Fan Noise

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Air System Engineering & Technology (ASET) Conference–Europe
Lyon, France • L'Espace Tête d'Or • 20 February 2018
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Learning Objectives

- **Origin of fan noise**
  - Tonal and Broadband noise
  - Noise prediction
  - Noise reduction means

- **ISO standards for measuring fan noise**

- **Acoustic system effect**
Origin of Tonal noise

- Periodic unsteady loading due to non-uniform mean flow velocity at the blade leading edge
  - Periodic fluctuation of the angle of attack $\rightarrow$ periodic fluctuation of the blade lift $F$ $\rightarrow$ noise generation at the blade passage frequency and its harmonics

- Interaction of the blade wakes with downstream stationary obstacles
Origin of Broadband noise (1)
Self-noise

- **Blade trailing-edge noise**
  - Scattering of the wall-pressure fluctuations in the turbulent boundary layer by the trailing edge
    - With or without separation of the boundary layer on the suction side

- **Vortex shedding noise** *(narrowband)*
  - Vortices in the wake of thick trailing edge
Origin of Broadband noise (2)

Interaction noise

- **Blade leading-edge noise**: interaction of the inlet turbulent flow with the leading edge
  - Inlet random flow velocity fluctuations $\rightarrow$ random lift fluctuations $\rightarrow$ broadband noise generation
Origin of Broadband noise (3)

Interaction noise

- Axial flow fans
  - Tip clearance noise
    - Interaction of the tip vortex with:
      - the blade itself or the adjacent blade
      - downstream stationary obstacles
  - Rotor-stator interaction

- Centrifugal fans
  - Interaction of the blade wakes with the volute cutoff
Noise prediction (1)

- **Tonal noise**
  - Input data of the noise prediction ➔ periodic forces on the blades
    - May be deduced from CFD computation (URANS simulation)
    - Far-field noise may be calculated by several methods (e.g. the Ffowcs Williams-Hawkings equation)

- **Broadband noise**
  - Much more complex to predict
    - **Analytical models** to predict specific noise mechanisms (e.g. Amiet's model to calculate the leading-edge or trailing-edge noise) ➔ the input data of the models (wall-pressure fluctuations or velocity fluctuations in the blade boundary layer) are difficult to assess by measurement or CFD simulation
    - **Hybrid methods** coupling an unsteady CFD simulation (LES) and a sound propagation code based on Finite/Boundary Element Method
    - **Lattice-Boltzmann Method** to predict the air and sound performance simultaneously
Noise reduction (2)
(some means)

- **Tonal noise**
  - Avoid inhomogeneous mean flow velocity at the impeller inlet
  - Keep obstacles as far as possible from the fan outlet

- **Broadband noise**
  - Serrations on the blade leading edge/ trailing edge
  - Porous material on the blade  European project "SmartAnswer" in progress
Fan noise measurement standards (1)

- **ISO 13347** "Determination of fan sound power levels under standardized laboratory conditions"
  - Test methods for measuring the sound power levels at the fan inlet or outlet or from the fan casing
    - Reverberant room method (part 2)
    - Enveloping surface methods (part 3)
    - Sound intensity method (part 4)
  - The air performance of the fan has to be measured simultaneously according to ISO 5801

- **ISO 5136** "Determination of sound power radiated into a duct by fans and other air-moving devices – In-duct method"
Fan noise measurement standards (2)

Reverberant room method
(inlet noise in category B configuration)

In-duct method

In-duct microphones with nose cones
Acoustic system effect (1)

Definition

- Difference in sound levels of the fan with and without a fitting or obstacle at its inlet or outlet

Origin

- Two main causes of SE
  - Deterioration of the flow conditions in the impeller due to the inlet/outlet obstacle
  - Acoustic loading effect due to the reflection of the sound waves radiated by the fan into the duct system.
Acoustic system effect (2)

- Disturbed flow at the fan inlet due to the inlet bend
  - Non-uniform mean flow increases the tonal noise level
  - Turbulence increases the broadband noise level

- Sound wave reflections by the ductworks modifies (i.e. increases or decreases) the fan sound power level

Diagram of a fan in a simplified system

20 Feb. 2018 www.aset-europe.com
AMCA ASET-Europe Conference, Lyon, France
Acoustic system effect (3)

Example of a backward-curved centrifugal fan with an inlet cabinet of various widths

Difference in the inlet overall sound power levels with and without the cabinet
(D: impeller diameter)
Conclusion

- Fan aeroacoustics is a complex matter coupling acoustics and fluid mechanics sciences
  - The noise generation mechanisms are not yet fully understood, especially those regarding the broadband noise
  - Progress are made in Computational Fluid Dynamics (CFD) and Computational Aeroacoustics (CAA) but these prediction methods require further knowledge and a tremendous computational effort
  - Experimental work is necessary to validate prediction results or make noise source diagnostic (e.g. source location by beamforming microphone array)

- The International Conference FAN 2018 (www.fan2018.org) will be a good opportunity to take stock of these issues
Questions?

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