AMCA International

Fan Noise

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ensemble, innover et valider

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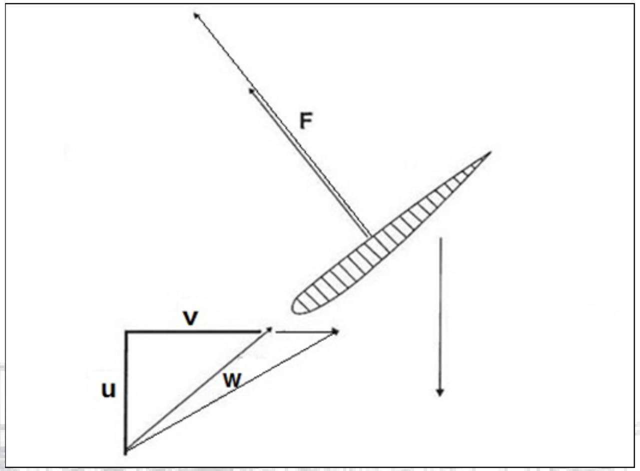
Copyright Materials

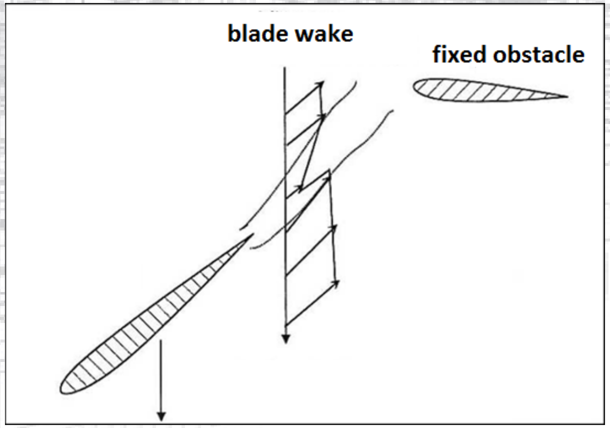
Learning Objectives

- 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

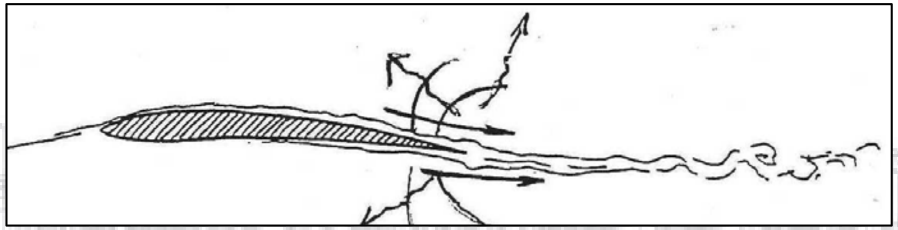
- Periodic unsteady loading due to non-uniform mean flow velocity at the blade leading edge
  - Periodic fluctuation of the angle of attack ➔ periodic fluctuation of the blade lift F ➔ noise generation at the blade passage frequency and its harmonics
- Interaction of the blade wakes with downstream stationary obstacles

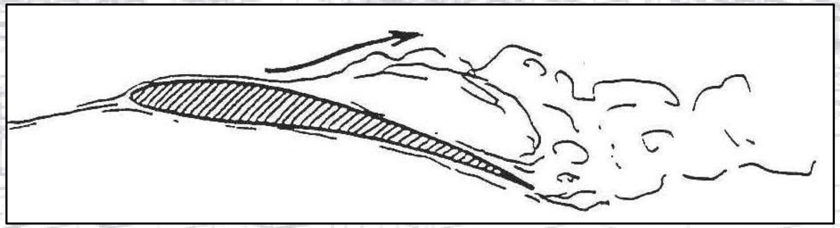




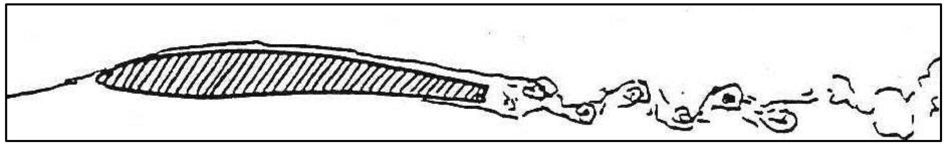
Origin of Broadband noise (1)
Self-noise

- 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



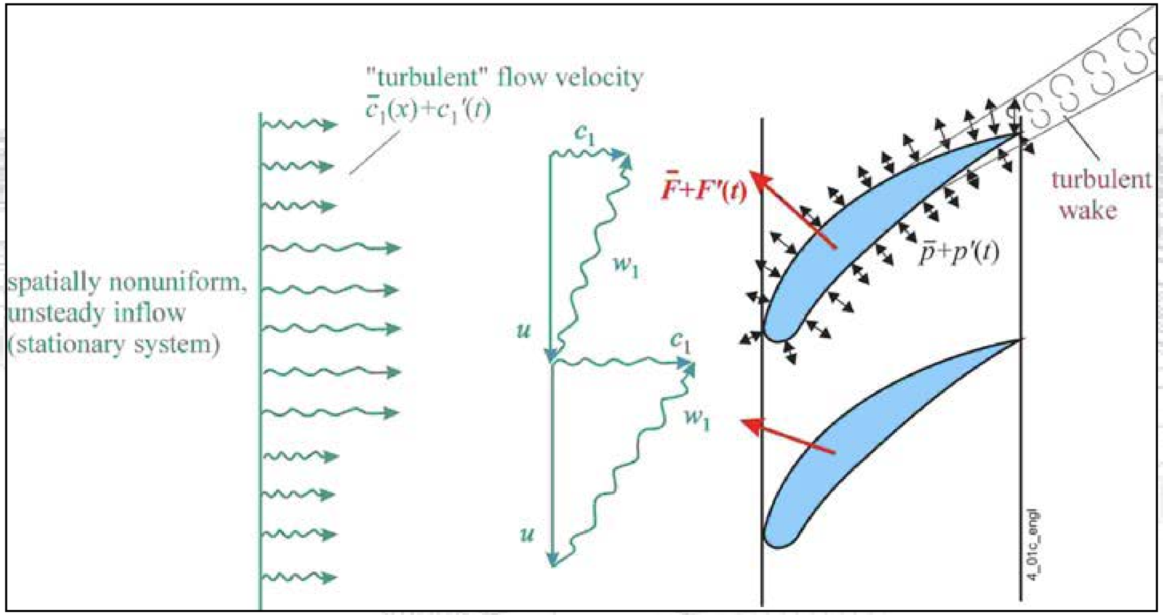


- Vortex shedding noise (narrowband)
  - Vortices in the wake of thick trailing edge

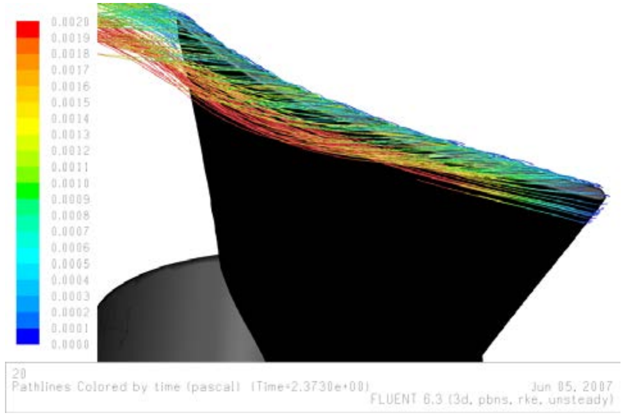


Origin of Broadband noise (2)
Interaction noise

- Blade leading-edge noise: interaction of the inlet turbulent flow with the leading edge
  - Inlet random flow velocity fluctuations ➔ random lift fluctuations ➔ broadband noise generation



Origin of Broadband noise (3)
Interaction noise



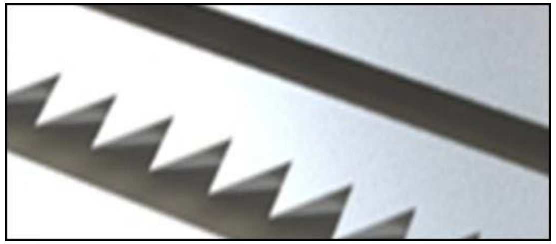
- Axial flow fans
  - Tip clearance noise
    - Interaction of the tip vortex with:
      - the blade itself or the adjacent blade
      - downstream stationary obstacles
  - Rotor-stator interaction
- Centrifugal fans
  - Interaction of the blade wakes with the volute cutoff

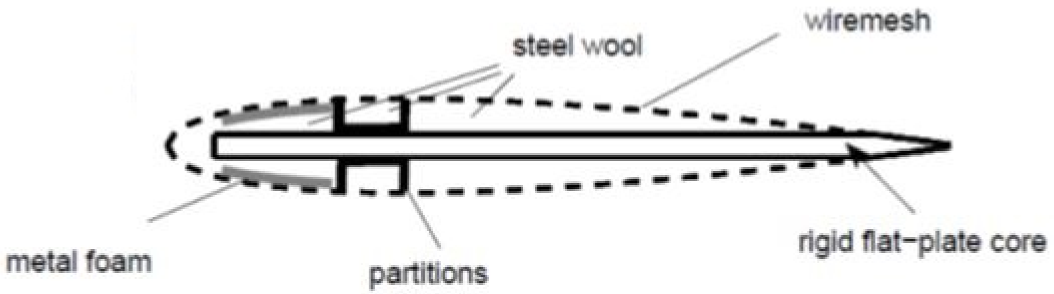
Noise prediction (1)

- 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





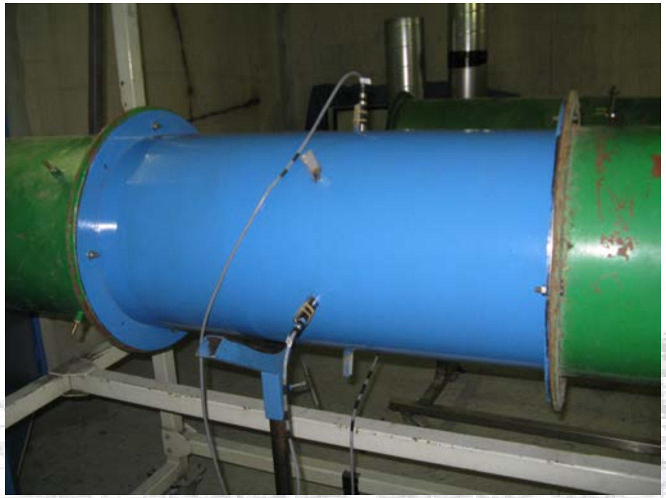
Fan noise measurement standards (1)

- 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)

    } These methods should give the same results
  - 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 microphones with nose cones

In-duct method

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

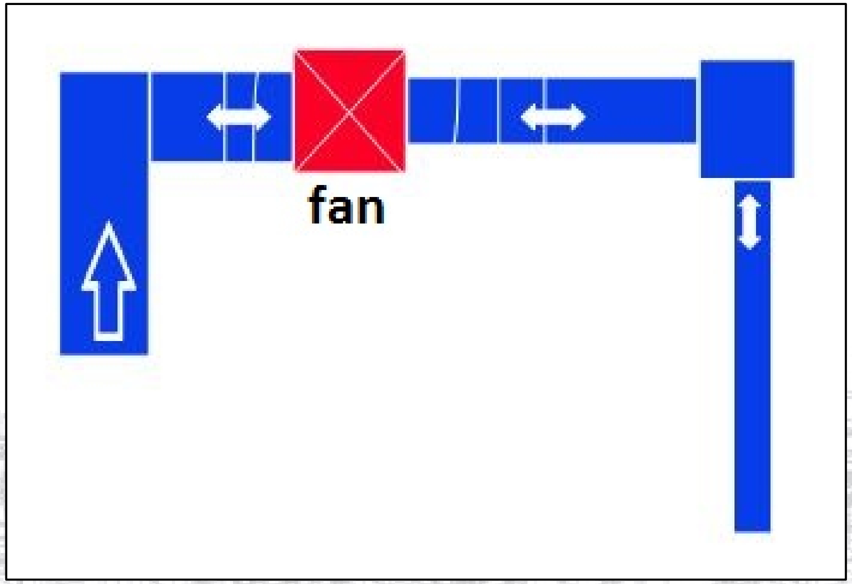
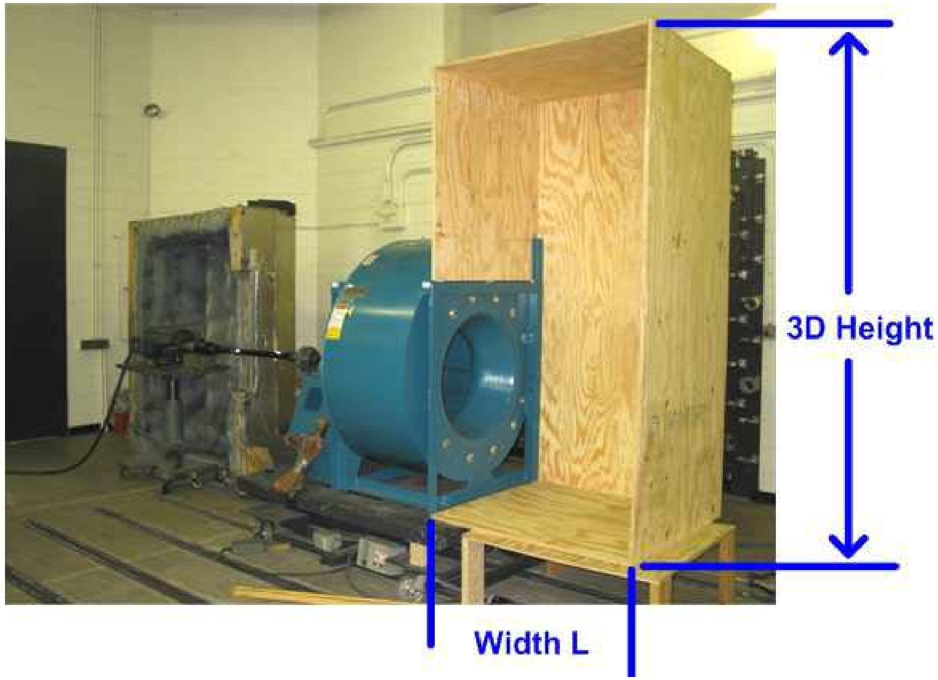
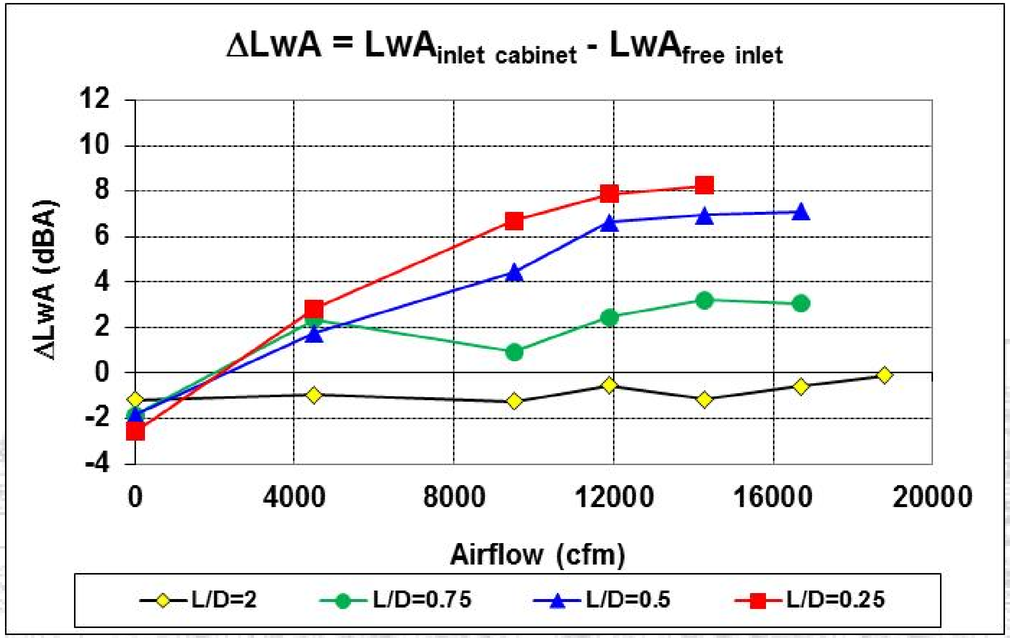


Diagram of a fan in a simplified system

Acoustic system effect (3)





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

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

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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