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Modeling atomization of a round water jet by a high-speed annular air jet based on the self-similarity of droplet breakup

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ABSTRACT

Based on the self-similarity of droplet breakup in the secondary atomization region, the atomization process of coaxial air-blast atomizer has been investigated. The relationship of Sauter mean diameter (*SMD*) with the effects of gas jet velocity, liquid jet velocity and diameter and liquid/gas mass flux ratio was obtained according to the breakup time and motion characteristic of droplet in air stream. The four parameters in the relationship of *SMD* were estimated according to the experimental results of nine coaxial two-fluid air-blast atomizers with air and water. The results showed that the obtained relationship of *SMD* can be used to predict the *SMD* of coaxial air-blast atomizer when $m > 13.99 d_l^{-0.1285} d_g^{-0.9415}$.

Keywords: Atomization; Air-blast; Coaxial; Droplet; Breakup; Self-similarity

1. Introduction

Gasification of liquid fuels in entrained flow gasifiers, and other industrial applications depends on effective atomization of liquid fuel to achieve high rates of mixing and evaporation. Disintegration of liquid jet injected into high-speed gas stream has been studied by many researchers. It is fundamentally different from that which occurs for the same liquid jet discharging into a stagnant gas. For cases in which the momentum flux of the gas stream is of the same order, or exceeds that of the liquid jet, the breakup and atomization is caused by the kinetic energy transfer from the gas to the liquid. This type of atomization is generally referred to as air-blast atomization (Lefebvre, 1989).

In the case of interest here, where a low-speed liquid jet is injected at the central axis of a high-speed coaxial air jet, detailed reviews of earlier work have been published by Lefebvre (1989), and more recently by Lin and Reitz (1998), Lasheras and Hopfinger (2000), Sirignano and Mehring (2000), and Babinsky and Sojka (2002). For combustion applications, many empirical correlations are available for the droplet size as a function of injection parameters (Lefebvre, 1989).

The liquid atomization of coaxial air-blast atomization can be divided into a near-field primary breakup region, and a far-field secondary breakup region (Lasheras et al., 1998). The primary breakup, which is dominant in the first few jet diameters, is essentially related to the non-miscible shear instability, and results in the stripping of the liquid jet by the high shear force at the gas/liquid interface. Further downstream, droplet atomization may also occur from the deformation forces exerted on the droplets by the turbulent motion of surrounding air, a process known as secondary atomization. Recently, Varga et al. (2003), Marmottant and Villermaux (2004) and Villermaux et al. (2004) observed and analyzed the successive steps of atomization of a liquid jet when a fast gas stream blows parallel to its surface. Experiments performed with various liquids in a fast air flow showed that the liquid destabilization proceeds from a two-stage mechanism: a shear instability first forms waves on the liquid and a Rayleigh–Taylor type of instability is triggered at the wave crests, producing liquid ligaments which further stretch in the air stream and break into droplets.

Eroglu et al. (1991) measured the breakup length *L* of a round liquid jet in an annular coaxial air stream and found

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