Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

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NextICE – The next generation of alternative fuel converters in the transportation sector

Alternative fuels, such as biofuels, fossil natural gas or synthetic methane have the potential to lower CO_2 emission of passenger cars, while pursuing the «energy-change». The conversion of such fuels into mechanical energy, however, requires the enhancements of today's internal combustion engines. The Institute for Dynamic Systems and Control (ETH/IDSC) investigates how the full potential of engines operated with alternative fuels can be utilized. In particular the thermal management of the exhaust aftertreatment system poses a challenging task. Recent pollutant emission limits are only met using advanced control engine strategies considering raw emissions and the efficiency of the exhaust aftertreatment system. Besides the IDSC the project partners are: Aerothermochemistry and Combustion Systems Laboratory (ETH/LAV) and Swiss Federal Laboratories for Materials Science and Technology (Empa).

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Introduction

Natural gas/methane

- Low CO_2 emission
- High knock resistance

Diesel-ignited gas engine

- Variable ignition energy
- Lean burn capability

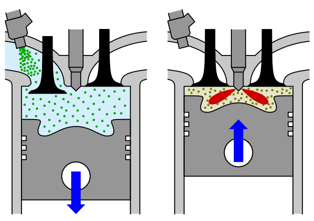

Fig 1: Diesel-ignited gas engine [1]

Challenge:

Efficient abatement of hydrocarbon emission

- Methane is hard to oxidize
- Low exhaust gas temperature
- Diesel-only operation at low load condition

Goal

Develop the thermal management for exhaust system of a diesel-ignited gas engine in order to meet recent emission standards.

Feasibility Dual-Fuel Mode

The feasible low-load operation in dual-fuel mode is limited by **Constraints**

m_{HC}	HC engine-out emission
Δm_{CO2}	CO2 reduction (over base Diesel engine)
ϑ_{exh}	Exhaust gas temperature

Feasible inputs (equivalence ratio ϕ and EGR rate x_{EGR}) are determined by using a semi-physical engine model.

- Minimal brake mean effective pressure $\approx$ 3.2 bar

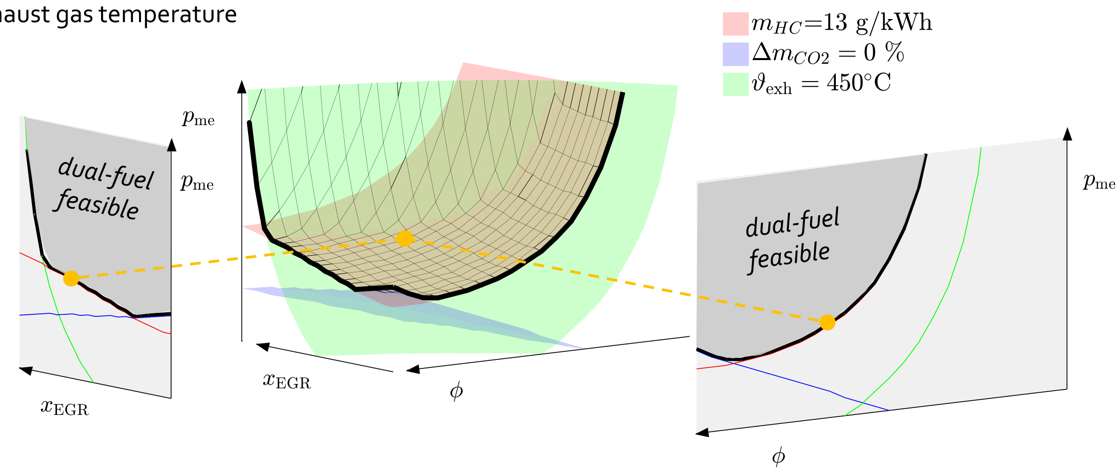

Fig 2: Simulative feasbility analysis

Optimal Low-Load Strategy

Find optimal inputs $\phi^*(p_{me})$ and $x^*_{EGR}(p_{me})$ by solving the optimization problem

$$\min_{\phi, x_{EGR}} f_s(\phi, x_{EGR})$$

$$s.t. \quad m_{HC} < 13\text{ g/kWh}$$
$$\Delta m_{CO2} > 0\ \%$$
$$\vartheta_{exh} > 450\ °C$$

Three exemplary cost functions:

Name	$f_S(\phi, x_{EGR})$	Goal
S_{HC}	$m_{HC}(\phi, x_{EGR})$	minimize engine-out HC emission
S_{CO2}	$m_{CO2}(\phi, x_{EGR})$	minimize CO2 emission
S_η	$-\eta(\phi, x_{EGR})$	maximize engine efficiency

Dual-Fuel specific: CO2-minimal strategy does not coincide with the maximum engine efficiency strategy.

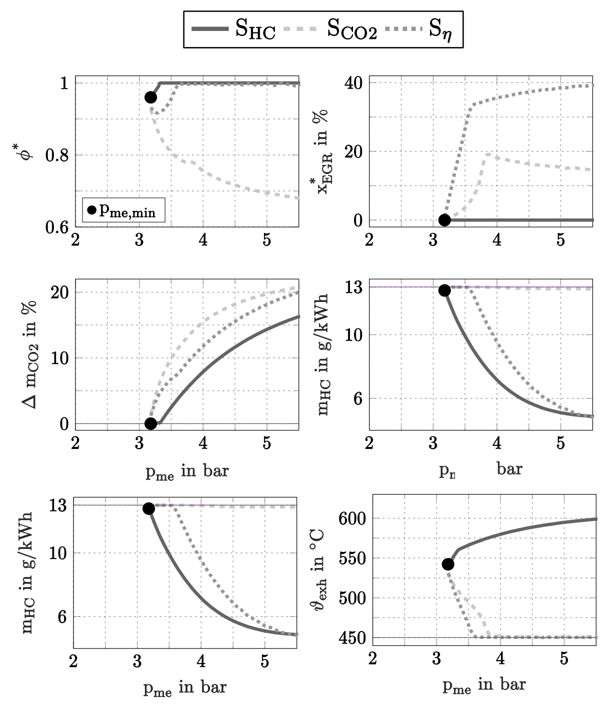

Fig 3: Optimal low-load strategies [2]

Expected impact

This research project is meant to show how the CO_2 emissions of internal combustion engines can be substantially reduced. The capability of converting methane gas in an efficient and pollutant-free way is considered to be helpful in pursuing the «energy-change». As the development of renewable energy sources evolves, the problem of balancing demand and supply in the power network becomes increasingly challenging. Methane production using excess electric energy based on electrolysis may help to mitigate this problem. Methane could be used for two purposes at the same time: as a cost-effective energy storage as well as a fuel for energy converters in automotive application. Engines fueled with this synthetic methane operate CO_2 neutrally. Consequently, gas engines represent a promising alternative to the emerging pure electric solutions as used in electric vehicles.

References

[1] Zurbriggen, F. J. Combustion control of a natural gas-diesel engine-feedback control and adaptation Dissertation, ETH-Zürich, 2016, Nr. 23022, 2016

[2] Hutter, R.; Ritzmann, J.; Elbert, P.; Onder, C.; Low-Load Limit in a Diesel-Ignited Gas Engine, Energies 2017, submitted for publication

Partners

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