Hydrogen enriched compression ignition internal combustion engine: A dual fuel study

Experimental investigation

By

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Engine research group

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Presentation Outline

1. Introduction
2. Experimental setup and cases
3. Results and analysis
4. Conclusion and future work

Decarbonizing CI engines

Carbon free pathways → Hydrogen

+

Ignition support + transitional technology → Diesel

Dual fuel compression ignition internal combustion engine

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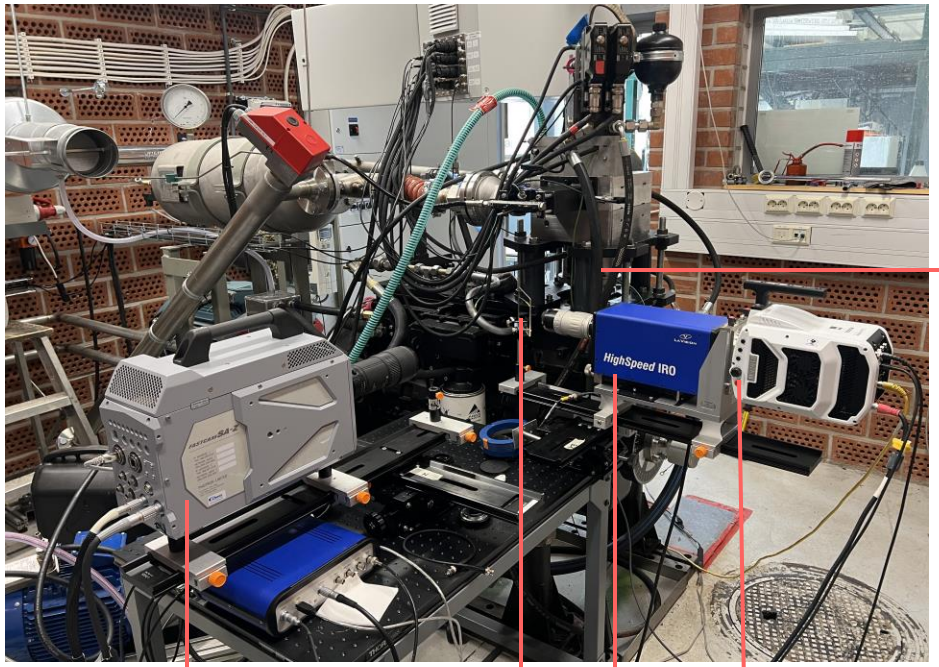
Research engines

Optical engine

1. Single cylinder, 4-stroke engine.
2. Cylinder displacement = 1.40 dm^3.
3. Compression ratio ~14.2:1.
4. Electrohydraulic valve actuation system (EHVA).
5. Optically accessible.
6. Rpm ~ 800-1200.



High speed color camera
Beam splitter
High speed intensifier
High speed monochrome camera
Optical piston assembly

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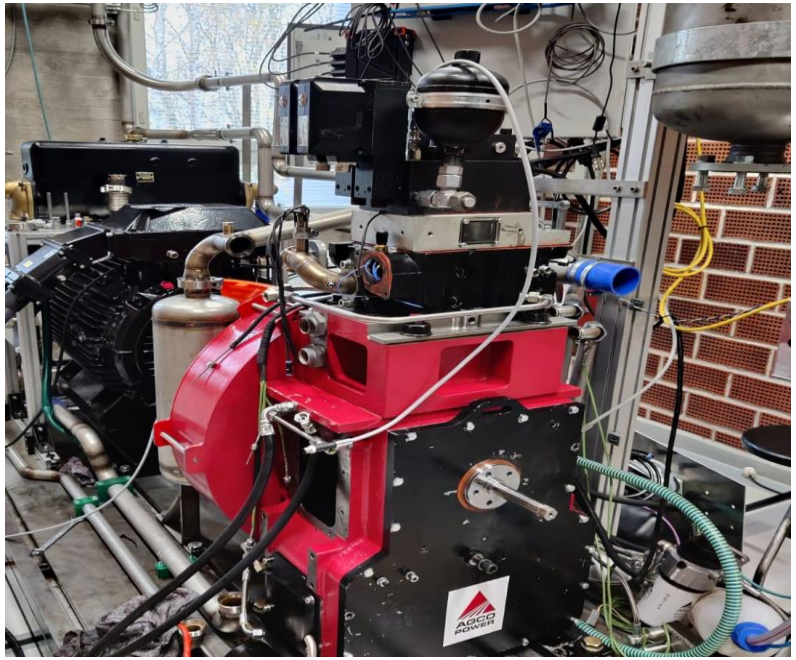
Full metal engine

1. Single cylinder, 4-stroke engine.
2. Cylinder displacement = 1.25 dm^3.
3. Compression ratio ~17.3:1.
4. Electrohydraulic valve actuation system (EHVA).
5. Full metal cylinder engine.
6. Rpm ~ 800-2000.

Micro-soot sensor (MSS)

Particulate Emissions Gaseous

Fourier transform infrared (FTIR)



Full metal engine test cases

Parameter	Value
RPM	1000
Intake air mass flow rate (kg/h)	40
Hydrogen energy share (in %)	0,10,20,30,40,50
Global lambda	1.47-1.59
Gas lambda	17.49-3.50
CA50 (CA Degrees)	6,8,10
Diesel injection pressure (bar)	1000
Total input fuel energy (MJ/h)	80

- **Direct injection (non-premixed) strategy for introducing diesel.**
- **Port fuel injection (premixed) strategy for introducing hydrogen.**

*** Please note CA50 → Crank angle at which 50% of total heat release has been achieved.**

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Optical engine test cases

Parameter	Value
RPM	1000
Intake air mass flow rate (kg/h)	30
Total input fuel energy (MJ/h)	60
Diesel injection pressure (bar)	1200
Hydrogen injection strategy	PFI
Start of diesel injection (DBTDC)	8
Hydrogen energy share (in %)	0,10,20,30,40
Gas lambda	17.65-4.41

30% H2 energy share

Parameter	Value
Start of diesel injection (DBTDC)	8,10,12

- **Skip firing strategy (firing every 7th cycle).**

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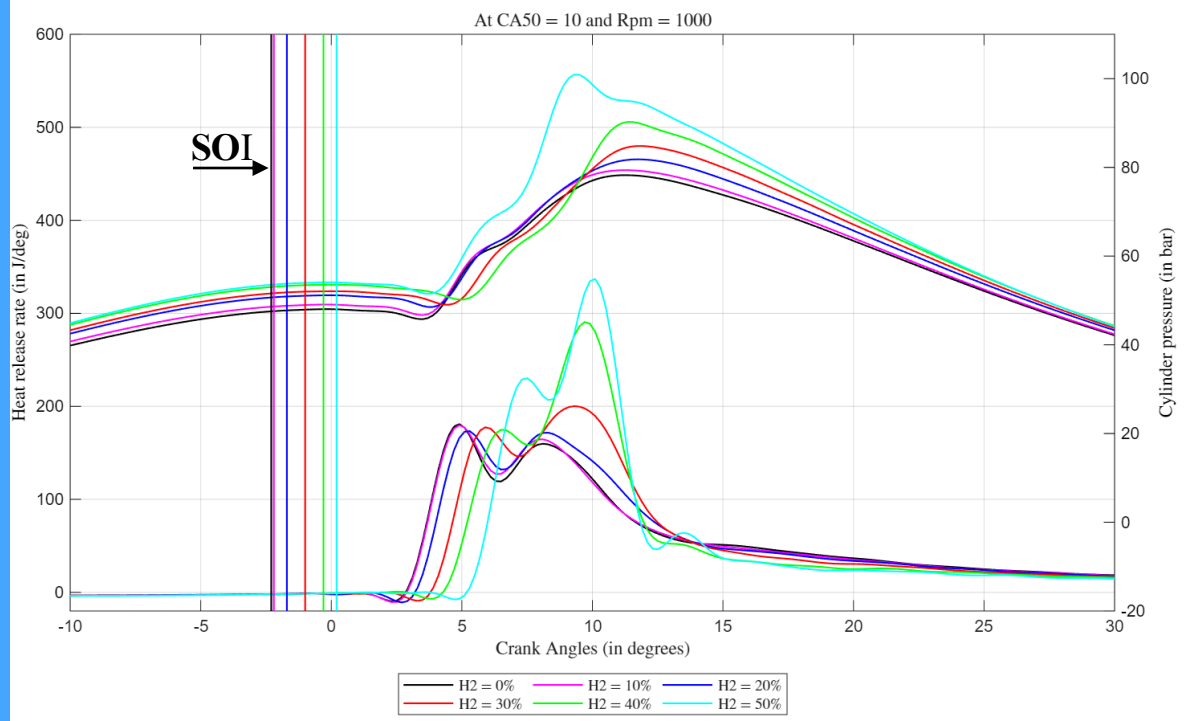
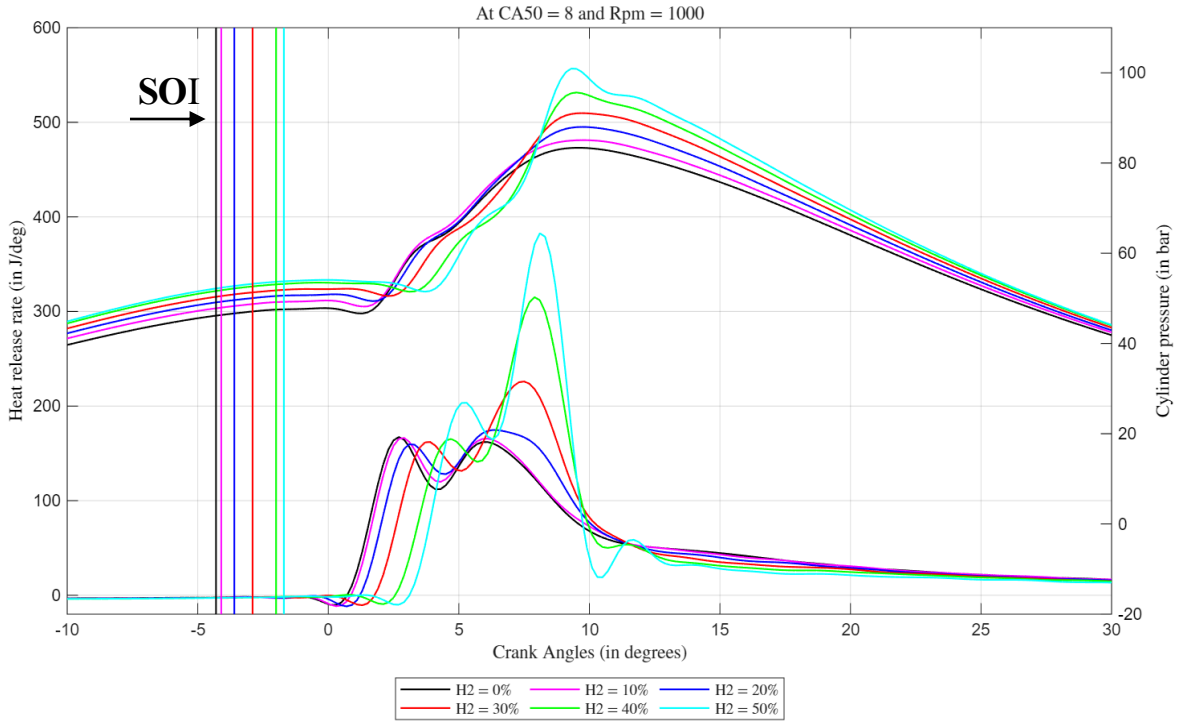
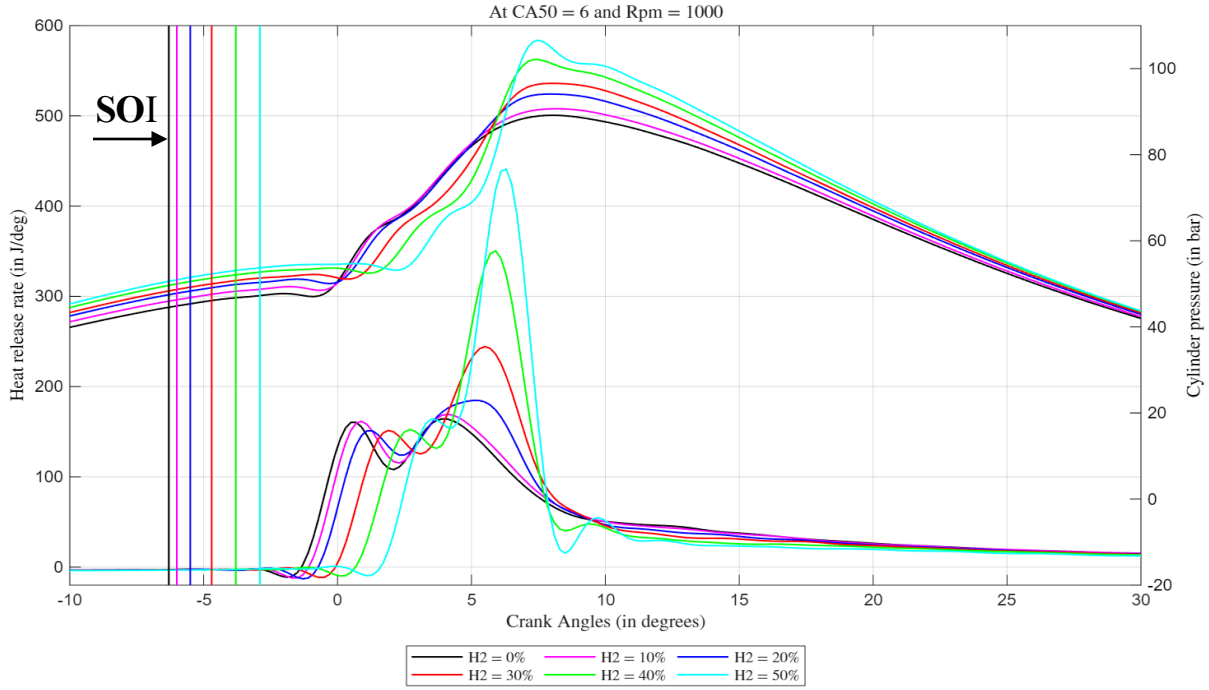
FULL METAL ENGINE RESULTS

COMBUSTION ANALYSIS

Experimental results







- **First HRR peak results from diesel.**
- **Second HRR peak results from premixed hydrogen.**

*** Please note Start of injection (SOI) is in CA Degrees.**

- **With an increase in H2 energy share the peak cylinder pressure and HRR increases for all CA50.**
- **With early CA50 the second HRR peak (related to premixed H2) increases.**

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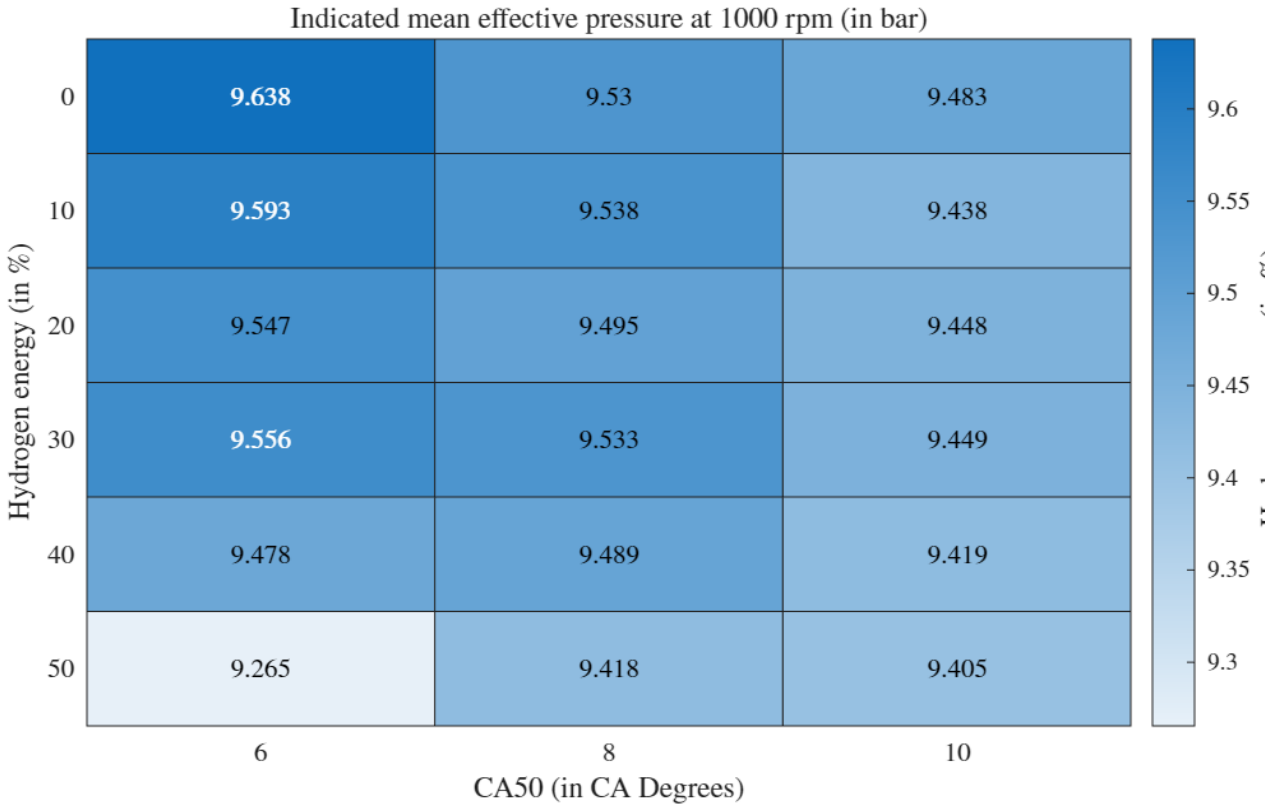
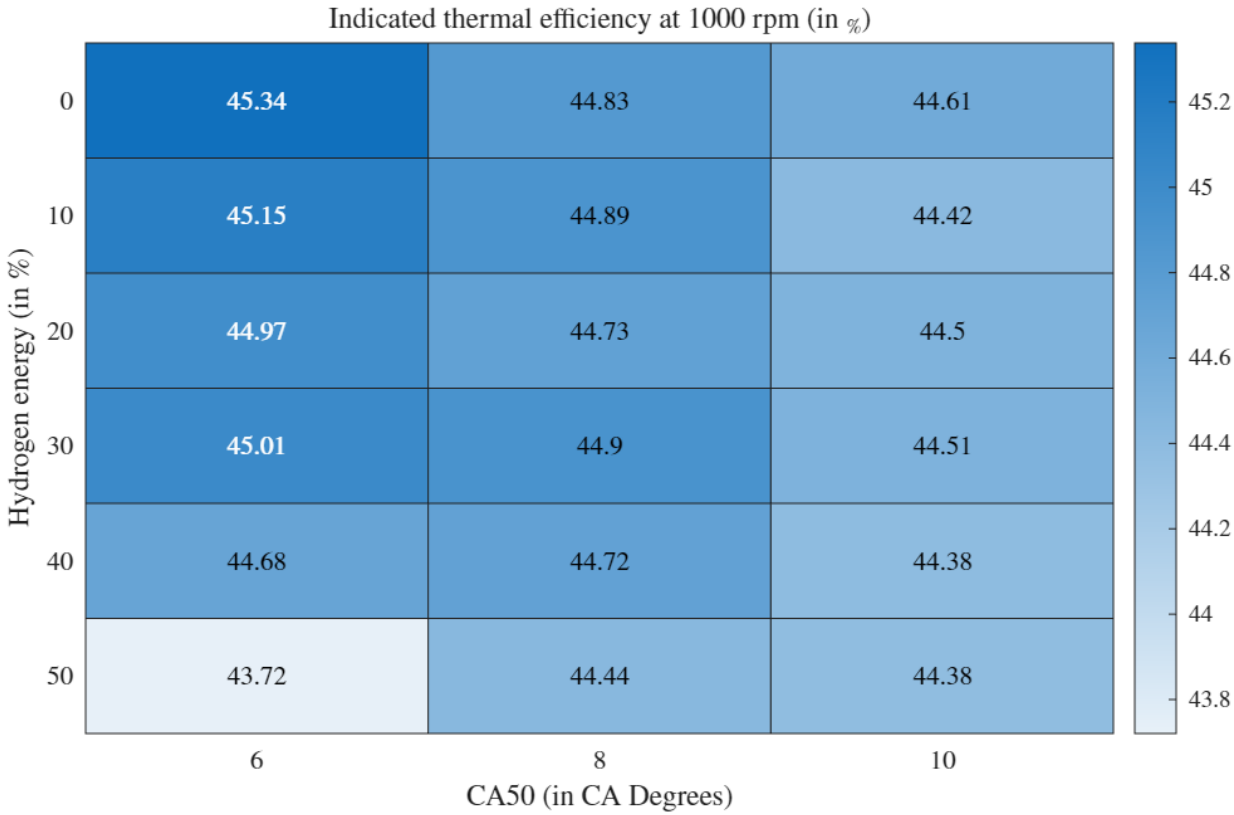
PERFORMANCE METRICS

Experimental results





- **IMEP and ITE remains nearly constant.**

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Highlights the constant total energy condition.

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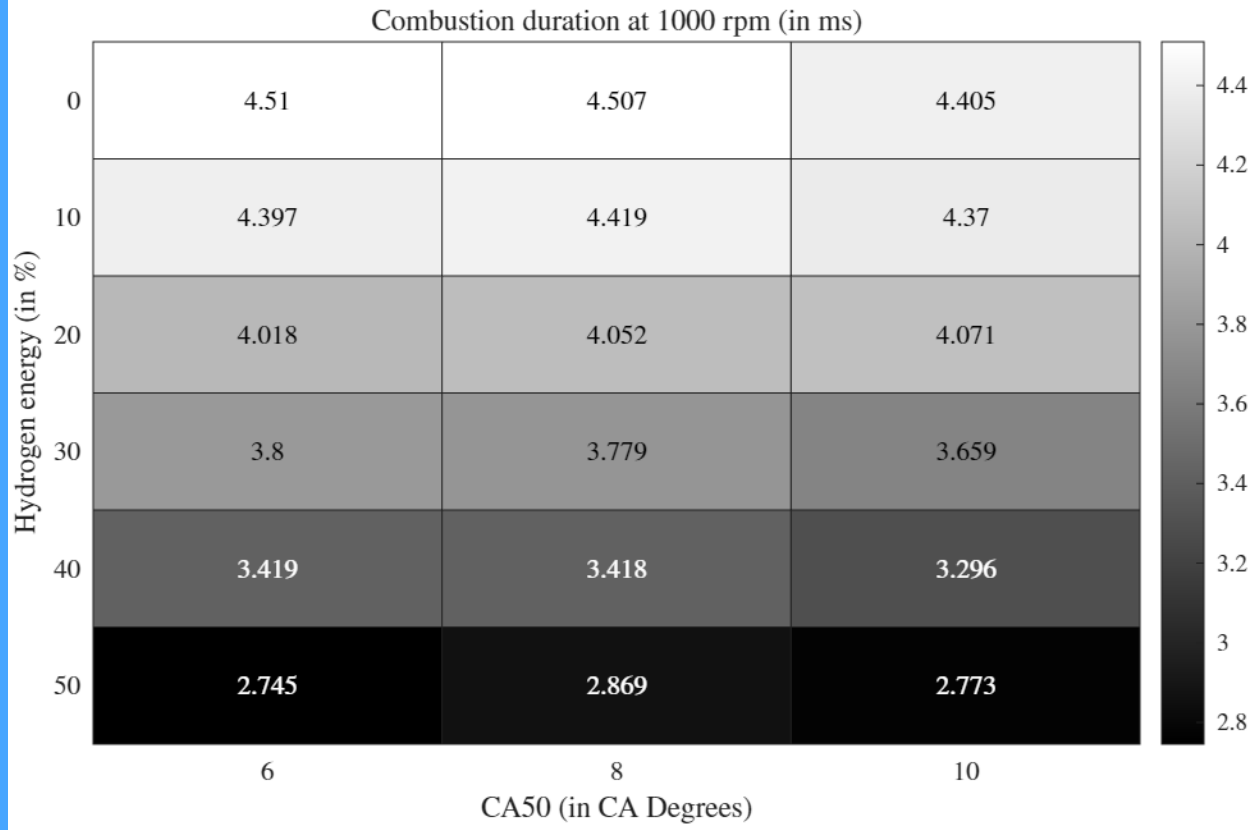
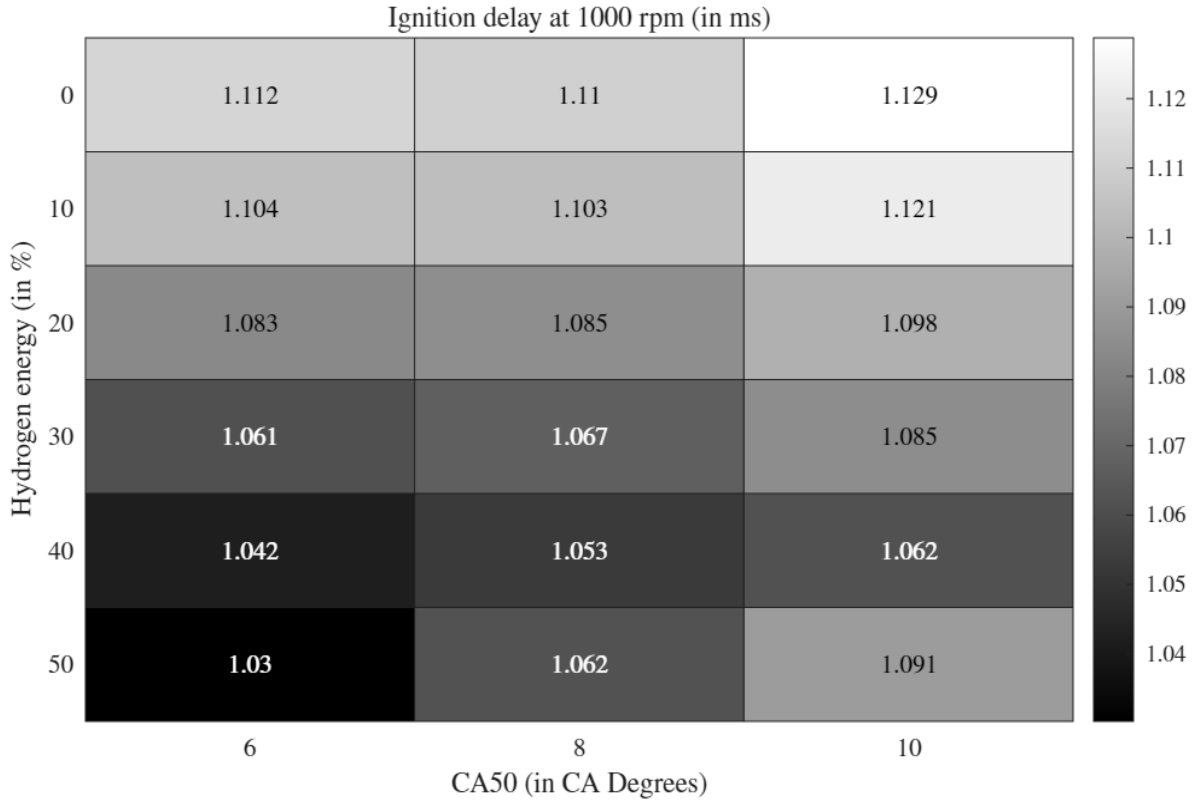
Experimental results





- **CD decreases with increasing HES**

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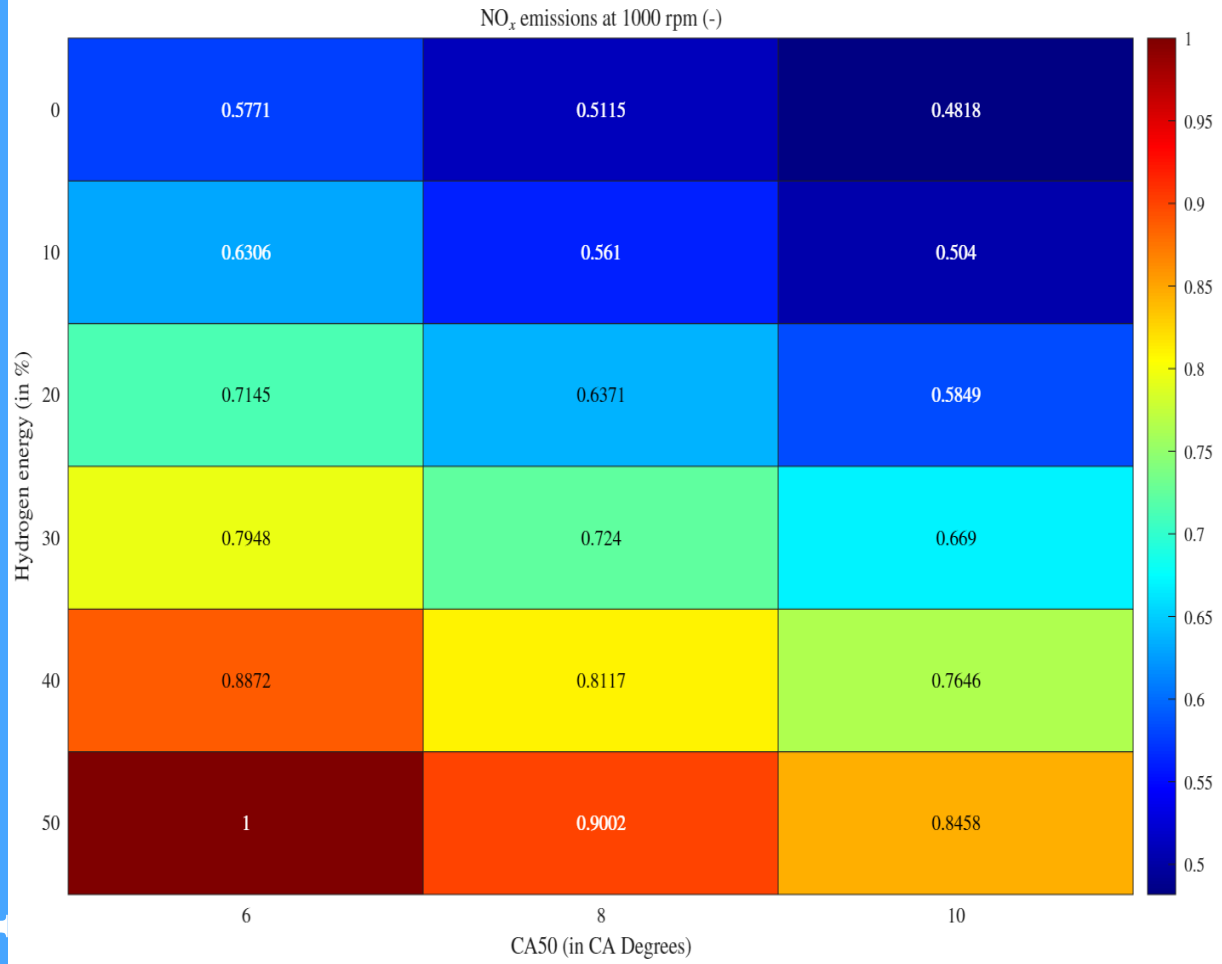
Indicating faster reaction rates.

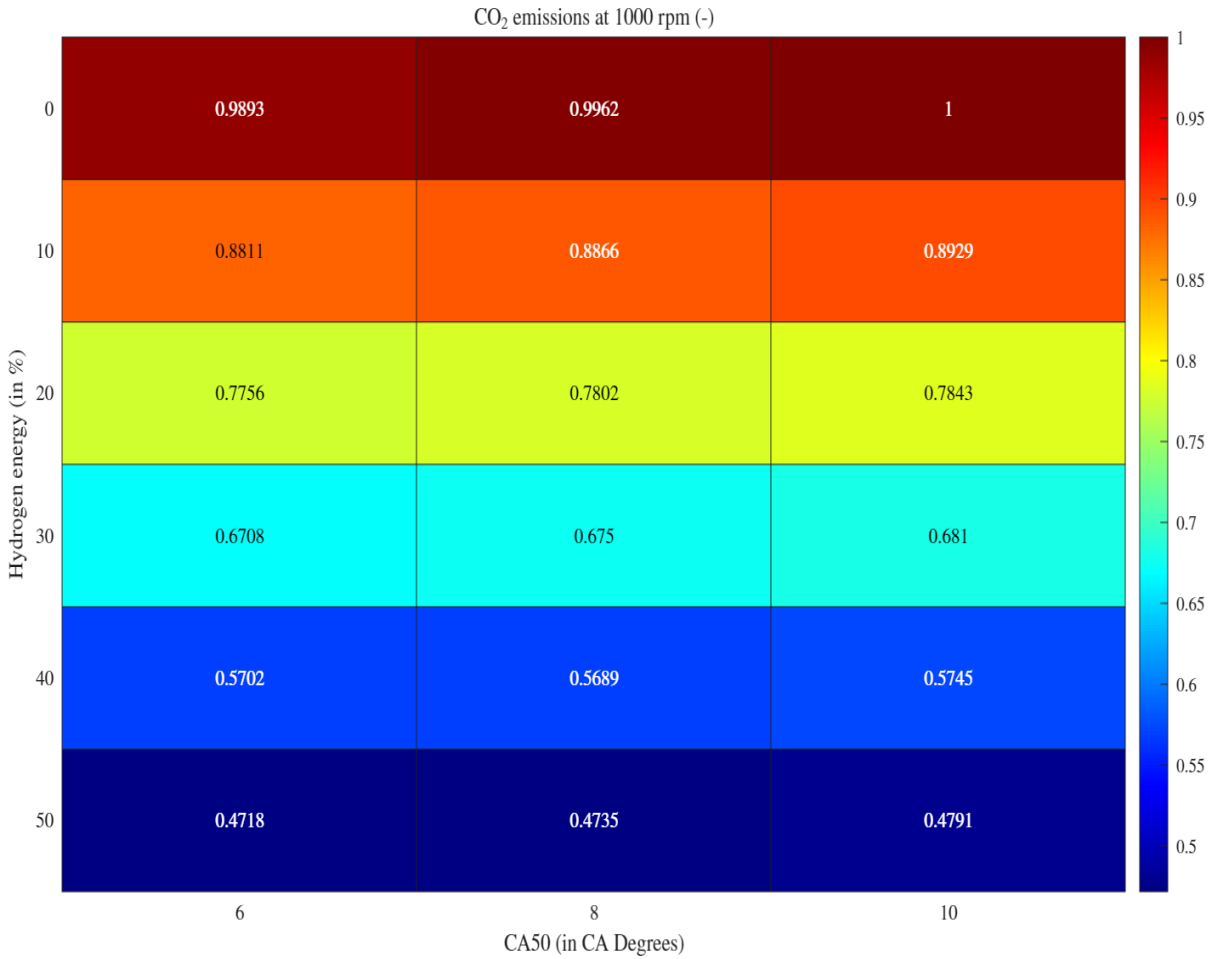
- **IDT remains constant for all the cases.**

*** Please note CD = CA90 – CA05, IDT = CA05 – SOI.**

EMISSIONS

Experimental results





- At any constant CA50 with increase in H2 energy share NOx increases.
- At constant H2 energy share NOx decreases with later CA50 values.

- At any constant CA50 with increase in H2 energy share CO2 decreases.
- CO2 emissions are independent of CA50 values.

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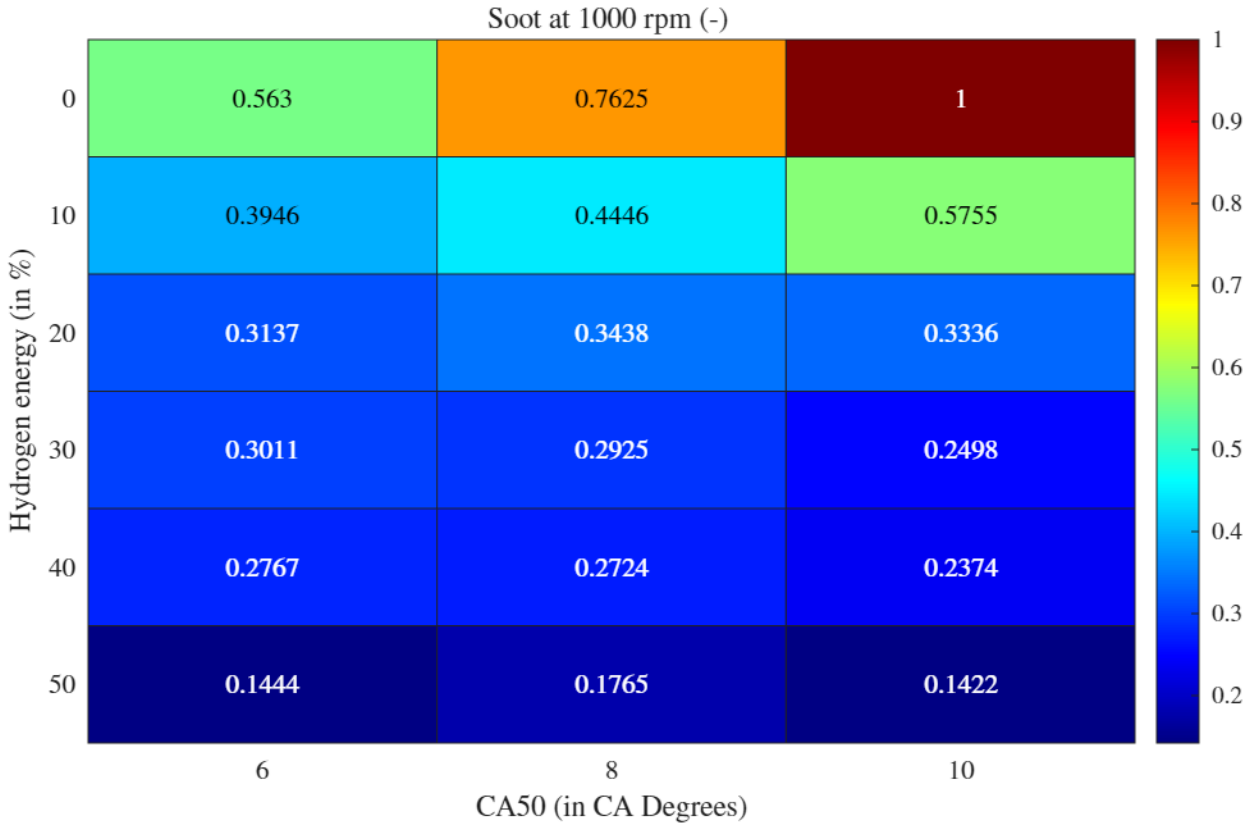
Experimental results



- **At any constant CA50 with increase in H2 energy share soot emissions decrease.**
- **Soot emissions do not seem to be dependent upon combustion phasing.**

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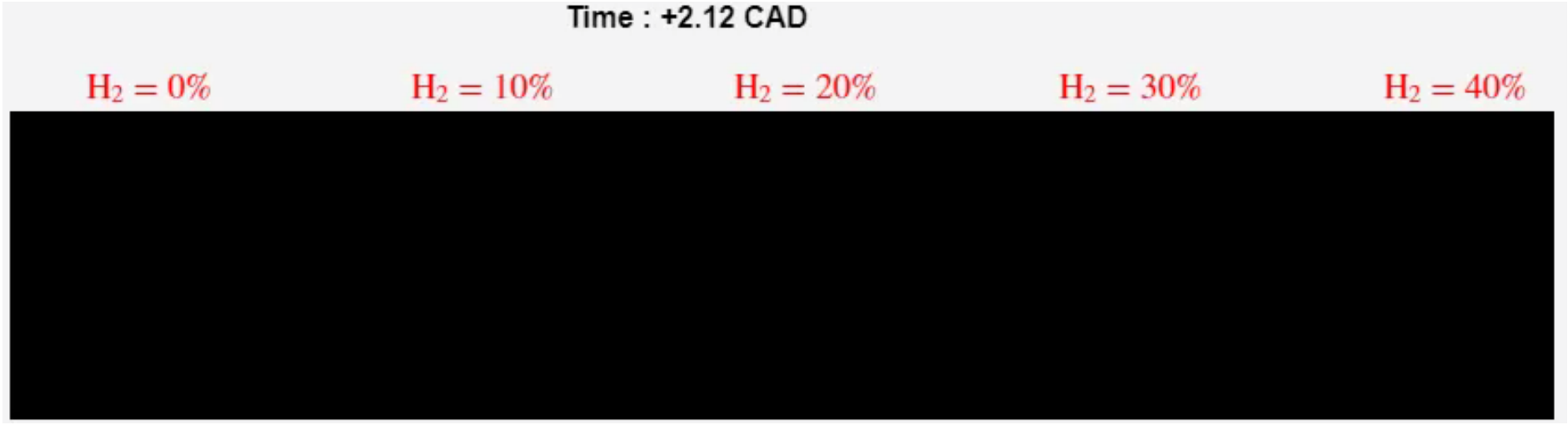
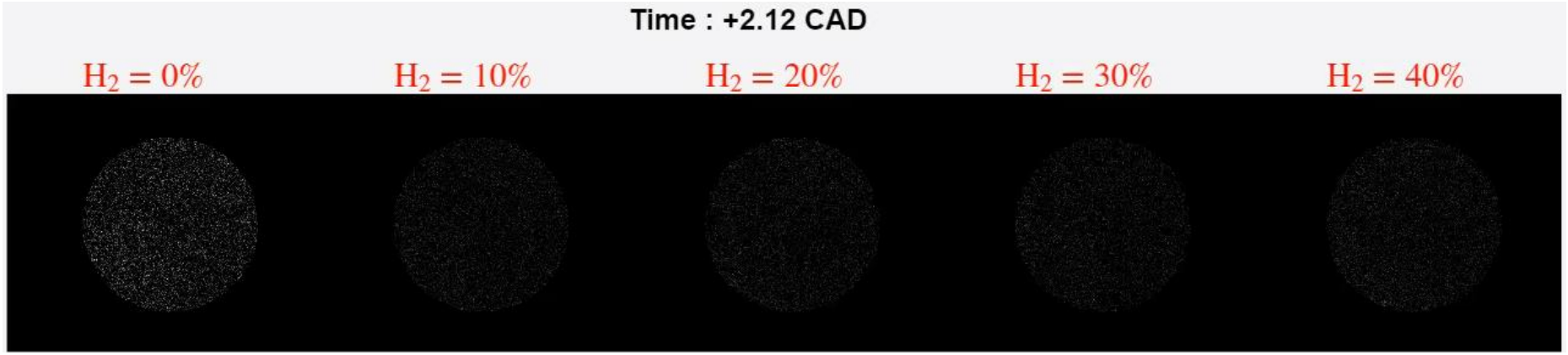
OPTICAL ENGINE RESULTS

H2 energy ratio swept between 0 - 40% at constant SOI of 8 DBTDC



Natural Luminescence



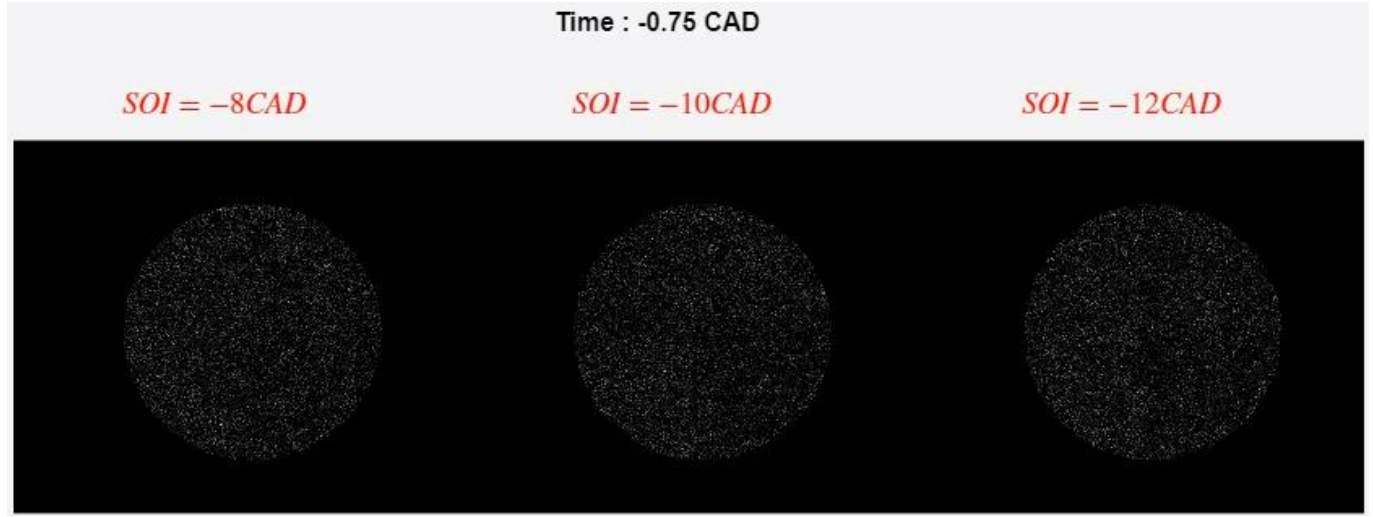
OH* Chemiluminescence

- H2 increases ⟶ Later ignition, Natural luminescence decreases, OH* increases

Decreased soot can be observed with decreasing flame natural luminescence intensity.

SOI swept between 8-12 DBTDC at constant H2 energy ratio of 30%

Natural Luminescence



OH* Chemiluminescence

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➢ Early injection ⟶ Early ignition

Summary & future work

Parameters	Hydrogen fraction	CA50
Heat release rate ↑	↑	Early ↑
NOx emissions ↑	↑	Early ↑
CO2 emissions ↑	↓	Independent
Soot emissions ↑	↓	Independent

- **IDT in optical engine tests > full metal engine with increase in HES.**

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Check using chemical kinetics simulations.

- **Limitations with HES (knocking observed)**

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Playing with lambda values (Full metal engine + Optical assessment).

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Acknowledgement

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THANK YOU