Combustion and Emissions Investigations using OME and Stoichiometric Operation in a Compression Ignition Engine

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Outline

- Introduction
- Testbench
- Results
- Conclusions

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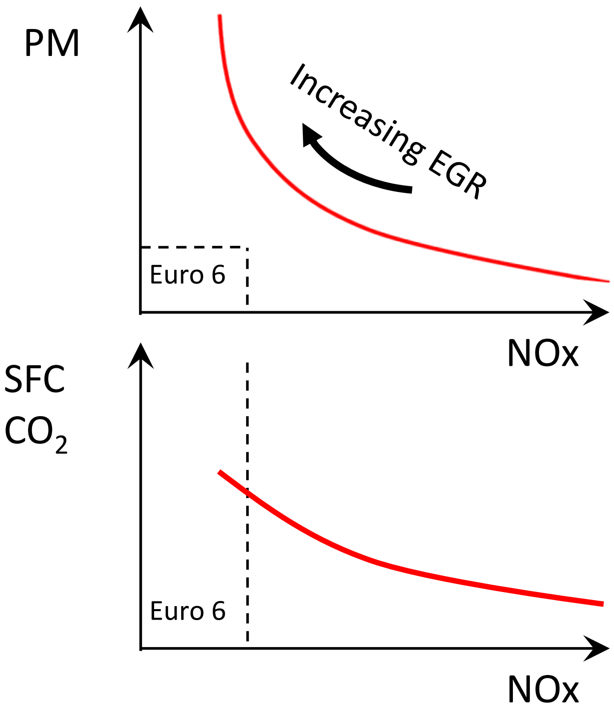
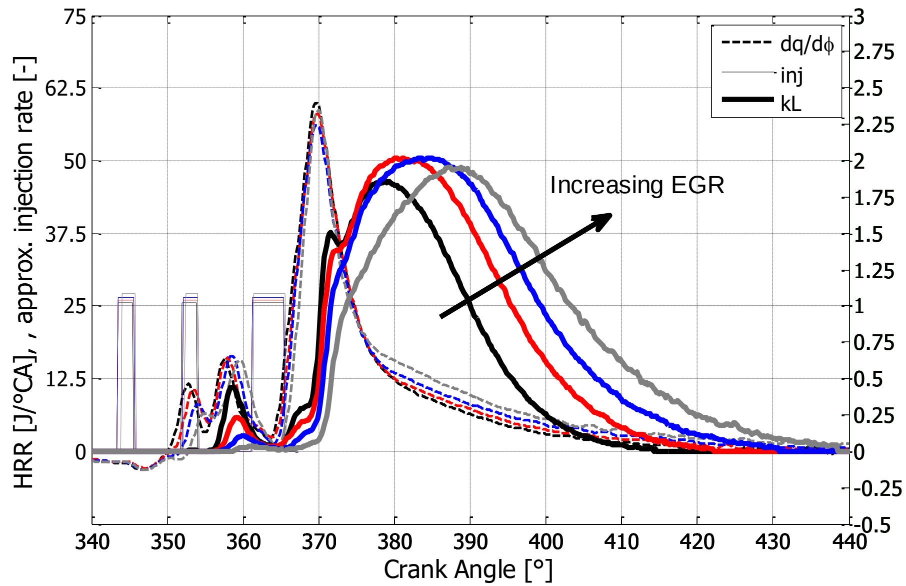
Motivation

- Influence of EGR on In-Cylinder and Tailpipe Soot



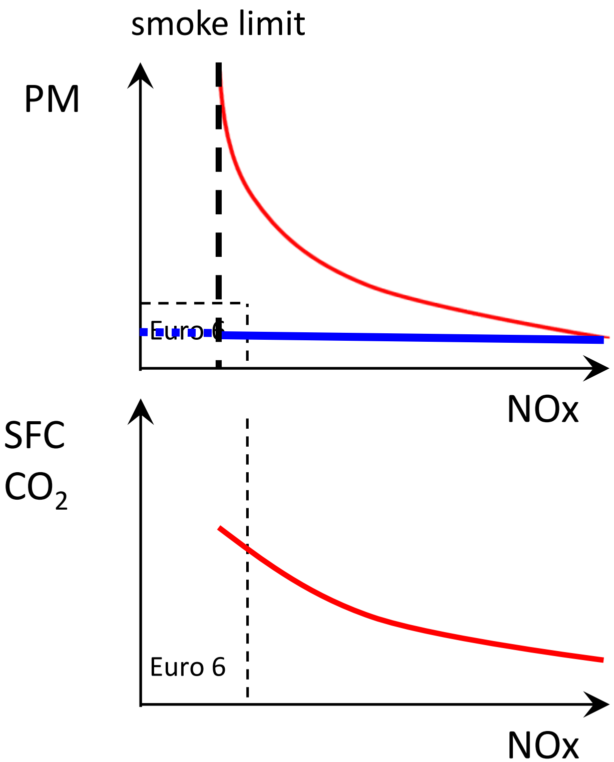


EGR 0%	**Soot: 4 mg/m³**	EGR: 1.1% λ: 2.3
EGR 10%	**Soot: 9 mg/m³**	EGR: 9.7 % λ: 1.9
EGR 20%	**Soot: 41 mg/m³**	EGR: 19 % λ: 1.7
EGR 30%	**Soot: 215 mg/m³**	EGR: 27.3% λ: 1.4

1)

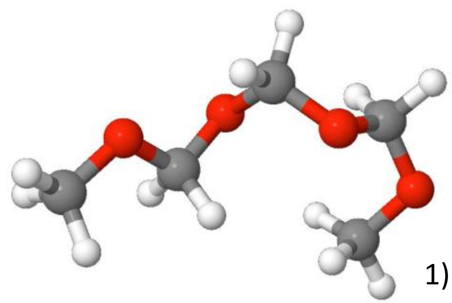
[1] Barro 2012

Motivation



Is there a magic fuel, which does not form soot?

OME: Polyoxymethylene dimethyl ether (also POMDME)



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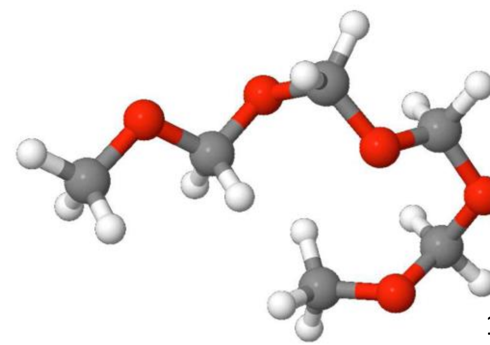
OME 3 (~80%)

$CH_3\text{-}O\text{-}CH_2\text{-}O\text{-}CH_2(O\text{-}CH_2)\text{-}O\text{-}CH_2\text{-}O\text{-}CH_3$

OME 4 (~20%)



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1) E. Jacob 2014

Experimental Setup

Engine specifications

Displacement	3.96 L
Bore/Stroke	165/185 mm
Compression ratio	13.77
Valves	2 Intake 1 Exhaust

Test bench limitations

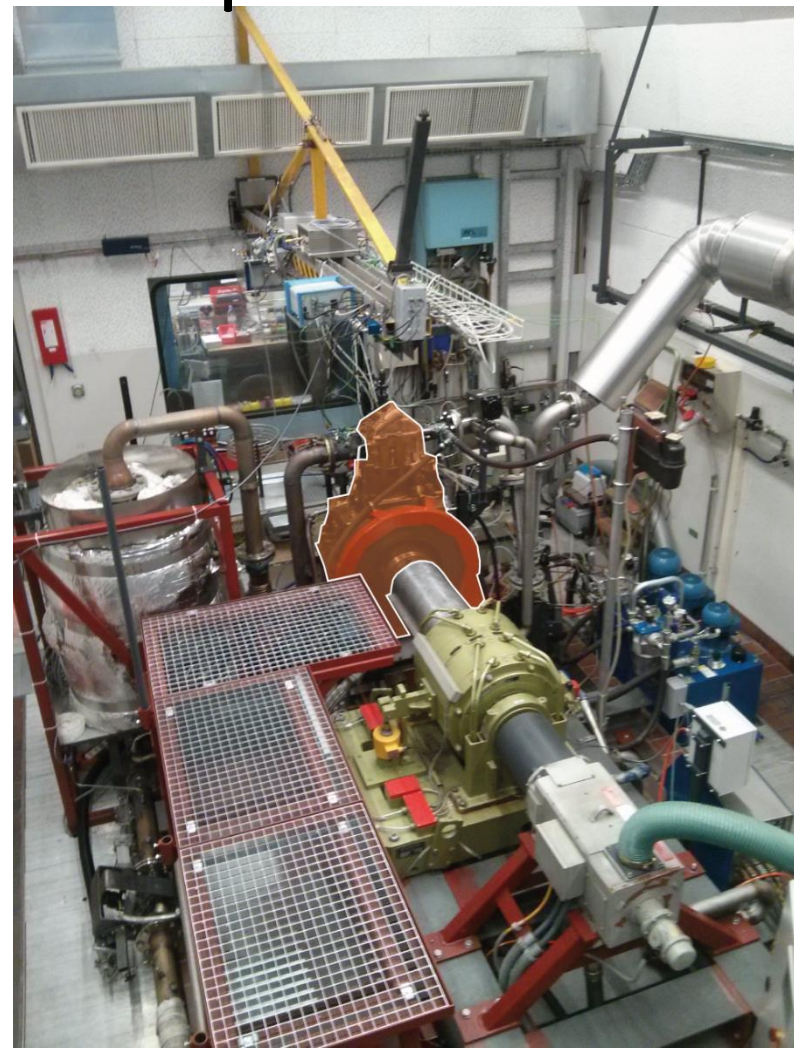
Intake pressure	≤ 4.5 bar
Intake temperature	20°C - 100°C
Exhaust temperature	≤ 700°C

Fuel supply

Injection pressure	≤ 1600 bar
# of fuel pumps	2
Injector nozzle	8 x 0.24 mm 8 x 0.29 mm

Exhaust analysis

HC	FID (C3H8) Airsense (CH4)
Nox/CO/CO2/O2	Standard
Soot	FSN / DMS 500 / TEM



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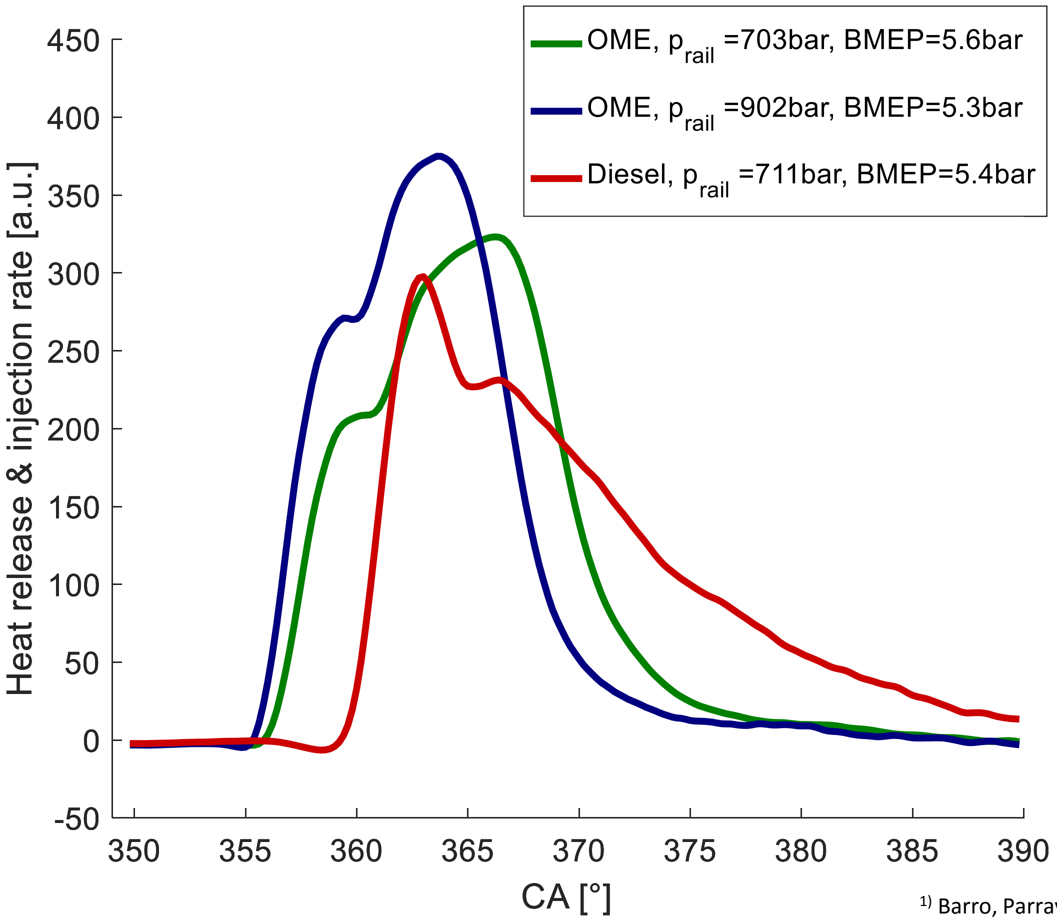
Comparison of Combustion Behaviour

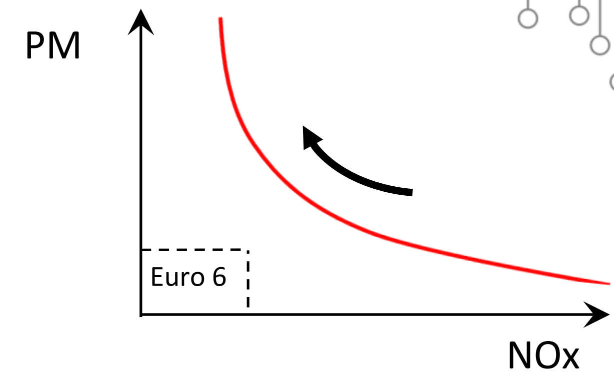
- OME vs Diesel



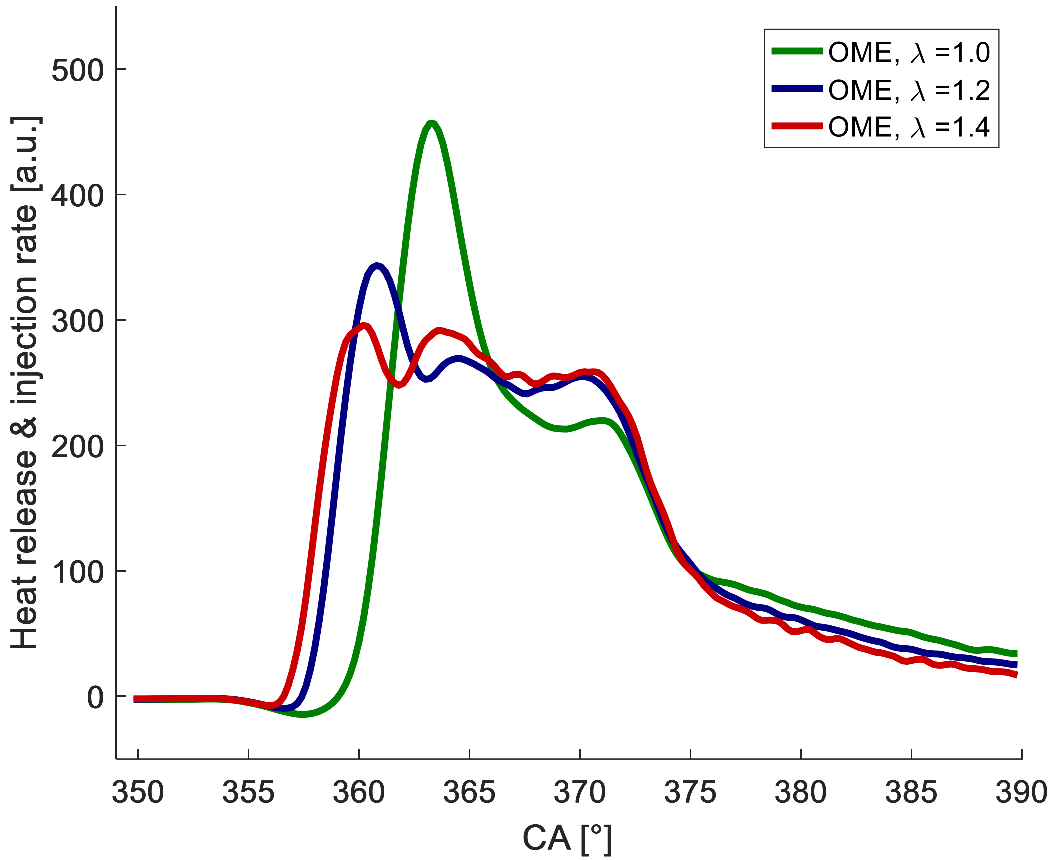
- Ignition delay different
  - Different CN
  - Different nozzle
  - Different hydraulic behaviour
- Different maximum diffusion combustion
  - Even with lower LHV
- Different late combustion behaviour

[1)] Barro, Parravicini, and Boulouchos, Fuel 2017, under preparation

Test Procedure #1



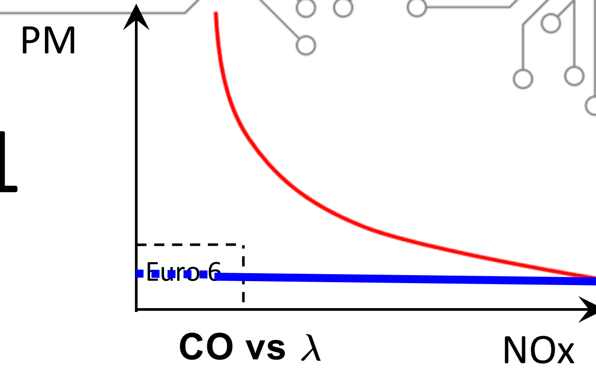
- Increasing EGR at constant fuel rate towards λ =1
- Increased EGR rate “replaced” fresh air



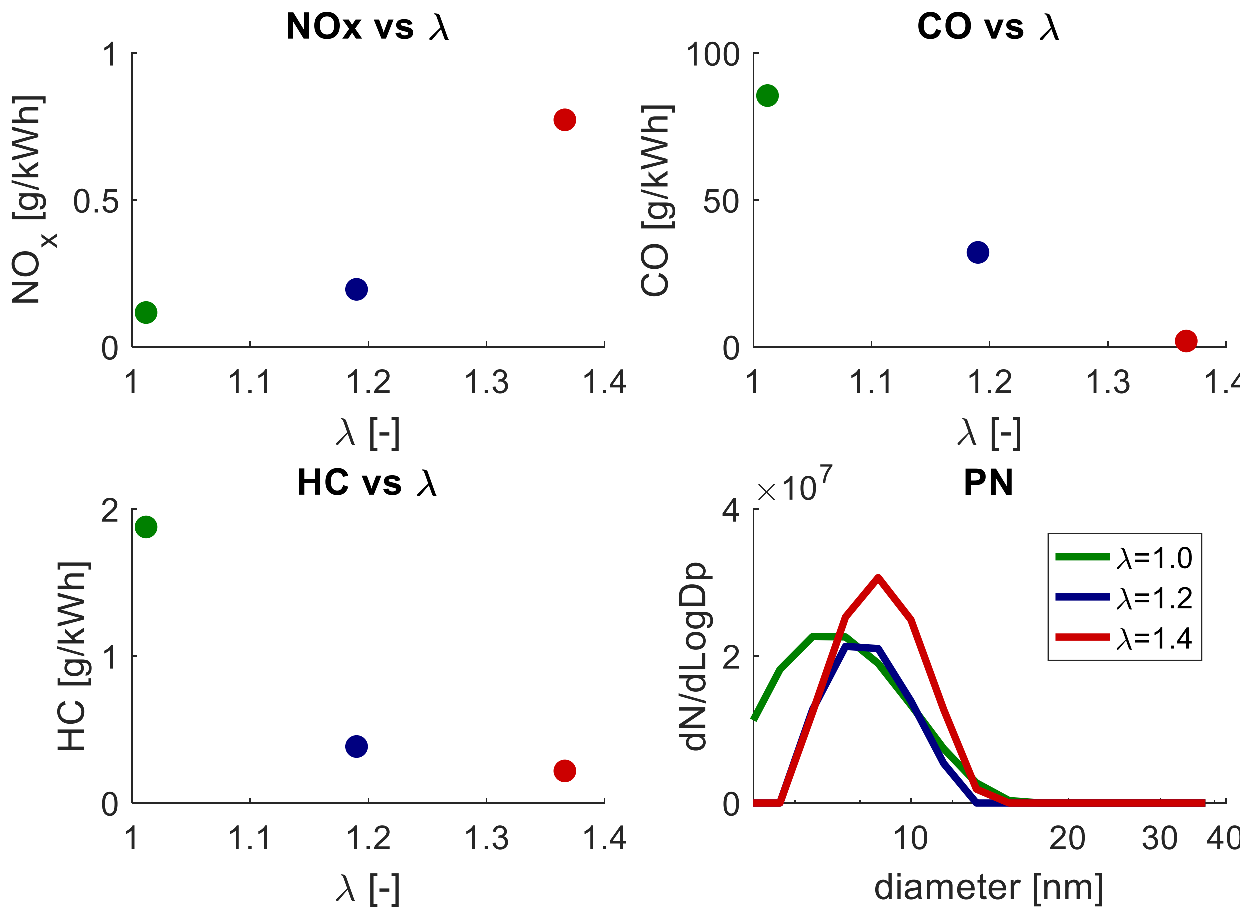
- Changing ignition delay due to lower reactivity with decreasing intake oxygen content
- Decreased diffusion combustion maximum at λ = 1
- Slower (but still decent) late phase combustion

[1] Barro, Parravicini, and Boulouchos, Fuel 2017, under preparation

Operation towards λ = 1



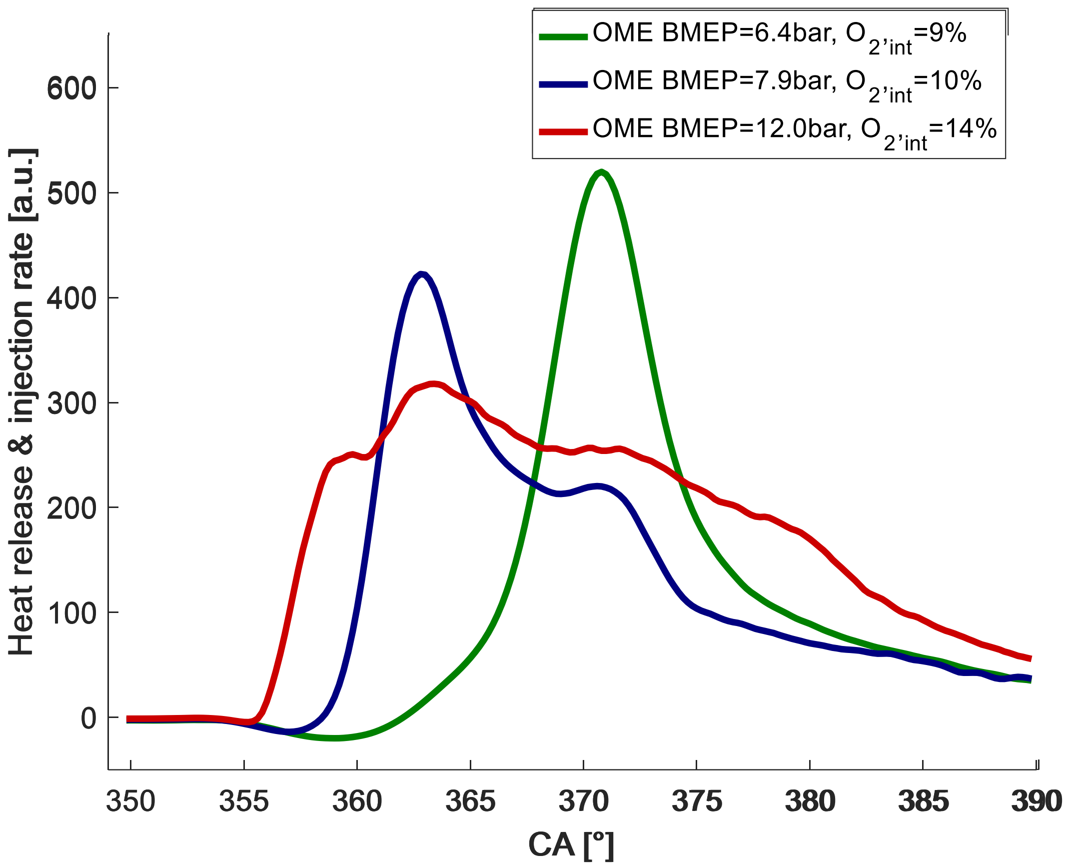
- Reducing NO_x with increasing EGR
- Increasing CO/HC with increasing EGR
- High CH_4 content in THC
- Particles detected in nucleation mode
- No significant PM



[1] Barro, Parravicini, Liati and Boulouchos, Fuel 2017, under preparation

Test procedure #2; Load Variation at λ=1

- EGR "replaced" with fuel to keep λ = 1 with increasing load



- Changing ignition delay due to lower reactivity with decreasing intake oxygen content
- Increasing premixed combustion portion with decreasing oxygen concentration
- Lowest intake oxygen close to PCCI operation

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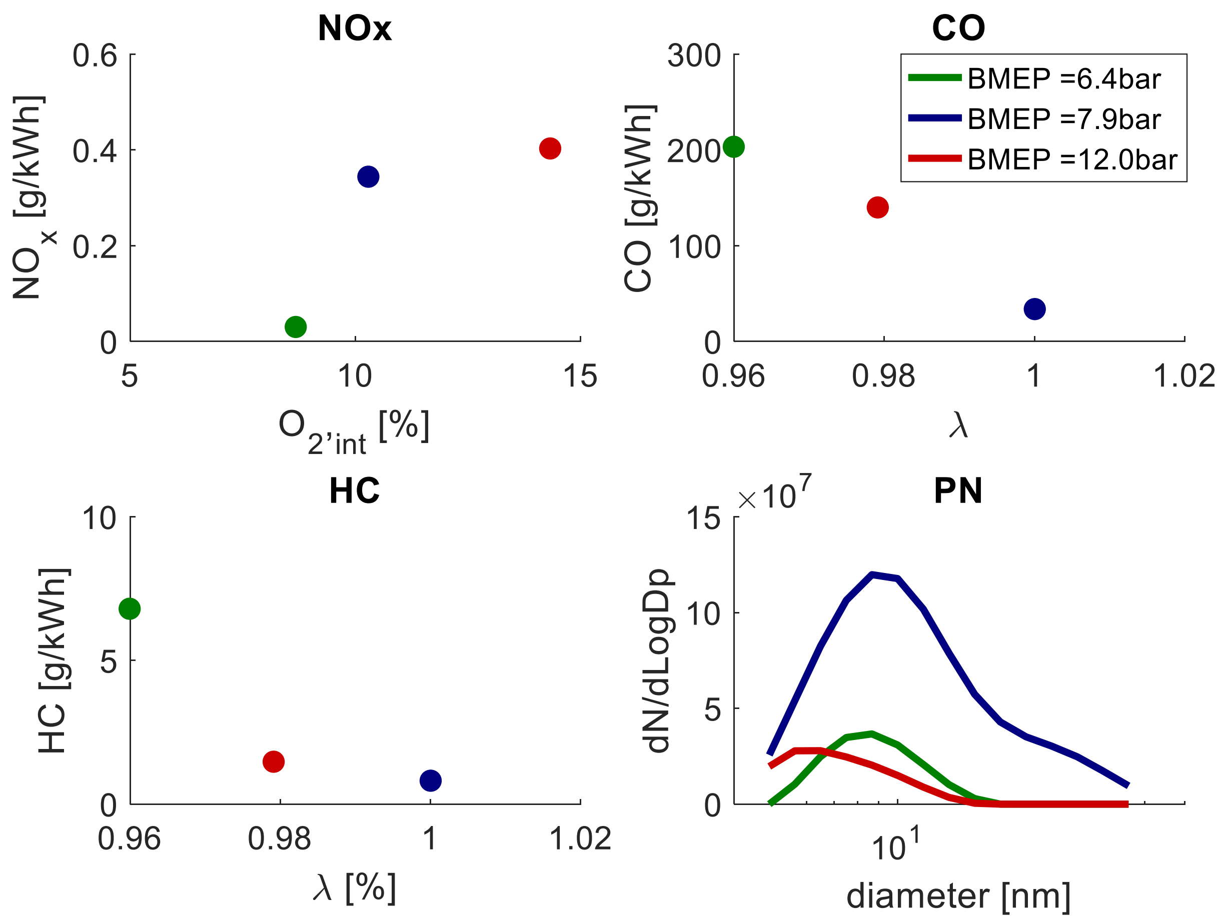
[1] Barro, Parravicini, and Boulouchos, Fuel 2017, under preparation

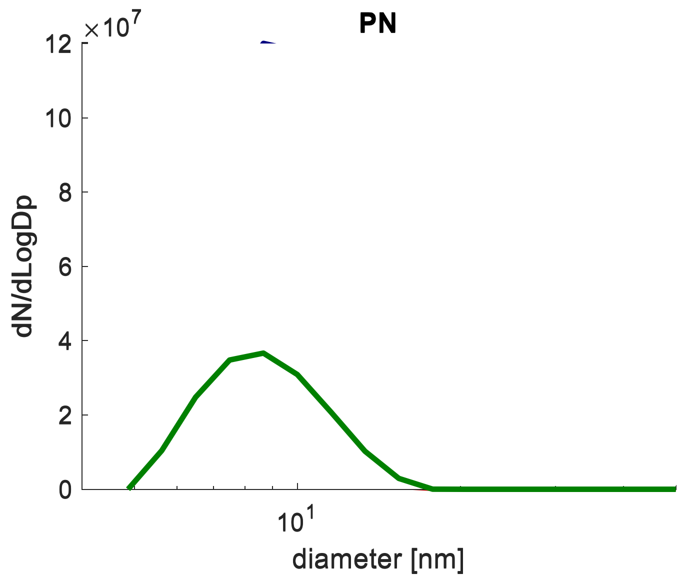
Operation towards λ = 1

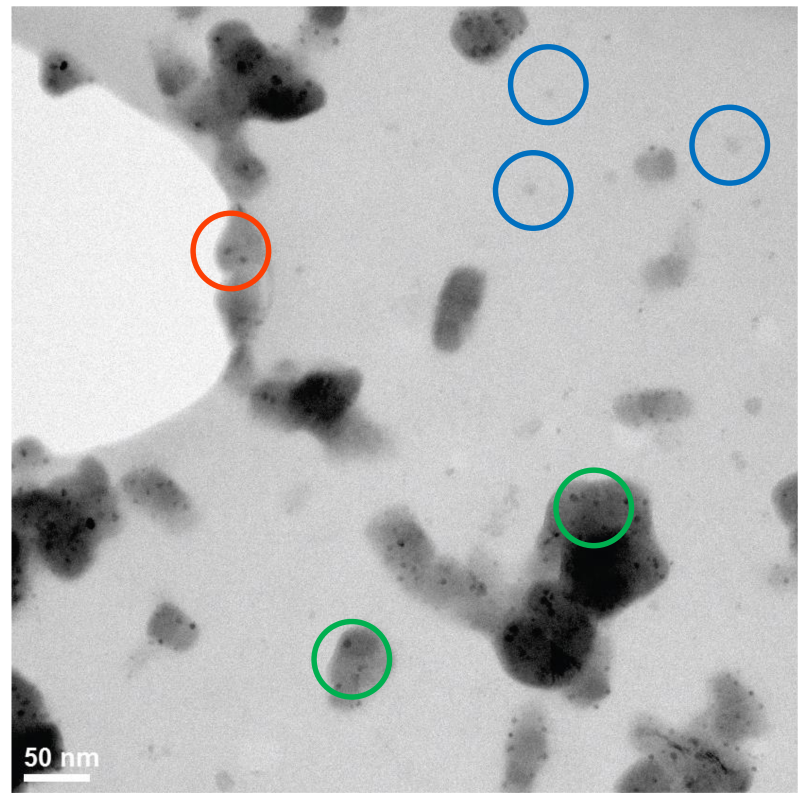
- Reducing NO_x with reducing intake O_2
- Increasing CO/HC with decreasing λ
- Particles detected in nucleation mode (&agglomeration mode for 7.9 bar)



[1] Barro, Parravicini, Liati and Boulouchos, Fuel 2017, under preparation

TEM Analysis





- Numerous small particles (blue)
- Small particles in agglomerates (green, zoom red)

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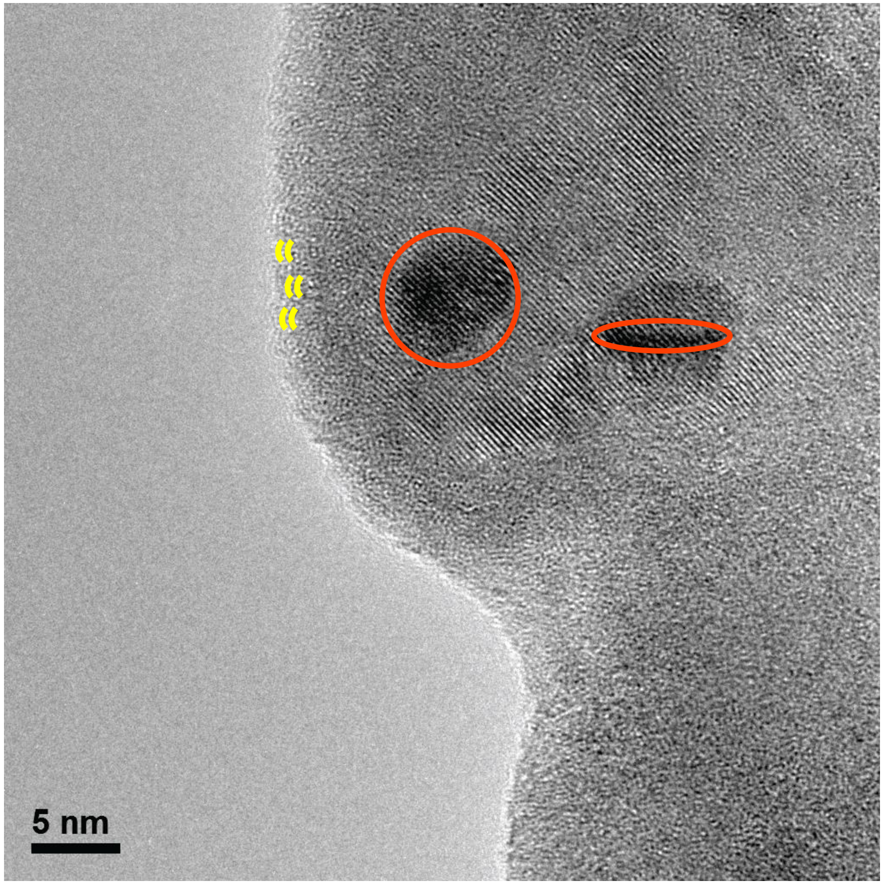
TEM Analysis

Yellow: soot

Red: Metal based nucleation core (unknown metal, unknown origin)



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Conclusions

- Comparison of Diesel and OME in a CI engine showed higher diffusion and faster late phase combustion rate
- OME showed the ability to be operated in stoichiometric conditions in diffusion combustion mode (even with very low intake oxygen concentration)
- The used setup showed significant particle number emission without significant particle mass
- Large number of non-soot particles; soot particles contain metal nucleation core

Acknowledgements

- Co-Authors, for their contributions
- Swiss Federal Office of Energy, for the financial support
- You, for your kind attention

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