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NUMERICAL ANALYSIS OF TURBULENCE AND HEAT EXCITED JET NOISE SOURCES

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ABSTRACT

The generation of noise in subsonic high Reynolds number single and coaxial turbulent jets is analyzed by a hybrid method. The computational approach is based on large-eddy simulations (LES) [1] and solutions of the acoustic perturbation equations (APE) [2].

The method is used to investigate the acoustic fields of one isothermal single stream jet at a Mach number 0.9 and a Reynolds number 400,000 based on the nozzle diameter and two coaxial jets whose Mach number and Reynolds number based on the secondary jet match the values of the single jet [3, 4]. One coaxial jet configuration possesses a cold primary flow, whereas the other configuration has a hot primary jet. Thus, the configurations allow to study the differences between single and coaxial jets and the distinct noise characteristics between hot and cold coaxial flow fields.

For the isothermal single jet the present hybrid acoustic computation shows convincing agreement with the direct acoustic simulation based on large-eddy simulations (Fig. 1). The analysis of the acoustic field of the coaxial jets focuses on two noise sources, the Lamb vector fluctuations and the entropy sources of the APE equations (Fig. 2). The power spectral density (PSD) distributions evidence the Lamb vector fluctuations to represent the major acoustic sources of the isothermal jet. Especially the typical downstream and sideline acoustic generations occur on a cone-like surface being wrapped around the end of the potential core. Furthermore, when the coaxial jet possesses a hot primary jet, the acoustic core being characterized by the entropy source terms increases the low frequency acoustics by up to 5 dB, i.e., the sideline acoustics is enhanced by the pronounced temperature gradient (Fig. 3).

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FIGURES

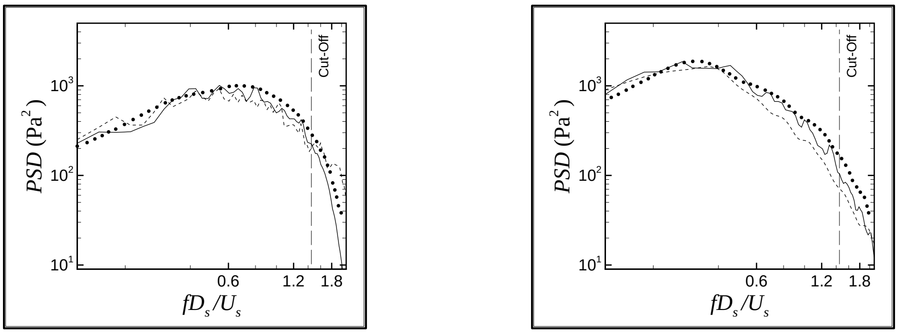
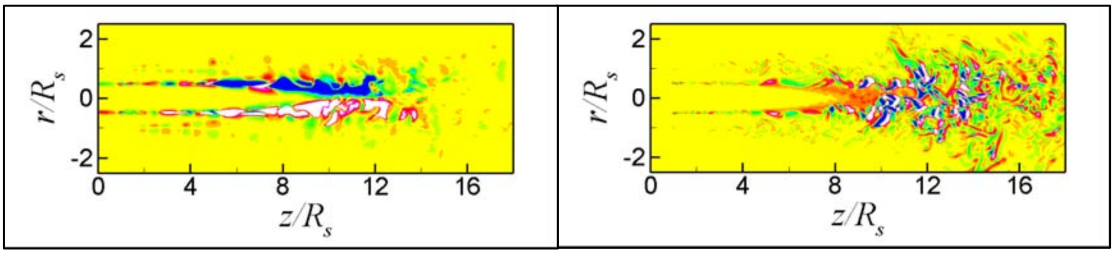


Figure 1: Sound pressure spectrum at the circumferential location $r = 15\ R_s$, the cut-off frequency is located at $fD_s/U_s = 1.45$ — (LES/APE), --- (LES), • (LES by Bogey and Bailly, single jet.



(a) $T'\partial\bar{s}/\partial r - s'\partial\bar{T}/\partial r,$ eqn. (7)　　(b) $(\overline{\rho a}^2/c_p)\bar{D}s'/Dt,$ eqn. (8)

Figure 2: Contours of the instantaneous entropy sources of the hot coaxial jet, (a) the r-component of the entropy term of equation (7) in the interval [$\pm 0.05\ a_\infty^2\ /R_s$], (b) the entropy source of equation (8) in the interval [$\pm 0.05\ \rho_\infty\ a_\infty^3\ /R_s$].

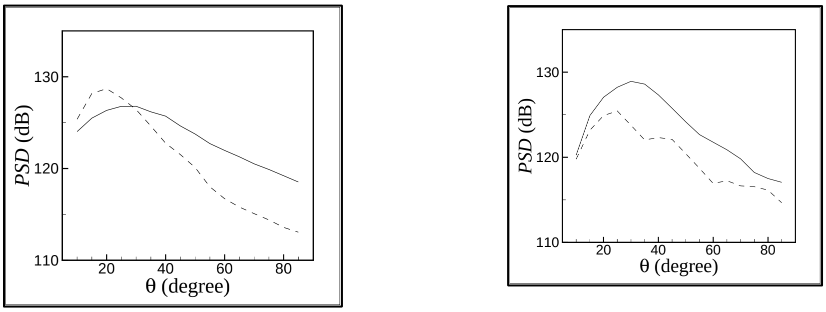


Figure 3: Comparison of the acoustic directivity for two Strouhal numbers at $r_p = 40\ R_s$, (a) $fD_s/U_s = 0.3$, (b) $fD_s/U_s = 0.5$: — (cj_h), --- (cj_c).