Fan Broadband Noise Generation and Suppression

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Outline

- Introduction to Fan Noise
- Generation Mechanisms
- Suppression Techniques
- Summary
Much of the data presented here is from NASA wind tunnel tests and FAA databases. Engine and fan noise data are company proprietary and not publicly available.
Noise data are presented here using a variety of metrics including sound pressure level (SPL) spectra, sound power level (PWL) spectra, and Effective Perceived Noise Level (EPNL).
Aircraft noise has an adverse effect on the environment and as a result it is regulated.
A Growing Problem

Projected growth of passenger traffic in the U.S.

Source: FAA Report
Community Noise Metric

Cumulative noise (CUM) margin is the sum of the individual margins. (Airbus 380-842 CUM Margin = 16.4 EPNdB)
Fan is one of the several engine noise sources.
Fan is a significant contributor to the overall engine noise emissions.

Estimated Source Level Breakdown for a High Bypass Ratio Turbofan
Directivity of Fan Noise

Approach Condition

Lateral Condition
Characteristics of Fan Noise

Fan noise has rich content and characteristics.

Source: NASA Data

Blade Passing Tones (Fan Tones)
Fan broadband noise is the non-tonal component of the spectrum (i.e., part not coherent to the fan shaft rate).
Fan Broadband Noise

- Fan noise is principally produced as a result of unsteady flow perturbations interacting with the fan blades and the outlet guide vanes.

- Fan broadband noise is generated by the interaction of flow turbulence with the blades and vanes.

- Important sources of fan broadband noise include ...
Inlet boundary layer (BL) turbulence is scattered into sound by the rotor blade tips.

Inlet turbulence impinging on the blades is another noise source.

Blade BL turbulence is scattered into sound at the trailing edge.
The principal source of fan broadband noise is the interaction of rotor wake turbulence with the fan exit guide vanes.
Generally rotor/stator interaction noise is more important than rotor self-noise though the latter should not be ignored.
Effect of Rotor Transmission

- Inlet/exhaust power noise split is partly governed by the rotor acoustic transmission which is controlled by the rotor geometry and flow swirl downstream of the rotor ...
Inlet/exhaust power noise split is partly governed by the rotor acoustic transmission which is controlled by the rotor geometry and flow swirl downstream of the rotor.

As the rotor blade count decreases, swirl becomes the primary barrier against the rotor acoustic transmission.
Effect of Tip Clearance

Tip gap does not have a significant influence on noise.

Source: NASA Data
Noise Mitigation
The advent of high bypass ratio engines has been a major factor in reducing both fan and jet noise.

Levels corrected for engine count and thrust level.
Acoustic liner is a common noise reduction technology used in aircraft engines today.
Overall, no significant difference was seen in the performance of SDOF, DDOF, and Bulk liners over a wide range of frequencies.

Source: NASA Data
Substantial noise reduction can be achieved using liners over a wide range of frequencies and tip speed conditions.
Vane Count

- Cut-Off OGV
  
- Cut-On OGV

- Cut-On OGV (Swept)

Reduce Broadband Noise

Reduce Tone Penalty
Vane count reduction can reduce R/S interaction broadband noise.

Source: NASA Data
Operating the fan close to its highest efficiency point at each tip speed should reduce fan noise by improving flow incidence on the fan blades.

*Open area exaggerated for illustration purposes.*
Broadband noise level reductions were measured for all fan operating conditions over a wide range of frequencies.
Soft Vane

Positive levels denote noise reduction.

Broadband Noise Reduction

Source: NASA Data
Over-The-Rotor (OTR) Treatment

FJ44 Engine

Standard Fan Case

Stainless Steel Foam Metal

OTR-Treated Fan Case

Frequency Range
0.5BPF – 1.5BPF

Frequency Range
1.5BPF – 2.5BPF

Broadband Noise Reduction

Source: NASA Data
Concluding Remarks

- Fan is an important source of aircraft engine noise whose importance is likely to grow with increasing engine bypass ratio.

- A better understanding of its source mechanisms and scaling laws should provide deeper insight for devising methods for mitigating it.

- Noise reduction benefits drawn from cycle change will likely reach a plateau requiring more reliance on noise reduction technology.

- More innovative noise reduction techniques may have to be brought to bear to make substantial breakthroughs in reducing fan broadband noise.
Questions?