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Evaluation of unsteadiness in effervescent sprays by analysis of droplet arrival statistics – The influence of fluids properties and atomizer internal design

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ABSTRACT

The ideal spray theory of Edwards and Marx was used to investigate the dependence of effervescent spray unsteadiness on fluid properties and atomizer internal design. Results demonstrate that fluid properties and internal design of atomizer directly affect the two-phase flow pattern inside the atomizer which consequently affects the spray unsteadiness of the atomizer. Water sprays are more unsteady when the air to liquid ratio (*ALR*) increases, whereas, more unsteady is observed for using glycerol/water mixture (high-viscosity Newtonian fluid) or glycerol/water/xanthan (non-Newtonian fluid) mixture as *ALR* reduces. In addition, sprays using low-viscosity or strong non-Newtonian fluids usually are more unsteady, regardless of *ALR*.

A short mixing chamber results in less unsteady for water but has no effect on spray unsteadiness for high-viscosity or non-Newtonian fluids at *ALR* of 0.15. Otherwise, the influence of mixing chamber distance on the spray quality is weak at *ALR* of 0.15. Large diameter of inclined aeration holes shows the low spray unsteadiness and good spray quality for water but causes more unsteady for glycerol/water/xanthan mixture at *ALR* of 0.15. Furthermore, the diameter of the inclined aeration holes has little influence on spray unsteadiness for glycerol/water mixture. Spray unsteadiness and quality are not affected by the angle of aeration holes for three fluids at *ALR* of 0.15.

1. Introduction

Understanding the steadiness of sprays is of critical importance in many areas of science and technology [1–6]. For example, unsteady spray has a negative influence in combustion application. It leads to the combustion noise increase [7] and it also causes droplet clustering in the atomization process itself, which can result in spatial and/or temporal inhomogeneities in heat release and influence flame stability [8–10]. Unsteady spray is not hope to take place in the spray drying process [11]. In the field of spray drying, it is important to recognize the uniform moisture content of particle and final particle size may be properly controlled.

Until recently, several methods have been developed to identify spray unsteadiness. Hardalupas and Horender [4] developed a method, which sampled time-dependent droplet velocity and size measurements using Phase/Doppler Particle Analyzer (PDPA), to determine the spray unsteadiness of a pressure swirl atomizer. A pressure oscillation based measurement method was developed by Jedelsky and Jicha [5] to determine the spray unsteadiness, which established the connection between the two-phase flow and the spray unsteadiness. Batarseh et al. [6] found that the instability of spray shape and velocity with a certain frequency, which depends on the operational parameters of the swirl two-fluid atomizer. Sutherland et al.'s entrainment study demonstrated the relationship between entrainment and spray unsteadiness [12]. Ghaemi et al. [13] and Kim and Lee [14] also indicated that two-phase flow patterns in the atomizer directly have a strong influence on the spray unsteadiness. Furthermore, Edwards and Marx [15,16] introduced ideal spray theory to study the spray unsteadiness. This method provides a frame work for evaluating spray unsteadiness: the interparticle arrival time distributions of steady sprays should obey inhomogeneous Poisson statistics, while unsteady sprays do not. Based on Edwards's ideal spray theory, Heinlein and Fritsching [17] and Fritsching and Heinlein [18] studied the droplet clustering in spray, which is an example of unsteady behavior caused by pulsating liquid disintegration. The results of Hodges et al. [1] showed that small droplets (<20 μm) exhibit spray unsteadiness behavior while the large droplet do not in the pressure-atomized swirl kerosene flames.

Effervescent atomization has recently become a focus of research interest for the various advantages of the technique, such as, fine and controllable spray at low injection pressures compared with other atomization methods [19–21]. However, Luong and Sojka [22] and Jedelsky and Jicha [5] presented that all the size class of droplet show the spray unsteadiness in effervescent

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