Mixing and entrainment in polymer-laden jet

Sheng-Hong Peng*, Yi-Bao Zhang*, and Heng-Dong Xi*†

We present an experimental investigation of the effects of polymer additives (PEO) on the entrainment of an axisymmetric circular water jet. The entrainment is studied by examining the turbulent/non-turbulent interface (TNTI) through simultaneous time-resolved particle image velocimetry (PIV) and planar laser-induced fluorescence (PLIF) measurements. The experiments were performed at a fixed polymer concentration ϕ (= 20 ppm) and Reynolds number $Re = 7075$, with the Weissenberg number Wi in the range of $(24.6 - 85.6)$. We analyse the geometric features and the entrainment velocity along the TNTI at different scales, and find that both the kinetic energy spectrum and the vorticity are significantly suppressed with polymer additives at small scales. The suppressed kinetic energy implies a suppression of small-scale viscous diffusivity, which accounts for the suppressed scalar mixing in the polymer-laden jet. It is also found that the engulfment flux is enhanced in the polymer-laden jet compared to the pure water case. In spite of the enhanced engulfment, it is worth noting that the nibbling process still dominates the entrainment, as it does in the Newtonian jet. It is shown that the fractal dimension of the TNTI is smaller in the polymer solution case, leading to a shorter TNTI length at small scales, which is more evident at large Weissenberg number. In the polymer-laden jet, the shorter TNTI length is compensated by the larger entrainment velocity at small scales. Since the viscous diffusivity is suppressed by the polymer additives, the viscous diffusion component of turbulent entrainment velocity along the TNTI is also suppressed and does not match the increased entrainment velocity. Our results imply that that the elastic stress diffusivity should be greatly enhanced and plays an important role in increasing the entrainment velocity for the nibbling process.

*School of Aeronautics and Institute of Extreme Mechanics, Northwestern Polytechnical University, Xi'an, 710072, China

†Email: hengdongxi@nwpu.edu.cn