Theoretical Investigation of Breakup Length of Primary Atomization: Energetic Approach

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Abstract

Atomization process plays a significant role in the combustion of liquid fuels injected into gas turbine, internal combustion (IC) engines and incinerators combustors in order to achieve proper mixing of fuel and air and for rapid evaporation and combustion. The atomization process is divided into primary atomization and the secondary atomization. The primary atomization, which is the bridge between the nozzle internal flow and the secondary flow, is further classified, by the predominant breakup mechanism, into four regimes. One of the regimes is the atomization regime, which is the relevant operational zone for most combustion systems. There are divided opinions regarding the predominant breakup mechanisms for the atomization regime, but plausibly is by: aerodynamics interaction, turbulence, cavitaion and bursting effect. The properties of jets of most interest are the breakup length and the drop size. The breakup length provides a measure of the growth rate of the disturbance created by the interaction of cohesive and disruptive forces on the liquid jet and, also, it defines the point or region where secondary atomization starts, which is the fully dispersed multiphase flow region. Experimental measurements have contributed significantly to the understanding and development of empirical and semi-empirical models for the breakup. Liquid breakup length correlations, based on extensive experimental data, for turbulent jets are mainly grouped into three categories. However, of interest is the breakup of entire liquid column as a result of the turbulent primary breakup mechanism. It is obvious that empirically developed models are bounded and are heavily depended on the experimental approaches and conditions. Thus, attempt has been made by some researchers to manipulate experimental data and correlations, mechanistically, to arrive at models for mean breakup length for the breakup of entire liquid column due to the turbulent primary breakup mechanism. With the general acceptance of these models, however, these models do not account for the aerodynamic interactions of the issuing jet with the continuous phase and viscous effect. Therefore, this work presents model that uses a more robust development approach, the energetic approach, for the determination of the breakup length for the turbulent breakup mechanism of the atomization regime of primary atomization process, which accounts for aerodynamic interactions and viscous effect. Nevertheless, simplification of the original model to a more simplified one, which does not account for the aerodynamic and viscous effects, predicted experimental data accurately more than its counterpart, which has been widely accepted and used. Therefore, the developed model will find application in combustion systems, especially diesel direct injection system, since most of their operational zone are with the atomization regime of the primary atomization process.

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