Emulsion Jet in Crossflow Atomization Characteristics and Dynamics

OVERVIEW

Jets in crossflow, Figure 1, are commonly used as a fuel injection system for various power generation and propulsion systems. This technique mixes an axial gaseous crossflow with a transverse-injected liquid prior to combustion. Successful designs have been produced, however, there is a need to reduce harmful emission levels of nitrogen oxides (NO_x) while maintaining high mixing performance. Water-in-fuel emulsions have had a demonstrated impact on the reduction of NO_x and soot formation through lowering flame temperature in diesel engines. The use of emulsions for a jet in crossflow has yet to be studied extensively but has the potential to greatly reduce harmful engine pollutants.

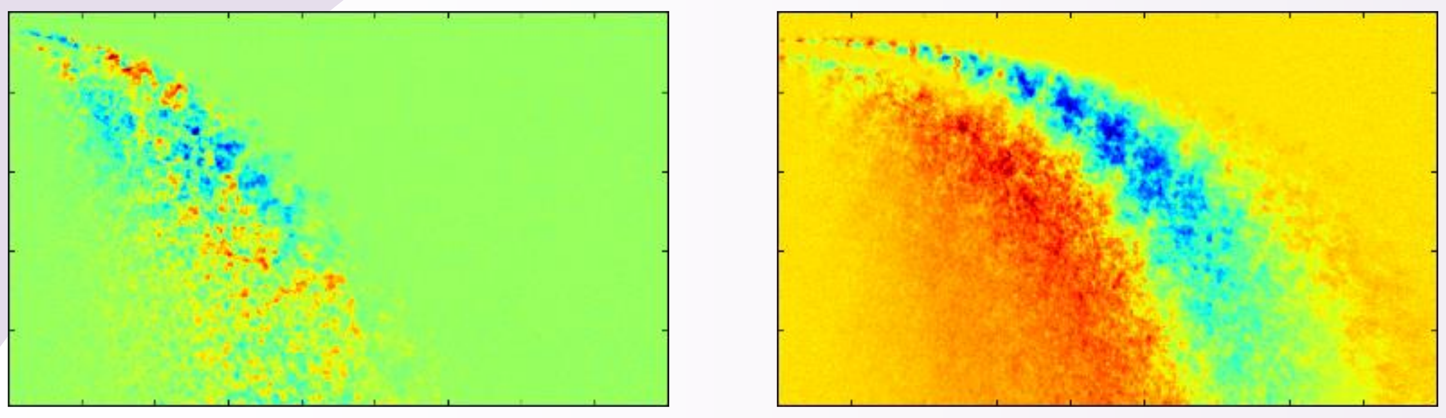
GOALS

This project seeks to investigate the atomization characteristics and dynamics of water-in-heptane emulsions injected into an air crossflow. Correlations of spray characteristics for neat liquids are to be established to see to what extent emulsions adhere to the correlations.

RESULTS

A jet in crossflow test section was constructed to replicate a practical engine. Air crossflow and liquid injection were set up to allow for a range of suitable conditions to be tested. Four liquids were tested allowing comparison between emulsions and non-emulsions: neat water; 40% water in heptane; 20% water in heptane; and neat heptane. Additionally, four injector geometries were investigated.

The effect of emulsions on jet dynamics were found through analyzing instantaneous high-speed video and laser scattering data. Jet penetration instabilities were found to increase for the emulsion cases over the neat liquids. Similarly, jet cross-sectional area was also found to exhibit greater instabilities when emulsions are utilized. Dynamic mode decomposition (DMD) was applied to high-speed video data to extract coherent spatial modes and their frequencies. Emulsions demonstrated similar high-frequency modes as neat liquids but contained a greater number of dominant low-frequency modal structures. Example modal structures are shown in Figure 2.



(a) (b)

Figure 2. DMD extracted spatial modes. (a) High-frequency neat liquid mode and (b) low-frequency emulsion mode.

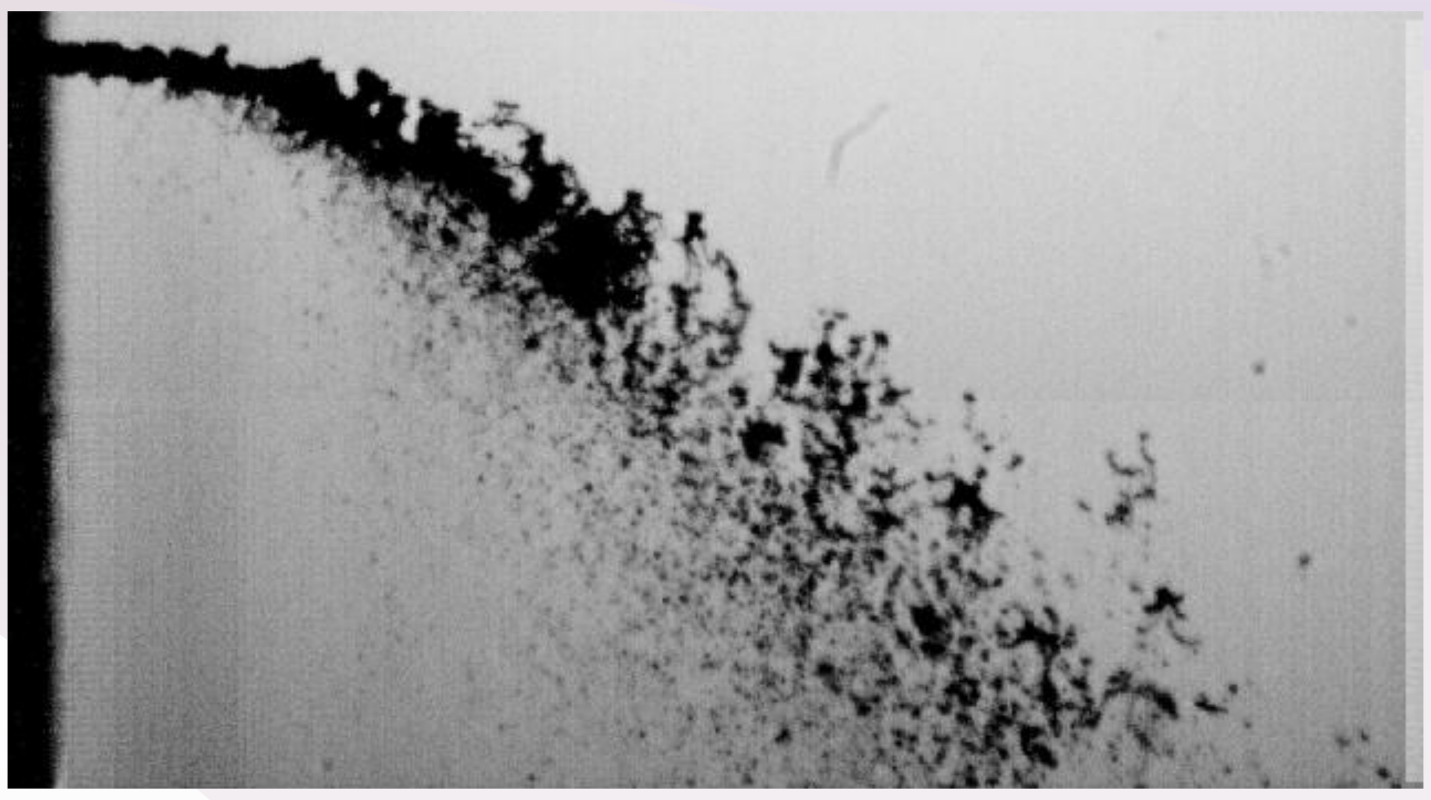
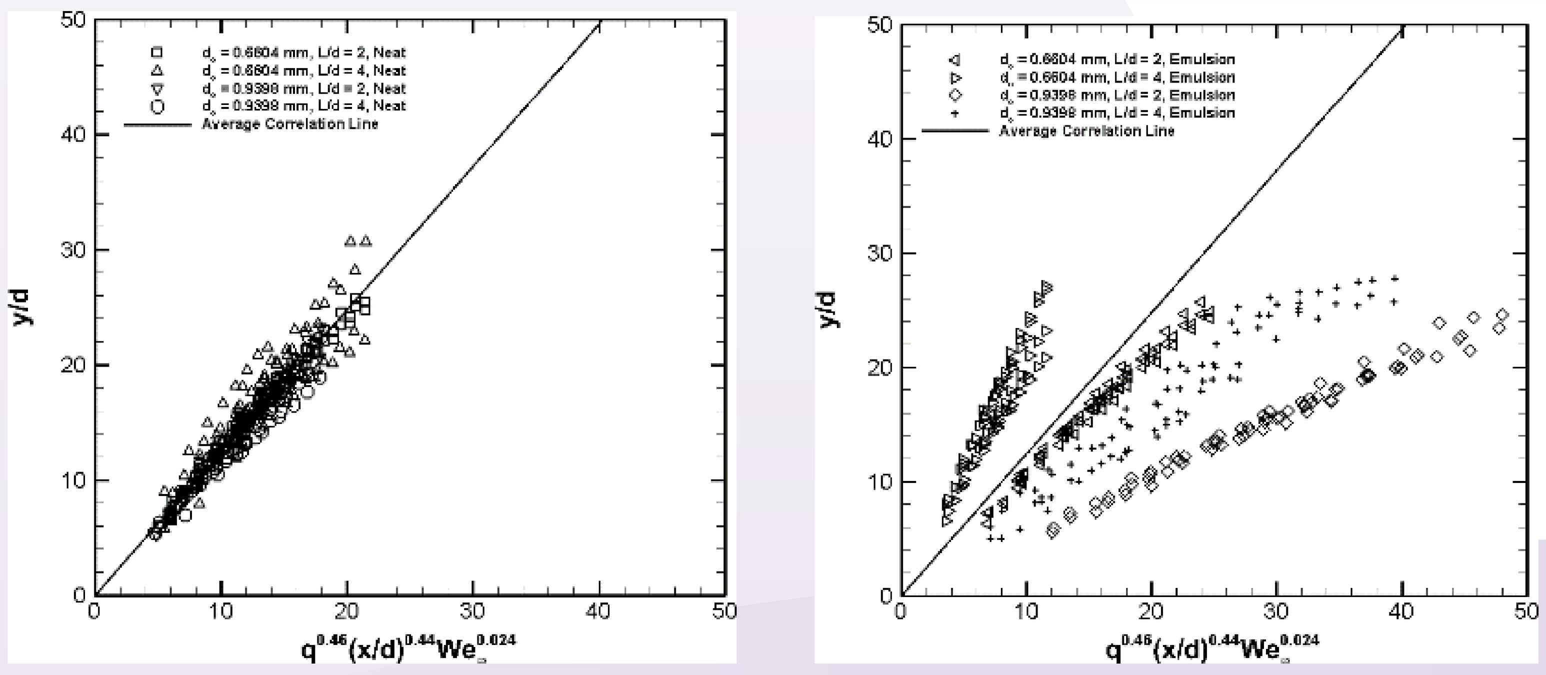


Figure 1. High-speed capture of a jet in crossflow.

Correlations for jet penetration length, *y/d*, Sauter mean diameter, SMD, and spray cross-sectional area were all found for neat liquids. These correlations predicted neat liquid characteristics to high accuracy for the different injector geometries. The emulsions were found to deviate from these correlations due to increased dynamical behavior and unaccounted correlation terms. The correlation of jet penetration length with neat liquid data is shown in Figure 3(a) and can be compared to the emulsion data in Figure 3(b). These correlations do, however, provide qualitative results for emulsions. Emulsion sprays have increased SMD values and can have increased cross-sectional areas over neat liquids.



(a) (b)

Figure 3. Jet penetration correlation with (a) neat liquid data and (b) emulsion data.

RECENT PUBLICATIONS

Leask, S. B., McDonell, V. G. and Samuelsen, S., (2018). “Emulsion Jet in Crossflow Atomization Characteristics and Dynamics”, accepted for publication ASME *J. Engr Gas Turbines and Power*.

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