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The Turbulent/Non-Turbulent Interface Characteristics in an Axisymmetric Jet

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Extended Abstract

It is generally understood that the turbulent/non-turbulent interface (TNTI) at the edge of turbulent flows controls the entrainment of mass, momentum, and scalars. The goal of this work is to shed light on the relationship between the TNTI characteristic features of a jet and entrainment of a passive scalar into it. To this end, the geometric properties and fractal dimension of the TNTI, as well as conditional scalar evolution across its thickness in a round turbulent jet at relatively high *Re* (*Re* = 10600) are analyzed using laser-induced fluorescence. Orthogonal sections of the jet are taken at 50 nozzle diameters downstream from the nozzle over 44 seconds to ensure self-similarity and convergence of the results. The scalar concentration threshold for detecting the TNTI is chosen as the inflection point of the pixel averaged concentration across all points inside the field of view, where the local concentration value exceeds the given threshold. Detached turbulent islands are excluded from this procedure, while irrotational holes inside the main body of the jet are included. Averaging over 1315 simultaneous concentration fields revealed a threshold value of 0.13 times the centreline concentration value (φ_c), and the TNTI of the jet is selected as the longest continuous isocontour of the threshold value, excluding islands and holes. The PDF of the radial position of the upper half of the TNTI exhibits a Gaussian distribution with negative skewness (see [1]) and with the mean value of 1.46 times the average concentration half-width ($b_{\varphi,1/2}$) of the jet. The mean intermittency factor is obtained from the cumulative distribution function of the TNTI position ([2]) and assumes a value of 0.5 at the average radial position. The cumulative average of the interface length, $\overline{L}_s^{TNTI}$, from all 1315 scalar fields quickly converges, i.e., $\overline{L}_s^{TNTI}/b_{\varphi,1/2} \approx 12$, indicating an adequate number of concentration fields is analyzed. Application of the box-counting and box-average filtering of the concentration fields revealed that the mean length of the TNTI in the orthogonal sections follows a power-law behaviour with a one-dimensional fractal dimension $D_1 \approx$ 0.28-0.32.

The TNTI unit normal (n_I) is calculated at each point using the gradient of the scalar concentration field. The PDF of the angle between the local interface-normal and radial unit vectors, ψ, is calculated showing a predominance of ψ = 0°. However, a second smaller peak is observed in the PDF at a value of ψ = 180°, indicating the intense corrugation of the TNTI surface. Therefore, it is beneficial to calculate the conditional statistics along the direction normal to the interface (x_n). The conditionally averaged concentration is calculated by interpolating the concentration values onto x_n using a bilinear interpolation scheme. The conditional concentration jump across the TNTI is approximately $0.23\varphi_c$, and the interface thickness is 0.64λ (where λ is the Taylor microscale, see [3]) or $0.04b_{\varphi,1/2}$. The curvature of the upper interface is obtained, showing that the orthogonal sections of the jet are mostly dominated by flat concave surface elements, i.e., smooth bulges. The joint PDF of the conditional jump and the interface curvature revealed that more intense values of scalar jump occur at flatter regions, independent of the curvature sign. It is also shown that conditionally averaged scalar dissipation and scalar variance are governed by a sharp gradient across the TNTI thickness.

References

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