Geometry Effects on Steady and Acoustically Forced Shear-Coaxial Jet Sprays

S. Teshome[*+], I.A. Leyva[+&], J. Rodriguez[+], D. Talley[+]
[*]UCLA, Los Angeles, CA, USA, [+]Air Force Research Lab, Edwards, CA, USA
steshome@ucla.edu and ivett.leyva@edwards.af.mil

Abstract

This experimental study investigated the mixing behavior and characteristics of dynamic flow structures of cryogenic, non-reactive shear coaxial jet sprays under varying flow conditions, with and without the presence of pressure perturbations due to acoustic forcing transverse to the flow direction. The role of injector geometry was examined using four shear coaxial injectors with different outer-to-inner jet area ratios and different inner jet post thickness to inner jet diameter ratios. Flow conditions at a high pressure spray (reduced pressure of 0.44) with varying outer-to-inner jet momentum flux ratios ($J \sim 2 - 20$) and maximum amplitude in the pressure perturbation (pressure antinode) at the jet axis location were considered. Nitrogen was used as the test fluid for the injector streams and to pressurize the chamber. The inner and outer jet temperatures were independently controlled so that the inner condensed flow was cooled down to or below the saturation temperature of the liquid. Back-lighting the coaxial spray resulted in a silhouette of the dense inner core, which appeared as a dark column. This distinguished it from the outer gaseous flow, and thus, enabled high speed images to capture the jet flow dynamics. Dark-core length measurements, pertaining to the unmixed portion of the dense inner flow, were used to indicate the extent of mixing under the different flow conditions and injector geometries. A basic application of proper orthogonal decomposition on the intensity fluctuation of the high speed images enabled the extraction of the spatial and temporal characteristics of the dominant flow structures that existed in the flow field at baseline conditions and during exposure to acoustic forcing.

The extent of the influence of outer-to-inner momentum flux ratio on mixing was dependent on the injector geometry. The dark-core lengths of the inner jet for injectors with large outer-to-inner jet area ratio (LAR), with both thin and thick inner jet posts, were more influenced by increasing momentum flux ratios. In contrast, the dark-core length of the inner jet for a geometry consisting of a small outer-to-inner jet area ratio (SAR) with a thin inner jet post was very insensitive to J for the range of values tested. The response of the injector flows to a pressure antinode was also dependent on the particular geometry. The flow of the SAR injector with a thin inner jet post showed a strong response to acoustics regardless of J, while the response of the other injectors to a pressure antinode was dependent on J. The observations from this study point to the significance of how simple design alterations in injector geometries may bring about drastic changes in the mixing and response of shear-coaxial jet flows to external pressure disturbances.

[&]Corresponding author: ivett.leyva@edwards.af.mil