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SIMULTANEOUS X-RAY RADIOGRAPHY AND X-RAY FLUORESCENCE MEASUREMENTS FOR AERATED-LIQUID SPRAYS

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The aerated-liquid (or effervescent, or barbotage) jet is a promising fuel injection scheme for efficient combustion in high-speed air-breathing propulsion systems. By preparing a two-phase mixture inside the injector with a small amount of gas to mix with the liquid fuel, the resulting aerated-liquid jet is capable of generating a well-dispersed plume for effective mixing with the ambient air and therefore for efficient combustion. In the past, structures of aerated-liquid jets were characterized by liquid-only measurements, using conventional and X-ray diagnostics, resulting in an incomplete understanding of the two-phase flows within the near field of spray plumes. In the present study, near-field structures of aerated-liquid jets discharged into a quiescent environment were explored, using simultaneous X-ray radiography for liquid phase measurement and X-ray fluorescence for gas phase measurement. Water and argon were used as the injectant and aerating gas, respectively. The experiment was carried out at the 7-BM beamline at the Argonne National Laboratory. This beamline is dedicated to time-resolved X-ray radiography, tomography, and fluorescence experiments for fuel sprays and associated phenomena. The X-ray source for the beamline is a synchrotron bending magnet, which produces nearly collimated, broadband X-ray emission. The X-ray photon energy was kept at 8 keV to provide a good compromise between absorption of the beam by the spray and excessive absorption by X-ray windows and ambient air. Raster scanning with a beam focus of 5 (V) × 6 (H) μm FWHM was used to interrogate a wide field of view of the spray. Two areas of interest will be presented. First, methodologies to derive quantitative liquid and gas mass concentrations and averaged plume properties within the aerated-liquid jets from the simultaneous radiography and fluorescent measurements were discussed. It was concluded that the present diagnostic approaches can give fairly good mass concentration profiles at locations beyond the first few mm of the flow field. The strong signal-trapping of the argon fluorescence signal by the surrounding liquid, however, was a significant limitation to quantitative measurements in the flow field immediately adjacent to the exit orifice. Ideas to mitigate this uncertainty were proposed for future efforts. Second, mass distribution profiles and averaged plume properties for representative aerated-liquid jets were explored. It was found that liquid and aerating gas exhibit different plume characteristics, even for the injection condition with vigorous mixing schemes to generate a uniform two-phase mixture inside the injector prior to the final injection. The gas plume stays along the injector axis and is narrower than the liquid plume, especially at the downstream locations for well-dispersed sprays. The potential mechanisms for the separation of liquid and gas plumes were proposed in this study.

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