Space-time (2D+T) spectral synthesis for studying vibration of and radiated noise from structures under a turbulent boundary layer excitation

Olivier Robin[1], Marc Pachebat[2], Nicolas Totaro[3], and Alain Berry[1]

[1]Groupe d'acoustique de l'université de Sherbrooke, 2500, boulevard de l'université, Sherbrooke, J1K2R1, Canada
e-mail: olivier.robin@usherbrooke.ca, alain.berry@usherbrooke.ca
[2]Laboratoire de mécanique et d'acoustique, 4, impasse Nikola Tesla, 13453 Marseille, France
e-mail: pachebat@lma.cnrs-mrs.fr
[3]Univ Lyon, INSA-Lyon, Laboratoire Vibrations Acoustique, F69621 Villeurbanne, France
e-mail: nicolas.totaro@insa-lyon.fr

The topic of vibration of and radiated noise from structures under a turbulent boundary layer (TBL) excitation has been studied for decades with various applications and scales ranging from cars to aircrafts as well as vessels and submarines [1, 2]. With large interest from several industries and research areas, it remains a critical research topic that is still looking for accurate and cost-effective simulation and measurement techniques. Interestingly enough, the literature records few experimental results in comparison with a very large number of publications dealing with numerical computations. Also, most of the publications concern vibration of structures and very little include radiated sound. This has two important consequences **(1) a reduced number of experiments is available for validating the results of numerical computations** and **(2) perception of the radiated sound from TBL-excited structures is hardly considered even it should be a primary goal for transportation applications**. In many numerical approaches used to predict vibrational responses of structures excited by turbulent flow, the cross-spectral density function describing the wall pressure fluctuations has to be coupled to a deterministic vibroacoustic model. Since a very large number of distributed points on the surface of the structure needs to be considered according to theory, usual requirements in terms of ideal mesh size are deemed unrealistic in many practical cases. Modeling techniques considered as hybrid approaches which combine statistical and deterministic methods were investigated in [3, 4, 5] so as to relax meshing constraints.

In [6], it was proposed to couple a space-time synthesis approach (*i.e.* several consecutive realizations of the wall pressure field, see an example in Figure 1) to a deterministic model so as to predict sound transmission loss of and radiated sound pressure from panels excited by a diffuse acoustic field (DAF) excitation. Both quantities were efficiently predicted and good agreement was obtained with measurements and finite element method predictions. The proposed method has several advantages, that can provide adequate solutions to points (1) and (2) previously expressed : **(1) Each realization of the wall pressure field and obtained vibro-acoustic results can be considered as a virtual experiment, or a series of them can mimic an experiment of variable length**, and **(2) The radiated sound pressure as a function of time and under a random excitation (DAF-TBL) can be obtained and used for listening purposes**.

The presentation will describe the suggested calculation process, and results obtained in the case of two panels excited by a diffuse acoustic field will be recalled. Measurements made on a rectangular aluminum panel with controlled simply-supported boundary conditions and tested in a low-speed anechoic wind-tunnel at a flow sped of 40 m/s [7] will be used as a test case for extending the approach to TBL excitation (see experimental setup in Figure 1).

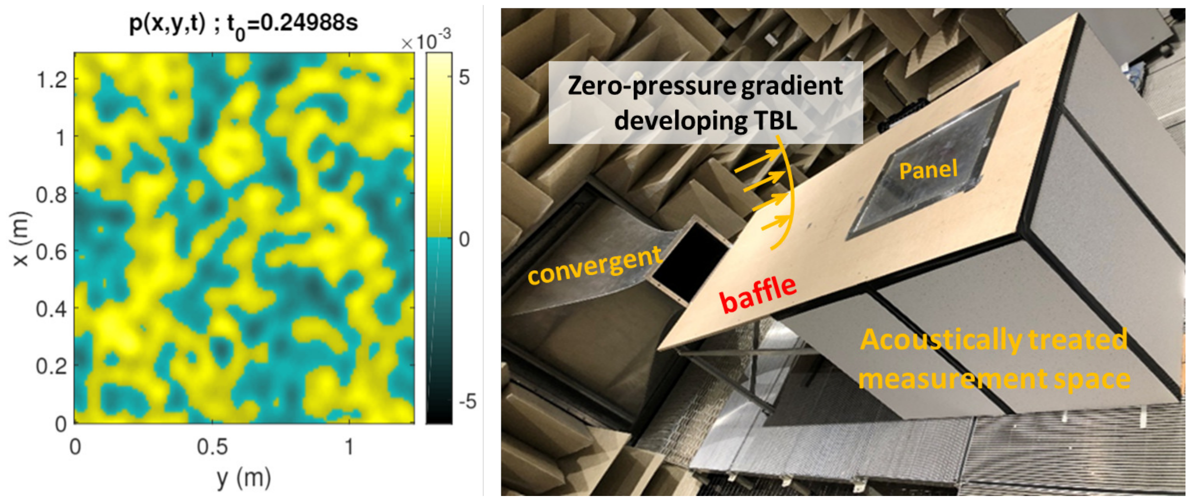

Figure 1: (Left) A realization of the wall pressure field in the case of a diffuse acoustic field excitation; (Right) The experimental setup used for measurements in wind-tunnel.

References

[1] E. Ciappi, S. De Rosa, F. Franco, J.-L. Guyader, and S.A. Hambric (Eds.), 'Flinovia - Flow Induced Noise and Vibration Issues and Aspects - A Focus on Measurement, Modeling, Simulation and Reproduction of the Flow Excitation and Flow Induced Response', Springer, 358 pages (2015).

[2] E. Ciappi, S. De Rosa, F. Franco, J.-L. Guyader, S.A. Hambric, R.C.K. Leung, A. D. Hanford (Eds.), 'Flinovia - Flow Induced Noise and Vibration Issues and Aspects II - A Focus on Measurement, Modeling, Simulation and Reproduction of the Flow Excitation and Flow Induced Response', Springer, 372 pages (2017).

[3] C. Hong, K.-K. Shin, Modeling of wall pressure fluctuations for finite element structural analysis, Journal of Sound and Vibration, **329** (10), (2010).

[4] L. Maxit, Simulation of the pressure field beneath a turbulent boundary layer using realizations of uncorrelated wall plane waves, The Journal of the Acoustical Society of America 140, 1268 (2016)

[5] M. Karimi, P. Croaker, H. Peters, S. Marburg, A. Skvortsov, N. Kessissoglou, Vibro-acoustic response of a flat plate under turbulent boundary layer excitation, Proceedings of NOVEM 2018 Noise and Vibration Emerging Methods; Ibiza, Spain (2018).

[6] O. Robin, M. Pachebat, N. Totaro, A. Berry. Évaluation d'une méthode de synthèse spectrale 2D+T pour la transparence de parois sous champ acoustique diffus. CFA / VISHNO 2016, Apr 2016, Le Mans, France.

[7] M. Jenzri, O. Robin and N. Atalla, Vibration of and radiated acoustic power from a simply-supported panel excited by a turbulent boundary layer excitation at low Mach number, Noise Control Engineering Journal (In press, 2019).