), noise, try different windscreens, fairing mods
AATT ANR FY16 OGL: “Supermic” – develop common in-flow reference array and calibration sources

- Proposal from Microphone Array Experimental Methods Team
  - (ARC: Horne, Burnside, GRC: Podboy, Stephens, LaRC: Bahr, Humphreys)

- Build on success with TTT small in-flow fairing array,
  - 10-20 dB background noise suppression relative to single microphone, $2 < f < 50$ kHz for in-flow acoustic measurement.
  - inherent level accuracy with small measurement capture angle, similar to LaRC SADA in QFF
  - Size is compatible with small (QFF) $\rightarrow$ large (14x22, 9x15, 40x80) acoustic test facilities
  - Test bed for assessing new sensors, processing algorithms, etc, Open design for govt, industry, university aeroacoustic facilities.

- FY16 tasks
  - ARC: build 3rd array for LaRC
  - GRC: continue development and calibration methods, goal +/- 0.5 dB level accuracy with 10-20 dB background suppression

- FY17 proposed tasks
  - assess in-flow array performance re SADA out-of-flow in QFF
  - Quantify characteristics of 4 array installations: 1) in-flow, strut mounted, 2) in-flow, wall mounted, 3) out-of-flow looking through shear layer, 4) out-of flow, looking through porous screen (Kevlar, s. steel)
Concluding Remarks

• Acoustic measurements of full, half-scale single and dual actuators at $M = 0, 0.15$ complete at ARC. Planning acoustic test tasks supporting FY17 AFC high-lift experiment.

• Velocity profiles from total pressure probe surveys in progress in ARC anechoic chamber.

• Small reference array optimization (windscreens, fairing aero) in progress at ARC, GRC.

• AATT ANR FY16 OGL task to further develop small in-flow array as a common research and reference array in progress.