Liquid and Vapor velocity measurements in Spray G

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Presentation Outline

• Experimental Setups
• Time evolution of the vapor velocity between neighboring plumes
• All different measurements indicate plume redirection towards the centerline
• Measured Vapor and Liquid velocity
• Droplets size changes as a function of time ASI and location
• Effect of temperature on droplets and gas velocity
**Experimental Setups**

### Unique high-speed velocity diagnostic (SNL)
- Custom pulse-burst laser
  - 100 kHz pulse pairs
  - with 15 mJ/pulse at 532 nm
- Applied PIV
  - 1µm zirconia particles seeded in ambient gas
  - Signal collected by 200 kHz imaging
  - Liquid-phase avoided by probing between plumes and moving downstream
  - Intensive image processing (preparing images, removing mist) and cross-correlation (sliding SOC)
  - Planar Velocity field

### High-speed DBI (SNL)
- 3.5W LED was used, emitting at 635nm
- driven at 100kHz, with 500ns pulses
- Line of sight, planar, light-transmittance measurement, indicating liquid phase

### Phase Doppler Interferometry (GM)
- Droplet Velocity, Direction and Size measured on these points:
  - Radial scan
  - Transverse scan
Time evolution of vapor velocity between neighboring plumes

- All plumes merge at center
- Neighboring plumes merge
- 15-mm axial velocity
- Upward motion
- Flow towards the injector

1. Plume arrival
2. Upward motion
3. EOI
4. Reversal time
5. Downward motion
6. Reversal time
7. Statistical Uncertainty
8. Plume Collapse

- Radial distance from injector [mm]
- Axial distance from injector [mm]
Different measurements indicate plume redirection to centerline.

Different measurements of vapor and liquid velocity and liquid concentration all indicate movement of the plume direction towards the centerline as a function of time ASI.

(please visit us at ILASS on effects of injection duration on spray collapse)

Plumes move to center.
Droplet and Liquid velocity Different

Spray head
Fast Droplets

Remember the PIV vapor puff?

But the air entrainment of the plumes creates a vapor recirculation between neighboring plumes.
Where is the liquid?

After 600us similar. Droplets?
Droplets are larger at the Spray head and collapse...
Droplets are larger at the Spray head and Collapse
Increased temperature makes droplets smaller but V higher.

High temperature increases the gas velocity between neighboring plumes and on the collapsed spray significantly. And...

...promotes droplet evaporation.

So, improved momentum transfer from droplets to ambient. Good.
In Summary
• The time evolution of the Liquid and Vapor velocity in Spray G were quantified.
• Different measurements indicate redirection of the plumes to the centerline (Do the LES and RANS models capture this trend? Please come to my SAE presentation on Wednesday) Thank you Sibendu Som, Kaushik Saha (ANL) and Tommaso Luccini, Gianluca D'Errico (PoliMi)
• the droplets are larger at the Spray head and the collapsed spray.
• Increased temperature makes droplets smaller but Velocity higher. Some videos shared on: https://ecn.sandia.gov/pub-links/ps001/

(Do the models capture this? Please stay for Lyle’s presentation right now)

Thank you for your attention
Spray G – Velocity and drop size observations

for injector #16, plume #1:
Substantial dataset with ~10,000 injections

Radial Scan

Transverse Scan

Scott Parrish, GM
ecn3
Plume inclination angle decreases with time.

Vector Angle

axial
radial

15 mm

Angle of max velocity vector [°]

Time after start of injection [ms]

EOI

Drill angle
Scott Parrish, GM
ECN3

Transverse Scan

for injector #16, plume #1:
Substantial dataset with ~ 10,000 injections

Z = 15 mm PIV (gas-phase) axial velocity

$Z = 15 \text{ mm PIV (gas-phase)}$

$\text{axial velocity}$
Liquid velocity analysis confirms that plume center moves towards injector axis during/after injection.
Injection duration affects spray collapse

- Operating at 573 K (with iso-octane), Sandia observes complete collapse for longer injection duration.
- Operating at 298 K (with surrogate fuel), Argonne does not.

Plume centroid at z = 10 mm, Argonne (ECN4)

2.6 ms inj. duration