ECN5 Guidelines for Spray G Topic 9 Evaporative Spray G

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Contents

Introduction

This document has been prepared in order to provide a baseline for the ECN Topic 9: Evaporative Spray G. The documents provides an overview of the data that is currently available, the questions of interest and focus for the incoming ECN5 and the specific data needed to advance with the study of those questions. The document will be updated when new data becomes available or there are new data requests or questions.

Contact the topic organizer for any question or comments about the topic (davasan@mot.upv.es)

Available data (Topic 9)

Available data listed here has been presented at ECN3 / ECN4 or any of the monthly webex. Please contact topic leader (davasan@mot.upv.es) or ECN organizer (lmpicke@sandia.gov) if you know of available data not listed here.

Variant conditions listed only specify differences with respect of standard Spray G.

Liquid Penetration, Vapor Penetration and Spray Angles.

Institution	Data	Source	Pos	Condition
UM	Liquid p, a, c Vapor p, a, c	DBI and MIE Schlieren	1	Spray G, G2, G3 Cold and hot G2 and G3
Sandia	Liquid p, a, c Vapor p, a, c	DBI and Mie Schlieren	1 & 2	Spray G, G2 9kg/m3 800K 3.5kg/m3 573K 7kg/m3 600K 7kg/m3 573K (double Spray G)
CMT	Liquid p, a, c Vapor p, a, c	DBI Schlieren	1	Spray G, G3 parametric variations:

				1 to 9 kg/m3, 300 to 800K, 680-1200us, 100-200 bar (120 conditions)
IM	Liquid p, a, c Vapor p, a, c	MIE Schlieren	1	Spray G, G2 (cold), G3 (cold) Cold = Ambient temp.
IFP	Liquid p, a, c	DBI, MIE Schlieren	1	Spray G, 6kg/m3 700K, 9kg/m3 800K
GM	Liquid p, a, c Vapor p, a, c	DBI, MIE Schlieren	1	Spray G
ANL	Vapor p	LES Eul simulations	1	Spray G
Polimi	Liquid p, a Vapor p, a	RANS Lag simulations	1	Spray G, G3

p: penetration, a: angle, c: contours

1: primary orientation (0 deg), 2: secondary orientation (22.5 deg) Check orientation

Velocity, density, concentration, mixture fraction.

Ins	Data	Source	Condition	Notes
GM	Vel and SMD	PDI Phase Doppler Interferometry	Spray G	Radial and transverse at 15mm from nozzle tip.
IFPen	Fuel mass concentration Temperature fields	p-DFB LIF two color LIF	Spray G 3.5 kg/m3 673K 6kg/m3 700K 9kg/m3 800K	*Iso*-octane + 0,03% vol. DFB Primary orientation
ANL	Fuel mass concentration (2mm slice) Fuel mass concentration (2d map side view)	Spray tomography Spray Radiography	Cold Spray G (300K) 3.15 bar (3.5kg/m3) 190 bar	8 nozzles 2mm from nozzle tip. Primary orientation
ANL	Mixture fraction 2d plots of velocity and liquid/vapor mass concentration, vapor mixture fraction	LES Eulerian simulation	Spray G 800K 3.5kg …	Transverse, radial, plume to plume at 1 ms and z = 15mm 10,15 mm z planes at 0.25, 0.5, 0.75 1 ms Some data until 2 ms
Polimi	Velocity, mixture fraction, liquid/vapor mass concentration	RANS Lagran Simulation	Spray G 3.5kg/m3 800K	3 components velocity, excel format t= 0.25 0.5 0.75 1 1.25 z= 10 and 15 mm
Sandia	Velocity fields from side view	PIV	Spray G Double SprayG (7kg/m3)	Primary and secondary orientation. Long injections (2ms)

			800K 3.5kg/m3 Spray G multiple 1	

Primary questions to focus and explore on ECN 5.

The main topics to be discussed in the ECN5 workshop are listed here. The topics and questions presented here have been selected given the importance they pose to the Evaporative Spray G topic and because they represent the areas where most work and effort is being put by the collaborating institutions. The areas of focus are subject to modifications to adapt to new exploratory approaches and breakthroughs. Contact the topic organizer to discuss the topics as well as current and future possible paths.

Spray behavior and plume interaction at Spray G nominal condition.

- How does the interaction of plumes develop with time?
- How are the velocity and mixing fields between plumes and inside the spray cone?
- How do the individual plumes change the direction over time?
- How does the plume attraction (spray collapse) start and develops over time? How is the velocity, fuel concentration, mixture fraction, temperature/gas pressure maps?
- Are the models able to capture interaction of plumes phenomena? Can they capture the plume attraction?
- What can be done to Lagrangian models to capture the differences in spray behavior with respect to diesel created by the different geometry (counterbore, L/D ratio).
- Do coupled (Eulerian-Lagrangian) models provide better results than standard Lagrangian models to describe external spray behavior?
- ………

Standardization of experimental methodologies, data processing / Experimental data validation

- How do the differences in experimental setup affect the liquid and vapor contours?
- How do the differences in the post-processing of data affect vapor and liquid penetration and cone angle?
- What can it be done to the processing to get around the differences in setups and acquired data?
- PDI and PIV velocity data comparison for validation at certain locations. Use of the Transverse Integrated Mass from Spray Radiography to provide another source of velocities.
- “Cold” conditions are measured because special equipment from some institutions cannot be heated. Assessment of differences between Spray G and “cold” Spray G at ambient temperature and same density.

Parametric variations beyond Spray G

The main parametric variations of interest from Spray G are listed here with a small description of the expected information to be extracted from them.

- Spray G nominal condition
- **G2: 333.15 K, 50 kPa: Flash boiling condition.** Interesting to compare the velocity, fuel mass concentration, liquid and vapor penetration and temperature distribution in comparison with the standard Spray G condition. Challenge to modelling community to capture the physics of flash boiling, there is currently **no data from Lagrangian simulations** at this condition.
- **Spray G3, early injection condition.**
- **G4: - 7kg/m3 – 573 K (Double Spray G)** Interesting to study plume attraction (spray collapse). How do the plumes change direction over time? Where does the plume attraction start? Can it be linked with different phenomena developing in the counterbore? How is mixing affected? …
- **G6: - 3.5kg/m3 – 800K.** Also interesting for Spray Collapse given the relation between enhanced evaporation and plume attraction that has been observed. There is experimental data from SNL, and modelling data from ANL and Polimi at this condition.
- **G7: 9kg/m3 – 800K.** Strong collapse case. There are currently results at this condition including: vapor and liquid contours (DBI, MIE, SC), fuel concentration mass and temperature fields maps.
- **6kg/m3 700K.** Also interesting for Spray collapse, some work has been done with this condition (penetration, angle, fuel mass concentration and temperature mixing)
- **G-M1: Spray G multiple 1 Spray G 680us main, 1ms dwell, 186 us post.** This condition is gaining interest between contributors to represent the multiple injection strategy in Spray G. How is the spray penetration and angle for the post injection? Is the penetration slope different than in the main? How are the velocity and fuel mass concentration fields? There is PIV data at this condition and there are plans to get ROI.
- **G3: 333K, 100 kPa: early injection condition.**
- **Partial parametric study /sweep.** There is DBI and Schlieren data available at an extensive range of temperature and density conditions that was used with the purpose of describing the behavior of sprays with focus on spray collapse phenomena.
    - Ambient gas density [kg/m3] 1–2.1–3–3.5–4–5–6–7–8–9
    - Ambient gas temperature [K] 300–333–400–500–600–700–800
    - Injection pressure [MPa] 10–20
    - Energizing time [ls] 680–2000
- See also: https://ecn.sandia.gov/gasoline-spray-combustion/target-condition/spray-g-parametric-variation/

Specific Data Requests

This section lists the data that would be most useful to have for ECN5, the requests have been prioritized because possible contributions from institutions are limited. Some of the data requested could already be available in some institutions. Please note that specific data requests are put to fill current gaps and do not limit the data the institutions can contribute to ECN Spray G topic. Contact the topic organizer and discuss available data or plans to obtain data that is not listed in these requests.

Note 1: There are many conditions listed in order to establish their priority. This does not imply that an institution has to provide data for all conditions and requests. Institutions are encouraged to submit any number of contributions (big or small), with the objective of filling the gaps between all contributors.

Note 2: The priority of the request and conditions is the order of the listings. The priority is given mainly to provide guidance to institutions that have the flexibility to reach several boundary conditions and/or obtain several kind of measurements. If an institution can only do one type of measurement or reach only certain boundary conditions, prioritization does not apply.

Experimental

- Velocity measurements (PDI / PDA) radial and tranverse scans
  - 2mm, 15mm (to validate current data), 10mm (Example locations at 15mm)
  - Conditions: Spray G, Spray G2, Double Spray G,3.5-800, 9-800, Spray G multiple.
- Fuel mass concentration maps
  - Spray G (orientation 1 to validate, and orientation 2), Spray G2, Double Spray G, 3.5-800, Spray G multiple.
- PIV measurements
  - Spray G (orientation 1 and 2), Spray G2, Double Spray G, 3.5-800, 9-800, Spray G multiple.
- Visualization measurements (DBI, Mie, Schlieren)
  - Spray G2, Double Spray G, 3.5-800, 9-800, Spray G multiple.
- ????

Modelling

Note: Requests have been coordinated with organizer of Topic 8 (Chris Powell) The priority of conditions from Eulerian simulations is the same for the 2 topics and data at side planes and z=2mm will be shared between the topics. Topic 8 will probably require data at different locations but **not** additional conditions.

Note 2: Please consider again that the intention of listing all requests is for prioritization and guidance for institutions that have capabilities/flexibilities of doing several things. Any number of contributions are welcome.

- **Lagrangian** or Eulerian simulations
  - Conditions.
  - **Spray G,** G2, G6, G4
  - Provide global parameters with respect to time.
    - Liquid (liquid volume fraction = 0.1%)
    - Vapor axial penetration (fuel mixture fraction = 0.01)
  - At 0.1-2ms (or max) in 0.1 ms steps, provide at axial positions z=2,15,10 mm.
    - 3 component gas and liquid velocities
    - Total liquid and vapor fuel mixture fraction (mass of liquid fuel and vapor fuel/mass of all mixture)
    - mass liquid fuel / volume (not liquid density)
    - total mixture density (fuel and all other gases / volume)
    - Temperature

        - Sauter mean diameter droplet size

- At 0.1-2ms (or max) in 0.1 ms steps provide at the side view “primary” and “secondary” cut planes (0-40 mm or domain max).
- See (https://ecn.sandia.gov/gasoline-spray-combustion/target-condition/spray-g-plume-orientation).