Effects of polymer additives on the entrainment of turbulent water jet

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

We present an experimental study on the effects of polymer additives on the entrainment of a circular water jet and their dependence on the polymer concentration ϕ (in the range of $0 - 40$ ppm) and Weissenberg number Wi (in the range of 2.0-85.6), at the Reynolds number $Re = 7075$. Extensive particle image velocimetry (PIV) measurements were performed between 0 and $74D$ (D is the inner diameter of the pipe) downstream of the nozzle. Our results clearly show that the polymer-laden jet exhibits two regimes along the flow direction compared to the pure water case. In the first regime, close to the jet exit, the jet spreading rate is smaller (entrainment is suppressed) and the centerline mean velocity decays more slowly. However, as the polymer-laden jet evolves further downstream, the entrainment rate is enhanced by up to 33% compared to that of the water jet. In this entrainment enhancement regime, the polymer-laden jet evolves into a new self-similar state. The turbulent intensities and Reynolds shear stress of different ϕ and Wi collapse onto each other, and they are also much stronger compared to that of the water jet. We have also extended the integral entrainment analysis to the polymer-laden jet by adding a polymer stress term to the momentum equation. Our results show that the enhancement of the entrainment is originated from the stronger production of the Reynolds shear stress in the polymer-laden jets, implying that the entrainment rate is intimately related to the energy-containing vortices in the polymer-laden jets.

[*]School of Aeronautics, Northwestern Polytechnical University, 710072 Xi'an, China

[†]Center for Combustion Energy, Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China