The Large Engine Research Facility at PSI

K. Hoyer[1*], P. Dietrich[1]
M. Dettwyler[2]
[1]General Energy Research Department, Paul Scherrer Institut, 5232 Villigen, Switzerland
[2]Kistler Intrumente AG, 8408 Winterthur, Switzerland

The Large Engine Research Facility (LERF) is a new research platform realized within the Competence Center for Energy and Mobility (CCEM) at the Paul Scherrer Institute and is currently used – in close cooperation with industrial and academic partners[§] - within the Hercules-β research program of the European Commission Framework Program FP7. The purpose of this facility is to develop new combustion management technology aimed at significantly reducing the NO_x production within the engine without compromising the engine efficiency or increasing the amounts of unburned hydrocarbons and particulate matter.
Beginning with the groundbreaking for the new building in April 2008 the installation of the LERF at the PSI has been completed within 7 months and the first start was realized in October 2008.

Introduction and Motivation

The purpose of this paper is to introduce the LERF and the associated research program. The endeavor is driven by the increased demands for the conservation of air quality put into legislation by the International Maritime Organization (IMO). To meet these requirements of reducing NO_x emissions by about 80% within emission controlled areas by 2016 necessitates increased efforts to identify the most promising techniques within stringent budgetary boundary conditions.

Description of LERF

The large engine research facility mainly comprises a Wärtsilä 6L20CR engine having a rated power of 1080 kW at nominal speed of 1000 RPM. It is coupled to an electric generator which is mounted on a common base frame. A frequency / voltage converter together with a transformer allows loading the engine at variable speed while still feeding the generated power synchronously to the medium voltage (16 kV) grid.

The test stand control system is implemented by AVL and allows three different control modes for the generator and engine respectively.

i) Torque / Speed
ii) Speed / Power
iii) Propeller Law / Speed

The shaft power and engine speed is measured using a Kistler torque flange mounted in-between the engine and the generator (T_{max}= 15kNm and Hall pickup 180 Cts/rev). Additionally a second encoder (Hübner POG-10DN-0900-TTL) is mounted on the free crank shaft end to ensure precise crank angle measurements which are essential for reliable indication measurements. The cylinder head # 6 at the free end side is extensively equipped using multiple sensor access ports for simultaneous measurements. These ports are tailored to hold a variety of sensors, e.g. piezoelectric sensors for precise thermodynamic analysis or absolute piezoresistive pressure sensors for referencing purposes. Additionally we provide a port for future optical sensors applications. Special care was taken to optimize sensor position for best measurement accuracy, sensor accessibility and the minimization of dead volume. Furthermore, the intake and the exhaust manifold pressures are accessible to absolute piezoresistive pressure transducers. All high frequency signals are fed via a front-end amplifier to a fast transient recorder which is triggered by the free-end encoder.

Besides the measurements of shaft power and indicated power, the engine is fully instrumented to obtain the flow of heat and energy in and out of the system, comprising air mass flow rate, fuel flow rate, cooling water temperature differences and flow rates. Additional measurements like charge air temperature and pressure, exhaust gas temperatures and turbocharger speeds etc. are directly obtained from the Engine Control Unit (ECU) via TCP Modbus interface.

For the exhaust gas composition analysis we use a FTIR spectrometer (AVL Sesam) capable of simultaneously measuring many exhaust species (H_2O, CO_2, CO, NO, NO_2, N_2O and others) at a rate of 1 Hz.

Additionally, for compliance with the Swiss federal air quality conservation regulation, we provided an exhaust gas after-treatment system using Vanadium based SCR with Urea as reducing agent.

Current Work

At this beginning stage of the project we are working on obtaining baseline measurements for the standard engine setup as delivered. To say, we will establish the global energy balance, the transient cylinder and inlet/outlet manifold pressures, the exhaust gas composition for the nominal stationary load steps.

---

* Corresponding author: Klaus.Hoyer@psi.ch
Towards Clean Diesel Engines, TCDE 2009

[§] Wärtsilä Corporation, ABB Turbo Systems, Kistler Instruments, and CCEM Partners

These baseline measurements from the newly manufactured cylinder head will be used to support a cooperative effort with ETH Zürich and provide calibration data for numerical simulation.

The first approach in reducing the NO_x will be a combination of 2-stage turbo charging (TC) and Miller timing of the intake valves.

Currently the assembly for the 2-stage TC system is being designed. In combination with the new charging system we will implement the variable inlet closure (VIC) system which allows control of the intake valve timing. This variability is especially important for engine start and partial loads, where the valve timing should stay unchanged with respect to the original engine setup.

In a later stage, limited use of HFO is planned to see the influences of the heavier fuel composition and sulfur on the combustion process especially concerning the production of soot and particulate matter with the extreme Miller timing.

Outlook

We anticipate[1] achieving NO_x reduction by more than 50% compared to the baseline measurements and will try to maximize the possibilities of the 2-stage TC / VVT combination. Challenges lie ahead resulting from the lower combustion temperature which will have a direct effect on the exhaust gas composition but also will influence the operational envelope of the EG after-treatment.

The dynamic response of the modified engine setup is also of great interest regarding load pickup for certification.

References

[1] C. Wik, B. Hallback, 'Utilisation of 2-stage turbo charging as an emission reduction means on a Wärtsilä 4-stroke medium-speed diesel engine', paper no. 101 , 25th CIMAC Congress, Vienna 2007