Physics behind Diesel Sprays

Masataka Arai*
Department of mechanical system engineering, Gunma University, Japan
arai@gunma-u.ac.jp

Abstract

Diesel spray formation that is a dominant phenomenological event for performance of diesel engine and its combustion emission, has been received much attention not only from engineering but also from scientific field. Cavitation in an injector, breakup process of a high-speed fuel jet, fuel spray development in a combustion chamber, and combustion process following these atomization processes contribute to the scientific and engineering progresses in hydrodynamics. Diesel spray cavitation suggests the physical importance of turbulence caused by cavitation bubble disruption. Liquid surface stability problem in a breakup process leads us to many liquid disintegration models and their numerical simulation methods. Measurement of a diesel spray promotes new scientific achievement of laser diagnostics. The engineering achievements of these items coupled usually with physical considerations of diesel spray. Then finding of unknown physics behind diesel spray is the essential of next engineering approach of diesel spray. This paper highlighted physical approaches concerning spray behavior such as liquid breakup, spray penetration, spray volume, velocity distribution, and air entrainment. Main contents are as follows.

1. Diesel Spray
   Macroscopic spray parameters: Spray angle, Breakup length, Core of spray, Spray penetration
   Microscopic spray parameters: Size distribution, Mean diameter, Spatial distribution, Turbulence
2. Demand of diesel spray and Task of Diesel Spray Injection
   Diesel spray combustion model
   Task of diesel spray: Fuel transportation to a desired space and at desired timing
3. Nozzle Flow and Cavitation
   High speed jet and nozzle cavitation, Cavitation number, Cavitation and Atomization
4. Breakup Behavior of Liquid Jet and Its Modeling
   Breakup model of liquid jet, Wall impingement model, Spray model
5. Diesel Spray Development
   Spray tip penetration: Catch-up motion of diesel spray and spray tail behavior
   Combustion phenomena of diesel spray: Set-off (no-flame or lift-off) length of diesel spray
   Interaction with wall and mutual interaction of sprays
   Ultra-high pressure injection
6. Air Entrainment and Spray Angle
   Definition of spray boundary and air entrainment
   Spray angle: Effect of ambient pressure and ultra-high pressure injection
7. Diesel Spray in High Density Surroundings
   Ultra-high boost engine, Homogeneous mixture, Spray behavior
8. Velocity Distribution inside a Diesel Spray
   PIV application for velocity measurement and Gaussian distribution of velocity
   Model of intense mixing zone

There are still too many unclear phenomena to describe breakup and spray development of liquid jet injected from diesel injector. Surface deformation related with cavitation and internal turbulence in a jet is a physically unclear problem concerning to the liquid jet disintegration. Liquid jet core near the exit of injector is hardly observed because of high dense droplet clouds surrounding it. As for the internal structure of diesel spray, only a little information is available for understanding the mixture formation and combustion of impingement spray. Further, there is almost no information for future diesel spray with ultra-high pressure injection system for ultra-high boost diesel engine. Then, it needs more fundamental measurement and deep physical understanding of diesel spray for future advancement of diesel engine and atomization technology

*Corresponding author: arai@gunma-u.ac.jp