Combined study by optical diagnostics and Direct Numerical Simulation of the flame stabilization in a Diesel-type spray

Fabien Tagliante

Ph.D. started in December 2015

Thesis Director (IFPEN): Gilles Bruneaux
Thesis co-Director (IFPEN): Christian Angelberger
Supervisor (IFPEN): Louis-Marie Malbec
In collaboration with: Lyle M. Pickett (Sandia National Laboratories) & Thierry Poinsot (CERFACS)
Scientific context of the flame stabilization under Diesel condition

The distance at which the flame stabilizes has a great impact on the soot production: What is the flame stabilization mechanism under Diesel condition?

**Experimental studies**

Pickett et al. SAE 2005-01-3843

- Flame stabilization by auto-ignition

**CFD studies**

Krisman et al. PCI 36 (2017) 3567–3575

- Edge-flames are involved in the flame stabilization process

**Real physics**

- Access to local values
- Access to all the quantities

**Disadvantages**

- Temporal and spatial resolution
- Difficult to measure simultaneous quantities

- 3D-DNS → too expensive to simulate a stabilized flame spray flame under Diesel condition
- RANS and LES → combustion model → assumption on the combustion regime
Scientific context of the flame stabilization under Diesel condition

The distance at which the flame stabilizes has a great impact on the soot production: What is the flame stabilization mechanism under Diesel condition?

**Objective of my PhD: To contribute to a better understanding of the stabilization mechanisms of a Diesel-type flame combining optical diagnostics and CFD**

**Experimental studies**

Flame stabilization by auto-ignition

- Pickett et al. SAE 2005-01-3843

- Temporal and spatial resolution
- Difficult to measure simultaneous quantities

**CFD studies**

Edge-flames are involved in the flame stabilization process

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- Access to local values
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- 3D-DNS $\rightarrow$ too expensive to simulate a stabilized flame spray flame under Diesel condition
- RANS and LES $\rightarrow$ combustion model $\rightarrow$ assumption on the combustion regime
Simultaneous and time-resolved optical diagnostics

\[ T_{amb} = 800K; \quad \rho_{amb} = 14.8 kg/m^3; \quad P_{inj} = 150MPa \]

- Broadband chemiluminescence (30 kHz) \( \rightarrow \) LOL detection
- 355 LIF (6 kHz) \( \rightarrow \) detection of cool flame areas (formaldehyde species)
- Schlieren images (30 kHz) \( \rightarrow \) Evolution of the gaseous jet envelope

3 simultaneous and time-resolved optical diagnostics
Focus on the high-temperature flame

- OH* chemiluminescence at 60 kfps to track the high-temperature flame

Auto-ignition → Event A

Downstream evolution of the LOL → Evolution B

Numerical setup

- Objective: To reproduce the $\alpha$ test conditions to distinguish the stabilization mechanisms thanks to local values

- 2D-DNS
- Gaseous injection + Synthetic turbulence
- Chemistry: 28 species transported

Non-simulated area due to:
- Very high Reynolds number
- Two phase flow
Numerical setup

- Objective: To reproduce the $\alpha$ test conditions to distinguish the stabilization mechanisms thanks to local values

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Diagram showing the setup with labels indicating areas of interest, symmetry, and distances.
$z_{st} = 0.048$

Heat Release = $4e11 \ W/m^3$
The DNS allows to:

- Isolate local reaction zone topologies identified at the lift-off

Focus on auto-ignition: Event A
Reaction zone topologies: isolated auto-ignition

- Isolated auto-ignition (AI-I)

Time: 0.002670

$z_{st} = 0.048$

Heat Release = $4e11 \, W/m^3$
Reaction zone topologies: auto-ignition assisted by burnt gases

- Auto-ignition assisted by burnt gases (AI-BG)

\[ z_{st} = 0.048 \]

Heat Release = 4e11 W/m³
LOL tracking with the reaction zone topologies identification

Like in the experimental study, two main stages are observed, stage A and B:

- Event A is attributed to isolated auto-ignition (AI-I) or auto-ignition assisted by burnt gases (AI-BG)
• Like in the experimental study, two main stages are observed, stage A and B:
  
  o Event A: isolated auto-ignition (AI-I) or auto-ignition assisted by brunt gases (AI-BG)
  
  o Evolution B: triple flame (TF) or lean/rich reaction zone (L/R RZ) \( \Rightarrow \) governed by the flow velocity
Conceptual model of flame stabilization

Thank you for your attention