Simulation of Biodiesel Jet in Cross Flow

E. Farvardin, A. Dolatabadi[1*]
Mechanical Engineering Department, Concordia University, Canada
e_farva@encs.concordia.ca and dolat@encs.concordia.ca

Abstract

Liquid jet in cross flow has many applications such as in gas turbine combustion chamber, ramjets, scramjets and agriculture industry. Furthermore, it can be served as a fundamental study of spray quality for different fuels as it illustrates jet disintegration, surface waves, primary and secondary breakups, effect of viscosity, effect of surface tension and the effect of density of the fuel on the final droplet size distribution, mixing, evaporation and combustion processes. In the last decade, scientists and industries have been attracted to the use of renewable energy such as biofuels. Biodiesel as an alternative for diesel, which is already in use by many industries such as transportation and energy, played a pioneer role in this direction. Moreover biodiesel has different renewable resources including Canola oil, cottonseed oil, animal fat, soybean oil, yellow grease and brown grease. Contrary to these advantages, the ignition, atomization and evaporation of biodiesel have been critiqued. In a recent comparative study by the authors, it has been shown experimentally that biodiesel has lower penetration depth comparing to diesel. The lower penetration depth is thought to be as a reason of primary breakup and jet column bending before the disintegration.

In this study, near field behaviour of a liquid jet in crossflow, i.e. deformation, primary breakup and penetration is investigated. Biodiesel, diesel and their blend are used as the liquid jets entering the cross flow of air. The primary breakup of biodiesel jet is simulated using the Volume of Fluid (VOF) numerical method. In order to, accurately, capture vortices including the horseshoe vortex in the gas and the liquid internal vortices, Large Eddy Simulation (LES) turbulence model is coupled with the VOF. The operating condition of this study is gas Weber number of 48 and 80 with a liquid to gas momentum ratio of 50 and 100. This work serves as a comparative study of biodiesel and diesel spray characteristics in cross flow.

The results show lower penetration depth of biodiesel jet comparing to the diesel jet. This behaviour is assumed to be due to the larger drag acting on biodiesel liquid columns which bends the jet more towards the downstream. This is in a manner that diesel jet owing to smaller drag penetrates more inside the crossflow of air before complete bending towards the cross flowing air. Several bag shapes are observed after the primary breakup of biodiesel at large Weber numbers, i.e. atomization Weber numbers, which argues the common classification of primary breakup regimes. This is in a manner that at the same Weber numbers, diesel show atomization mode of breakup. On the other hand, biodiesel droplets at downstream of the domain have lower velocities which can be as a result of having wider wakes surrounding the biodiesel column. Ultimately, the windward trajectory of VOF-LES simulation is compared with the DPM simulation results. Apparently, the results of VOF-LES seem to be in better agreement with the experimental shadowgraph results in comparison with the DPM trajectories.

* Corresponding author: dolat@encs.concordia.ca