Proceedings of the 7th International Conference on Fluid Flow, Heat and Mass Transfer (FFHNT'20)
~~Niagara Falls, Canada~~ Virtual Conference – November, 2020
Paper No. 184
DOI: 10.11159/ffhmt20.184

Effect of ambient turbulence on the evolution and mixing of passive scalar in turbulent jet

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Extended Abstract

Most experimental studies of turbulent jets have been in quiescent flows, yet recent work shows modified structure and entrainment mechanisms in the presence of ambient turbulence [1,2]. Experimental research is carried out to study the effect of ambient turbulence on the large-scale and small-scale structures in an axisymmetric jet as compared to those in a quiescent ambient. The scalar field of an axisymmetric turbulent jet (Re = 5800) is obtained in an ambient turbulence generated by a random jet array (RJA). The random jet array generates an approximately homogeneous and isotropic turbulent field with negligible mean flow having a turbulent kinetic energy (TKE) of 4.4 cm^2/s^2 along the jet centreline in the measurement field. An orthogonal cross section of the jet is obtained in both a quiescent and a turbulent ambient at x/D = 20, 30, 40, 50 and 60 using laser-induced fluorescence to obtain scalar concentrations.

In the presence of ambient turbulence, the jet is advected by the large scale eddies of the ambient turbulence created by the RJA resulting in a jet path that meanders about the geometric centreline path (followed by the jet in a quiescent ambient). The scalar concentration data of the orthogonal cross-sections is, therefore, analysed relative to the geometric centreline of the cross-section, as for the quiescent case, providing information on time averaged concentrations. It is also analysed relative to the instantaneous centre of mass of the cross-section, to remove the effect of the meandering of the path due to the large scale eddies providing information on the jet structure and dynamics.

Changes to the large scale structure of the turbulent jet due to the ambient turbulence are observed from the mean concentrations profiles, rms concentration profiles, intermittency profiles and probability density function of the centreline concentration of the scalar concentrations in the jet cross-sections at x/D = 20, 30, 40, 50 and 60. First comparing the spatial average concentration data (i.e. analysis about the geometric mean), it is apparent that the mean concentration decreases, the rms concentration increases, the jet become more intermittent and of greater width, while peak instantaneous concentrations are lower. To provide insight on the change in structure of the turbulent jet in the turbulent ambient, the analysis of the jet in a quiescent ambient is compared to the analysis following the centre of mass of the jet in a turbulent ambient. Compared to the analysis relative to the geometric centre, the mean concentration is higher and the rms concentration is lower, indicating that the structure of the jet is maintained although its centre is advected laterally by the large scale eddies in the ambient turbulence. The pdf of the centreline concentration indicates lower instantaneous values, and the intermittency profiles indicate that the radial position of the edges of the jet is more variable. The entrainment into the jet can be characterized by investigations of the interface between the jet fluid and the ambient fluid, that is at the turbulent non-turbulent interface (TNTI) in the quiescent ambient case and at the turbulent turbulent interface (TTI) in the turbulent ambient case [3,4].

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