# Measurement of continuous liquid jet length in atomizers with optical connectivity, electrical conductivity and high-speed photography techniques

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**Abstract**

## Introduction

The atomization process of a liquid jet has been described as a two stage process. During the first stage, which is referred to as "primary atomization", the gas-liquid interface is initially perturbed close to the nozzle exit. The perturbations develop until finally the continuity of the jet is interrupted and the bulk liquid disintegrates to droplets and ligaments. In the second stage, referred to as "secondary atomization", the products of "primary atomization" are further broken to smaller pieces. The distance from the nozzle exit up to the point where the liquid jet is broken is defined as the "breakup length" and it marks the extent of the primary atomization zone and determines the quality of atomization.

The method that is mostly used for the measurement of the breakup length is photography. However there are cases where photographic measurements are problematic, since the density of the spray droplets might obstruct the imaging of the liquid jet. However, high-speed imaging can improve the measurements as the temporal record of the liquid jet evolution might reveal where the liquid jet continuity is interrupted.

Alternative methods have been proposed. A recently proposed method is the optical connectivity technique [1]. A laser beam is introduced into the liquid jet through the base of the liquid nozzle. The laser beam then travels along the liquid jet in the way light travels though an optic fiber up to the point where the continuity of the liquid jet is interrupted. The addition of a fluorescent dye in the jet liquid makes the volume of the liquid jet luminous (as in figure 1) and distinguishable from the surrounding products of atomization (Figure 2). Fluorescence is also red-shifted in comparison to the laser wavelength noise and scattered light noise can be suppressed by the use of optical filters. There is a limitation for long continuous liquid jet, since laser intensity losses due to refraction of light along the liquid jet length are inevitable.

Another method is the electrical conductivity technique [2]. A potential is applied between the liquid jet nozzle and a probe downstream. Provided that the atomized liquid is conductive, there will be conduction of electricity, as long as a continuous liquid jet is present. In this way, the length of the continuous liquid jet is detected. This technique is independent of the length of the measured liquid jet but there are divergent opinions on whether transfer of charge is solely due to a continuous liquid jet, coupled by another process [3] or if the concept of a continuous liquid jet until breakup holds [4].

The purpose of the paper is to compare the continuous liquid length measured with the above techniques under various operating conditions of a coaxial airblast atomizer.

## Materials and Methods

A coaxial airblast atomizer is placed vertically with the jets exhausting downwards. The internal and external diameters of the liquid nozzle exit where 2.3mm and 2.95 mm respectively and of the gas nozzle is 14.95mm making the gas to liquid area ratio about 25. Further details of the description of the atomizer can be found in [5].

For the optical connectivity technique a steel tube with a quartz window is inserted into the tube that delivers the liquid to the jet nozzle. The laser beam from an Nd:YAG laser, is guided into the steel tube and exits just before the liquid jet nozzle, in a direction parallel to the liquid jet so that is follows the liquid jet. The liquid is doped with Rhodamine WT dye. The liquid jet becomes luminescent due to the excitation of the dye by the laser beam and is imaged with an Andor ICCD Camera coupled with a long pass filter to suppress scattered light.

For the electrical conductivity technique, an electrical circuit was built around the liquid nozzle exit. A solid state battery supplied constant voltage up to 10V (adjustable by 0.1mV increments) between the liquid nozzle and the probe. The probe was a straight stainless steel rod of 1mm diameter and was aligned normal to the central axis of the liquid nozzle. A resistance of 1MΩ was also connected in series, between the voltage source and the nozzle and was used as a reference for the resistance of the liquid jet. A 12-bit A/D card connected to a PC recorded the voltage drop between the liquid jet nozzle and the probe.

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A high-speed camera (Photron Fastcam APX RS) was used to image the liquid jet. The camera was synchronized to the data acquisition card, so that it recorded a frame simultaneously with the acquisition of the voltage drop across the liquid nozzle and the probe of the electrical conductivity technique. Back illumination of the liquid jet by a collimated beam of light entering the camera lens directly was the preferred method of illumination as it provided strong signal. An incandescent light source was used to provide constant illumination and avoid problems with flicker that are found with fluorescent sources of illumination that are affected by the mains frequency.

**Final paper**

The final paper will present a comparison of the continuous liquid jet measured by the optical connectivity, electrical conductivity and high-speed photography techniques. The advantages and disadvantages of the techniques will be evaluated and the extent of the applicability of each technique will be discussed. It is expected that the photographic information of the liquid jet, while the electrical conductivity probe interacts with the liquid jet, will provide an insight on the operation of the electrical conductivity technique and its influence on the atomization process, which is missing from the literature.

**References**


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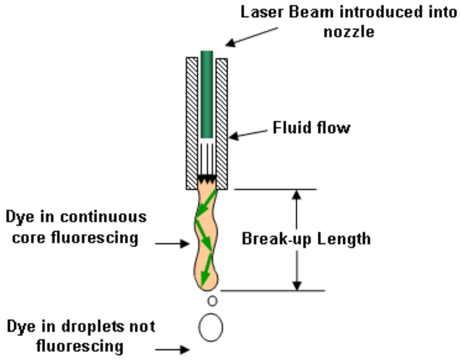
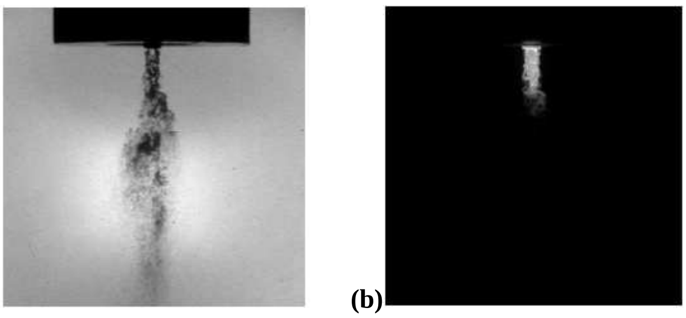



**Figure 1.** Principle of the optical connectivity technique



**(a)** **(b)**

**Figure 2.** Simultaneous (a) photographic and (b) optical connectivity imaging of the liquid jet, which shows that the optical connectivity technique identifies objectively the length of the liquid jet.