ABSTRACT

Atomization of fuel is an important pre-requisite for efficient combustion in devices such as gas turbines, liquid propellant rocket engines, internal combustion engines and incinerators. The overall objective of the present work is to explore air-assisted atomization strategies for high viscosity fuels and liquids. Air-assisted atomization is a twin-fluid atomization method in which energy of the gas is used to assist the atomization of liquids. Broadly, three categories of air-assisted injection, i.e., effervescent, impinging jet and pre-filming air-blast are studied. Laser-based diagnostics are used to characterize the spray structure in terms of cone angle, penetration and drop size distribution. A backlit direct imaging method is used to study the macroscopic spray characteristics such as spray structure and spray cone angle while the microscopic characteristics are measured using the Particle/droplet imaging analysis (PDIA) technique.

Effervescent atomization is a technique in which a small amount of gas is injected into the liquid at high pressure in the form of bubbles. Upon injection, the two-phase mixture expands rapidly and shatters the liquid into droplets and ligaments. Effervescent spray characteristics of viscous fuels such as Jatropha and Pongamia pure plant oils and diesel are studied. Measurements are made at various gas-to-liquid ratios (GLRs) and injection pressures. A Sauter Mean Diameter (SMD) of the order of 20 µm is achieved at an injection pressure of 10 bar and GLR of 0.2 with viscous fuels. An image-based method is proposed and applied to evaluate the unsteadiness in the spray. A map indicating steady/unsteady regime of operation has been generated. An optically accessible injector tip is developed which has enabled visualization of the two-phase flow structure inside the exit orifice of the atomizer. An important contribution of the present work is the correlation of the two-phase flow regime in the orifice with the external spray structure. For viscous fuels, the spray is observed to be steady only in the annular two-phase flow regime. Unexpanded gas bubbles observed in the liquid core even at an injection pressure of 10 bar indicate that the bubbly flow regime may not be beneficial for high viscosity oils.

A novel method of external mixing twin-fluid atomization is developed. In this method, two identical liquid jets impinging at an angle are atomized using a gas jet. The effect of liquid viscosity (1 cP to 39 cP) and surface tension (22 mN/m to 72 mN/m) on this mode of atomization is studied by using water-glycerol and water-ethanol mixtures, respectively. An SMD of the order of 40 µm is achieved for a viscosity of 39 cP at a GLR of 0.13 at a liquid pressure of 8 bar and gas pressure of 5 bar. It is observed that the effect of liquid properties is minimal at high GLRs where the liquid jets are broken before the impingement as in the prompt atomization mode. Finally, a pre-filming air-blast technique is explored for transient spray applications. An

SMD of 22 μm is obtained with diesel at liquid and gas pressures as low as 10 bar and 8.5 bar, respectively. With this technique, an SMD of 44 μm is achieved for Jatropha oil having a viscosity 10 times higher than that of diesel.