Impact of the Operation Strategy and Fuel Composition on the Emissions of a Heavy-Duty Diesel Engine

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Outline

- Motivation
- Testbench
- Results
- Conclusions

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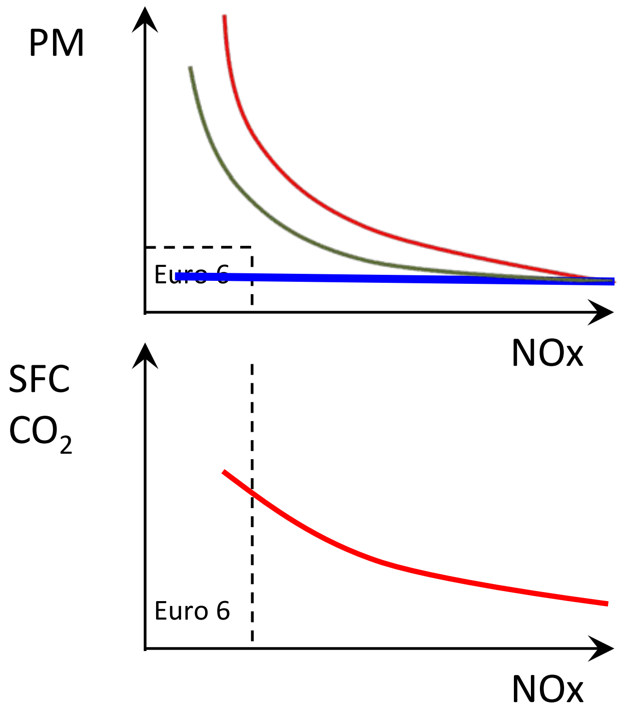
Motivation



- Bio fuels / synthetic fuels offer a beneficial trade-off behaviour (i.e. soot formation reduction due to oxygen or reduced aromatic content)
- Reduction in lower heating value does not allow an investigation of the phenomenological emission characteristics of the fuel used, due to changes in the injection parameter
- Goal: Investigation of operating strategy options using different fuels under similar injection characteristics (fuel pressure, duration of injection) and cost functions to account for various engine component setups

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MTU 396

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	7 x 0.24 mm 8 x 0.24 mm

EGR

External roots blower	< 8% intake O_2

Exhaust analysis

NOx/CO/CO2/O2/HC	Standard
Soot	FSN / DMS 500

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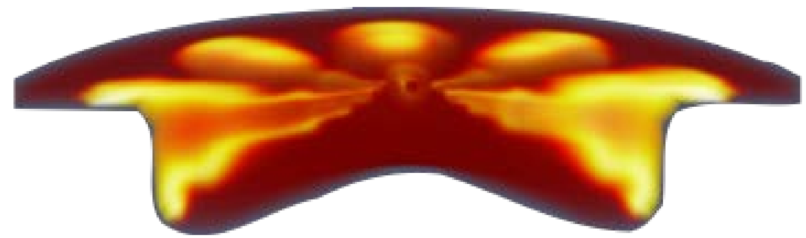
Overwiev: Operating Conditions

- Diesel
  - 7-Hole Nozzle Base (reference)
  - 7-Hole Nozzle EGR variation
  - 8-Hole Nozzle Base



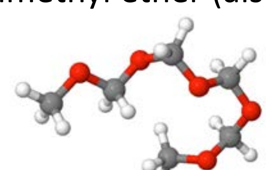
- OME Blend
  - 8-Hole Nozzle Base
  - 8-Hole Nozzle EGR variation
  - 8-Hole Nozzle SOI variation

Diesel: $LHV = 43.5\ MJ/kg$, $\rho = 827\ kg/m^3$, $AFR_{stoich} = 14.5$

OME: $LHV = 19.4\ MJ/kg$, $\rho = 1046\ kg/m^3$, $AFR_{stoich} = 6$

Ca. 22% OME for volumetric Blend LHV ~8/7 * LHV Diesel

OME: Polyoxymethylene dimethyl ether (also POMDME)



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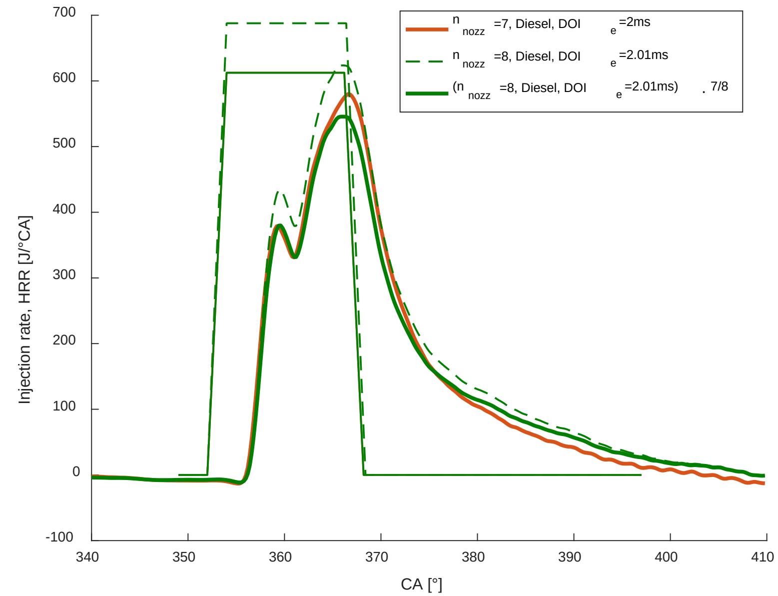
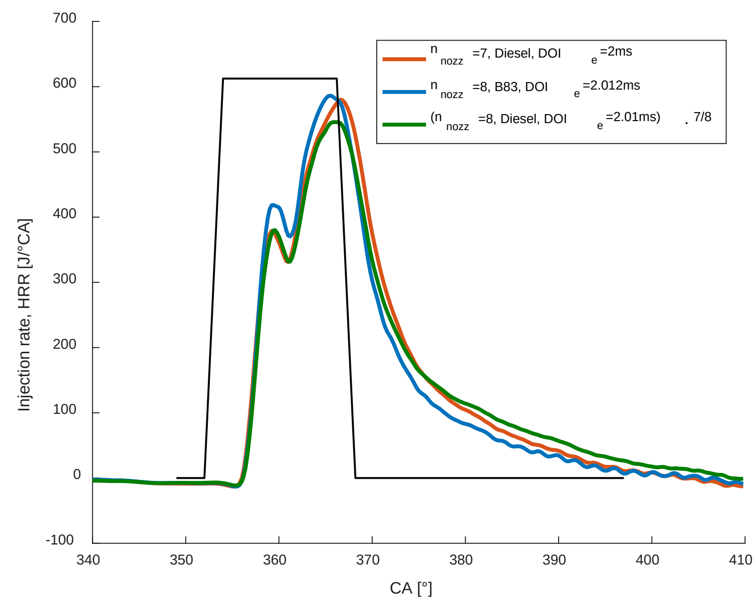
[1] E. Jacob 2014

Results: Heat Release Rate Comparison

- Diesel
  - 7-Hole Nozzle Base (reference)
  - 7-Hole Nozzle EGR variation
  - 8-Hole Nozzle Base



- OME Blend
  - 8-Hole Nozzle Base
  - 8-Hole Nozzle EGR variation
  - 8-Hole Nozzle SOI variation



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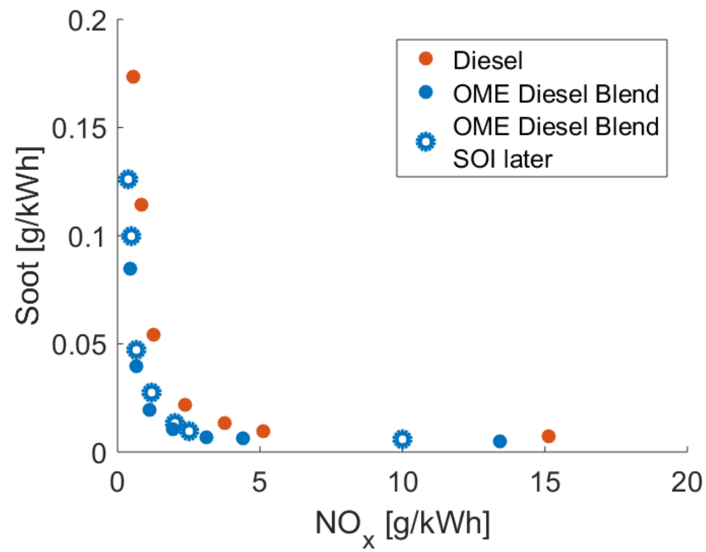
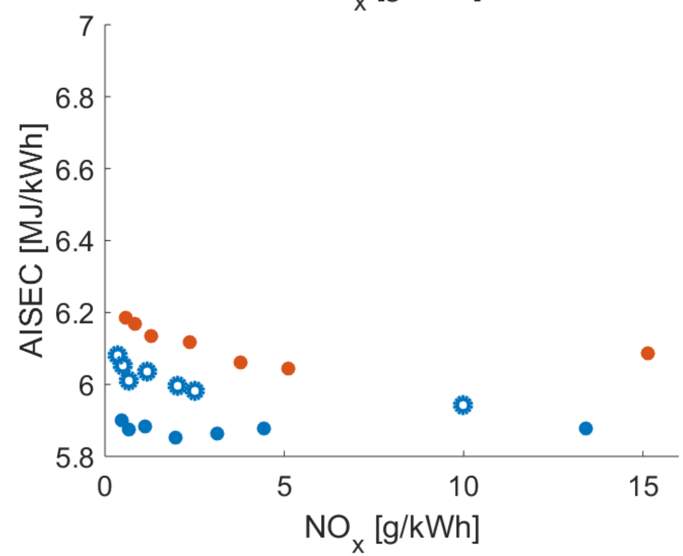
Results: Specific Emissions Comparison

- Diesel
  - 7-Hole Nozzle Base (reference)
  - 7-Hole Nozzle EGR variation
  - 8-Hole Nozzle Base

- OME Blend
  - 8-Hole Nozzle Base
  - 8-Hole Nozzle EGR variation
  - 8-Hole Nozzle SOI variation





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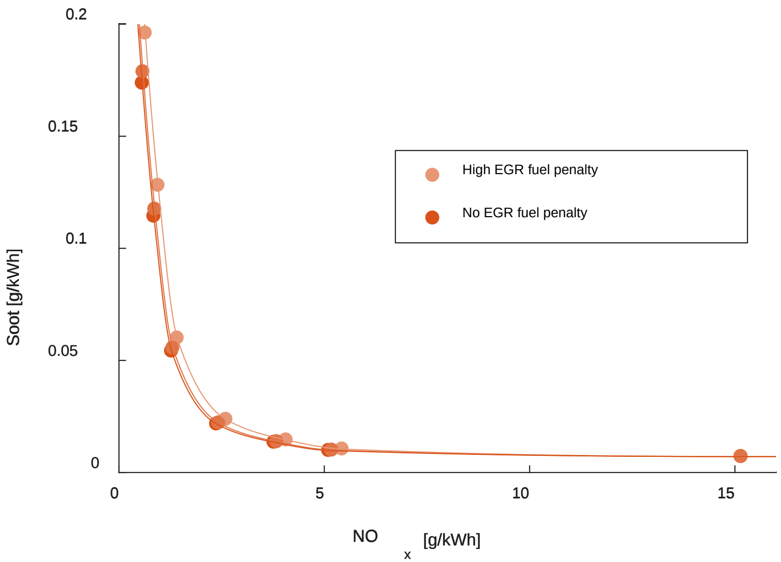
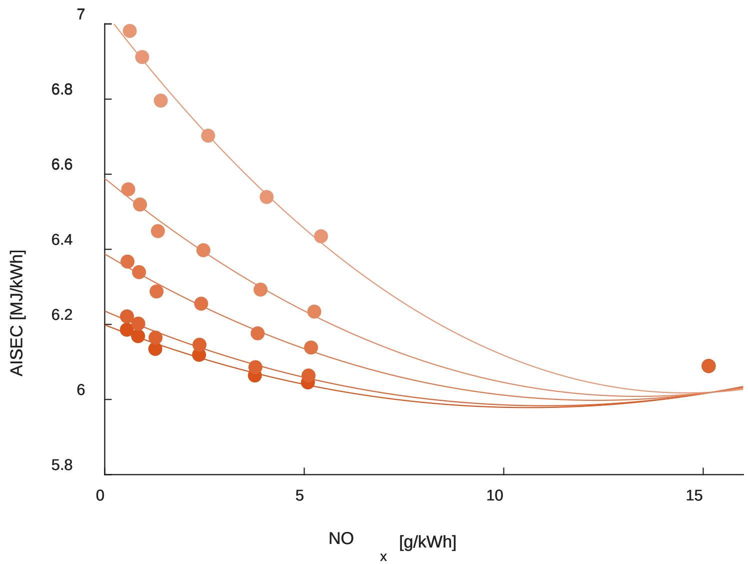
Results: Compensation for Auxiliaries

- Diesel
  - 7-Hole Nozzle Base (reference)
  - 7-Hole Nozzle EGR variation

- Penalties for energy consumption of full engine auxiliaries (i.e. EGR, Turbocharger, DPF, SCR)

- Example EGR fuel penalty





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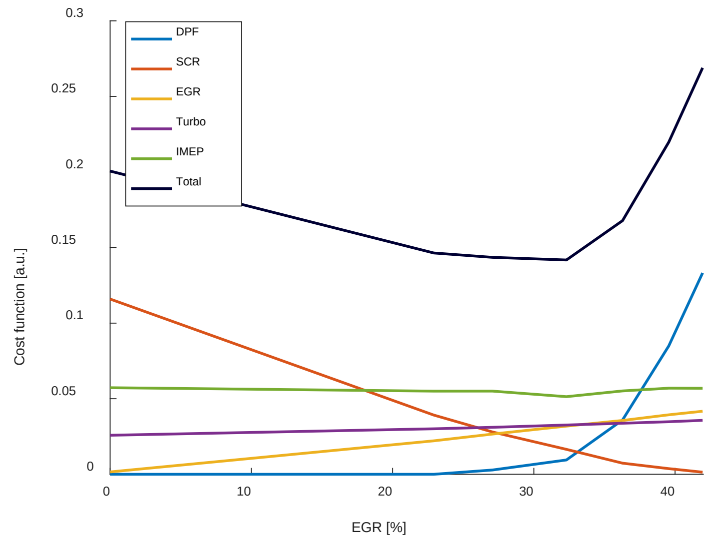
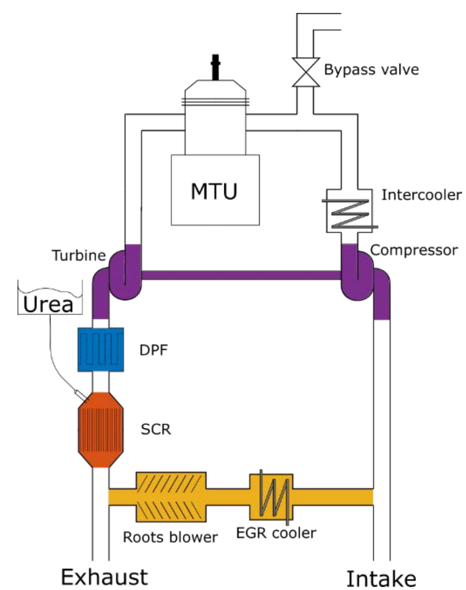
Results: Compensation for Auxiliaries

- Cost Function
  - DPF
    - Raw soot emissions
  - SCR
    - Raw NOx emissions
  - EGR
    - EGR mass
  - Turbocharger
    - Exhaust enthalpy
  - IMEP
    - HP cycle efficiency





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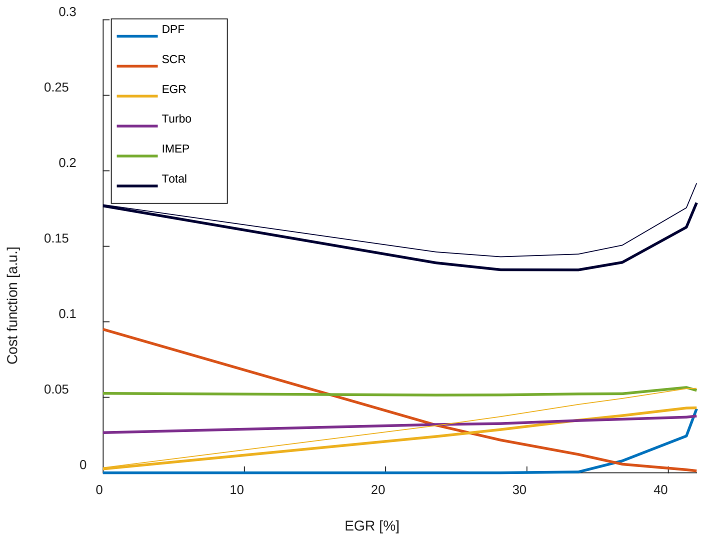
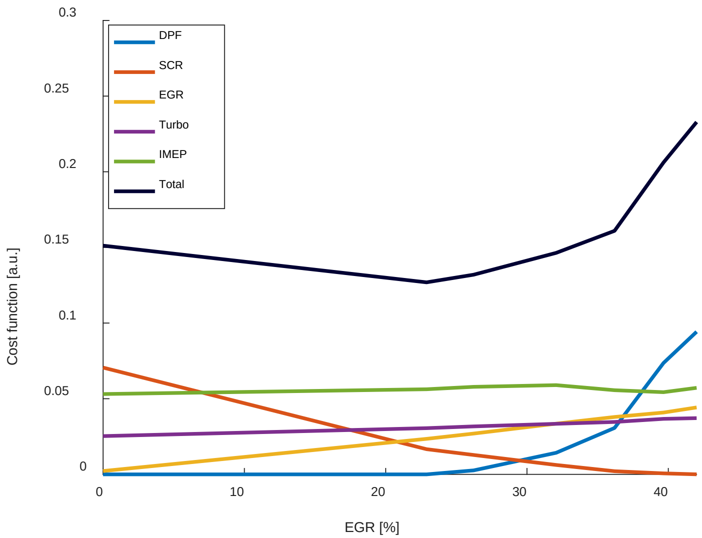
Results: Compensation for Auxiliaries

- OME blend with variation in EGR penalty
- Lower DPF cost ratio due to reduced raw soot emissions



- OME blend with later SOI
- Higher DPF cost ratio and lower SCR cost ratio due to shifted trade-off behaviour



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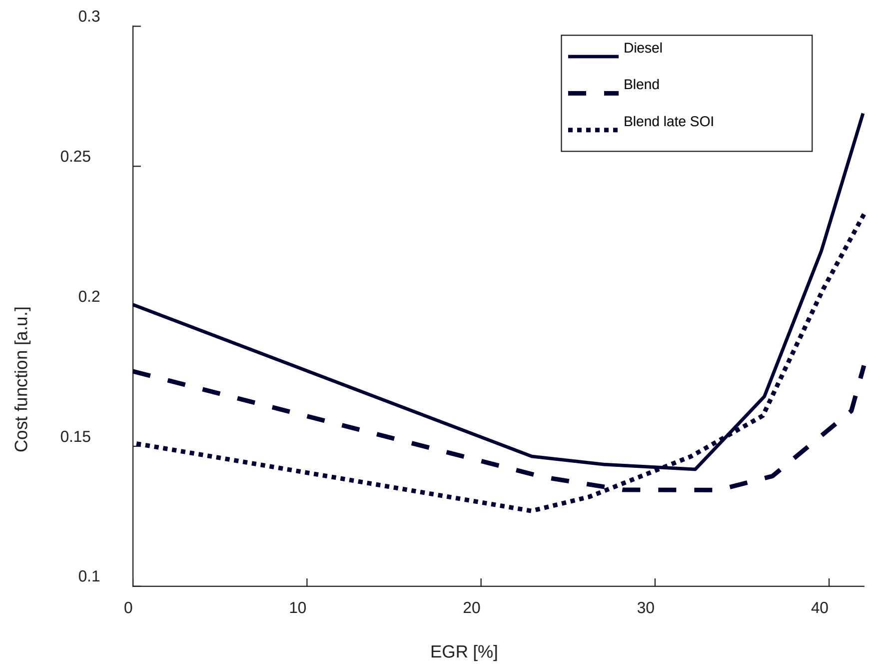
Results: Cost Weight of the Strategies

- Comparison of
  - Diesel
  - Diesel OME blend
  - Diesel OME blend with later SOI
- Equal cost function for all cases
- Fuel costs / fuel CO_2 not included
- Diesel case is worse due to higher raw emissions and lower indicated efficiency
- Best strategy option depends on auxiliary consumption
- Best available option in the calculated example with later SOI



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Conclusions

- A flexible testbench has been set up to compare combustion and emission characteristics of different fuels and strategies
- Combustion characteristics of different fuels lead to a different trade-offs
- Different engine setup strategies have been analysed, using a cost function for auxilaries
- The optimum operation of an engine depends on the engine set up, the operating condition and the fuel used

Outlook

- A model based approach is under development (including emission modelling of various fuel blends) to allow strategy and component setup optimization

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