Spray Development and Vaporization

Guidance on Experiments and Simulations to be Performed

Please address your questions to:

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Experimental Objectives

- **Results will be used:**
  - to check the reproducibility of the measurements between facilities
  - to measure possible dispersions between injectors and/or experimental installations
  - as input data for model calibration (base condition, “Spray A”)
  - to assess model predictions when operating conditions are varied
  - as reference for comparison between different models

Modeling Objectives for ECN2

(M1) Can different groups match the parametric variations performed by experimentalists?

(M2) Are the ECN-1 definitions for various parameters adequate? If not, compare ECN-1 definitions with improved definitions.

(M3) Code performance comparison: Use same grid size, similar models, etc. Do all codes provide same results?

(M4) If you have implemented new spray, turbulence models, compare them against the results of the *baseline/standard suggestions* (cf. Slide 10)

Ambient Conditions – Experiments

- Densities
  - 3.8, 7.6, 15.2 and 22.8 kg/m^3
- Temperatures
  - 440, 700, 800, 900, 1000 and 1200 K
- Fuel injection pressure
  - 50, 100 and 150 MPa
- Oxygen concentration
  - 0 and 15 %

X-ray radiography:

- Fuel Injection pressure: 150 MPa
- Ambient temperature = 301 K
- Ambient density: 22.8 kg/m^3 (N_2 at 21 bar)

Data Needed from Experimentalists - 1

- Macro-spray development and vaporization:
  - Liquid penetration vs. time (liquid-length)
  - Extinction profiles (both axial and radial)
  - Vapor-phase penetration (Siebers method)
  - Fuel concentration profiles (both axial and radial)

2-D extinction maps and distribution profiles will be used for comparison between facilities, operating conditions and injectors.

Data Needed from Experimentalists - 2

- Microscopic spray development and vaporization:
  - Macroscopic parameters in the near-field using Long Distance Microscopy (LDM): Tip penetration, spray width, etc.
  - Microscopic features (fuel ligaments, droplet formation…, LDM)
  - Liquid-length extinction and dispersion (LDM)

  - **X-ray radiography data:**
    - Spray tip penetration (up to 12 mm)
    - Centerline density at 1ms ASOI (up to 12 mm)
    - Radial density distribution at 1ms ASOI at 0.2, 2.8, 5.0 and 10.0 mm from nozzle outlet

Proposed ECN-1 definitions: Experiments

- Liquid penetration:

  Diffused back-illumination (DBI) is the reference technique for liquid-length measurements. Both time-resolved and time-averaged results, based on light extinction can be provided.

- Vapor-phase penetration:

  Both Schlieren and DBI might be used for vapor penetration as it has been seen that measured spray tip penetration was not very sensitive to threshold or experimental arrangement.

- Axial and radial profiles:

  Axial (centerline) and radial (every 5 mm) profiles of light extinction can be provided for comparison (2-D map is preferred)

- Fuel concentration (optional):

  If available, fuel concentration, either in the liquid or vapor phases represent valuable data (2-D map or axial and radial profiles)

Proposed ECN-2 definitions: Simulations

- **Liquid Penetration: (Priority list defined in slide 10)**

Preference 1: Place a set of spheres (with radius 1 mm) along the injector axis every 0.1 mm or less. Then look for all the droplets being in each of such spheres and compute the void fraction in them. The distance of the farthest one having a void fraction higher than 0.1% represents the spray penetration.

If you have further questions about the definition, please contact:
Tommaso Lucchini (tommaso.lucchini@polimi.it)

Preference 2: Distance from the nozzle outlet to the farthest axial position encompassing 99% of the injected mass

If you are unable to implement preference 1, please implement preference 2.

Proposed ECN-2 definitions: Simulations

- **Vapor penetration: (Priority list defined in slide 10)**

Maximum distance from the nozzle outlet to where the fuel mass fraction is 0.1%

- **Axial and Radial profiles (Compare results at:)**

7.6 kg/m3, 700 K, 150 MPa: 0.01, 0.03, 0.065, 0.11, 0.16, 0.23 ms
22.8 kg/m3, 900 K, 150 MPa: 0.015,0.05, 0.10, 0.18, 0.28,0.40 ms

- **X-ray radiography data:**

Projected density vs. transverse position @ 0.681 ms from ASOI, at the following axial locations: (a) 3.2 mm, (b) 6 mm, (c) 9 mm

Please contact Sibendu Som (ssom@anl.gov) if you have questions regarding comparing your simulation results againt x-ray data

Priority List - Simulations

- Densities:
  - 3.8, 7.6, 15.2 and 22.8 kg/m^3
- Temperatures:
  - 301, 440, 700, 800, 900, 1000 and 1200 K
- Fuel injection pressure:
  - 50, 100 and 150 MPa
- Oxygen concentration
  - 0 and 15 %

Base case: 22.8 kg/m3, 900K, 150MPa
Priority 1: Effect of Density
Priority 2: Effect of Temperature
Priority 3: Fuel injection pressure

Minimum requirement

1) Simulate base case + effect of at least one parameter in order of priority
2) Within a parameter, you may wish to simulate only the ones marked in red (e.g. in Effect of Density, you can choose to simulate only 22.8 and 7.6 kg/m^3 densities).

Table of test cases

Test case # (file labels)	Gas density (kg/m^3)	Gas temperature (K)	Injection pressure (MPa)
0	22.8	900	150
1	7.6	900	150
2	22.8	440	150
3	22.8	900	50

All the other parameters must be taken constant: Oxygen concentration = 0, Initial dodecane temperature = 363 K, etc …
(see target conditions at ECN web site for SPRAY A)

Quantities to be compared

Quantities	File Labels
Liquid penetration	LPL
Vapor penetration	VPL
Vapor Mass fraction	VMF
Vapor Mass fraction standard deviation	VSD

Spatial positions and timings

- Spatial positions
  - At centerline (Ox) and radial positions :

    (x= 10mm, x=25mm, x=45 mm)

- Timing
  - in steady-state (1400µs ASI)

Format of submitted results

- Text file name and formats (Time in ms, Distance in mm)
- For liquid and vapor penetrations :
  - GROUP_LPL_VPL.dat (9 columns)
  - Format : time, LPL_Case0,LPL_Case1,LPL_Case2, LPL_Case3, VPL_Case0, VPL_Case1, VPL_Case2, VPL_Case3
- For Centerline profiles
  - GROUP_VMF_Centerline.dat (9 columns)
  - Format : x, VMF_Case0,VMF_Case1,VMF_Case2,VMF_Case3, VSD_Case0, VSD_Case1, VSD_Case2, VSD_Case3

GROUP = IFPEN, ANL, Sandia, CMT, …

Format of submitted results

- Text file name and formats (Time in ms, Distance in mm)
- For radial profiles : (3 files)
  - GROUP_VMF_Radial_??mm.dat (9 columns)
  - Format : radius, VMF_Case0,VMF_Case1,VMF_Case2,VMF_Case3, VSD_Case0, VSD_Case1, VSD_Case2, VSD_Case3
- For x-ray data: (3 files)
  - GROUP_PD_TP_3.2mm.dat, GROUP_PD_TP_6mm.dat, GROUP_PD_TP_9mm.dat
  - Format : Projected density vs. Transverse position

GROUP = IFPEN, ANL, Sandia, CMT, …

Final remark and future steps

- This session will be focused at ECN2 only on the spray A tests, while new conditions will be considered after.
- In this first call only txt file are required. Contributors might be asked to provide some images of the entire spray before the meeting.
- Similarly, some non-steady results might be asked later depending on the availability of experimental results.

Simulation Baseline : RANS

Turbulence model	RANS: RNG k-ε
Spray models:	
Injection	Blob: Reitz et al. SAE 870598
Atomization & Breakup	KH-RT: Similar to Beale et al. Atom. and Sprays, 1999
Collision	O'Rourke: Similar to Amsden et al. KIVA-2 manual
Drag	Dynamic: Similar to Liu et al. SAE 930072
Evaporation	Amsden et al. KIVA-3 manual
Heat Transfer	Amsden et al. KIVA-3 manual
Dispersion	Stochastic: Similar to Amsden et al. KIVA-3 manual
Grid:	
Dimensionality	Full-3D domain
Smallest grid size	0.25 mm
Time-step size (s)	Min: 5E-7

- **Contributors are invited to provide one set of results according to this baseline**
- **If your code cannot model the baseline, you are still invited to contribute**
- **In all cases, the model set-up, constants used must be specified**

Simulation Baseline : LES

Grid:	
Dimensionality	Full-3D domain with
Smallest grid size	0.08 mm for high-fidelity LES 0.20 mm for lower-fidelity LES
Preferred time step	Min = 1E-7 s

- **Since LES results will be presented for the first time at ECN, it was difficult to establish a baseline for different models**
- **You are invited to present results with different approaches. Eulerian-Eulerian approaches are welcome!**
- **In all cases, the model set-up, constants used must be specified too**

Deadlines

- Experimental data used for spray analysis
  - Results ready by the end of June 2012
  - Guidelines on how to submit results will be provided shortly

- Computational results:
  - All results must be provided by the end July 2012

Thank you