Observation of the Atomization of Fully-developed Like-Doublet Impinging Sprays

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Introduction

Doublet impinging jets design is generally used for atomization and mixing of the liquid propellants in low-thrust rocket engines.
Introduction

◆ The main causes of liquid jet to breakup and atomize

• Hydrodynamic instability
• Aerodynamic instability
Introduction

◆ Parameters controlling the impinging spray

- Impinging angle
- Orifice diameter
- Jet velocity/momentum
- Momentum ratio
- Density/Viscosity/Surface tension
Objective

This research investigated the mechanism of atomization of the impinging jets, with the aid of coupling PLIF and MALVERN techniques, detailed SMD distribution was measured.
Literature Review

◆ Increase jet velocity the droplets size decreased
   (Vassallo and Ashgriz, Dombrowski and Hooper et al.)
◆ Working fluid with lower surface tension creates smaller droplets
   (Kang, Lai and Huang et al)
◆ Working fluid with higher viscosity creates larger droplets
   (Lai and Huang)
The outcome (coalescence, separation, and shattering) of binary droplet-droplet collision was differentiated by Webber number

(Qian, J., Law, C.K 1997)
Experimental Methods

MALVERN

Droplet Size Distribution in the probing beam

PLIF

Mass Distribution

The fraction of the liquid mass within the probing beam of Malvern

The fraction of liquid analyzed

SMD $0.35$ (SMD of 35% of mass of the larger droplets in the spray)
Experimental Methods

◆ PLIF (Planer Laser Induced Fluorescence)

\[ f_{x,y} = C_f I_0(x, y) m_{x,y} \]
Experimental Method

◆ Malvern Spraytec particle size analyzer
Experimental Method

◆ The sketch of Malvern measurement

![Diagram of Malvern measurement setup](image)
Results & Discussion

Jet velocity increased from 28.6 m/s to 57.3 m/s

As jet velocity increased the SMD decreased.
Results & Discussion

- Lowered the surface tension from 71.8 to 52.2 (10^{-3} N/m) by adding 10% acetone.

Lower surface tension $\rightarrow$ Smaller SMD $\rightarrow$ Higher collision probability.
Results & Discussion

◆ Increased the viscosity from 1.19 to 1.69 (10^-3 N·s/m^2) by adding 20% glycerol
◆ The surface tension decreased from 52.2 to 44 (10^-3 N/m)

Viscosity also has an obvious effect on droplet size especially near the impinging point
Results & Discussion

As the ambient pressure increase (160 torr ~ 760 torr) the droplet size increase.

Aerodynamic instability is one of the controlling factor of droplets size at downstream position.
Conclusion

◆ As jet velocity increased, the droplet size decreased due to higher hydrodynamic and aerodynamic instabilities.

◆ Impingements with lower surface tension liquid produced smaller droplets near the impinging point,

◆ Higher viscosity liquid produced larger droplets because the jets is more stable (low Re)

◆ Aerodynamic instability cause the SMD decrease

◆ Secondary collisions cause the SMD increase especially near the impinging point.
Thanks for your attention!