Efficient Methane Engines for Light Commercial Vehicles

The use of methane for Light Commercial Vehicles (LCV) is a meaningful measure to reduce CO_2 and pollutant emissions while maintaining an attractive payload. Methane engines for this class of vehicles are usually based on diesel engines with modifications to enable premixed spark ignition combustion. Due to comparably low sales numbers, the technical potential of such methane engine is not fully exploited nowadays. This project has therefore the target to:

- enhance the combustion process for a LCV engine, focusing on gas exchange, boosting, compression ratio and charge motion,
- enhance efficiency by implementing exhaust gas recirculation (EGR) with focus on internal EGR as well as hot and cold external EGR,
- enhance efficiency and component cooling by water injection.

The quantitative goal is to reduce fuel consumption / CO_2 emissions by 20% for typical operation profiles of LCVs.

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Research questions

The project focuses on the following points:

- Charge air motion (piston bowl shape and swirl level) to find a good compromise between fast combustion and low wall heat losses,
- Valve timing and boosting (for example Miller and Atkinson cycle) for reduction of pumping work and maximum temperature,
- Compression ratio for an optimum compromise between knocking limit and efficiency,
- Exhaust gas recirculation (EGR) to reduce pumping work during part load operation and knocking limit during high load operation,
- Ignition concepts to enable stable combustion for diluted mixtures.
- Water injection to enhance the combustion process, turbocharger balance and engine cooling,

Approach

To achieve the project goals, both simulation and experimental validation are performed in parallel. The following tools are used:

- 1D simulation (GT-Power) by Empa,
- 3D CFD simulation (Open FOAM) and 1D-3D coupling by Politecnico di Milano and FPT Motorenforschung,
- Validation on engine test bench by Empa.

Validation

The Methane engine on a the testbed is shown in Fig. 1. It is equipped with a rapid prototype engine control unit and closed-loop center of combustion control which allows to operate the engine with the most efficient spark advance in the whole range.

The engine is gradually updated with the components of interest and the experimental data is used for model validation and calibration (1D and 3D).

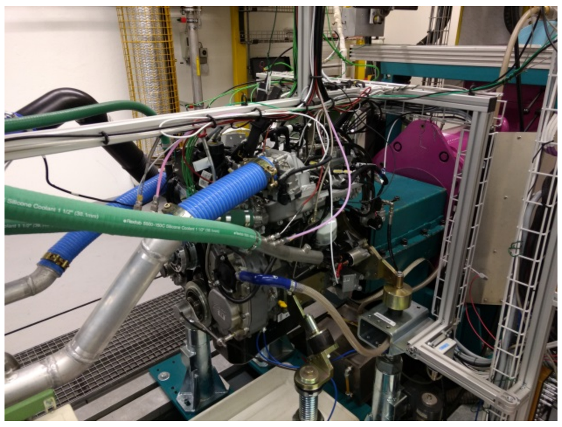

Fig. 1 Engine on a testbed

1D simulation

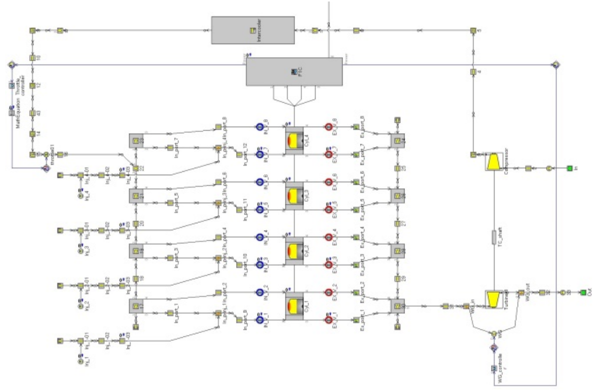

Fig. 2 GT-Power (1D) model of the engine

The 1D GT-Power model of the engine is shown in Fig. 2. It consists of sub-models representing engine components like:

- Intake manifold with throttle valve,
- Exhaust manifold with turbocharger and waste gate Valve,
- Intercooler,
- Cylinder.

Basically it is a complete virtual model of the engine where a correct modeling of combustion (heat release) is crucial to achieve good results. In order that the model can be used in a predictive sense, a predictive combustion model has to be parameterizes and validated. This is done using experimental data.

First results (Fig. 3) show good correlation between simulation and measurements for an early stage of the combustion model.

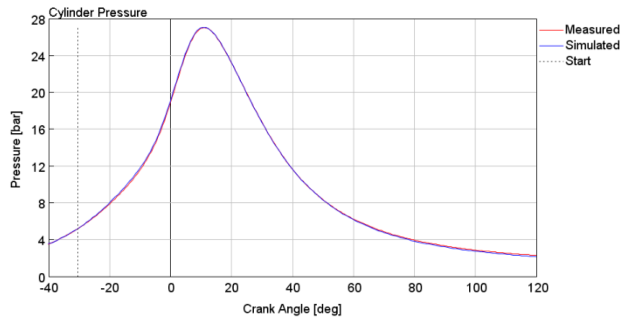

Fig. 3 Cylinder pressure - experiment and simulation

3D CFD simulation

For the simulation of fundamental effects such as mixing, flow motion and turbulence levels, 3D CFD is used. One question is how exhaust gas has to be fed back to the intake manifold in order to give an uniform EGR level across all four cylinders. Multiple CFD simulations of different engine configurations were performed to asses different possibilities. Fig. 4 shows an example of such a simulation. The most promising configuration has been identified and will be implemented on the test engine.

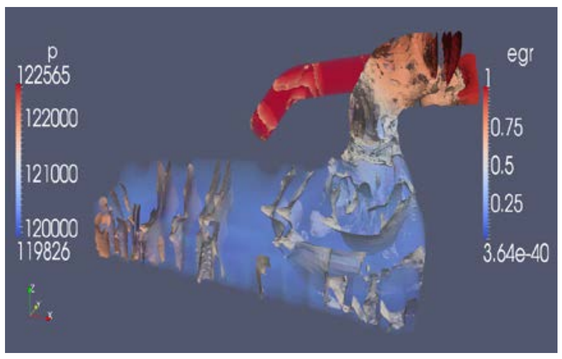

Fig. 4 CFD simulations results – pressure and EGR

Outlook

Experimental data for CDF calibration has been generated and post-processing is ongoing. As next steps, the engine will be modified to asses different swirl levels and compression ratios. Exhaust gas recirculation, water injection and ignition systems will be the focus in 2018.

Partners

Empa
Materials Science and Technology

FPT POWERTRAIN TECHNOLOGIES
FPT Motorenforschung AG

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