Study of airfoil self-noise

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April 2024

Introduction

This study reflects an analysis of airfoil self-noise production between the two most lifting conditions as previously established by Brooks, Pope, and Marcolini[1]. In general, airfoil self-noise is caused by the interaction between an airfoil blade and the turbulence produced in its own boundary layer. As seen below, we can distinguish two modes. A turbulent boundary layer-trailling edge noise will create a broadband sound, while a laminar boundary-layer-vortex shedding noise will generate a tonal sound.

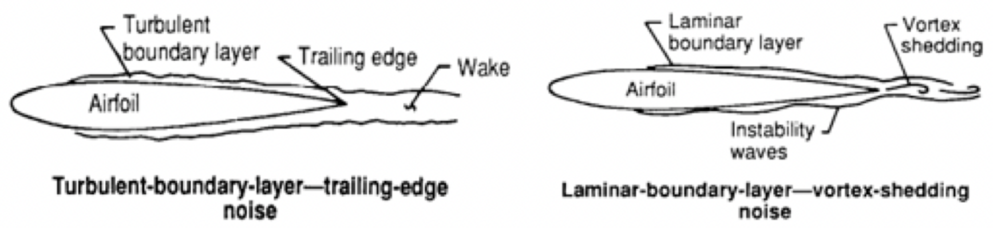

Figure 1: Airfoil Self-Noise Modes[1]

The goal of this study is to determine the generation of these sounds depending on the type self-noise mode, but also to locate them on the airfoil by using beamforming. These experiments are realized in an anechoic vertical low-turbulence open-jet wind tunnel at TU Delft. We studied the NACA 0018 model with the set beamforming positioning as seen below (with green being the airfoil).

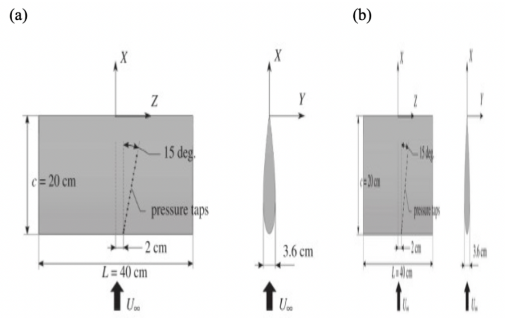

Figure 2: Sketch of the NACA 0018 model. (a) Top view. (b) Side view[2]

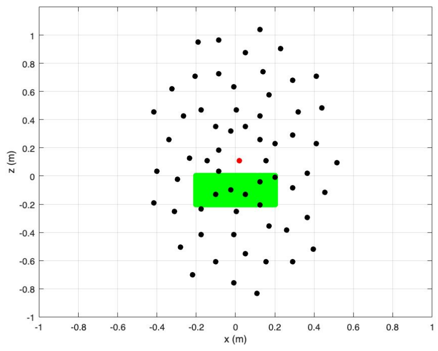

Figure 3: Microphone Array Distribution

Experimental measurements and results

A easy effective way to observe the airfoil self-noise mode is to calculate the average spectra of all microphones. As seen on the figures, a tonal type noise will have a fundamental tone with harmonics. In general, these tonal type noise are due to the angle of attack. It can be seen as well that higher angles of attack with same free stream velocity lead to a higher frequency of the fundamental tone. For a trailling-edge noise, we observe a broadband band type noise. This is a common noise type when the airfoil is not severely inclined or when we have a relatively high Reynolds number.
Obtaining the fundamental tone is important to optimize airfoils to reduce the radiated noise. However, it is also important to locate the sound sources. Beamforming is a common method to evaluate this task. For a tonal type noise, we can identify the scattering noise at the vortex because the beamforming output highlights noise after the trailing edge. Finally, for a broadband type noise, we can see that the radiated noise is located on the trailing edge.

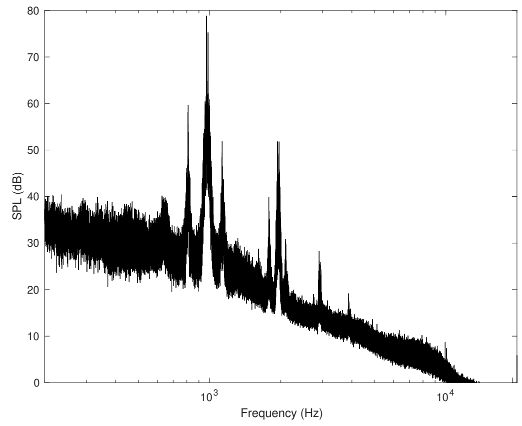

Figure 4: Laminar-boundary-layer-vortex shedding noise

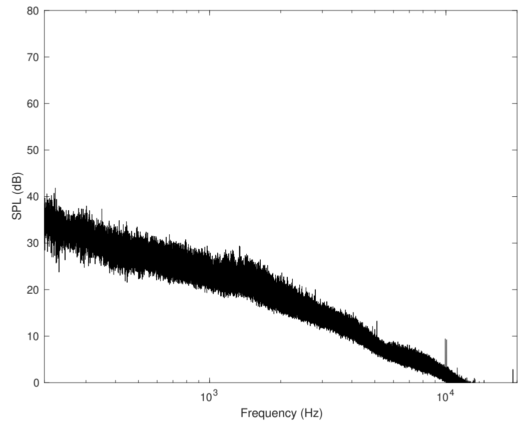

Figure 5: Turblent-boundary-layer-trailling-edge noise

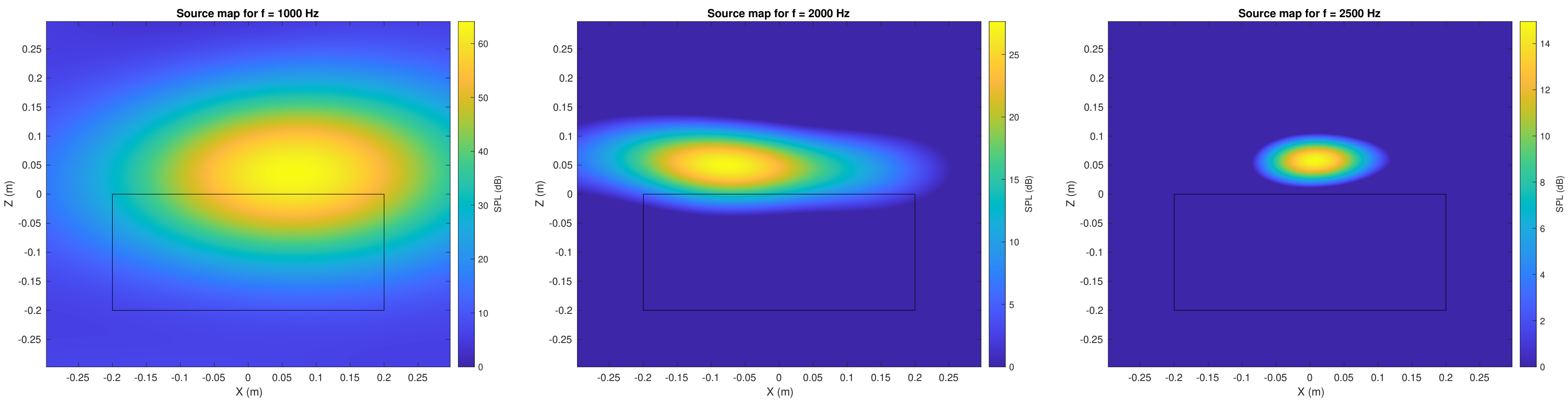

Figure 6: Beamforming output for a laminar-boundary-layer-vortex shedding noise with different frequencies of interest

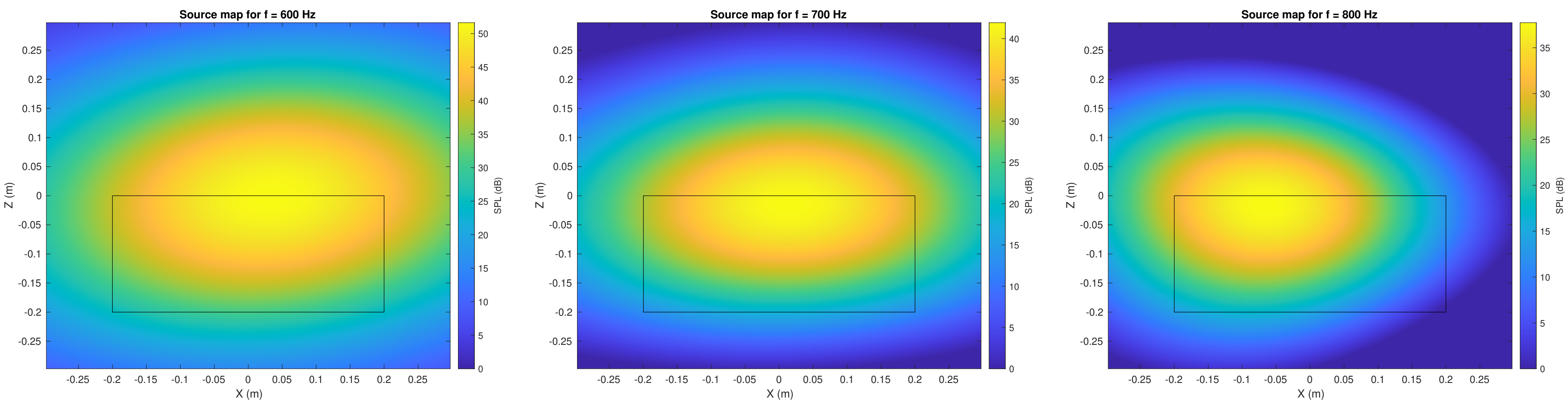

Figure 7: Beamforming output for a turbulent-boundary-layer-trailling edge noise with different frequencies of interest

References

[1] Thomas F Brooks, D Stuart Pope, and Michael A Marcolini. *Airfoil self-noise and prediction*. Tech. rep. 1989.

[2] Alejandro Rubio Carpio et al. "Mechanisms of broadband noise generation on metal foam edges". In: *Physics of Fluids* 31.10 (2019).