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Three-dimensional tomographic reconstruction of unstable ejection phenomena of droplets for electrohydrodynamic jet

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ABSTRACT

The electrohydrodynamic (EHD) jet is becoming increasingly popular within industrial printing areas based on phenomena induced by electrical potentials. Regardless of the physical observations of unstable ejection phenomena in regions possessing high electric potential, quantitative visualization is still necessary; no report exists exemplifying quantitative visualization. Thus, the size, shape and position of EHD droplets were reconstructed in this study using developed three-dimensional tomography methods. Two computer-synthesized phantoms for the liquid meniscus containing small satellite droplets were generated according to actual images captured by two high-speed cameras. These droplets were made in order to numerically reconstruct droplet behavior. Four three-dimensional tomography methods, such as the algebraic reconstruction technique (ART), the adaptive algebraic reconstruction technique (AART), the simultaneous iterative reconstruction technique (SIRT) and the multiplicative algebraic reconstruction technique (MART), were developed to accurately mimic droplet movement using multiple image views. Four basis functions including the cubic B-spline, cosine, o-Moms and Keys basis functions were adopted in order to improve the performance of the tomographic reconstructions. After completing a comparison of the four tomography results, the MART method in association with the cubic cosine basis function was selected as the means to significantly improve reconstruction accuracy. Additionally, it was the applied method for the reconstruction of the droplet behavior from experimental projections by two cameras.

1. Introduction

The electrohydrodynamic (EHD) spraying of liquids is becoming an increasingly popular topic spurred by its application in physical, chemical, biological and engineering research areas such as micro-detectors, micro-dispensing of small sub-nanoliter volumes of fluids for sensors, flat panel displays, and biochips [1–4]. For industrial printing, the EHD jet generates sub micron droplets from the apex of a liquid meniscus under high voltages resulting in improved printing quality due to the EHD jet's ability to print micro sized patterns using various inks. The EHD jet produces various phenomena caused by changing the amplitudes of the electric potentials. Thus, the nonintrusive determination of numbers, sizes and locations of the droplets is required to measure component fractions and distributions for analysis of a two-phase flow.

Electrohydrodynamics may be applied to different fields according to the various ejection conditions. If a smaller droplet size or a higher frequency is required, an applied voltage should be increased, allowing for the observation of unstable ejection phenomena under a special condition. Thus, the three-dimensional movement and shape of droplets should be analyzed using a developed three-dimensional tomography to investigate a boundary of a stable ejection. Since satellite droplets may not be seen or droplet trajectory may not be observed exactly by the naked eye, the three-dimensional tomography method for analysis of the droplet behaviors was developed in this study.

Tomography methods are effective tools of noninvasive and quantitative measurements of thermal flows [5]. A line-of-sight optical projection of a two-phase flow is expressed as a ray integral of certain properties such as density or temperature of an object along a direction of an incident ray as shown in Fig. 1. A spatial distribution of the properties about the object can be reconstructed from the line integrals of the properties. This distribution is deemed the projection data according to the computerized tomography technique.

The projection data can be obtained by the integral method along the incident direction as follows:

$$\psi(s,\theta)=\int_{-\infty}^{+\infty} f(x,y)dt \tag{1}$$

where $\psi(s,\theta)$ is the projection data, and $f(x,y)$ is the object function that represents the object to be reconstructed, which is integrated along the coordinate axis t. The Cartesian coordinate system (s,t)

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