Engine Combustion Network

ECN 6 - Diesel Combustion Comittee

UNIFIED GUIDELINES FOR:

- Topic 4. Reactions that lead to ignition — Evatt Hawkes (UNSW)
- Topic 5. Combustion (lift-off, flame structure) — B Somers (TUe), JM Garcia-Oliver (CMT)
- Topic 6. Emissions (soot, NOx, UHC) — Scott Skeen (Sandia)
- Topic 7. Spray B (diesel) in engines — Louis-Marie Malbec (IFPEN)
- Topic 8. Fuel effects on compression ignition — Yuanjiang Pei (Aramco)

May 3rd, 2018

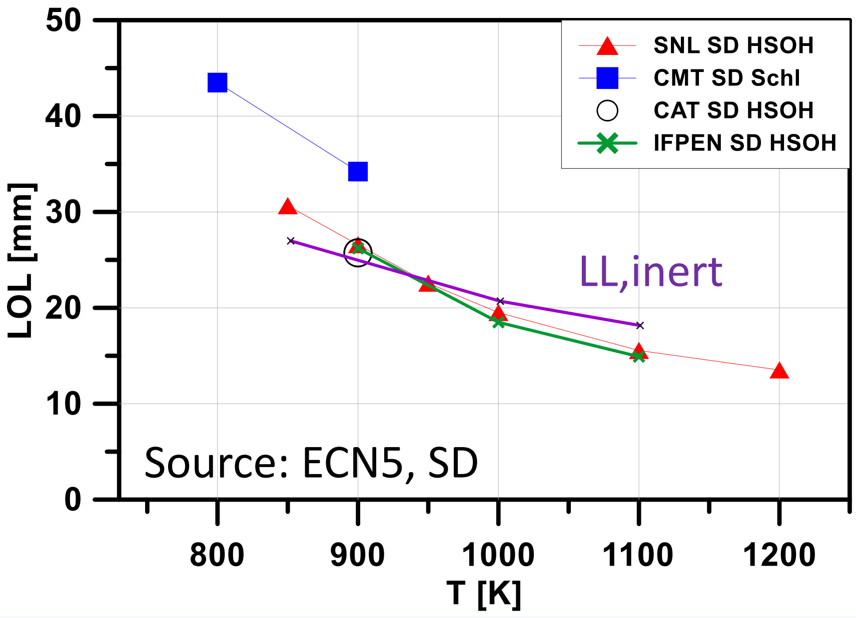
CONTENTS

INTRODUCTION. OVERVIEW

- General guidelines to include different ECN groups working on **Diesel combustion** topics
  - For each topic:
    motivation – objectives – requested info

- Main drivers for ECN6 compared to previous ECN
  - Merging SA/SC/SD analyses
  - How large are differences among modellers regarding HRR?
  - What improvements does LES bring?
  - Consideration of multiple injections under reacting conditions, a highly transient problem

- SA: Large experimental and modelling database
- SC/SD: Experimental database is already available
  - No CFD modelling up to now
  - Interesting test cases due to interaction between evaporation and combustion
- For ECN6, a comparison of SA/SC/SD should be carried out
  - Nozzle diameter could be considered just another parametric variable
  - To keep a reasonable effort, only reference conditions are requested for SC/SD nozzles



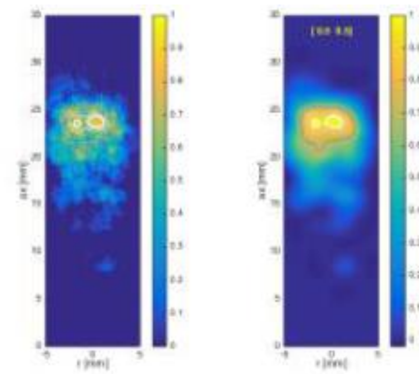
- TOPICS

    1. IGNITION SEQUENCE
    2. FLAME STRUCTURE
    3. HEAT RELEASE
    4. MULTIPLE INJECTION
    5. SOOT
    6. ENGINE
    7. FUELS

1. IGNITION SEQUENCE

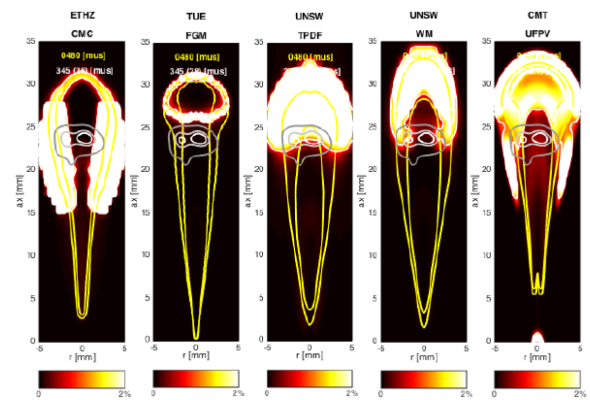
- **MOTIVATION**
  - ECN5 has shown important differences among models on ignition location and sequence
  - Experiments have shown higher probability for ignition in radial periphery. Head-on view shows a "ring" of ignition for Spray A (C/D as well). What does model show from "head-on" view?
  - What is the impact of slight changes in cone angle on early penetration, mixing and therefore ignition?
  - Does LES bring new info into the game?

ECN4-Ignition Probability



ECN4-Ignition CFD

Base(**900K**, 15%)
Same time instances



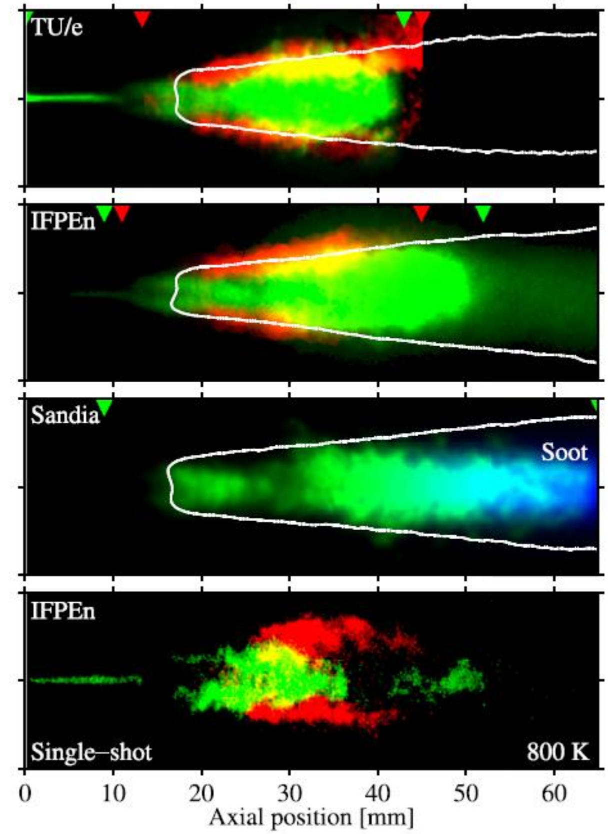
1. IGNITION SEQUENCE

- **OBJECTIVE**
  - Evaluation of ignition location & timing
    - How similar/different is this picture among nozzles?
    - Sensitivity to cone angle in the spray modelling
  - A comparison of Z field before ignition will be carried out (topic 3)
- **REQUESTED INFO (detailed instructions in appendices)**
  - Experiments
    - Mixture fraction, location and timing at ignition
      - IFPEN experiments for ECN5 available
      - Other groups doing similar things are welcome
      - Review of ECN experimental database to derive line-of-sight ignition locations
    - Detailed penetration measurements are needed, especially at early timings.
  - Model
    - Ignition delay timing
    - Field variables: Time- and spatially resolved species from SOI (Start of Injection) to slightly after SOC (start of combustion)
    - Small variation of cone angle to check sensitivity of ignition to mixing field

2. FLAME STRUCTURE

- **MOTIVATION**
  - SA flame structure analysed in detail in past ECN workshops
  - Can models capture
    - the transition from SA to SD?
    - Differences between SC/SD?
  - Does LES bring in new info?

SA



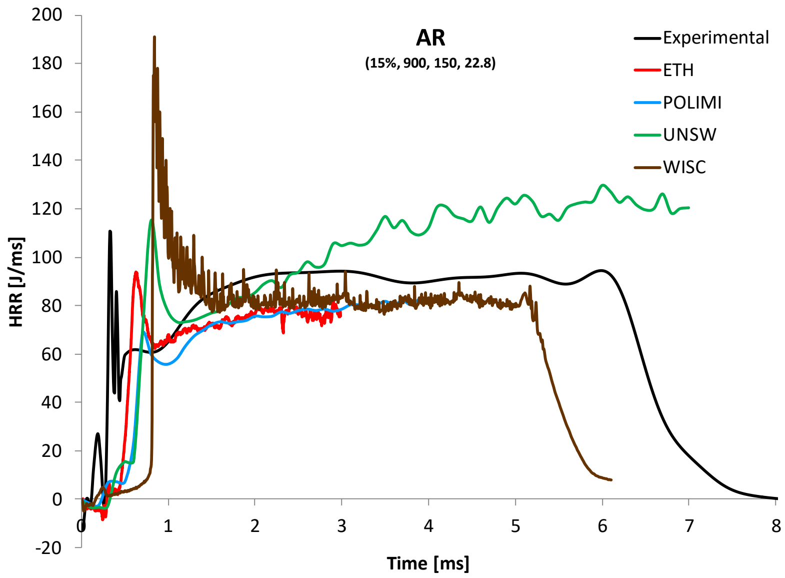
N. Maes et al. / Combustion and Flame 174 (2016) 138–151

- **OBJECTIVE**
  - Evaluation of accuracy of models for flame structure definition in both small and large nozzles
    - LOL
    - Detailed spatial structure: CH2O, OH fields
    - Z field under reacting conditions

2. FLAME STRUCTURE

- **REQUESTED INFO (detailed instructions in appendices)**
  - Experiments
    - SA/SC/SD: LOL from OH*
      - Time-resolved high-speed OH*, comparison among ECN facilities in progress
    - SC/SD: Detailed spatial structure: CH2O, OH fields
  - Modelling
    - Time-resolved LOL
    - Field variables: Time- and spatially resolved species from start of combustion (SOC) until end of injection (EOI)

- **MOTIVATION**
  - How accurate/similar are our modelling approaches in terms of heat release rate (HRR) predictions
    - Important for industry
  - Introduced at ECN3, but never considered again
    - Have we improved this picture?



Source: ECN3, Combustion indicators

3. HEAT RELEASE RATE

- **OBJECTIVE**
  - Quantification of HRR in SA/SD conditions
    - Comparison among vessels
    - Evaluate differences among models in chemical HRR
  - Coordination with Topic 7 (engines)
- **REQUESTED INFO (detailed instructions in separate doc)**
  - Experiments
    - Measurements of pressure in constant-volume cells.
  - Modelling
    - Time-resolved chemical HRR (and Pressure, if a constant-volumen vessel is simulated)
  - A coordinated routine has been prepared and will be used to derive HRR from pressure

4. MULTIPLE INJECTION

- **MOTIVATION**
  - Usual injection strategy in Diesel engines
  - Highly transient compared to single-pulse cases used until now
  - Major role of combustion model (mech + TCI) because of the interaction between pulses

- **OBJECTIVE**
  - Evaluation of predictibility of current models with a split injection strategy
    - Pilot 0.5 ms , dwell 0.3/0.5/0.7 ms, main 0.5 ms
  - Coordination with Topic 3 (spray mixing)

- **REQUESTED INFO (detailed instructions in appendices)**
  - Experiments
    - Detailed penetration (schlieren)
    - LOL/ID as from OH*
  - Simulations
    - Time-resolved LOL
    - Field variables: Time- and spatially resolved species from start of combustion (SOC) until end of second injection (EOI2)

5. SOOT

- **MOTIVATION**
  – Expanding on work from ECN5 with O2/N2 vs EGR (pre-burn) conditions for Spray A

- **REQUESTED INFO (detailed instructions in appendices)**
  – Time-resolved field variables (consistent with Ignition/Flame structure submission)
  – Everyone must use the SAME chemical mechanism for their primary submission of the Standard Spray A condition and the O2/N2 condition.

6. ENGINES

- **MOTIVATION**
  - Progress towards predictive models in engine environment.
  - Understand and model the effects of confinement, aerodynamics, and real engine opration (Diesel fuel, multi-hole nozzles, multi injections) on mixing and combustion processes.
- **OBJECTIVE**
  - Study the effect of geometry and flow on mixing /combustion processes
- **REQUESTED INFO (detailed instructions in appendices)**
  - Basic metrics of the spray in engine: liquid length, vapor penetration, lift-off length, ignition delay.
  - Additional: same data in free jet configuration.
  - CFD: Time resolved fields variables

7. FUELS

- **MOTIVATION**
  - Understand the fuel effects on spray at CI conditions as an additional dimension for model development and validation
- **OBJECTIVE**
  - Summarize the available experimental and computational fuel effect studies for future directions
- **REQUESTED INFO**
  - For both experiments and simulations for two or more fuels (different physical or/and chemical properties) at one of the following conditions - Spray A, C or D

7. FUELS

- **REQUESTED INFO**
  - Fuels used, with physical and chemical (e.g., cetane or RON number) properties
  - In nozzle flow:
    - Needle lift for different fuels
    - Cavitation comparison (mainly for simulations)
  - Non-reacting spray at different ambient T conditions:
    - liquid length/vapor penetration length vs. time
    - Mixing field (fuel mass fraction) at different timing if available
  - Reacting spray at different ambient T conditions:
    - Ignition delay and lift-off length
    - OH* contour
    - Soot mass vs. Time or other available data
- Please use the ECN definitions, if different, please specify

OPERATING CONDITIONS

- **NOMINAL TEST MATRIX**

PARAMETRIC VARIABLE	ACRONYM	O2 [%]	Ta [K]	Dens [kg/m3]	Pinj [MPa]	Inj Duration
Standard Spray A	Ai	**0**	900	22.8	150	LONG
	Ar	**15**	**900**	**22.8**	**150**	**LONG**
Temperature	T2	15	**800**	22.8	150	LONG
Injection pressure	I1	15	900	22.8	**100**	LONG
	I2	15	900	22.8	**50**	LONG
Multiple injection	MAI/MAI2	**0**	900	22.8	150	0.5 ms pulse - 0.5/0.7 ms dwell - 0.5 ms pulse
	MAR/MAR2	**15**	**900**	**22.8**	**150**	**0.5 ms pulse - 0.5/0.7 ms dwell - 0.5 ms pulse**

– Ambient composition:
  - Non-EGR: XO_2=15%, XN_2=85%
  - EGR(pre-burn): XO_2= 15%, XN_2=75.15%, XCO_2=6.23%, XH_2O= 3.62%

OPERATING CONDITIONS

- **SPRAY IN VESSELS**
  - Long injection (except for multiple injection): 5 ms
  - Priorities for each topic
    - IGNITION SEQUENCE / HRR / Soot
      - Nozzle: SA/SC/SD
      - Conditions: SA (EGR/non-EGR) + T2 (800K)
    - FLAME STRUCTURE / Soot
      - Nozzle: SA/SD
      - Conditions: SA (EGR/non-EGR)
    - MULTIPLE INJECTIONS
      - Nozzle: SA
      - Conditions: MAI/MAR

OPERATING CONDITIONS

- **SPRAY IN ENGINES**
  - Injection duration: 1.5ms
  - Spray B
  - Variations
    - Temperature: 800K and 1000K
    - Injection pressure: 50 and 150MPa
    - Density: 15.2kg/m3
    - %O2: 13% and 21%
    - Swirl or engine speed
    - Notes:
      - These conditions are for TDC
      - SOI: near TDC
  - Geometry: engine (+free jet if possible)
  - If possible, variable liquid angle

SOME WORDS ON CFD. MODELS

- **TCI model**
  - Reference well-mixed
  - Each participant can additionally submit calculations with a particular TCI closure

- **Chemical mechanism**
  - Reference (ALL groups should use):
    T. Yao, Y. Pei, B.-J. Zhong, S. Som, T. Lu, et al., A compact skeletal mechanism for n-dodecane with optimized semi-global low-temperature chemistry for diesel engine simulations, Fuel 191 (2017) 339-349.
  - Additional submissions with a different chemical mechanism are welcome, but not required.

SOME WORDS ON CFD. MODELS

- **RANS vs LES**
  - Reference RANS
  - LES submissions are welcome

- **Soot models**
  - Reference (ALL groups should use):
    K.M. Leung, R.P. Lindstedt, W.P. Jones, A simplified reaction mechanism for soot formation in nonpremixed flames, Combustion and Flame (1991) 87(3–4) 289-305

- **SUBMISSION OF MODELLING FIELD VARIABLES**
  - Field variables to be reported:

MORE DETAILS IN APPENDICES

Data	ACRONYM	
Axial velocity (m/s)	U	
Radial velocity (m/s)	V	
Mixture fraction	Z	
Temperature (K)	T	
Density (kg/m^3)	RHO	
Mixture fraction variance	Zvar	OPTIONAL
Turbulence kinetic energy (m^2/s^2)	K	OPTIONAL
Turbulence kinetic energy dissipation rate (m^2/s^3)	EPS	OPTIONAL
Viscosity (molecular, kg/m/s)	VIS	OPTIONAL
Viscosity (turbulent, kg/m/s)	VIST	OPTIONAL
Scalar dissipation rate (1/s)	CHI	OPTIONAL

Data	ACRONYM
Species mass fraction (kgi/kg)	YC12H26
	YO2
	YCO2
	YH2O
	YCO
	YCH2O
	YOH
	YCH
	YH
	YO
	YC3H3
	YHCO
	YC2H2
Production/destruction rate of species (kgi/m3/s)	$\dot{\omega}$C12H26
	$\dot{\omega}$YO2
	$\dot{\omega}$YCO2
	$\dot{\omega}$YH2O
	$\dot{\omega}$YCO
	$\dot{\omega}$YCH2O
	$\dot{\omega}$YOH
	$\dot{\omega}$YCH
	$\dot{\omega}$YH
	$\dot{\omega}$YO
	$\dot{\omega}$YC3H3
	$\dot{\omega}$YHCO
	$\dot{\omega}$YC2H2
Soot Volume Fraction	SVF

SOME WORDS ON CFD

- **SUBMISSION OF MODELLING FIELD VARIABLES**

MORE DETAILS IN APPENDICES

- Time discretization:
  - From Start of Injection (SOI) until 100 μs after Start of Combustion (SOC+100) field variables should be reported with $\Delta t = 10\ \mu s$
  - From 100 μs after SOC until End of Injection (EOI) field variables should be reported with $\Delta t = 50\ \mu s$
- Spatial resolution: Uniform Cartesian mesh
  - Radial: 0 to 20mm; 0.04mm spacing (501 points)
  - Axial: 0 to 100mm; 0.2mm spacing (501 points)(if using a smaller mesh, the spacing should be maintained).

DEADLINES & PARTICIPANTS

- SUBMISSION DEADLINES
  - All the requested information should be submitted by Monday June 18th 2018
- PARTICIPANTS

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