On the Way towards Defossilization of Diesel Engines

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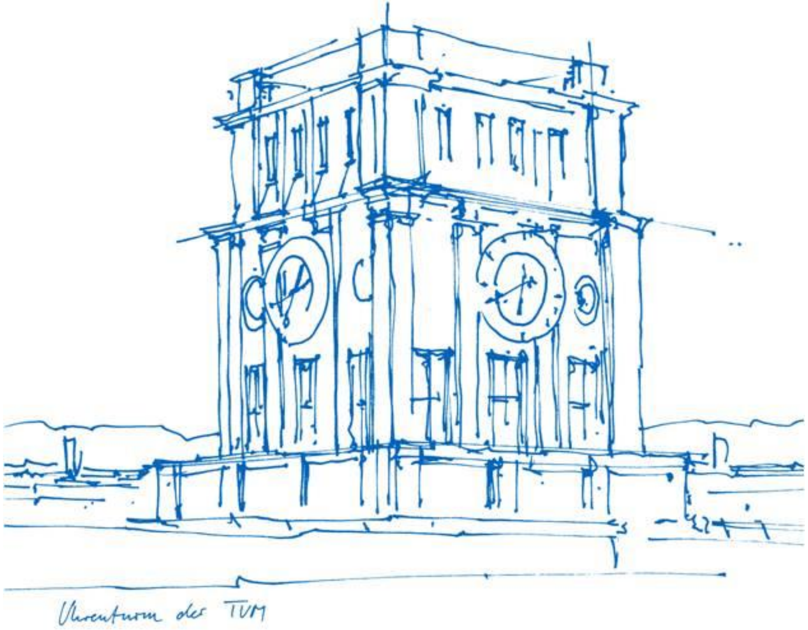
Graz, 22. September 2021



“My engine is continuing to make great progress”

- Rudolf Diesel, 1895

2021…

Air pollution from fossil fuels is TWICE as deadly as thought and is linked to 20 per cent of deaths worldwide, scientists warn

July 14, 2021
4:59 PM CEST
Last Updated a month ago

Retail & Consumer

EU proposes effective ban for new fossil-fuel cars from 2035

The allure of green fuels looks to end shipping's loveless marriage with oil.

05 Aug 2021 ARTICLE MARINE & SHIPPING

BUSINESS | ENERGY | JOURNAL REPORTS: ENERGY

Can E-Fuels Save the Combustion Engine?

Proponents say they should be part of a low-carbon future. But cost and efficiency remain hurdles.

Sources:
https://www.dailymail.co.uk/sciencetech/article-9239795/Fossil-fuel-pollution-causes-one-five-premature-deaths-globally-study.html
https://www.reuters.com/business/retail-consumer/eu-proposes-effective-ban-new-fossil-fuel-car-sales-2035-2021-07-14/
https://www.lr.org/en/insights/articles/the-allure-of-green-fuels-looks-to-end-shippings-loveless-marriage-with-oil/
https://www.wsj.com/articles/can-e-fuels-save-the-combustion-engine-11621037390

Why alternative fuels?

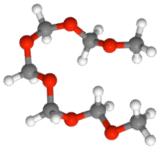
- Combustion of fossil fuels generates greenhouse gases and air pollutants
- Finite reserves of crude oil
- Battery-electric powertrain not always reasonable (e.g. long-haul trucks, shipping)
- Difficult handling and storage of hydrogen as an energy carrier

→ Solution: Liquid synthetic energy carriers! Targeting:

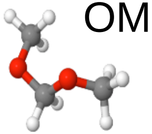
- Use of existing infrastructure
- Minimal adjustment of engine
- Non-toxic for humans and environment
- Closed carbon-cycle
- Lowest emissions of pollutants

→ Polyoxymethylene dimethyl ether (pretty close to these targets)

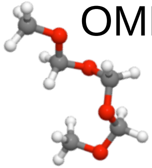
Polyoxymethylene dimethyl ether – OME



OME_5



OME_1

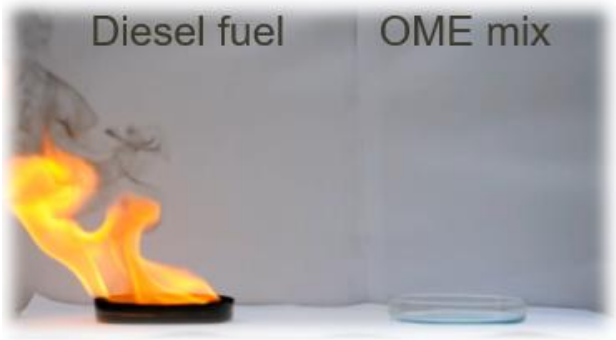


OME_3

- Oxygenated Diesel fuel with different chain lengths
- No C-C bonds, leading to soot free combustion
- Promising studies with mix of $OME_{3…5}$
- Synthesis from H_2 and CO_2 – using renewable energy, biomass, carbon capture

… but:

- Need for a lot of energy (conv. efficiency ~38 %[1])
- May attack common rubber sealings due to polarity
- Heating value (vol.) 1.7 times lower than with Diesel
- Still produces pollutants, especially NOx



Source:
[1] Burre J, Bongartz D and Mitsos A. Production of Oxymethylene Dimethyl Ethers from Hydrogen and Carbon Dioxide—Part II: Modeling and Analysis for OME3–5. *Industrial & Engineering Chemistry Research* 2019; 58: 5567–5578.

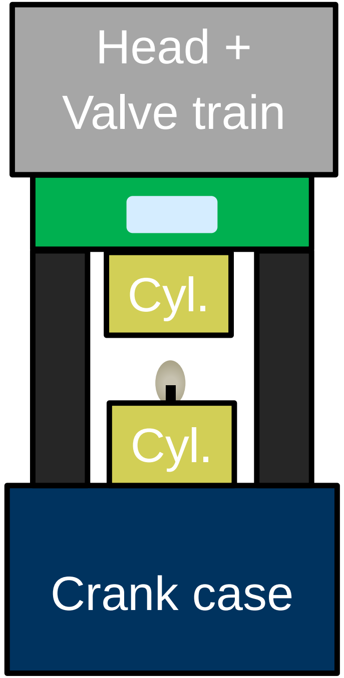
Experimental carrier

Single-cylinder research engine

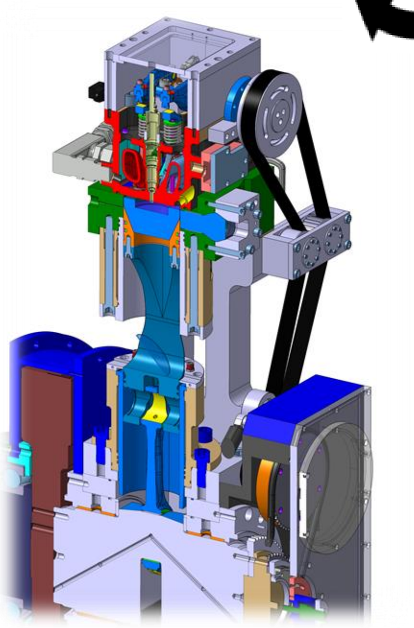
- 1.8 l cylinder volume (heavy-duty)
- Common-rail with up to 2500 bar fuel pressure
- Injector with higher nozzle flow for OME (x1,7)
- Intercooled exhaust gas recirculation
- Exhaust gas analysis: Particle (10/23 nm), soot mass, VOC, CO_2, O_2, NO, NO_2, CH_4, NH_3, OME_{1-3}, …

Experimental carrier

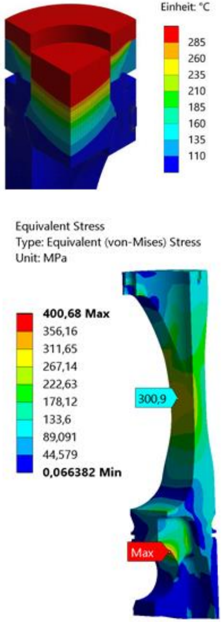
Optical engine



CAD



FEM



Assembly

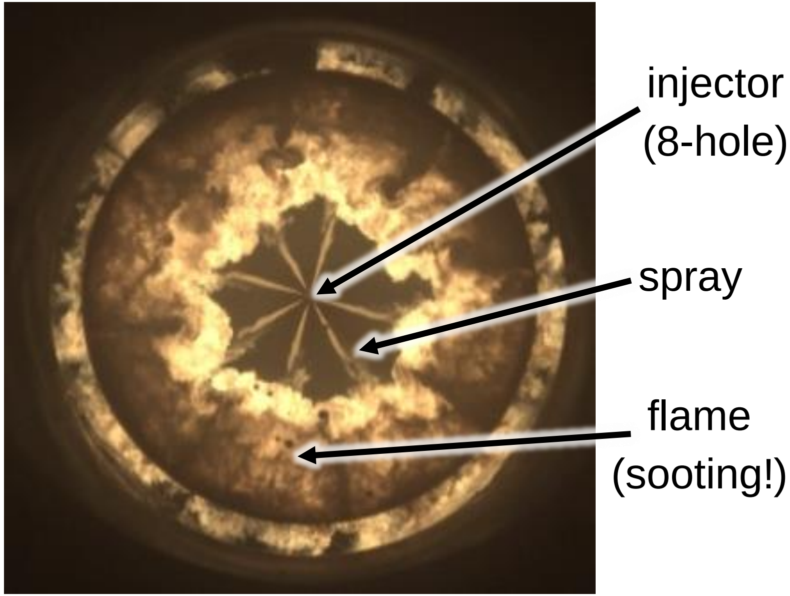
Single-cylinder research engine

Optical setup

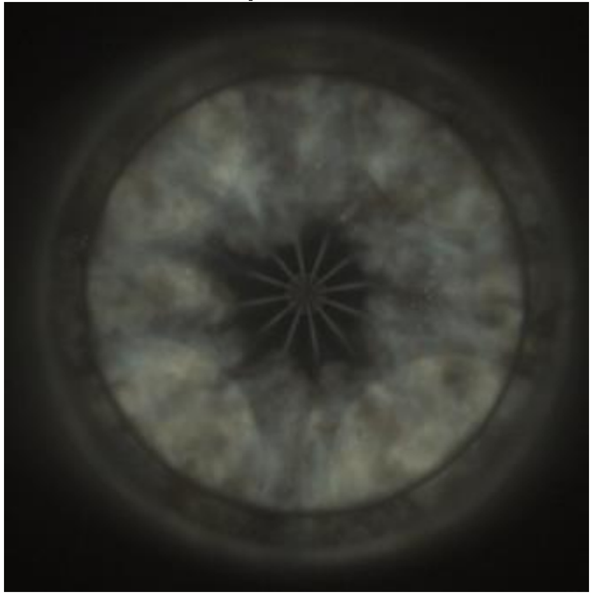
Experiments

Optical combustion analysis

Diesel fuel



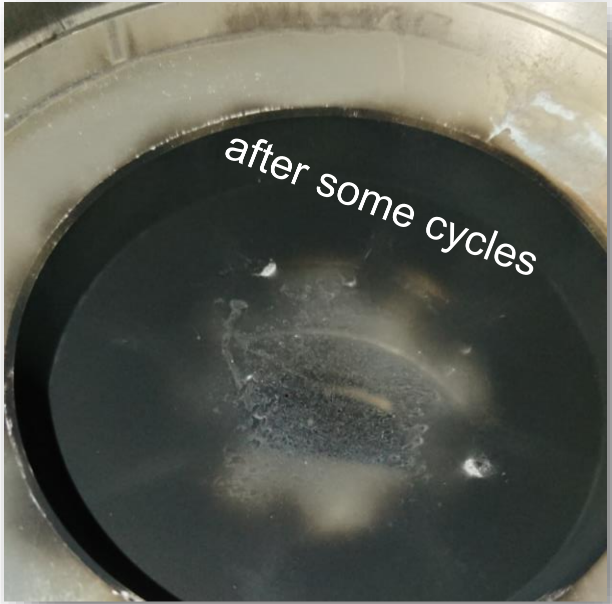
OME with exposure x 100



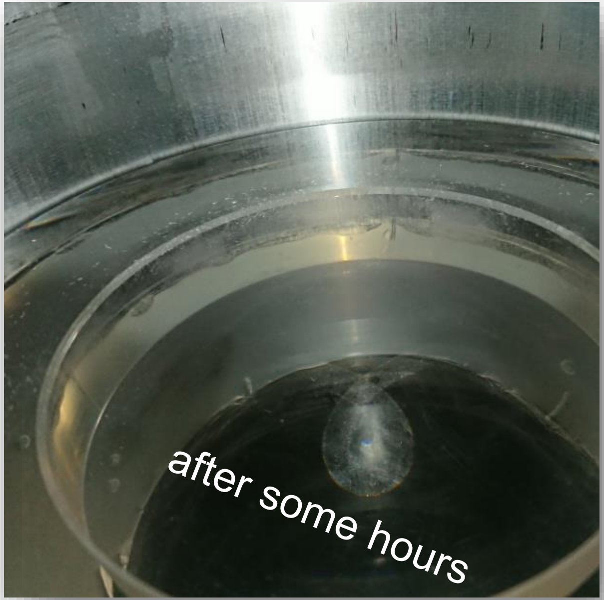
Experiments

Optical analysis

Diesel fuel



OME with exposure x 100



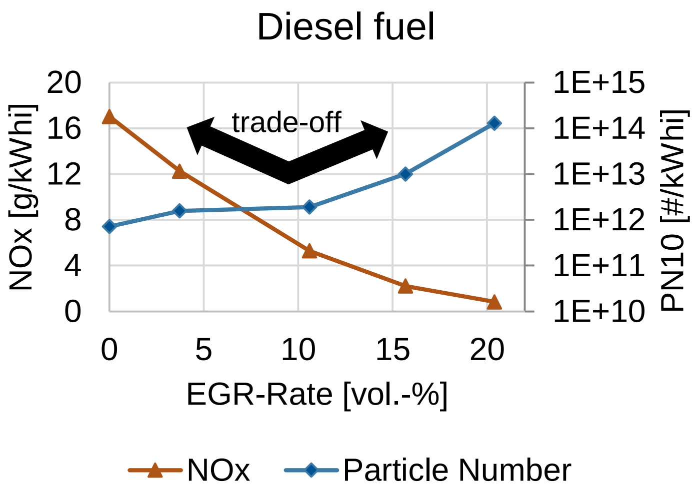
Findings for OME:

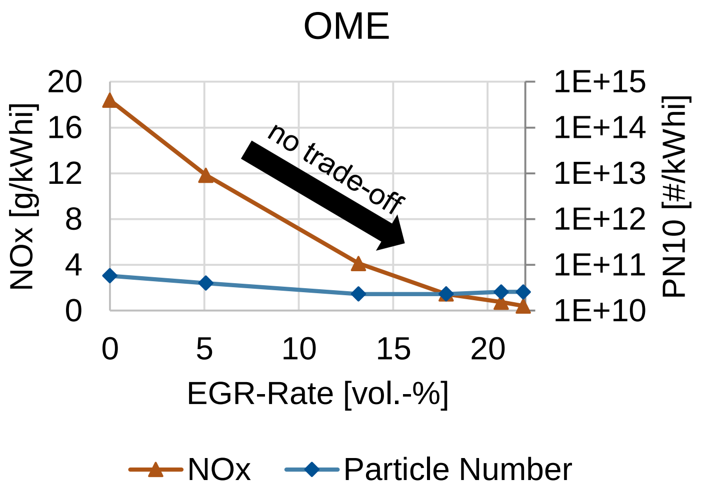
- No soot tendency, only chemiluminescence
- Earlier ignition (shorter ignition delay)
- Faster combustion in later stage
- Good mixture preparation, even at low rail pressure

Experiments

Combustion analysis

- Exhaust gas recirculation (EGR)





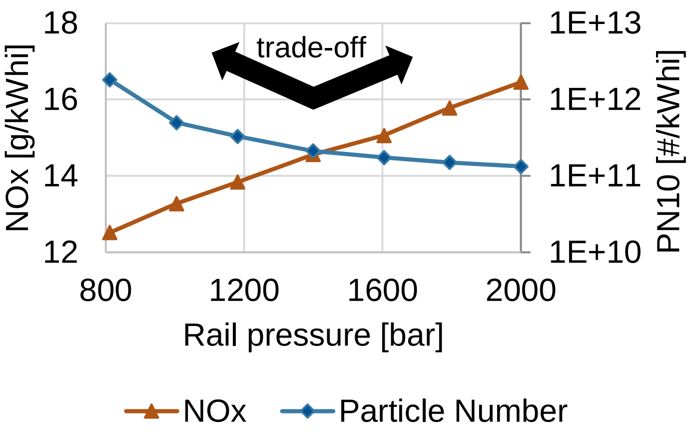
EGR variation - speed: 1200 rpm, IMEP: 13 bar, rail pressure: 1800 bar, injection pattern: PI/MI, center of combustion: 8° a. TDC

Experiments

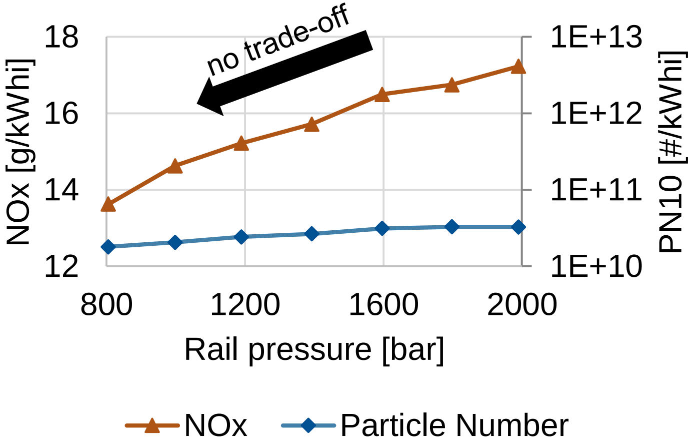
Combustion analysis

- Injection pressure

Diesel fuel



OME



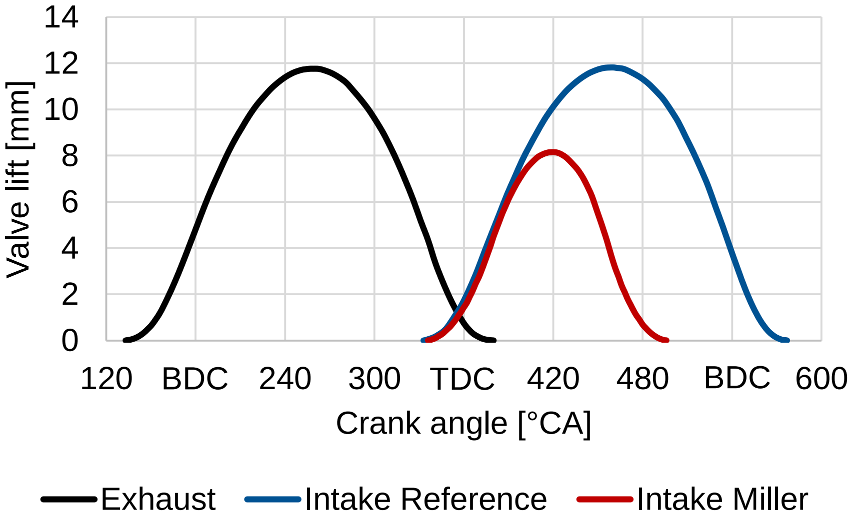
Rail pressure variation - speed: 1200 rpm, IMEP: 13 bar, EGR-rate: 0%, injection pattern: PI/MI, center of combustion: 8° a. TDC

Experiments

Combustion analysis

- Miller valve timing

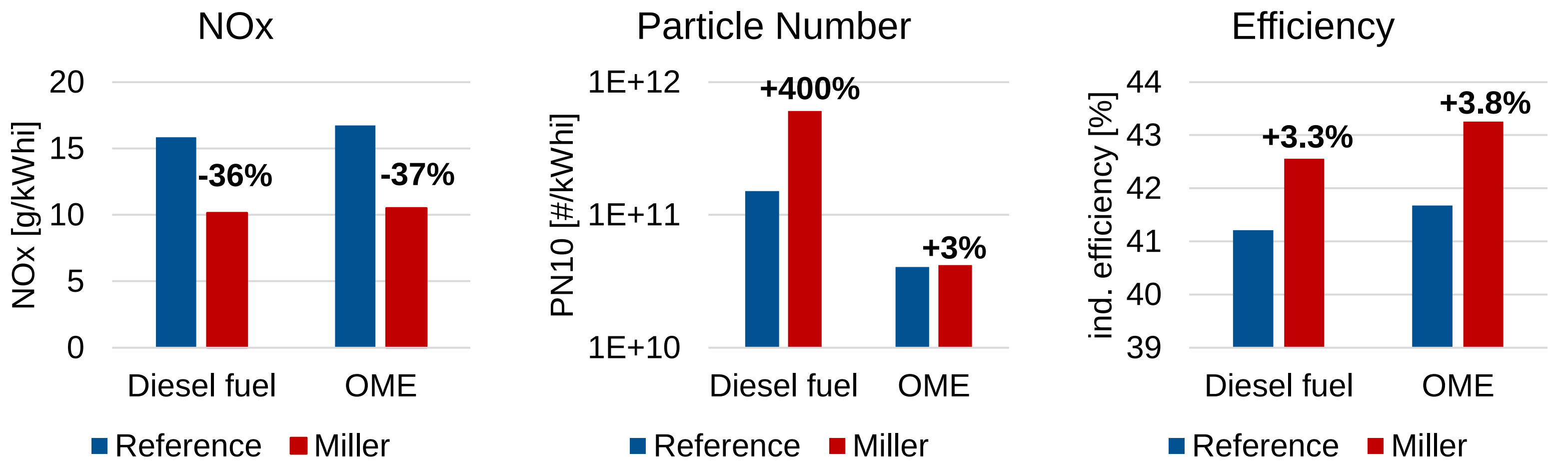
- Common measure in gasoline engines
- Reduces effective compression
  → Higher efficiency
- Reduces cylinder temperatures
  → Less NOx formation



Experiments

Combustion analysis

- Miller valve timing



Intake valve timing variation - speed: 1200 rpm, IMEP: 13 bar, EGR-rate: 0%, injection pattern: PI/MI, center of combustion: 8° a. TDC

Summary

OME as Diesel fuel substitute

- Potentially climate-neutral, energy-intensive production
- Adaptation of the engine necessary
- Extremely low particle emissions, no particle-X trade-offs
- New paths for engine simplification and optimization

➡ There is still a lot of potential and a lot to do!

Thank you! Questions?

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