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Adjoint-based Sensitivity of Jet Noise to Near-nozzle Forcing[1]

SEUNG WHAN CHUNG, University of Illinois, RAMANATHAN VISHNAMPET, ExxonMobil Upstream Research Company, DANIEL BODONY, JONATHAN FREUND, University of Illinois — Past efforts have used optimal control theory, based on the numerical solution of the adjoint flow equations, to perturb turbulent jets in order to reduce their radiated sound. These efforts have been successful in that sound is reduced, with concomitant changes to the large-scale turbulence structures in the flow. However, they have also been inconclusive, in that the ultimate level of reduction seemed to depend upon the accuracy of the adjoint-based gradient rather than a physical limitation of the flow. The chaotic dynamics of the turbulence can degrade the smoothness of cost functional in the control-parameter space, which is necessary for gradient-based optimization. We introduce a route to overcoming this challenge, in part by leveraging the regularity and accuracy with a dual-consistent, discrete-exact adjoint formulation. We confirm its properties and use it to study the sensitivity and controllability of the acoustic radiation from a simulation of a $M = 1.3$ turbulent jet, whose statistics matches data. The smoothness of the cost functional over time is quantified by a minimum optimization step size beyond which the gradient cannot have a certain degree of accuracy. Based on this, we achieve a moderate level of sound reduction in the first few optimization steps.

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