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Session:

# Analysis of flow-induced noise sources in an axial flow fan using LES coupled with FW-H equation

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## Introduction

An axial flow fan used for cooling and ventilation generates small pressure rise and large flow rate in the axial direction. In the subsonic flow of the fan, it is known that the loading noise produced by fluctuating forces acting on the blade surfaces is a major source of the noise. Therefore, we analyse the flow-induced noise sources in an axial flow fan using large eddy simulation (LES) coupled with the Ffowcs Williams-Hawkings (FW-H) equation to predict unsteady flow fields and propagating noise.

## Numerical details

We consider an axial flow fan inside an outdoor unit of an air-conditioner, operating at the design condition of the flow coefficient ($\Phi = Q/\rho R_{tip}^2 U_{tip}$) of 0.346, where $Q$ is the volumetric flow rate, $R_{tip}$ is the blade tip radius, and $U_{tip}$ is the tip velocity (Fig. 1(a) and 1(b)). The Reynolds number of the fan is Re = $R_{tip}U_{tip}/\nu$ = 547,000. A dynamic global model [1] is used for a subgrid-scale model of an LES, and an immersed boundary method in a non-inertial reference frame [2] is adopted. Coordinates, computational domain, and boundary conditions are shown in Fig. 1(c). To predict the flow-induced loading noise from unsteady flow fields, we use a method

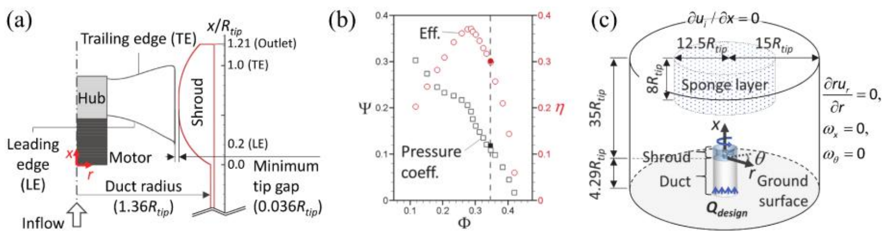


**Fig. 1** Axial flow fan configuration: (a) side view; (b) fan performance curves: the pressure coefficient (Ψ) and efficiency ($\eta$) versus the flow coefficient (Φ); (c) schematic diagram of the coordinates, computational domain, and boundary conditions. In (b), solid symbols are from present LES at the design condition.

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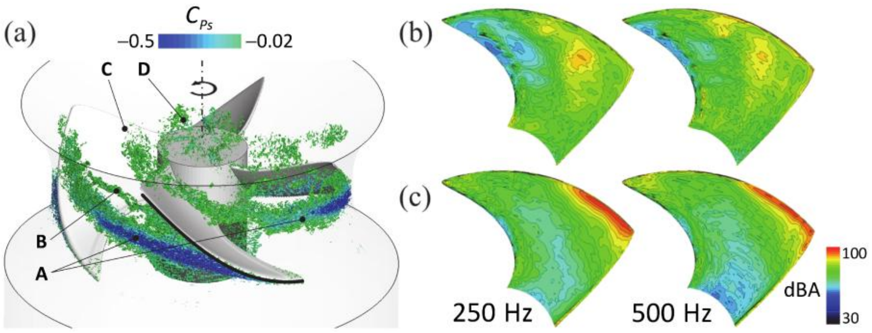


**Fig. 2** (a) Iso-surfaces of $\lambda_2$ = -200 coloured with the static pressure coefficient from an instantaneous flow field. (b, c) Contours of the 1/3-octave band averaged power spectral density of pressure fluctuations on the blade: (b) suction surface; (c) pressure surface.

proposed by Succi [3]. The computational grids are about 200 million which are partitioned over 512 processors.

## Results and discussions

In Fig. 2(a), instantaneous vortical structures are illustrated together with the contours of the static pressure coefficient. The tip-leakage vortex (TLV; A), vortex ropes (B), blade wake (C), and hub edge separation (D) are observed in this figure. Among them, the TLV acts as a major source of pressure fluctuations on the blade surface. On the suction surface (Fig. 2(b)), high pressure fluctuations associated with the inception of the TLV exist around the mid-chord of the blade tip. On the pressure surface (Fig. 2(c)), high pressure fluctuations at the aft part of the blade tip are noticeable, as the TLV impinges on the blade. The effects of the blade pressure fluctuations on propagating noise and the relation between the flow fields and noise will be further discussed at the presentation.

## Acknowledgments

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## References

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