SmartAnswer – Aerodynamic and acoustic investigation of automotive fan-driven cooling systems.

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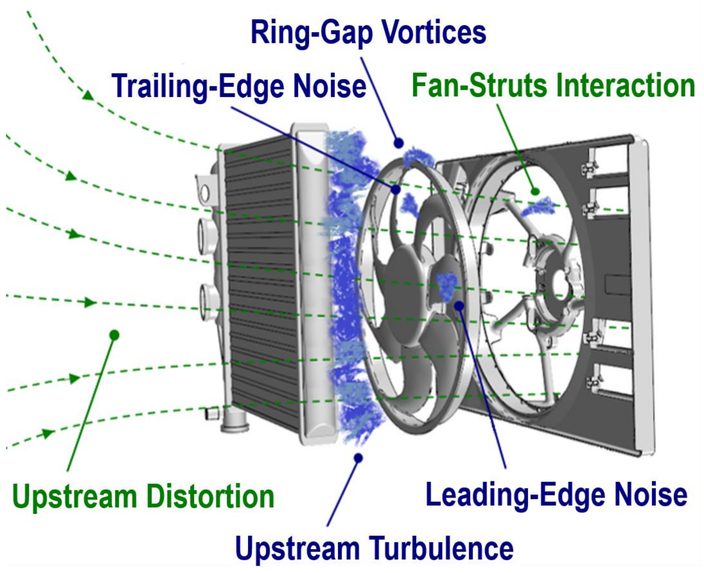
Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

Host institution: von KARMAN INSTITUTE FOR FLUID DYNAMICS

Partnership: ÉCOLE CENTRALE LYON; Valeo

Motivation

In modern and electric automotive engines, the cooling fan has become one of the **greatest source** of tonal and broadband **noise**.



Automotive engine cooling module with noise mechanisms [1].

Different noise-generating mechanisms develop around and on the fan itself:

- **Leading-edge noise,** caused by the impinging turbulent flow generated in the heat exchanger;
- **Trailing-edge noise,** due to flow BL separations on the blades;
- **Tip-clearance noise,** caused by the flow recirculation in the gap between the fan and its casing;
- **Interactions** between the rotor wake with the downstream struts;
- **Non-uniformity** of the upstream flow due to acoustic installation problems.

Main Objective

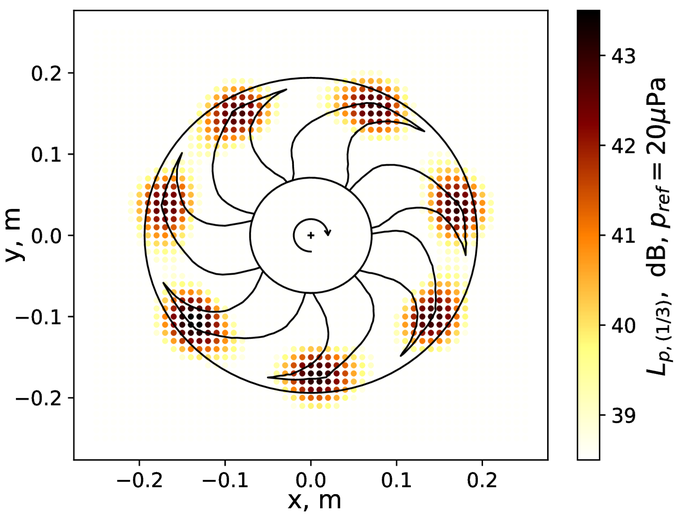
To **locate, quantify,** and **predict** the **broadband** sources emitted by the **fan-driven cooling system**, determining the relative importance of the different **sound-generating mechanisms**.

Sound-Sources Localization

The automotive cooling module working at **three** different **operating conditions** is investigated using a **microphone array** method.

Experiments on an **open-rotor** and on a **full-module** configurations were conducted in the **ALCOVES anechoic chamber** of the VKI.

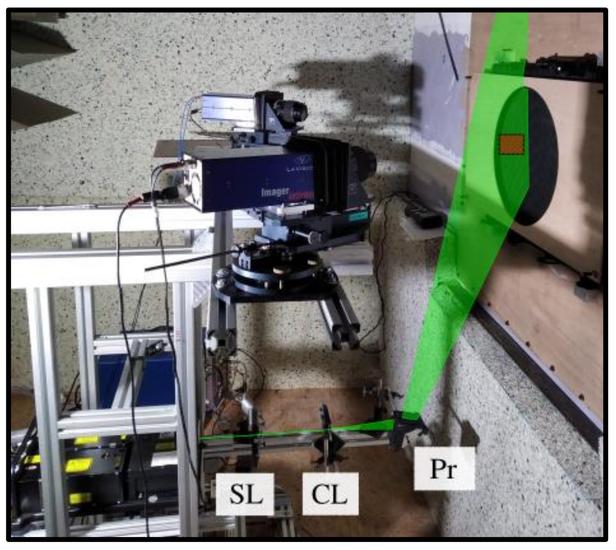
Microphone antenna in upstream of the open-rotor configuration.



The acoustic data are post-processed using a **Rotating Source Identifier** algorithm.

Sound-source distribution for the full-module at nominal working conditions.

Flow Characterization past a Radiator

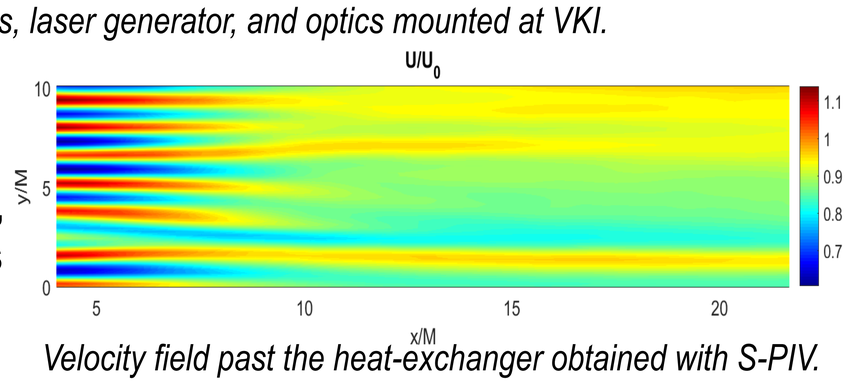


Turbulent flow characterization past the radiator is needed to comprehend the effect of the its **metallic grid** on the fan.

A **Stereo-PIV setup** is designed and installed and **2 configurations** are analyzed: with and without the holed-wood panel, in order to replicate the **flow contraction** caused by the fan casing.

S-PIV setup, with cameras, laser generator, and optics mounted at VKI.

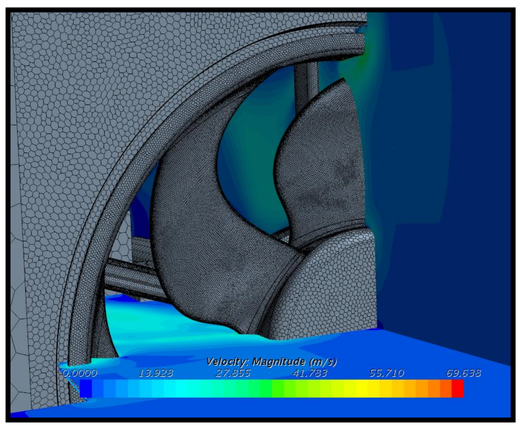
The **isotropic** and **homogeneous** levels of the flow are studied, treating the radiator as a **turbulence grid**.



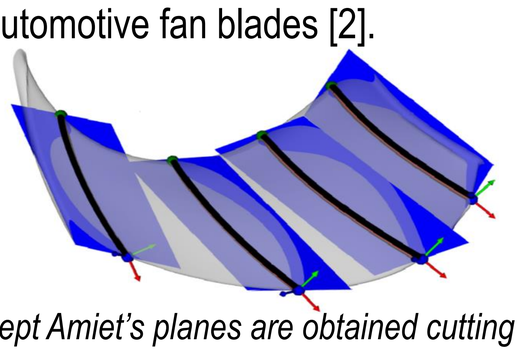
Velocity field past the heat-exchanger obtained with S-PIV.

Acoustic Prediction Methodology

A **low-order noise methodology**, based on **Amiet's theory**, is proposed to take into account the **effect of swept** automotive fan blades [2].



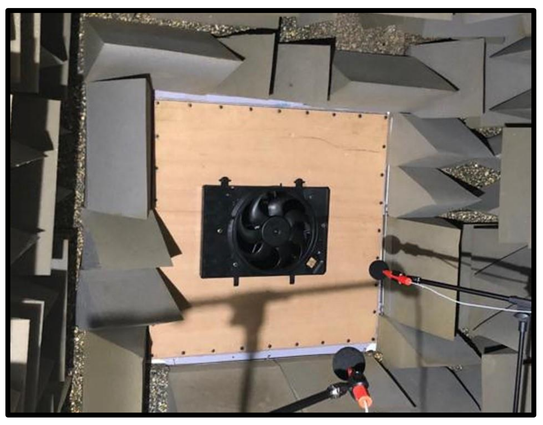
RANS computation is carried out to feed the sound prediction.



Swept Amiet's planes are obtained cutting the blade in strips.

Turbulence-interaction and **self-noise** are predicted based on a **steady-RANS** simulation.

Modelled results are compared with acoustic **far-field measurement**.



Far-field noise of the fan is measured at VKI.

Conclusions

1. For high frequencies, the **main sources** are located at the **tip of the blades** and their locations vary depending on the working conditions.
2. The radiator, found to be **acoustically transparent**, doesn't affect considerably the sound emissions if it is located **sufficiently upstream** in order to smooth out the highly **anisotropic** and **inhomogeneous** flow that it produces.
3. The **sweep angle** is an effective way of mitigating the noise sources and **needs to be accounted for** in a low-order prediction.

References

[1] Amoiridis, O., Zarri, A., Zamponi, R., Christophe, J., Schram, C., Yakhina, G., Moreau, S., "Experimental Analysis of the Sound Radiated by an Automotive Cooling Module Working at Different Operational Conditions," *AIAA/CEAS 2020*, Online Event, 2020.

[2] Zarri, A., Christophe, J., Moreau, S., Schram, C., "Influence Of Swept Blades On Low-Order Acoustic Prediction For Axial Fans", submitted to MDPI Acoustics Journal, 2020.

MARIE CURIE ACTIONS

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