Unraveling the complex dynamics of buoyant miscible jets: from Newtonian to viscoplastic fluids

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We experimentally study the flow dynamics of a buoyant miscible jet where a Newtonian fluid is injected through a circular nozzle into a large tank filled with a Newtonian/viscoplastic fluid. Since the dimensions of the tank are large in our experiments, the jet is assumed to be a free jet, implying that the wall effects on the jet flow are negligible. Using a combination of various non-intrusive experimental techniques, i.e., time-resolved tomographic particle image velocimetry (TR-Tomo PIV), high-speed imaging, planar laser-induced fluorescence (PLIF) and ultrasound Doppler velocimetry (UDV), we investigate the effects of the injection velocity, the density difference, the viscosity ratio, and the rheological parameters (in particular, the yield stress) on the jet flow behaviour. We consider neutrally buoyant, negatively buoyant, and positively buoyant jets in different configurations. In order to characterize our buoyant jet behaviour, we employ different jet flow features, including the laminar length, the penetration length, the jet radius, and the turbulent kinetic energy. Based on our results, in neutrally buoyant jets, the laminar length decreases by increasing the injection velocity. Besides, in positively buoyant jets, the density difference helps to increase the laminar length[1]. In negatively buoyant jets, the jet penetration length reaches a steady-state value. Moreover, increasing the viscosity ratio generally leads to a decrease in the jet radius[2]. In addition, the yield stress of the ambient fluid completely changes the turbulent kinetic energy behaviour. Finally, we succeed to classify various jet flow regimes versus the dimensionless numbers that govern the flow in each buoyant jet category.

[1] H. Hassanzadeh, *et al*., *Phys. Rev. Fluids.* **6**, 054501 (2021).
[2] H. Hassanzadeh, *et al*., *Environ. Fluid Mech.* **22**, 337 (2022).