Engine Combustion Network

Topic 2 – Primary atomization (near-nozzle flow)

Guidelines for ECN 5

Michele Battistoni, University of Perugia

michele.battistoni@unipg.it

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Topic Focus

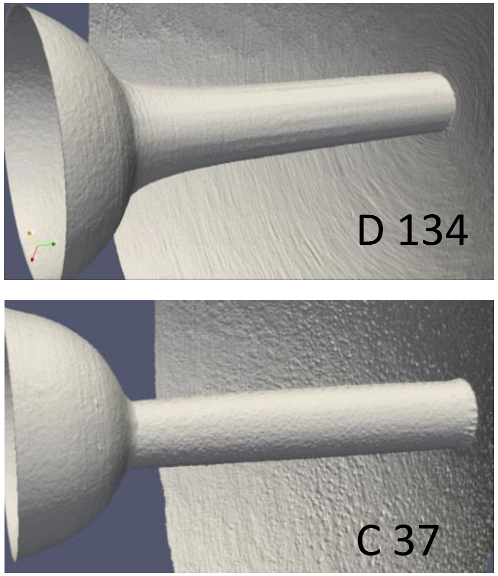
- Diesel injectors near-nozzle region: within first ~10 mm
  - Injectors list: single-hole spray A, C and D; multi-hole spray B
- **Common objectives** (both experiments and simulations)
  - Rate of injection, rate of momentum
  - Liquid penetration, cone angle vs. time (first ~10 mm)
  - Liquid mass distribution (axial and radial profiles, 2D projections)
  - Droplet size or phase interface area (axial and radial profiles, 2D projections, local pdf)
    - Comparison of A vs. B: complex internal flow effects on atomization
    - Comparison of A vs. D: hole diameter effects on atomization (non cavitating)
    - Comparison of C vs. D: cavitation effects on atomization
- Additional **specific objectives for experiments**
  - Provide uncertainties on measured quantities
  - Physics description under non-evaporative (*cold*) and evaporative (*nominal*) conditions to understand the spray processes
  - Explore higher chamber/fuel temperatures to assess supercritical behaviors
- Additional **specific objectives for simulations**
  - Physics details under non-evaporative (*cold*) and evaporative (*nominal*) conditions
  - Encourage high-fidelity simulations, including SOI and EOI behaviors
  - Link with internal nozzle flow: desirable seamless internal-external simulations
  - Assess impact of model for: turbulence, compressibility, real EOS and properties

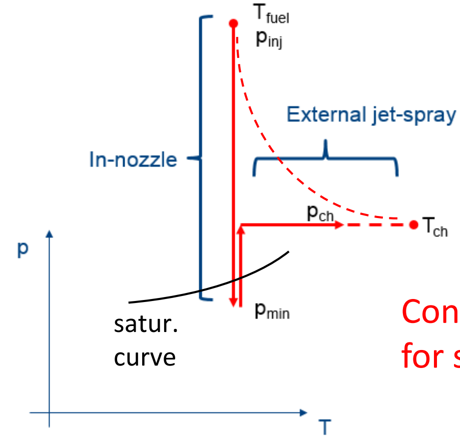
Target conditions and injectors

- Nominal conditions are the same for A, B, C and D injectors (cf. website)
  - n-dodecane at 1500 bar and 363 K, chamber at 60 bar, 900 K (0% O_2 non-reacting, 15% O_2 reacting)
- Nozzle geometries – full 3D high res. surface files:
  - Spray A: 210675 - download .stl file here
  - Spray B: 211201 - download .stl file here, recommended ESRF 110 MB stl file
  - Spray C: 210037 - high resolution ~700 MB .stl file soon available for download here, or upon request (do not use 165 MB stl file)
  - Spray D: 209134 - high resolution ~700 MB .stl file soon available for download here, or upon request (do not use 177 MB stl file)
- Needle lifts: available here for spray A and B, coming soon for C and D (or upon request)
- Non evaporative (cold) conditions (Argonne test conditions): n-dodecane at 1500 bar and 343 K (spray A), 338 K (spray B); chamber at 20 bar, 303 K (100% N_2).

New data for C, D available soon

- New spray C and D <u>high resolution STL</u> files, at 1.17 µm voxel size, and ~2 µm uncertainty (available now, ~700 MB STL files).
- Needle lift will be measured soon (~Aug/Sept. 16).
- New spray C and D near-field <u>spray radiography</u> from ANL (~ Aug/Sept. 16)
- New <u>SMD</u> for C and D from ANL, Brighton, SANDIA (~ Aug/Sept. 16)
- New data under <u>supercritical conditions</u> for spray C and D from Brighton and SANDIA



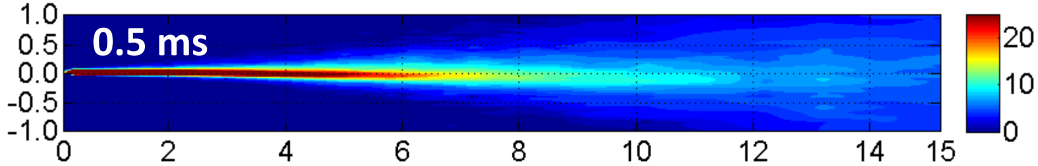


Conceptual path for spray C

A look back: results from ECN 4 …

Spray A

Argonne x-ray radiography



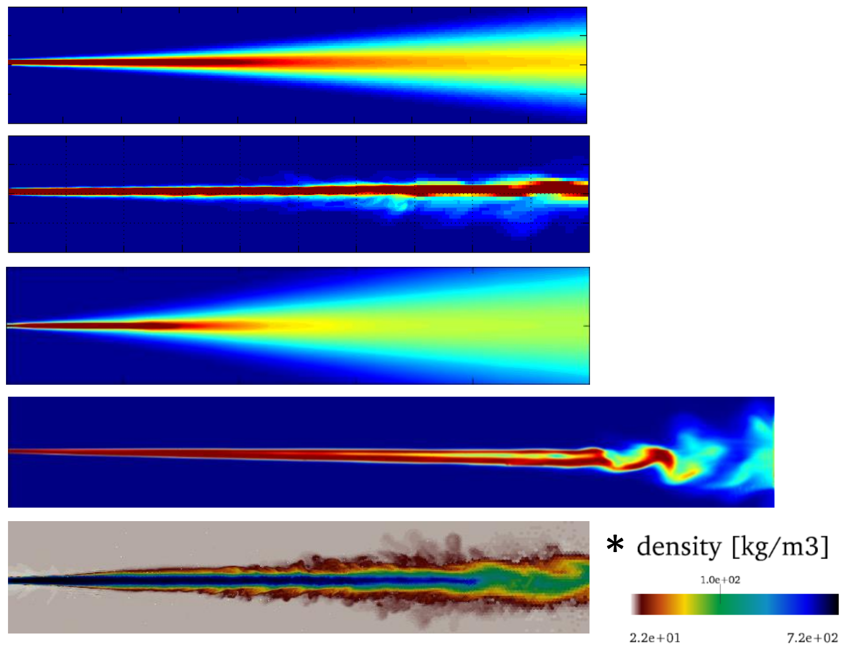
Argonne RANS

Argonne LES

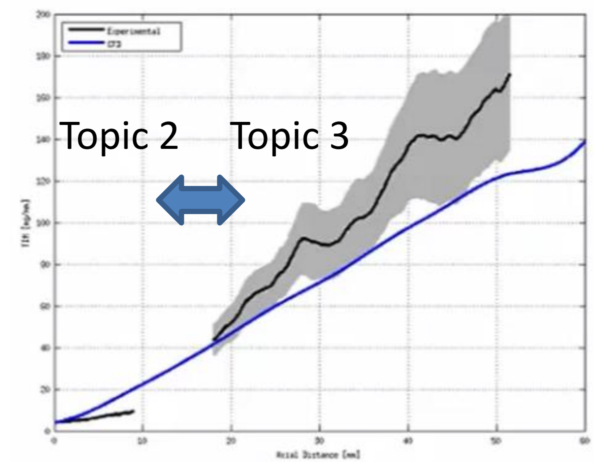
CMT RANS

IFPEN LES

BOSCH* LES



TIM vs. axial dist., from M. Bardi ECN 4.7 (guidelines for Topic 3)



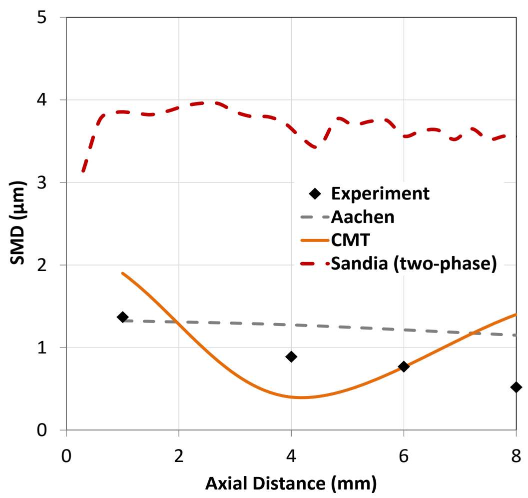
- Challenge: improve predictions and reduce data scatter

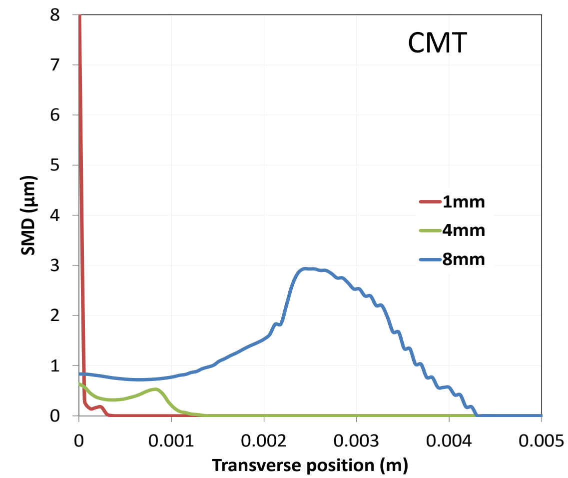
A look back: results from ECN 4 …

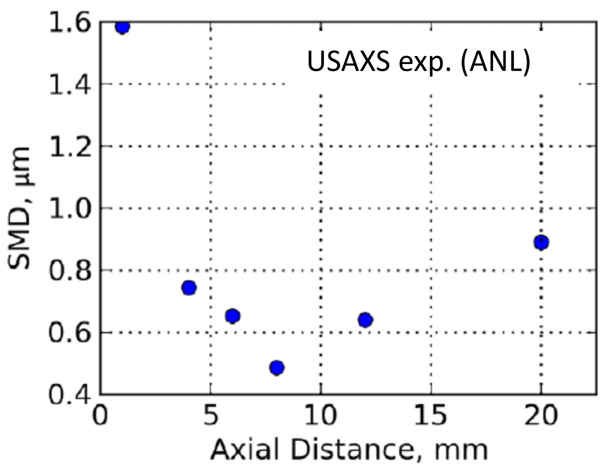
Axial SMD profiles

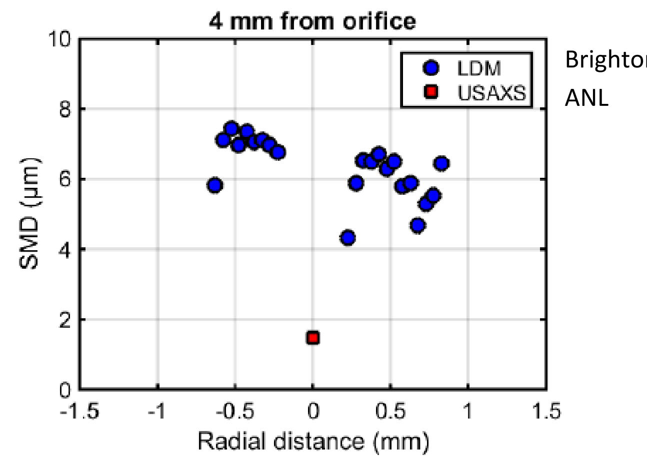
Spray A

Radial SMD profiles









- Challenge: improve predictions and reduce data scatter

New challenges for ECN 5

- Extend the analysis to include spray C and D
  - Effect of cavitation (C vs. D) on spray breakup
  - Effect of hole diameter (A vs. D) on spray breakup
  - Effect of number of holes and orientation (A vs. B) on spray cone angle

- Compare more methodologies
  - Experiments
    - Long-distance microscopy / Laser extinction / X-ray radiography / Ultra-Small Angle X-ray Scattering
  - Simulations
    - Seamless internal and external flow / 1-way coupled internal and external flow / External flow only
    - Two phase flow approach: single-fluid, multi-fluid, immiscible VOF/LS

- More focus on fluid properties, to help reducing uncertainties
  - knowledge of actual local p, T and mixture comp. in the near-field is key for ρ, μ, σ and subsequent spray evolution

- Increase of time-resolved and space-resolved data (SMD)

Notes on requested output data

For all injectors:

- Mass flow rate and momentum flow rate at the nozzle exit
- Fuel spray tip penetration and near nozzle cone angle vs. time
- Contour plots of projected liquid density at 0.1, 0.5 and 1.0 ms after SOI
    - Projection plane is 0° plane (injector in the theta = 0 position)
- Transverse integrated mass (TIM) vs. axial distance at 0.1, 0.5 and 1.0 ms after SOI
- 2D contours of liquid volume fraction (LVF) across cross-section at 0.1, 0.5 and 1.0 ms after SOI at x = 0.1, 0.6, 2.0, 6.0, and 10.0 mm
- Axial and radial profiles of projected density, density and LVF, time-averaged between 0.5-1.0 ms, at x = 0.1, 0.6, 2.0, 6.0, and 10.0 mm (locations for radial profiles)

- Mean droplet size (SMD) at x = 1, 4, 6, 8, 12, 20 mm time-averaged around 1.0 ms
    - SMD at the above axial positions (spatially averaged on the cross section)
    - Radial profiles of SMD vs. radial position at the above axial positions (spatially averaged on the smallest possible sampling region – method dependent)
    - PDF of droplet diameters at above axial positions

- Dynamics: peak projected density and Full Width Half Maximum (FWHM) of distribution at x = 0.1, 2, 6 mm for entire injection event (in intervals of 20 µs)

Submissions

- Deadline for submissions: end of the year
- Interactions with other topics will require some coordination
  - topic 1: nozzle flow and fluid properties effects
  - topic 3: near nozzle velocities (from TIM), and SMD from Lagrangian models
  - topic 7.1: spray B spreading angle variation

Participants

- Experiments:
  - Argonne, Brighton, GaTech, Sandia
- Simulations:
  - Argonne, CMT, GaTech, Perugia, Sandia

- Possible additional volunteers:
  - UW-Madison, Zagreb,
  - Bosch-US?, IFPEN?, PoliMi? TU Munich? UTas?

- who else? Call for participants!!

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