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Isolating acoustic source terms in turbulent jets

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1 Introduction

Jet noise is loud, disruptive, and demonstrably harmful. Noise emitted by aircraft is associated with a myriad of negative societal consequences, including lower test scores in school children, and increased risk of cardiovascular disease and mental health disorders (Hygge *et al.*, 2002; Clark *et al.*, 2020). Solving the problem of jet noise requires a fundamental understanding of aerodynamic sound-generating mechanisms. Despite their deleterious effects, sound waves compose a minuscule fraction of the total energy within a jet. This scale disparity between turbulent-flow fluctuations, and far-field-pressure perturbations, is the primary impediment in aeroacoustic research (Lighthill, 1952). Recent developments in modal decomposition techniques enable the construction of acoustic sources, however extant models fail to capture the complete spectrum of jet noise (Maia *et al.*, 2019). The current research proposes a data-processing approach, which facilitates isolation of acoustic source terms in turbulent jets.

2 Approach

Recent research postulates a link between far-field sound and turbulent fluctuations, through coherent flow structures (Jordan & Colonius, 2013). In round jets, the azimuthal homogeneity allows decomposition of coherent structures into azimuthal Fourier modes. The relative contribution of mode shapes can then be analysed in a source-modelling framework (Cavalieri *et al.*, 2013). Depending on the when the azimuthal decomposition is performed, non-linear azimuthal-mode interactions may be implicitly excluded. By varying the order of operations when constructing acoustic sources, the interactions between different mode structures can be quantified.

3 Results

Propagation of the normal-axial component of the Lighthill stress tensor was performed, for two different cases. The first considered a source term constructed using azimuthally decomposed flow variables. Alternatively, the source itself was azimuthally decomposed. Mathematically, any difference arising between the two methods could be attributed to non-linear azimuthal-mode interactions. An absolute difference for the $m = 0$ azimuthal mode, and Strouhal number of 0.4 is presented in figure 1. Evidently, there is a significant contribution of non-linear effects.

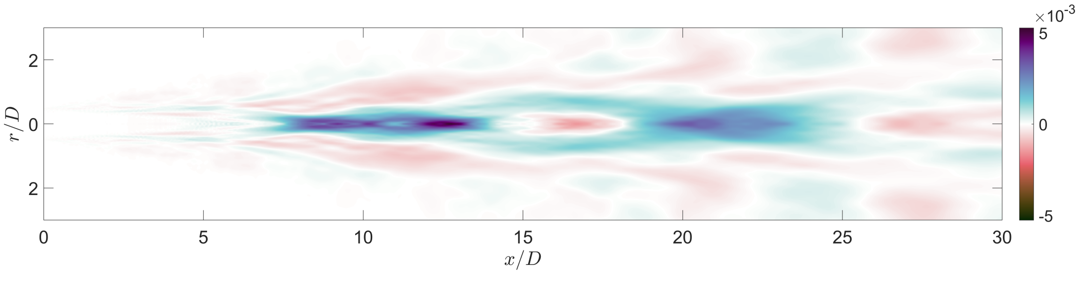

Figure 1. Absolute difference between linear and non-linear Lighthill stress tensor $T_{xx}(m = 0, St = 0.4)$

The resulting sound field for the linear and non-linear cases were computed, to discern whether the different source structures affect sound radiation. Figure 2 shows the acoustic spectra at three different observer polar locations. Spectral proper orthogonal decomposition (SPOD) was used as a filtering method to remove spurious noise sources. For the dominant first SPOD mode, a non-negligible difference is observed between the two source-construction approaches.

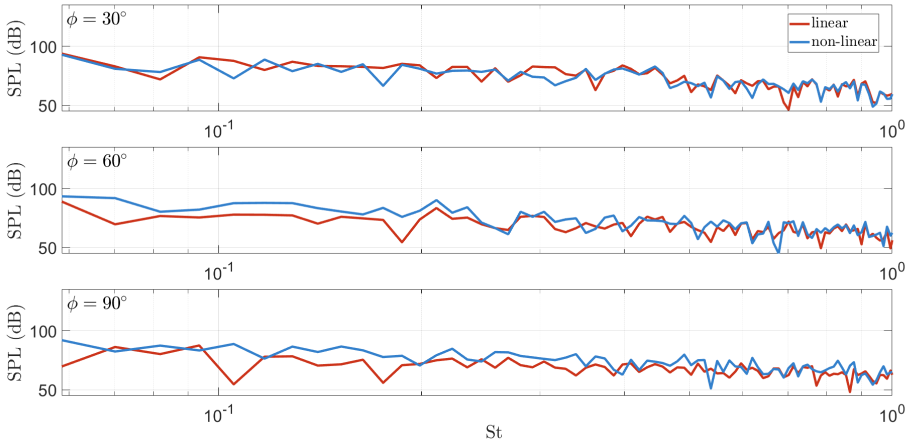

Figure 2. Propagated sound field for linear and non-linear Lighthill stress tensor T_{xx}, first SPOD mode

4 Conclusions

A methodology applied to data from a high-fidelity numerical simulations for Lighthill's equivalent source term was shown as a possible approach to explore the azimuthal mode interactions that underpin the acoustically important source modes.

References

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