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Press Release

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Shared research: MaK EMI MINI project presented at the Motorship Propulsion & Emissions Conference

Hamburg, Germany – The second phase of the Emission Minimisation (EMI MINI) research project, a joint effort to reduce marine engine emissions, is nearing completion. Funded by the German government and involving leading diesel engine design experts, including Caterpillar®, AVL Deutschland, L'Orange, WTZ Roßlau and the University of Rostock, the first phase of the project, EMI MINI I, ran from 2002 to 2005. That phase produced major building blocks for today's MaK Low Emission Engine (LEE) technology. The second phase, EMI MINI II, which has run from 2006 to 2009, has now almost been finished. This phase has placed special emphasis on optimising the Caterpillar Common Rail (CCR) system to allow for MaK emission levels 50 % below current IMO I regulations.

"The combined efforts of five experts in marine engine technology have borne fruit", said Dr Udo Schlemmer-Kelling, Manager Research at Caterpillar Motoren in Kiel at today's Motorship Propulsion & Emissions Conference in Copenhagen, Denmark. "Beginning with comprehensive spray chamber investigations, we have not only improved the software tools to better understand the combustion process, but also set precise development targets for the injection system manufacturer, carefully verified results in a single-cylinder research engine and then combined it all in an advanced MaK LEE production engine. EMI MINI has proven that research and serial production can be linked in a highly efficient way", he declared.

A strategy for emission reduction

Back in 2000, Caterpillar Motoren identified three emission levels for the MaK marine product to meet short to midterm emission regulations. These were a base line IMO I engine, an IMO-compliant engine with invisible smoke emissions and a Low Emission Engine which meets the expected NOx emission range of IMO II and is also smoke-invisible. In addition, the strategy favoured the enhancement of proven technology inside the engine, which has clear advantages in terms of cost, complexity and maintenance.

Since then, IMO I-compliant engines have become the norm, more than 80 MaK marine engines rely on Flexible Camshaft Technology (FCT) for invisible smoke, and the first MaK IMO II-compliant engines are already in service at sea. Thanks to EMI MINI I, the NOx emissions of these LEE engines have been reduced by 30 %. To achieve emission levels as low as 50 % below IMO I, however, additional research had to be carried out within the framework of EMI MINI II.

Perfect partnership

The University of Rostock contributed a detailed investigation of injection spray parameters on a special test bench, yielding important data on how to optimise injection components for different fuel qualities. The knowledge gained from this has also been used by AVL to develop, improve and verify calculation models in their CFD-FIRE software, enabling Caterpillar Motoren to calculate and predict the combustion processes of MaK marine engines. In this simulation, the influence of the nozzle flow on spray propagation and droplet break-up and thus on the mixture formation, combustion and emission formation is demonstrated. It not only helps to reduce development time and costs but also allows to view the chemical and physical processes inside the engine which cannot be achieved with current measurement techniques.

The results of spray investigation and simulation led to improvements in the single-circuit Common Rail system used on MaK marine engines. L'Orange optimised the design of the electronically controlled injectors comprising nozzle element, pilot valve and oil-cooled solenoid. Special emphasis has been placed on multiple injection capabilities as a prerequisite for future emission reduction. Further tests with different rail pressures, injection parameters, compression ratios and charge air temperatures took place at WTZ Roßlau using their single-cylinder research engine. Investigations have shown that by combining certain NOx reduction measures with Common Rail capabilities, i.e. variable injection pressure, variable injection timing and multiple injections, a NOx reduction of 50 % compared with IMO I can be achieved with only a slight increase in fuel consumption and Filter Smoke Number (FSN).

Validation and optimisation

Parallel to the research, simulation and development efforts taking place at different locations, Caterpillar Motoren Kiel also carried out many real engine tests on a MaK 6 M 32 C and a 6 M 20 C engine, both equipped with Caterpillar Common Rail (CCR). On these engines different combustion chamber designs and compression ratios were verified. The Miller Cycle strength was gradually modified and combined with various Common Rail trims. For detailed investigations regarding functional safety, lifetime and wear of components, an additional test rig capable of marine diesel and Heavy Fuel Oil (HFO) operations was used.

For transient operation, it is very important to avoid visible smoke emission. The MaK engine concept for improved emission reduction combines the advantages of FCT and CCR to allow independent adjustment of the air and fuel systems during operation. The FCT system can switch on and off the Miller cycle, which influences the amount of trapped air in the cylinder. The CCR system can change the injection parameters during the acceleration process. As a result, smoke emissions are significantly reduced and remain below visibility at any given load.

The base line for all emission reduction measures was an IMO I serial production engine with a NOx cycle value of 11.7 g/kWh. Testbed trials with the modified MaK 6 M 32 C and 6 M 20 C engines showed that the Miller Cycle is a suitable tool for even further reduction of the NOx. The loss of peak cylinder pressure which this causes can be compensated for by an increased compression ratio, thus keeping efficiency constant. And when equipped with CCR and FCT, MaK marine engines can meet the requirements of IMO II without visible smoke.

The way towards IMO III

Even though IMO II with 30 % less NOx has been achieved, it became apparent that NOx values of 50 % below IMO I were not achievable without penalties in terms of efficiency. Injection system trims like adapted rail pressures, timings and multi-shots were able to reduce the NOx cycle value by only about 10 % below IMO II (40 % below IMO I). Trimming the engine to 6 g/kWh NOx (50 % below IMO I), resulted in an efficiency drop of 2 to 3 %. An increase in smoke emissions could be overcome by suitable injection trims. However, to achieve the given target of EMI MINI II, it was found that additional research was required.

Caterpillar Motoren carried out additional development and simulations. Higher compression ratios and a stronger Miller Cycle were the right tools for the NOx target of 6 g/kWh. But a stronger Miller Cycle requires a higher boost which only can be delivered by a two-stage charging system, Also, for higher compression ratios a redesign of the cylinder head would be needed. Smaller and therefore more valves give the opportunity to reduce the valve lift without sacrificing engine breathing. A reduced valve lift permits an increase in the compression ratio without compromising the piston crown design. Combined, these measures not only keep efficiency constant even at 6 g/kWh NOx, but also provide the basis for a further reduction to 2 g/kWh NOx, and thus to IMO III requirements.

Small is beautiful

Publicly funded projects involving numerous industry partners have a tendency to become slow and inflexible, especially where they focus on too many targets at the same time. That's why EMI MINI not only has a clear mission but is also narrow in scope: to reduce medium-speed marine engine emissions well beyond IMO I and IMO II, addressing IMO III. And that's why EMI MINI involved only five partners, each of them with proven expertise in one aspect of the overall emission reduction process.

The EMI MINI project underscored the huge potential of the current MaK medium-speed marine engine design. Introduced from 1992, the MaK long-stroke engine family comprising M 20 C, M 25 C, M 32 C and M 43 C has won a reputation for performance, reliability and fuel economy. With the latest findings it has become clear that this proven platform is also capable of meeting IMO III emission limits not expected until 2016. Customers enjoy peace of mind, knowing that MaK engines ordered today are based on technology which not only has been sold more than 4,000 times but will continue to be sold and further developed over the next decade and possibly even beyond that.

According to Schlemmer-Kelling, "The EMI MINI results and the present MaK LEE production engine guarantee the future of the MaK medium-speed, long-stroke design philosophy. I am confident that our technology approach, together with our in-house engineering expertise, will find suitable ways to cope with ever more-stringent emission regulations. That's why the seven project partners of EMI MINI I and II have already agreed to take part in a successor project named FAME (Fuel Air Management for Emission Reduction) starting in September 2009."

Characters: 9,235

Pictures available on request:

1.) **FCT Unit mounted on a MaK 8 M 32 C LEE Marine Engine**
2.) **MaK 6 M 32 C Marine Engine with Caterpillar Common Rail**
3.) **Chemical Tanker Fure West powered by MaK 7 M 43 C LEE – world's first IMO II-compliant, medium-speed, HFO-fuelled marine engine afloat**

About Caterpillar Marine Power Systems

Caterpillar Marine Power Systems, with headquarters in Hamburg, Germany, groups all the marketing and service activities for Cat and MaK marine engines within Caterpillar Inc. The organisation provides premier power solutions in the medium- and high-speed segments with outputs from 93 to 16,000 kW in main propulsion and 10 to 7,680 kWe in marine generator sets. The sales and service network includes more than 2,100 dealer locations world-wide dedicated to support customers in ocean-going, commercial marine and pleasure craft wherever they are.

More information is available at: www.Marine.Cat.com.

About Caterpillar

For more than 80 years, Caterpillar Inc. has been making progress possible and driving positive and sustainable change on every continent. With 2008 sales and revenues of $51.324 billion, Caterpillar is the world's leading manufacturer of construction and mining equipment, clean diesel and natural gas engines and industrial gas turbines. The company also is a leading services provider through Caterpillar Financial Services, Caterpillar Remanufacturing Services, Caterpillar Logistics Services and Progress Rail Services.

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