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Competence Center Energy and Mobility

CELaDE

Clean and Efficient Large Diesel Engines

Scope of project

The project is organised in 3 tasks emphasising the development and validation of the turbulence-thermo-chemistry interactions in the combustion process of large internal combustion engines, diagnostics of NO for high pressure combustion and quantitative two-dimensional soot diagnostics in high pressure combustion as well as cylinder-pressure based algorithms for future heavy duty diesel engines controls.

Goals and activities

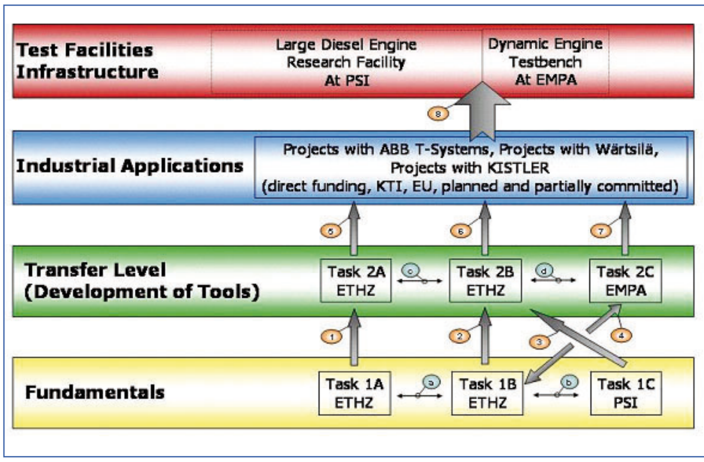
Task 1 A: ETHZ/LAV

This task deals with the development of improved submodels for integration in CRFD (Computational Reactive Fluid Dynamic) codes for the accurate simulation of diesel engine combustion (heat release rate) and pollutant formation (mainly NOX and soot).

The modelling approach taken is based on the Conditional Moment Closure (CMC) concept. The model for auto-ignition has been successfully implemented by coupling a two-phase flow field solver to a CMC based combustion solver. This approach allows for capturing of chemistry-turbulence interaction during all three phases of Diesel combustion. Hence good predictions of ignition delays, as well as capturing of the partially premixed and subsequent diffusion controlled combustion have been demonstrated. Furthermore, the approach enables simultaneous computation of NOx formation without the need for adding a separate mechanism.

Task 1 B: ETHZ/LAV

This task refers to the generation of detailed data through non-intrusive, both optical and non-optical methods in order to be able to validate the computational models of the previous task. The experiments will be carried out at the dedicated extensively instrumented single-cylinder research engine with partial optical access (under construction) and at the single-shot compression machine, both at LAV/ETHZ.



Strategic project structure and interdependence between the project partners and tasks.

For validating simulation results and better understanding of the fast evolving process in the combustion chamber and in the exhaust system including the response characteristics of catalytic aftertreatment devices (oxidation catalysts, selective catalytic reduction, Diesel Particulate Traps etc) a very fast and accurate Airsense Mass Spectrometer was delivered and set into operation by September 2007.

Task 1 C: PSI

Laseroptical spectroscopic measurements will be carried out by the Combustion Research Laboratory of PSI at the High-T/High-pressure spray combustion cell at PSI and in a second phase at the single-shot-compression-machine at ETHZ. The scope is to identify spatial distribution and temporal evolution of NOx and soot concentration during combustion.

Main Investigator
Konstantinos Boulouchos, ETHZ

Project Partners
ETHZ
PSI
Empa

Task 2 A: ETHZ/LAV

Insight from Task 1A will be used to generate zero-dimensional, phenomenological models, capable of predicting engine behaviour also during transient operation.

Phenomenological models for diesel heat release rate, NOx and soot emissions had been developed at ETH/LAV and implemented in the combustion analysis-software of the LAV. This setup allowed to test the models extensively on experimental data and to optimise their parameters with genetic algorithms. Currently the model is being implemented in the engine-process simulation software of ABB Turbo Systems.

Task 2 B: ETHZ

Minimal invasive methods, both optical and non-optical, will be further developed and implemented in the single-cylinder engine and a multi-cylinder engine to demonstrate the capabilities of new sensors for in-situ, online monitoring of engine combustion.

The soot emissions from a four cylinder production passenger car diesel engine were measured over its entire operating map using miniaturized multi-color pyrometers in three cylinders and an FSN system in the exhaust stream.

Characteristic features of the measured in-cylinder KL-factor histories (representative for the soot concentration) were correlated with the total soot emissions measured in the exhaust stream. Due to its high time resolution, such a system is well suited to the characterization of soot emissions during transient engine operation.

The few systems to sample particle and gas directly from the combustion chamber available are mostly built for use with gasoline engines and therefore not suitable for the high cylinder pressures in diesel engines. Therefore it was decided to develop such a system at LAV. The LAV particle and gas sampling system is controlled using a hybrid electromagnetic-hydraulic system. This allows an exactly defined time (dependent to the crank angle) to open the sampling valve as well as the desired duration. In addition, a dilution/purge system is integrated to ensure sufficient cooling, dilution of the sample volume, and freezing of the chemical composition. The mechanical functionality could be verified during first tests.

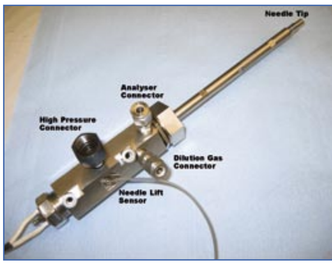
Task 2 C: Empa

With a specific focus on heavy-duty diesel engines Empa will develop methods and algorithms to deduce relevant engine operation parameters on the basis of fast and accurate analysis of cylinder pressure, using subsequently this information for control purposes.

It is believed that future stringent emission legislation can only be met by precise controlling of injection, the exhaust gas circulation rate, the turbocharging device and the exhaust gas treatment systems. To realize that it is imperative to know the thermodynamic state of the cylinder charge. The knowledge of the thermodynamic properties of the cylinder charge for each cylinder and each single cycle would allow completely new and better control and diagnosis possibilities. Such in-cylinder pressure transducers are produced by the project partner Kistler (Winterthur).

This year preliminary experiments were carried out on a prototype EURO VI engine on Empa's existing heavy duty test bench.

Single Cyclinder Research Engine test facility as it is currently under construction.



Fully assembled particle and gas sampling system. While running, the needle tip will project 1cm into the combustion chamber. The hydraulic system will be driven with pressures of 600 bars up to 1000 bars.

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