Experimental control of jet-surface interaction noise

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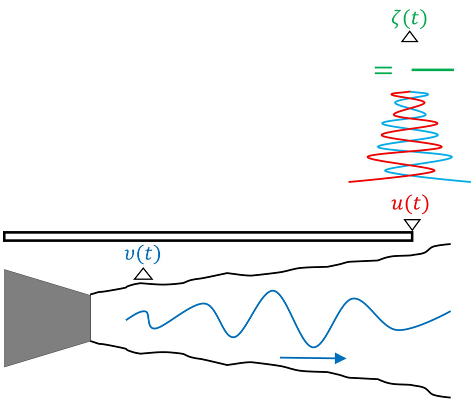
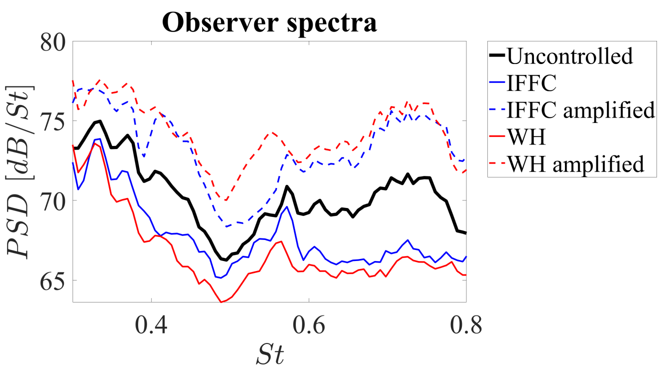
This paper presents an experimental application of reactive control to jet installation noise based on destructive interference. The work is motivated by the success of previous studies in applying this control approach to several flow systems, among which turbulent jets[1,2,3]. We exploit the fact that jet-surface interaction (JSI) noise is underpinned by wavepackets that can be modelled in a linear framework and develop a linear control strategy where piezoelectric actuators situated at the edge of a scattering surface are driven in real time by sensor measurements in the near field of the jet, the objective being to reduce noise radiated in the acoustic field at a given observer position. The control mechanism involves imposition of an anti-dipole at the trailing edge to cancel the scattering dipole that arises due to an incident wavepacket perturbation, as schematically described in figure 1(a). We explore two different control strategies: (i) the inverse feed-forward approach (IFFC), where causality is imposed by truncating the control kernel, and (ii) the Wiener-Hopf (WH) approach, where causality is optimally enforced in building the control kernel. We show that the Wiener-Hopf approach has better performance than that obtained using the truncated inverse feed-forward kernel. Broadband noise reductions of up to 75% (corresponding to $\approx 6\,dB$) are achieved, as shown in figure 1(b).

For the Wiener-Hopf approach, we explore the directivity pattern of the noise modifications achieved along a polar arc. Specifically, the control reduces the radiated noise for all the upstream polar positions, where JSI noise has its preferential propagation direction, and amplifies the intensity of the acoustic emissions for downstream polar positions. This result is consistent with the physics of installed jet noise radiation, given that JSI is not the dominant noise source for downstream polar positions where, on the contrary, 'direct' jet noise dominates over the installed one. We, finally, explore robustness features of the controller to changes of the flow conditions. Specifically, we calculate the control kernel for a given jet Mach number, M^* and explore control effectiveness for M variations in the range $M^* \pm 50\% M^*$. We show that control remains still effective and the control authority monotonically reduces as the Mach number moves away from M^*. Specifically, noise reductions achieved decreases of $\approx 60\%$ for $M = M^* + 50\% M^*$.



(a)



(b)

Figure 1: (a) Schematic representation of the wave-cancellation strategy for the JSI noise control. υ denotes the near-field sensor, u the actuator and ζ the observer in the acoustic field. (b) Power spectral densities at the observer position ζ.

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[1]Maia et al., *Phys. Rev. Fluids* **6(12)**, 123901 (2021)
[2]Maia et al., *Phys. Rev. Fluids* **7(3)**, 033903 (2022)
[3]Audiffred et al., *J. Fluid. Mech* **994**, A15 (2024)