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Elyar Allaf-Akbari, Nasser Ashgriz

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An Electrospray in A Gaseous Crossflow

Elyar Allaf-Akbari & Nasser Ashgriz
Department of Mechanical and Industrial Engineering,
University of Toronto, Toronto, Ontario, Canada M5S 3G8

Abstract

An experimental study on the dynamics of an electrospray (ES) injected into a test chamber with a gaseous crossflow is presented. The study is relevant to the ion introduction into mass spectrometers that use ES as the ion source. Bending and trajectory of the ES plume is determined for a range of air crossflows and for different ES injection locations with respect to the crossflow centerline. It is shown that the ES injection conditions correlate with the intensity detections of a mass spectrometer. The effect of crossflow on the cone jet and ES performance are also discussed. A new hysteresis phenomenon for the electrospray in crossflow is detected.

Keywords: Electrospray, crossflow, plume, cone jet, hysteresis, mass spectrometry

1. Introduction

Electrosprays have a broad range of applications, such as in MEMS and microfluidics (Chiarot, et al., 2011), emulsion production (Barrero & Loscertales, 2007), fuel injection (Deng, et al., 2007; Kyritsis, et al., 2004), etc. (Bailey, 1988). Their most important application, however, is to generate ions for mass spectrometry (MS) (Fenn, et al., 1989; Cole, 1997; Pramanik, et al., 2002). Therefore, there are numerous investigations on various aspects of their operation, such as the operating modes. Cloupeau & Prunet-Foch (1990), Jaworek & Krupa (1999), and Sultan et al. (2011), have reviewed different operating modes of ES. Some of these modes are: dripping, spindle, cone jet, and multi-jet. In the cone jet mode, a conical liquid meniscus is formed at the tip of ES nozzle, emitting a charged jet from its apex (Smith, 1986; Taylor, 1964; Zeleny, 1917). This jet later breaks into fine charged droplets, which form a conical plume due to the repulsion among the droplets, i.e., space charge. Valaskovic et al. (2004) and Nguyen et al. (2014) tried to improve the ES performance in the cone jet mode by monitoring the ES plume, and cone, respectively. Park et al. (2004) studied the effect of different solution flow rates and guard plates, i.e., different equipotential fields, on the plume angle and on the onset voltage of cone jet mode. Wang et al. (2012) investigated the effect of surface tension and ionic strength of the spraying solution on the plume angle and jet breakup length. Dynamics of droplets and the shape of the plume in stagnant gaseous environment have been simulated by Ganan Calvo et al. (1994), Wilhelm et al. (2003), and Grifoll and Rosell-Llompart (2012). For detailed discussion on the modelling of ES plumes, the reader is referred to Arumugham-Achari et al. (2015) and the references therein.

Studies on the formation and dynamics of electrosprays in a gaseous flow are limited. Gañán-Calvo et al. (2006) mixed the flow focusing technique with electrospraying and achieved smaller droplets and more stable spraying, in comparison to individual flow focusing or ES. They also discussed the jet instability and