Empirical Correlations for Breakup Length of Liquid Jet in Cross Flow-A Review

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Abstract

The injection of liquid into a high-speed cross flow in combustion systems can be found in the practical applications such as diesel engine, gasoline engine, gas turbine, ramjet and scramjets etc. The application of chemicals to crops in agricultural field and the injection of liquid friction modifiers onto the rail surface are another application of cross flow. Numerous studies have, therefore, been conducted to characterize the liquid jet atomization process in a cross flow. Previous studies of liquid injection in uniform and non-uniform cross flows include analyses of controlled and uncontrolled liquid jets atomized in both subsonic and supersonic airstream. The primary breakup process including column and surface breakup, breakup length, penetration height, jet width, droplet size and droplet velocity have attracted considerable attention. A detailed survey of the empirical correlations related to liquid jet trajectory and penetration height available in the literature was carried out many investigators. As one of atomization characteristics, breakup length is of prime importance in air-breathing propulsion systems.

In this study, the empirical correlations for the prediction of breakup length of liquid jet in cross flow are reviewed and classified. Many empirical correlations have been developed to predict the breakup length of liquid jet in a cross flow. The breakup length can be divided into column fracture height and column fracture distance. Around ten and twelve different correlations have been developed to predict the column fracture height and column fracture distance, respectively. It is known that the breakup length of liquid jet in a cross flow is a basically function of the liquid to air momentum flux ratio. However, Weber number, liquid-to-air viscosity ratio and density ratio, Reynolds number or Ohnesorge number were incorporated in the empirical correlations depending on the investigators.

The existing correlations for column fracture height can be classified as three groups such as momentum flux ratio form, Weber number form, and other parameter form. For column fracture distance, the existing correlations can be categorized as four groups such as the constant form, momentum flux ratio form, Weber number form, and other parameter form. It is clear that there exist the significant discrepancies of predicted values by the existing correlations even though many correlations have the same functional form. The possible reasons for discrepancies will be summarized as the different experimental conditions such as jet operating condition and nozzle geometry, measurement and image processing techniques introduced in the experiment, difficulties in defining the breakup location etc. The evaluation of the existing empirical correlations for the prediction of breakup length of liquid jet in a uniform cross flow is required.