The frequency dependence of the characteristics of coaxial jet flows

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Single and coaxial jet flows are responsible for significant noise generation in aircraft. Unfortunately, the sound generation mechanisms concerned are very low efficiency acoustic sources and their physical features need to be known with some precision if accurate prediction of the total noise radiated is to be achieved. Significant progress in understanding the source mechanisms has been made since the acoustic analogy formulation of Lighthill (1952) as reported by Morris & Farrasat (2003). When only the noise from mixing mechanisms is considered, the two point space-time correlation of the Reynolds stresses provides the basis for these source models. This is representative of both the efficiency and dynamic of the mechanisms of conversion of the turbulence kinetic energy into acoustic energy. The model for this must reflect the physical features such as anisotropy and inhomogeneity and the multi-scale dependence of the turbulence is also important. The use of the integral length and time scales together with the convection velocity for the turbulence velocity components in the main direction of the flow is the most common way to introduce the two first features. However, since the turbulence field has a multi-scale character, these integral properties must be thus interpreted as average scales only. Therefore, the problem is how to introduce this multi-scale nature of the turbulence to the model of the correlation tensor so that the individual dynamic of the frequency turbulence components and their interaction can be taken into account.

The multi-scale character of the turbulence field in a coaxial jet flow is examined to develop improved fundamental models of the source mechanisms responsible for noise generation in these flows. The turbulent statistical properties such as the space-time correlation functions together with the length and time scales provide a basis for modelling these mechanisms using the acoustic analogy approach. It is important that these models include as much of the flow physics as possible. Significant progress has been made in attempting to model the inhomogeneous and anisotropic nature of the turbulence field in the recent years but the description of its multiscale character still remains problematic. In this paper, the frequency dependence of the turbulence statistics is investigated in detail to provide a better method for modelling the turbulence as a potential source of sound. It is shown how frequency dependence length and time scales, as well as the convection velocity, can be derived using a complex coherence function in the frequency domain instead of the two point space-time correlation functions normally used.

A series of two-point measurements in a Mach 0.25 coaxial jet flow combining LDA and HWA measurements have been performed. Integral length and time scales as well as their frequency dependence are derived experimentally and analytically. The results are reported for a range of flow conditions and the post-processing of the data includes a comparison of the sample-and-hold and slotting analysis procedures.

The frequency dependent length and time scales, which may be interpreted as the component of the integral length and time scales associated with individual turbulent frequency components, are found to decrease with Strouhal number. The results indicate the possibility of the existence of a universal Strouhal number dependence for the co-axial results reported. The Strouhal number is based on the local convection velocity obtained from the phase of the complex coherence function and on the global integral length scale. This result will have important implications for jet noise source modelling as modelling of this frequency dependence can be used together with the limited data available from RANS calculations to provide estimates of the radiated noise. This is further strengthened by the inclusion of the results from other jet flow configurations including single jets at different Mach numbers and Temperature ratios and coaxial jets with varying velocity ratio. The results from the various configurations are shown in the figure below.

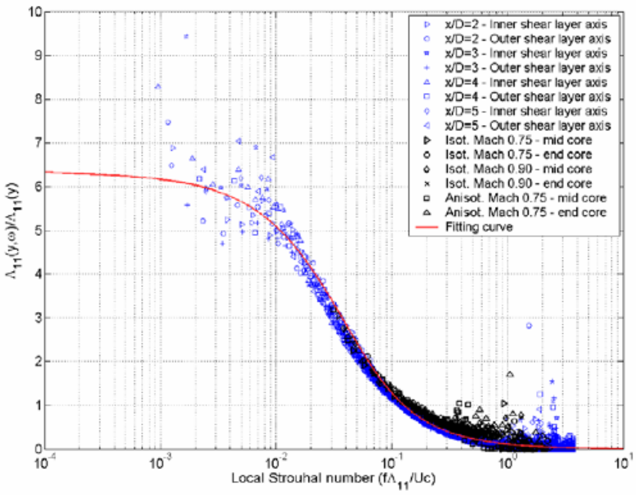

Fig. 1 Normalised Frequency Dependent Length Scale