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Internship and PhD thesis proposal 2027 : Mitigation of wall pressure fluctuations beneath a turbulent boundary layer using textured surfaces

The acoustic signature of a naval vessel depends on the noise radiated by the turbulent boundary layer developing along its hull. As illustrated in Figure 1, two contributions can be distinguished : - Direct noise, resulting from the acoustic radiation of the turbulent flow ; - Indirect noise, resulting from the radiation of structures excited by the turbulent boundary layer. The second contribution, which is generally dominant, depends on the spatio-temporal properties of wall-pressure fluctuations (the wavenumber-frequency spectrum). As shown in Figure 2, the most energetic component corresponds to the convective peak, which represents the hydrodynamic signature of turbulent structures convected within the boundary layer. However, for low-Mach-number flows, the wall-pressure components in the subconvective region are generally of particular interest, as they are strongly coupled to the structure's flexural waves.

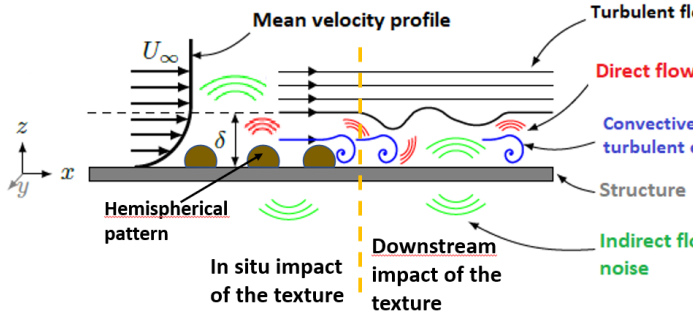


FIGURE 1 – Influence of textured surfaces on the acoustic radiation of a turbulent boundary layer.

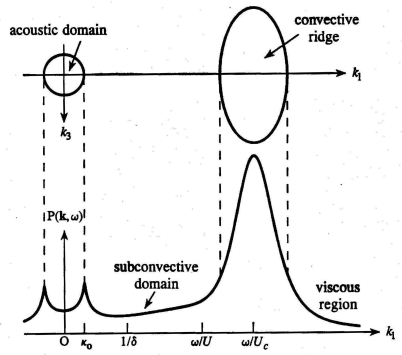
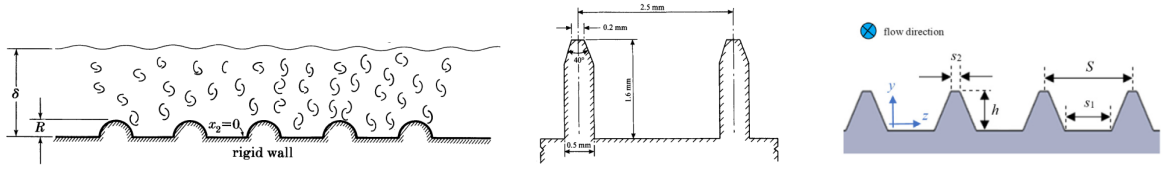


FIGURE 2 – Typical shape of the wall-pressure spectrum [1].



(a) (b) (c)

FIGURE 3 – Exemples de surfaces texturées : (a) réseau d'éléments de rugosité [2], (b) rainures avec un grand rapport d'aspect [3], (c) rainures triangulaires [4].

The objective of the ANR MOLLUSC project (*Mitigation Of waLL pressure fluctuations using textUred SurfaCes*) is to reduce wall-pressure fluctuations over a given frequency range using textured surfaces, such as riblets or periodic arrays of hemispheres (see Figure 3). ENSTA's contribution to this project involves designing textured surfaces and characterizing their performance in a vertical water-flow test facility, as shown in Figure 4. During the internship, wall-pressure measurements will be carried out to characterize the changes induced in the wall-pressure spectrum by different textured surfaces. To determine the optimal texture height h, the friction velocity u_τ and the turbulent boundary-layer thickness δ upstream of the texture must first be determined. For riblets, most studies have considered values of the dimensionless texture height $h^+ = hu_\tau/\nu$ ranging from 8 to 18, where

ν is the kinematic viscosity. During the internship, the parameters h et u_τ along the test section will be estimated using a 2D RANS simulation of the flow. During the PhD, the simulations may be extended to 3D to provide a more accurate description of the flow within the square cross-section, and flow visualizations will be performed using particle image velocimetry (PIV), combined with an optical-flow algorithm, upstream, downstream and at the location of the textures. These visualizations will make it possible to investigate how the textured surfaces modify the structure of the boundary layer.

(a)



(b)

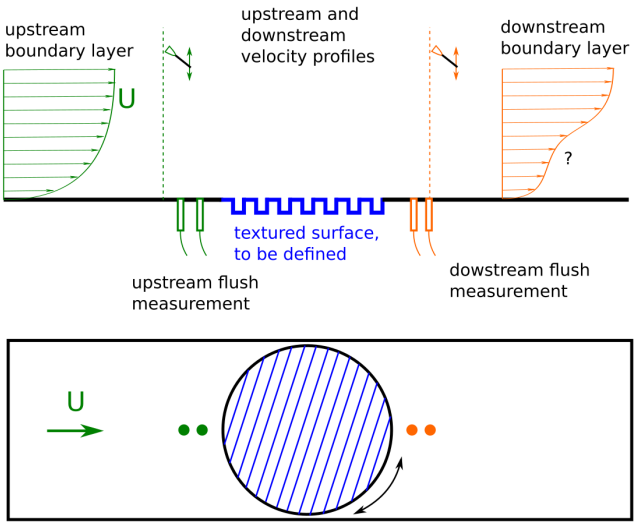


FIGURE 4 – (a) View of ENSTA's vertical water tunnel, and (b) schematics of the experimental setup aiming at characterizing the reduction of wall pressure fluctuations achieved by textured surfaces.

Objectives and Work Programme

The objective of this project is to investigate the reduction of wall-pressure fluctuations using textured surfaces in a vertical water tunnel. The main tasks of the internship are :

1. Characterize the frequency-wavenumber spectra of wall-pressure fluctuations using a hydrophone array for a flat reference surface ;
2. Measure wall-pressure spectra upstream and downstream of different textured surfaces to identify the frequency bands in which pressure fluctuations are reduced or amplified ;
3. Perform two-dimensional RANS simulations of the test facility to characterise the friction velocity u_τ and the turbulent boundary-layer thickness δalong the test section.

Practical Information

— **Candidate profile :** Final year Master or Engineering student with a strong background in fluid mechanics and/or acoustics, and a strong interest in experimental work.
— **Supervisors :** B. Cotté (Associate Professor) and X. Plouseau-Guédé (Postdoc).
— **Duration :** 5 to 6 months.
— **How to apply :** Please send your CV, cover letter, and academic transcripts to benjamin.cotte@ensta.fr.

Références

[1] M.S Howe, *Acoustics of Fluid-Structures Interaction*, Cambrige Univ., 1998.

[2] M.S Howe, The turbulent boundary-layer rough-wall pressure spectrum at acoustic and subconvective wavenumbers, *Phil. Trans. R. Soc. A*, 1988.

[3] K.-S. Choi, Near-wall structure of a turbulent boundary layer with riblets, *J. Fluid Mech.*, 1989.

[4] C. Muhammad and T.P. Chong, Mitigation of turbulent noise sources by riblets, *J. Sound Vib.*, 2022.