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Effect of flow conditions on spray cone angle of a two-fluid atomizer †

Maziar Shafaee*, Sayed Abdolhossein Banitabaei, Mehdi Ashjaee and Vahid Esfahanian
School of Mechanical Engineering, Tehran University, Tehran, 11155-4563, Iran

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Abstract

A visual study is conducted to determine the effects of operating conditions on the spray cone angle of a two-fluid atomizer. The liquid (water) jets exit from peripheral inclined orifices and are introduced into a high-speed gas (air) stream in the gravitational direction. Using a high-speed imaging system, the spray cone angle is determined for Reynolds numbers ranging from 4×10^2 to 9×10^2 and different Weber numbers up to 140. The droplet sizes (Sauter mean diameter) and their distributions are determined using a Malvern Mastersizer X. The results show that the spray cone angle depends on the operating conditions, especially in lower values of Reynolds and Weber numbers. An empirical correlation is also obtained to predict the spray cone angle in terms of these two parameters.

Keywords: Correlation; Spray cone angle; Two-fluid atomizer; Visual study

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1. Introduction

Two-fluid atomization (also termed as twin-fluid, two-phase, pneumatic, and aerodynamic atomization) is a liquid disintegration technique applied to various spraying systems. This type of atomization may be divided into two categories: air-assist and air-blast atomization. In both processes, the bulk liquid to be atomized is transformed into a jet or sheet at a relatively low velocity, and then exposed to a high-velocity gas stream [1]. The kinetic energy of the gas flow is used as a source of atomization to shatter the bulk liquid into ligaments that subsequently break up into droplets [2, 3].

The penetration, spray dispersion angle, and droplet sizes related to the breakup process of liquid jets and air/fuel distributions are very important parameters in propulsion systems that require combustion efficiency and the regulation of pollutant emissions [4]. The spray angle is also one of the important external spray characteristics for evaluating atomizer performance. Most sprays have a conical shape, and the cone angle is usually defined as the angle between the tangents to the spray envelope at the atomizer exit.

Many practical systems require atomizers that distribute fuel in a less concentrated and lower penetration spray. The spray angle of a two-fluid atomizer should be able to mix the two fluids, causing the liquid jets to be disintegrated perfectly through the gas stream.

In combustion systems, the value to be selected for the cone angle is dependent on the shape of the combustion chamber prior to the air and fuel mixing conditions. The spray angle of a gas turbine combustor greatly affects its vital parameters, including the quality of air and fuel mixing, wall temperature, propulsive power, combustor durability, emission quality, and efficiency of energy utilization. Chatterjee et al. [5] investigated the effect of the spray cone angle on the combustion performance of a liquid fuel spray in a gas turbine combustor, and observed that an increase in spray cone angle increases the wall temperature. Therefore, developing an accurate method for predicting the spray cone angle in such atomizers is very important.

Guo et al. [6] investigated the two-phase spraying characteristics of a gas-liquid nozzle used for the humidification of smoke. They found that, at the given gas pressure, the spray angle gradually increases with the increase of the liquid phase velocity, whereas, at the given liquid pressure, the spray angle decreases with the increase of the gas pressure. Chen and Lefebvre [7] investigated the influence of ambient pressure and liquid physical properties on spray cone angles for a low-injection-pressure (less than 2 MPa) effervescent atomizer. They observed that for low ambient pressures, the value of the spray cone angle increases continuously with the increase of the gas to liquid mass ratio (GLR), whereas at higher pressures, it has a maximum value at an intermediate GLR. They explained that the decrease in cone angle at high GLRs is caused by the transition of the two-phase flow inside the atomizer exit orifice. Varde [8] used a liquid fuel spray injected into a gaseous environment to investigate the effects of nozzle

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* Corresponding author. Tel.: +98 912 7034912, Fax.: +98 21 77305225
E-mail address: mshafaee@ut.ac.ir

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