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Cavitation Effects on the Dispersion of Glowing Sprays in the Near-nozzle Region

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Quantifying the effect of cavitation in spray formation can significantly help our understanding of spray atomization. Laser Induced Phosphorescent tagging (LIP) can help in this aspect by providing quantitative measurements of dispersion in the near-nozzle region. The current work uses a flush mounted pressure transducer together with Diffuse Back-illumination Imaging (DBI) to correlate pressure fluctuations to cavitational bursts. Information on the pressure fluctuations is then combined with LIP to quantitatively determine the deviation of cavitational burst dispersion from the non-bursting case. It shows that while the spray width may increase due to the cavitational fluctuations, it does not necessarily enhance the dispersion of the spray itself.

Keywords: Spray, atomization, cavitation, pressure, phosphorescence, dispersion

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Introduction

The dispersion and atomization of sprays has been an important issue for decades. The many effects that influence spray breakup, such as entrainment, turbulence, surface wave instabilities, pressure fluctuations, and cavitation result in a physically complex breakup mechanism. In order to understand the breakup as a whole, it is necessary to understand the individual phenomena that characterize it.

Cavitation, the formation of vapour cavities close to the nozzle entrance and the internal nozzle flows associated with this phenomenon, has been found to greatly influence spray breakup and atomization [1-5]. However, the influence of cavitation on the dispersion and velocity is still quantitatively unclear. Desantes et al. [6] and Mitroglou et al. [7], and Ganippa et al. [8] found that an increase in spray angle is observed related to the presence of cavitation bubbles, indicating that cavitation can dramatically influence the atomization process. However, without internal nozzle flow information, like that obtained from transparent nozzles or x-ray imaging, investigating cavitational effects is difficult. Bilus et al. [9] showed that unstable cavitation generates pressure fluctuations in the surrounding flow and found that the strength of the cavitation effect on the spray could be strongly correlated to the pressure fluctuations. These pressure fluctuations can thus be used to correlate cavitation events to qualitative and quantitative measurements.

In the present study, Diffuse Back-illumination Imaging (DBI) is used to determine spray width increases correlated with measured pressure fluctuations, presumably of cavitational bursts. Furthermore, quantitative measurements of dispersion and velocity are determined using Laser Induced Phosphorescent (LIP) tagging [10] and the measurements correlated to cavitation events are compared to the average case.

Experimental setup & Method

The continuous spray used in this investigation is pressure-generated using a custom-built mount with a single-hole 200 μm nozzle (see figure 1) with a length/diameter ratio (L/d) of 10. The line pressure used is either 70 or 110 bar and driven by a 200 bar nitrogen reservoir. In the DBI setup the spray is illuminated by a white light LED (100W, 6500K) in front of a 50° diffuser (Thorlabs GmbH, Germany). The high speed camera (Photron SA-Z, Photron limited, UK) is operated at 100-120 kHz with an exposure time of 248 ns. The 144x1024 pixel field of view has a resolution of 12-18 μm/pixel. A flush-mounted charge pressure sensor (116A, PCB Piezoelectronics), amplified by a charge amplifier (KISTLER 5011) measures the dynamic pressure at a rate of 250 kHz, synchronized to the camera through a delay/pulse generator (DG535 Stanford Research Systems) and acquisitioned using a DAQ device (NI-USB 6221).

To obtain the spray width from the DBI images a full-width-half-maximum value is determined immediately downstream of the nozzle exit. These widths are then correlated to the pulse amplitude of the measured pressure signal.

To generate the phosphorescence, a molecular complex based on europium is added to water [11], creating a solution with a surface tension $\gamma = 0.03$ N/m (all other properties of the fluid of remain unchanged). When the phosphorescent solution is excited with 355 nm UV light, it emits red (613 nm) light with a half-life of approximately 1 ms.