Vibroacoustic responses of a panel subject to a turbulent boundary layer excitation

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Predicting the vibroacoustic responses of structures subject to random pressure fields is important in the design of aerospace structures. The objectives of such investigations vary from minimizing structural fatigue damage to reducing noise radiation from the structure [1, 2]. To predict the vibroacoustic responses of a structure excited by boundary layer turbulence, the turbulent pressure field should be obtained on the surface of the structure. This can be done using direct numerical simulation (DNS) or large eddy simulation (LES). However, these simulations are computationally very expensive. Compared to DNS, the computational cost using LES is reduced by only resolving the larger structures in the turbulence and using numerical models to account for the effects of the smaller scales [3, 4]. However even using LES, to accurately resolve the transient hydrodynamic flow field for high Reynolds numbers still requires long simulation run times and large data storage. Due to the high computational cost of the aforementioned transient simulations, statistical methods have been proposed to mitigate these performance constraints. Statistical methods use mean flow data from a steady-state Reynolds-averaged Navier Stokes (RANS) solution [5, 6]. An advantage of these methods is that they are capable of predicting the mean values of turbulent boundary layer parameters with reasonably high fidelity, even for complicated morphology of the surface and various flow conditions. RANS mean flow data has been used as an input to semi-empirical models to predict the body's surface pressure spectrum under a turbulent boundary layer (TBL) [7]. Recently, an uncorrelated wall plane wave (UWPW) technique to synthesize the wall pressure field in terms of a deterministic load was introduced [8]. The advantage of using the UWPW technique is that it is a non-intrusive technique that defines deterministic loads. As such, it can be used in conjunction with any element-based numerical method, such as the finite element method (FEM) to investigate the vibrational response of a structure excited by a TBL as well as the boundary element method (BEM) to investigate the acoustic radiation from a structure exited by a TBL. In this work, a hybrid UWPW-FEM technique is used to predict the structural and acoustic responses of a rectangular baffled panel in low Mach number flow, as shown in Figure 1. Analytical expressions are used to estimate the TBL parameters over the surface of the panel. The spectrum of the wall pressure fluctuations is evaluated from the TBL parameters and by using semi-empirical models from literature. The wall pressure field underneath the TBL is synthesized by realisations of uncorrelated wall plane waves. The UWPW-FEM approach is adopted to compute the structural and acoustic responses of the panel for each realisation of uncorrelated wall plane waves. The responses are then obtained from an ensemble average of the different realisations. Numerical results are compared with experimental data obtained in an anechoic wind tunnel at the Université de Sherbrooke.

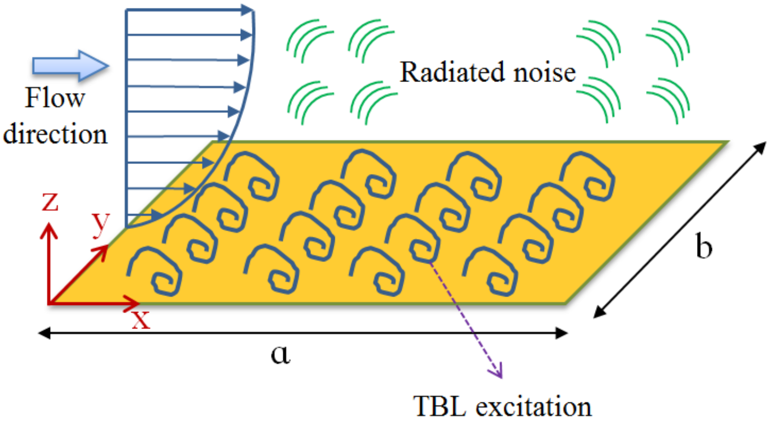

Figure 1: Radiated noise from a baffled panel under TBL excitation

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