Small Angle X-Ray Scattering (SAXS) on Droplet Size and Liquid Contents of Condensed Supercritical Ethylene Jets

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Abstract

Injection of supercritical fluid is an increasingly important research area in the development of high-speed air-breathing propulsion technologies. The use of endothermic hydrocarbon fuels as primary coolant around combustor inevitably creates thermally cracked hydrocarbon mixtures at supercritical conditions. The subsequent injection of the supercritical fluid into the air-breathing combustor can considerably affect the combustion behavior of an engine, due to liquid generation through homogeneous nucleation processes. Further understanding on the liquid condensation processes and the plume structures of supercritical jets, however, was limited by the capability of conventional diagnostic techniques. The objective of this study is to assess the feasibility of applying the small angle x-ray scattering (SAXS) technique to the study of supercritical jets. The x-ray source at the 8-ID beamline at the Argonne National Laboratory was utilized for this study. Pure ethylene with desired temperature and pressure was injected into a chamber filled with nitrogen at the desired pressure. Effects of injection temperature, injector internal geometries, and ambient pressures on droplet size and liquid content were also investigated. It was found that the SAXS technique is capable of measuring droplet size and liquid contents inside a condense jet. The droplet size inside a condensed supercritical ethylene jet is on the order of 100 nm, which is much smaller than that generated from industrial atomizers. The average droplet size weighted by liquid volume fraction increases with both axial and radial distance within the condensed jet, due to droplet evaporation and gas expansion processes. The injection temperature is the most dominant factor in determining droplet size and liquid contents. At an injection temperature close to the ethylene critical temperature, the injected plume contains bigger droplets and higher liquid contents. Based on the present measurements, the effects of injector internal configuration on droplet size and liquid contents cannot be clearly verified.

Key words:
Supercritical Jet, Small Angle X-Ray Scattering, SAXS, Homogeneous Nucleation, Droplet, Air-Breathing Propulsion

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