Pressure-Swirl Atomization of Water-in-Oil Emulsions

OVERVIEW

Water addition into hydrocarbon fuel has the potential to decrease pollutant emissions (NO_x, SO_x and Soot) and avoid excessive thermal stresses in combustion systems. Implemented properly, Introducing a water-in-fuel oil emulsion into a gas turbine enhances the breakup of liquid fuel, producing a finer spray droplet size distribution, promoting the onset of secondary atomization (microexplosions), all resulting in increased system efficiency. The cycle efficiency also increases due to the additional mass throughput from the water present and allows wider nozzle turndown. The effects of the water fraction in ultra low sulfur diesel fuel (DF2), its discrete water droplet size distribution and the injection pressure drop on the overall spray are investigated for a large flow capacity pressure-swirl atomizer, widely implemented today in Megawatt size industrial gas turbines. Laser diffraction, mechanical spray patternation, and high speed cinematography are diagnostic methods utilized in the current experimental investigation conducted at atmospheric pressure.

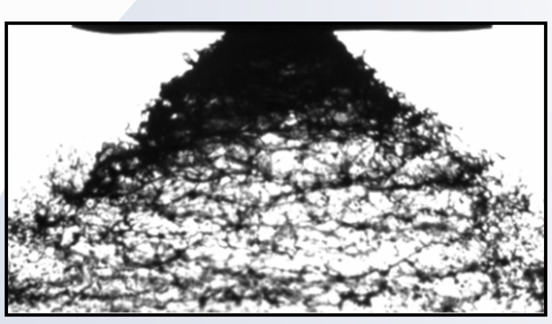
GOALS

The current experimental investigation aims to:

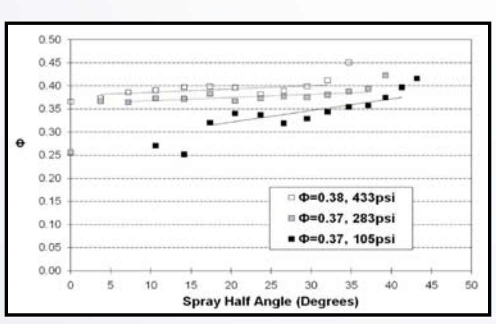
- Create a controlled water-in-oil emulsion with measurable discrete water droplet distribution statistics
- Understand how the amount of water and its discrete droplet size distribution impacts the breakup process for an emulsion spray
- Quantify the representative spray droplet size (SMD) for emulsions composed of less than 40 mass percent water
- Measure the local spray water/DF2 mass fraction (Φ) versus radial position
- Compare the droplet distributions of the emulsion spray with the sprays of its neat components
- Distinguish any differences between natural unstable emulsions and emulsions stabilized with surfactants

RESULTS

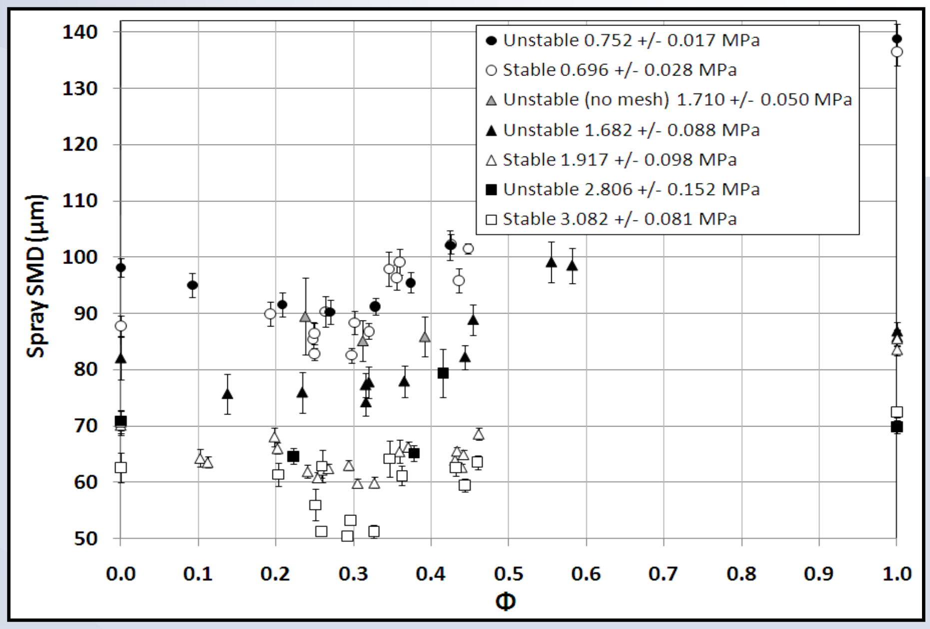
High speed cinematography reveals a significantly different spray breakup phenomena when water is present in DF2. Spray patternation results show a local disparity in Φ, with values lower then the overall Φ toward the spray's axial center and higher values at the spray periphery for both stable and unstable emulsion cases. Spatial and temporal variation intensifies as the discrete water droplet distribution becomes wider with larger water droplet SMD. Measuring the spray SMD using laser diffraction, the droplet size decreased when discrete droplets were



High Speed Exposure of Stable Emulsion Spray (0.689 MPa, Φ = 0.28)



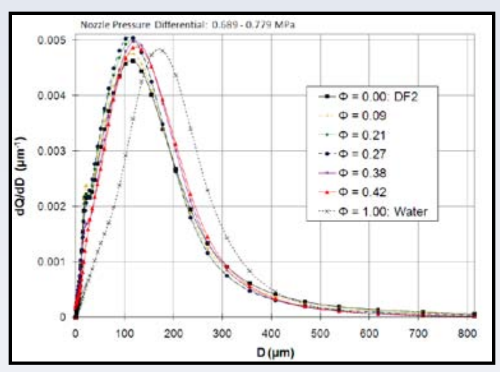
Local Φ vs. Radial Position of Spray (Unstable, Φ = 0.38)



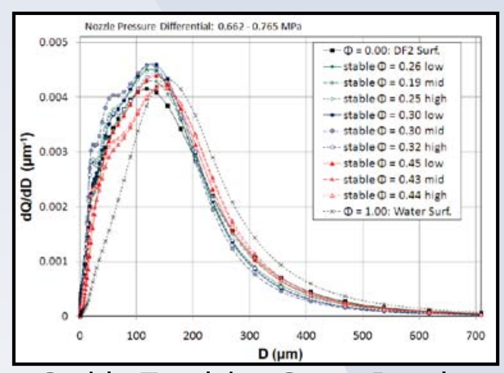
Influence of Water Fraction on Spray SMD for Stable and Unstable Emulsions

RESULTS

introduced up to Φ = 0.3. This occurred for stable and unstable cases, and required a fine quality water droplet distribution from 1 – 100 µm. The trend in spray droplet size is apparent for every case considered, both stable and unstable. Removing the staining mesh element, resulting in a coarser unstable emulsion, the spray SMD increased with Φ, highlighting the role of emulsion quality upon atomization. The change in spray size distribution with Φ is compared below; near 0.7 MPa pressure differential. The water droplet distribution are visible left of the peaks.



Unstable Emulsion Spray Droplet Size Distribution



Stable Emulsion Spray Droplet Size Distribution

RECENT PUBLICATIONS/PAPERS

C.D. Bolszo, A.A. Narvaez, V.G. McDonell, D. Dunn-Rankin and W.A. Sirignano (2010) Pressure-Swirl Atomization of Water-in-Oil Emulsions. *Atomization & Sprays* (Pending).

C.D. Bolszo, M. Rohani, A.A. Narvaez, V.G. McDonell, D. Dunn-Rankin and W.A. Sirignano (2010) Breakup of Water-in-Oil Emulsions in Liquid Jets and Conical Sheets, Proceeding of ILASS Americas 22nd Annual Conference, Cincinnati, OH, USA, May.

C.D. Bolszo, A.A. Narvaez, V.G. McDonell, D. Dunn-Rankin and W.A. Sirignano (2010) Pressure-Swirl Atomization of Water-in-Oil Emulsions, Proceeding of ILASS Americas 22nd Annual Conference, Cincinnati, OH, USA, May.

PERSONNEL

Graduate Student: Chris Bolszo
Undergraduate Student: Guillermo Gomez
Staff: Adrian Narvaez and Rich Hack
Principal Investigator(s): William Sirignano, Vince McDonell and Derek Dunn-Rankin

Project Sponsor: Siemens Power Generation