Optimization of tonal noise control with flow obstruction

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Long Abstract

Extended abstract

The present study focuses on the tonal noise produced by low-speed axial fans that are often used in cooling and air-conditioning systems. Such a noise component is not only a major part of the overall noise produced by such ventilation systems (about half or more depending on the operating condition), but also the major source of annoyance (subjective noise) when the tones emerge by more than 10 dBs over the broadband level. In order to limit this nuisance, several passive and active noise control devices have been proposed. A common feature seen for instance in automotive engine cooling fans is to modify the blade distribution to create an axisymmetric fan with static balance that redistributes the acoustical energy at the blade passing frequency and its harmonics into more rotational harmonics. Yet, no complete control can be achieved and moreover the asymmetric blade distribution perturbs the turbulent flow field within the fan and consequently potentially increases the broadband noise component and the perceived overall sound. More recently Gerard et al. have proposed a passive-active control of the tonal noise based on periodic obstructions placed upstream of the axial fan as shown in Fig.1, which can completely alleviate the tonal noise without modifying the overall sound and fan performances significantly [1-4]. Yet the exact noise control mechanism is still controversial and the optimization of the obstruction (shape and position) to achieve an optimal tonal noise control is still empirical and relies on several mock-up designs and lengthy experimental trial and error tests. An unsteady numerical procedure is proposed here, which can bring both a better understanding of the noise mechanism control at stake, and a more efficient optimization procedure for the obstruction shape and position.

The unsteady numerical simulation of the ducted axial fan relies on the Lattice Boltzmann Method and is achieved with the flow solver Powerflow from Exa. It mimics the complete experimental set-up at Université de Sherbrooke shown in Fig.2. A detailed analysis of the mean and statistics of the turbulent flow of the ducted fan without the obstruction will be first presented. A good agreement with the flow and acoustic measurements achieved in this experimental set-up is found, which validates the numerical model. Note that the acoustic validation not only involves the noise spectra at several positions but also the directivity around the ducted fan. A second simulation with a fixed obstruction at a given position is then achieved and validated against similar measurements. The noise mechanism of the passive control achieved by the obstruction will then be deciphered for the first time.

To achieve the optimal flow control by obstruction, Gerard et al. [3] showed that slowly rotating the obstruction allowed a modulation that could be used to facilitate the shape and position optimization. Such a method is first reproduced numerically and showed to correctly account for the corresponding experimental set-up in Fig.2 and to yield the proper acoustic results. A complete numerical procedure in four steps is then proposed and a maximum of six simulations is shown to provide the optimal shape and position of the obstruction to minimize or alleviate the tonal noise at the blade passing frequency as a single pattern periodic obstruction is used.

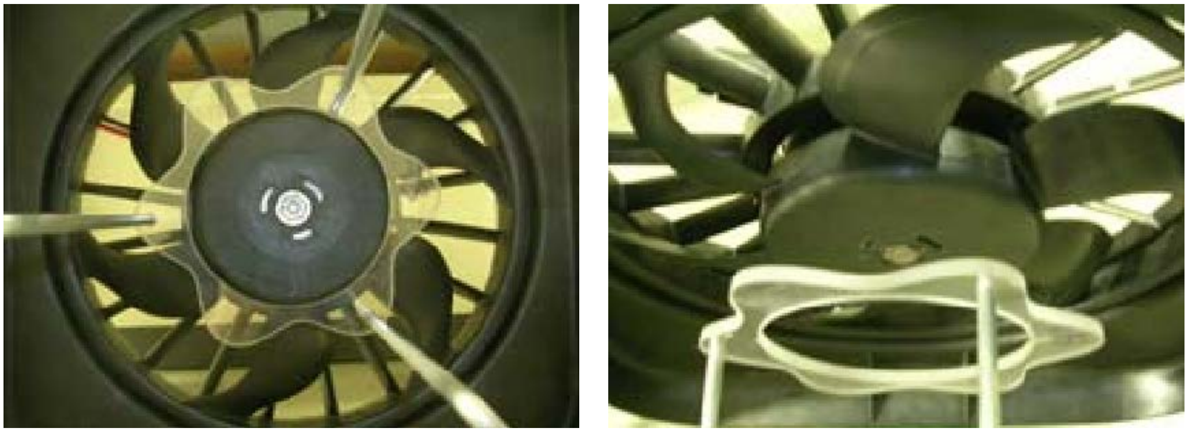

Figure 1. Wavy obstruction in front of an axial engine cooling fan (Gerard, 2009)

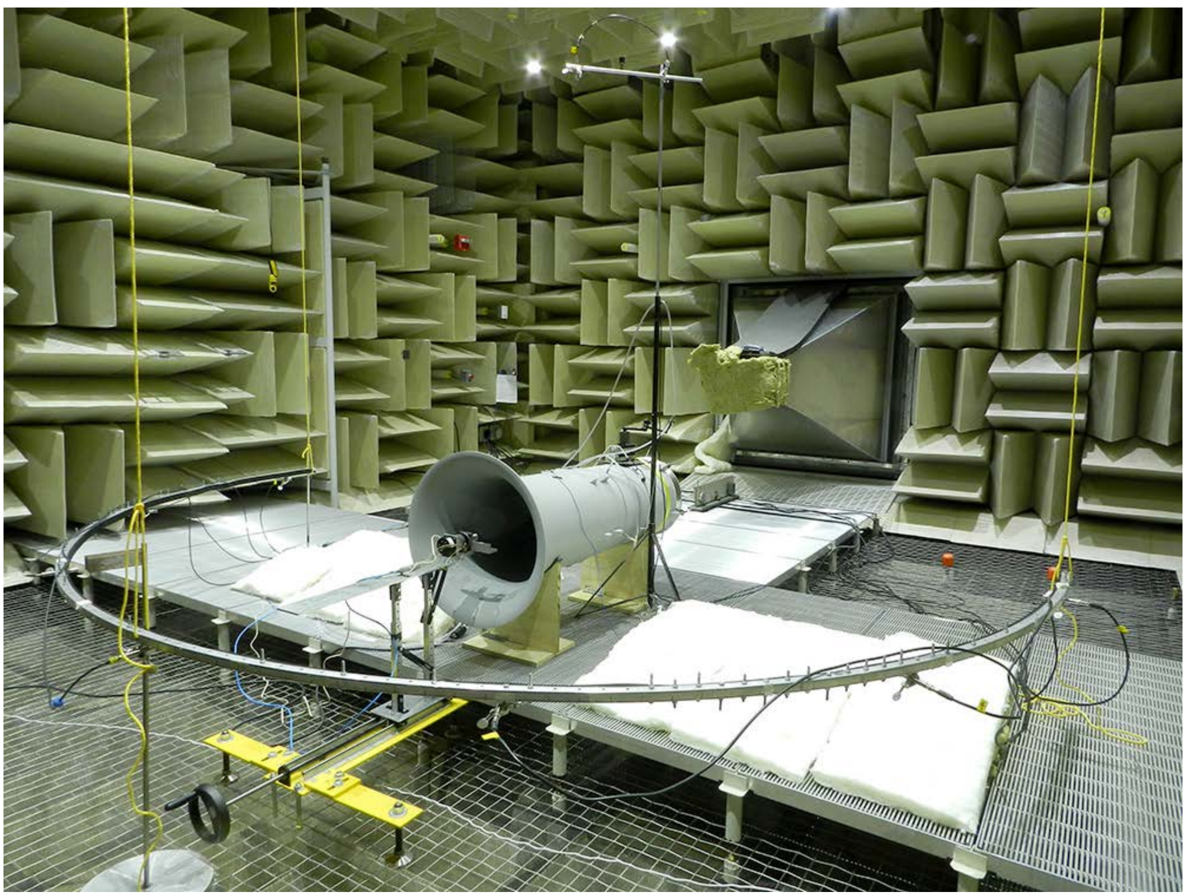

Figure 2. Experimental Set-up at Université de Sherbrooke

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