UKFN Short Research Visit Report

The near-field turbulence of jets with different nozzle geometries

Dr Daniele Fiscaletti (University of Bristol) visiting Dr Oliver Buxton (Imperial College London)

The SRV was organized into four two-days meetings, for a total of eight days of visit to Dr Oliver Buxton, Senior Lecturer in Experimental Aerodynamics at Imperial College London. The goal of this SRV was to investigate how the nozzle geometry affects the structure of the near-field turbulence in a jet at $Re_D=10^4$. Three-dimensional velocity vector fields obtained from tomographic particle image velocimetry (PIV) were examined with statistical techniques and dedicated mathematical algorithms. In particular, three datasets of tomographic PIV at three different downstream locations, i.e. at x/D=2, 10, 25, were investigated. In addition to this, planar PIV data at high spatial resolution were also analysed.

Proper orthogonal decomposition (POD) was applied to the velocity vector fields with the aim of investigating the energetic modes within the flow. POD was applied both to planar and tomographic velocity vector fields. In figure 1, mode 3 of the POD of the planar velocity fields is presented for three different nozzle geometries, i.e. round, fractal, and square. As it can be observed, mode 3 of the round nozzle carries the evidence of the Kelvin-Helmholtz azimuthal vortices, whereas the other nozzle geometries seem effective in suppressing those coherent structures. The suppression of the Kelvin-Helmholtz vortices is particularly important for aeroacoustic purposes, as it is considered at the basis of the attenuation of the far-field low-frequency noise. Even if not reported here, some differences between round and fractal nozzles were also observed when analysing the tomographic results, especially regarding the highly-energetic low modes.

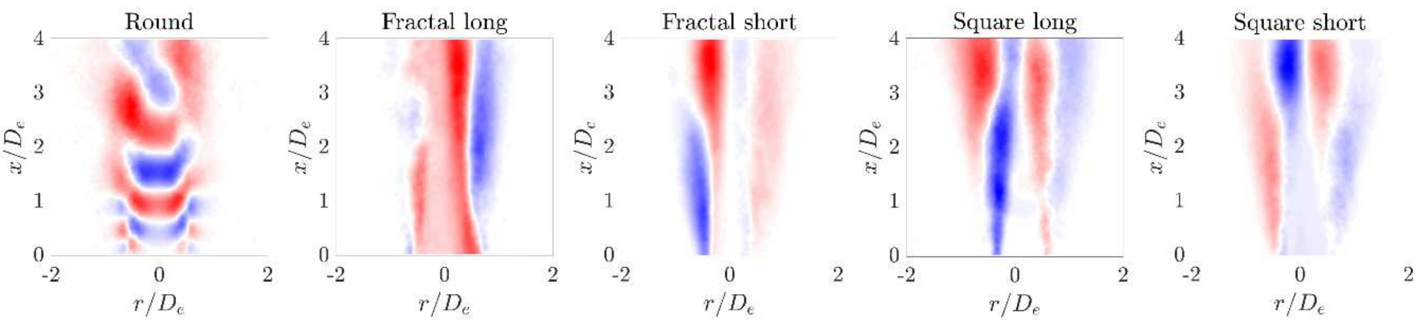

Figure 1. Mode 3 of the streamwise velocity fluctuations (u') along the streamwise

Conditional averaging was applied to the tomographic velocity fields at x/D=25 with the aim of examining the mechanical properties of the internal layers of intense shear (ILIS) within the turbulent flow. ILIS are responsible for the entrainment of internal fluid, and, therefore, they govern the transfer of mass and momentum among different regions within the turbulent flow. Specifically, the entrainment velocity is dependent on the thickness of the ILIS. After having identified the ILIS as tiny regions characterised by intense shear vorticity, conditional averaging enabled to determine the streamwise velocity profile across the ILIS themselves, and from this, the thickness of the ILIS. In figure 2, the magnitude of the shear component of the vorticity after the triple decomposition proposed by Kolar (2007) is presented. In figure 3, the jump in the streamwise velocity profile across the ILIS, from which the thickness of the ILIS themselves was estimated.

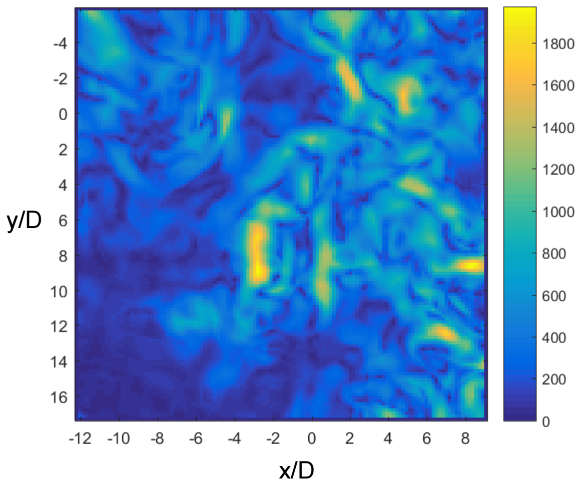

Figure 2. Snapshot of the magnitude of the shear component of the vorticity in a jet with fractal nozzle.

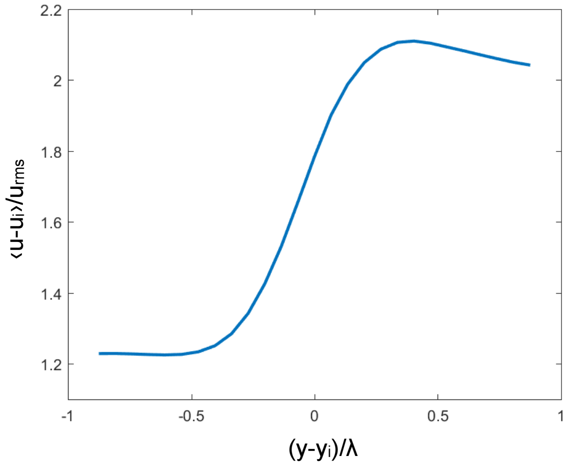

Figure 3. Profile of conditionally averaged streamwise velocity across the ILIS.