Press

Joint diesel research project completed

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Multinational team led by Wärtsilä and MAN Diesel successfully complete the major HERCULES cooperative research project into the technology necessary for higher-efficiency engines with ultra-low emissions for ships.

A team of more than 40 European engine component suppliers, equipment manufacturers, universities, research institutions and shipping companies, led by the major diesel engine groups MAN Diesel SE and Wärtsilä Corporation, has successfully completed the major 43-month cooperative research project under the name HERCULES (High Efficiency R&D on Combustion with Ultra-Low Emissions for Ships) with a budget of EUR 33 million, partly funded by the European Union (EUR 15 million) and the Swiss Federal Government (EUR 2.5 million).

The results from HERCULES will allow the participating companies to develop marine diesel engines with technologies, components and equipment that will achieve drastically lower gaseous and particulate emissions, while at the same time gaining increased engine efficiency and reliability, thereby reducing fuel consumption, CO2 emissions and engine life-cycle costs. The results of the research are being shared among the participants and are expected to be incorporated in engines introduced during the next ten years or so.

The project has been undertaken through a series of nine interrelated work packages (two missing numbers were reserved for packages that were not adopted):

1. Extreme design parameters
Knowledge about a diesel engine operating under extreme conditions was gained with advanced research engines capable of coping with severe mechanical and thermal loads. These engines feature for instance variable valve timing, common rail fuel injection etc. allowing the researcher to adapt to whatever running conditions.

This work package included a study of the influence of advanced working cycles on engine performance and emissions, finding design and material solutions for engine components operating under extreme conditions and performing full-scale and rig tests to evaluate the technologies.

The fuel spray and combustion conditions were studied by using optical equipment to look into the combustion chamber through quartz windows.

Vital engine components situated around the combustion chamber and reciprocating parts were evaluated and redesigned with respect to the increased mechanical load and thermal load applying advanced design and material solutions.

2. Advanced combustion concepts
Three-dimensional CFD (computer fluid dynamics) simulation tools were applied to engine combustion for optimising the combustion systems, involving the development of new models as well as the extension and adaptation of existing sub-models. The developed models were applied to a very large number of cases and the result compared to measured data to ensure the models validity over a wide range of engine types and sizes and varying operating conditions.

A particular achievement was the development, manufacture, installation and testing of a novel test rig for the fundamental investigation of fuel sprays, combustion and emissions formation in large-bore two- and four-stroke engine cylinders. This spray/combustion chamber has an internal diameter of 500 mm and can operate at maximum pressures up to 200 bar.

Combustion system optimisation tests have already been performed to identify and verify combustion concepts for achieving lower emissions.

3. More-capable turbocharging systems
The potential benefits of variable-geometry turbocharger systems as well as systems with power take-in/take-out and multi-stage turbochargers were investigated. New concepts for variable turbocharging were also studied and developed. The potential of power take-in/take-out systems was verified with prototype tests on two-stroke engines, while that of two-stage turbocharging was verified on four-stroke engines.

Power take-in systems have great potential for improving part-load behaviour of two-stroke engines as turbocharging efficiency and thus charge air pressure are considerably increased in comparison to using conventional electrically-driven blowers.

Two-stage turbocharging systems were shown to improve considerably the performance on four-stroke engines, showing potentials for reducing NOX emissions by up to 50% at certain load ranges together with some savings in fuel consumption. Good part-load performance was ensured by using a variable inlet valve closure (VIC) system which enables the Miller effect to be varied according to engine mean effective pressure (BMEP).

4. Turbocompound, 'hot engine'
The potential benefits of combined cycle systems, also known as turbocompound, were investigated for ship machinery. Different turbo-compound alternatives were simulated in computer models. These included 'hot mode' simulations with a two-stage turbocharging system.

A substantial number of prototype 'hot engine' components were developed, manufactured and tested (piston, cylinder liner, steam injection system, exhaust valve seat ring, turbocharging system, etc.). These components are resistant to heat and hot corrosion and can actively contribute to the principle of low heat rejection, as well as to a heat balance that is state-of-the-art from the points of view of heat recovery and overall system efficiency.

A further goal of this work package has been search not the optimal solution for the individual machines (engine, turbocharger, power turbine, boiler and steam turbine) but to find the combined optimum for the total process. The main success criteria are optimal efficiency (reduction of CO2) of the system as a whole.

This search for optimal efficiency of the total system has confirmed that dedicated design of gas power turbines, boiler elements suitable for operating under high exhaust gas pressure and steam turbines developed to actual steam conditions must be made if optimum efficiency is to be obtained. Calculations confirm that choosing the optimal combination of known machinery gives potential for improving combined efficiency by some 3 to 5%.

6. Emissions reduction methods (internal – water)
Various ways to use water inside engine cylinders to reduce NOX emissions generation at source were studied and further developed: the intake air humidification and fuel water emulsion systems for four-stroke engines, and the Direct Water Injection (DWI) as well as the scavenging air moistening (SAM) systems for two-stroke engines.

Appropriate computer simulation approaches have been devised for above techniques. Extensive simulations were run for identifying the most suitable geometries and operational parameters.

The systems were further developed on the basis of field testing as well as the experience from additional endurance tests in the laboratory.

The systems have been tested successfully in collaboration with the shipping companies A.P. Moller-Maersk Group and Wallenius Lines in prototype installations on board some of their vessels.

7. Emissions reduction methods (internal – exhaust gas)
Particulate matter emissions from two- and four-stroke marine diesel engines were characterised in terms of physical and chemical properties; size distributions were measured, and particulate matter deposited on filter samples was chemically analysed.

The results showed that engine tuning parameters did not have sufficient influence to significantly reduce particulate matter emissions. However, fuel quality did have an impact. Particulate emissions decrease with increasing fuel quality and decreasing sulphur content.

Data resulting from these measurements provided a basis to investigate particulate emissions systematically and to state that the current particulate formation models will have to be adapted.

Correlation with after-treatment technologies investigated in work package No.8 showed that there is a need to explore new technologies for marine diesel engines running on heavy fuel oil in order to reduce particulate emissions to the same extent as for passenger cars.

A complete exhaust gas recirculation (EGR) system for two-stroke engines was developed including a novel exhaust gas cleaner (scrubber). A potential for NOX emission reductions up to 70% was confirmed. Investigations on different combustion gas recirculation (CGR) systems were carried out.

8. Emissions aftertreatment
Aftertreatment of engine exhaust gases was also studied. Non-thermal plasma (NTP) equipment has been used to demonstrate NOX reduction at laboratory scale under conditions representative of the exhaust gas composition from a two-stroke research engine. Results showed that considerable development work needs to be done before NTP systems can be considered a viable proposition for large diesel engines.

A wet scrubber prototype was designed and tested on a four-stroke research engine. With the research engine the prototype removed an average of 95% of the SO2 and 42.8% of the particulate matter in the exhaust gases, according to ISO 8178.

The shipboard monitoring system was installed on the 8-cylinder two stroke engine of the "Maersk Montana" and is operational.

Attention has also been given to new measuring techniques. A measuring concept for emissions originating from individual engine cylinders has been developed on the basis of preliminary tests and simulations. The sampling proved to be the most critical issue in the arrangement and must be further improved to obtain better results.
Further, Infra-Red spectroscopy was tested against the standard NOX measuring method.

9. Reduced friction engine

One way to increase engine efficiency is to reduce internal engine friction losses. This requires developments in lubrication and tribology.

During the research, valuable information regarding the friction losses was obtained and significant differences depending on engine size were found. A new, "environmentally friendly", non-metallic bearing material with improved mixed friction properties and reduced friction losses was developed and a new bearing geometry concept was created.

A tribometer (friction test-rig) with the unique capability to determine accurately and reliably the friction losses and wear resistances of piston ring and cylinder liner materials was studied.

A hydraulic simulation model and a device to predict accurately and measure the fuel injection rate of a common-rail fuel injection system was developed. A common-rail system with optimised fuel injection characteristic for a 1000 kW/cyl engine was tested, and a significant reduction of fuel consumption was achieved.

Simulation techniques for a tuned/adaptive mass damper were developed, and a significant reduction of the vibration levels was achieved, allowing a much wider engine operating field.

11. Adaptive and Intelligent engine
The objective for the 'adaptive and intelligent' engine was to create engine systems and components that adapt to prevailing operational conditions as well as to component status. This involved self-learning systems based on monitoring with reliable measuring equipment with goal-oriented performance under all boundary conditions, together with engine mode changes based on manual or self-detected requirements.

Significant improvements in performance and reduced emissions were obtained by using an advanced embedded speed controller, also by introducing a new method for sharing the load of several generating sets or propulsion engines in a ship, with self adapting properties and fault-tolerant operation.

A new adaptive multimodel controller structure for optimized performance of non-linear processes was developed. Tests were also made with dual control for speed and timing using advanced controllers with increased accuracy. Advanced engine balancing diagnostics for common rail engines were tested and verified.

A new method was also developed to ensure advanced fuel injection system reliability by a novel redundancy strategy. Improvements were also achieved in the reliability of adaptive control methods for gas engines by the development of new methods for accelerometer sensor analysis and condition monitoring.

The next step – HERCULES-B
MAN Diesel and Wärtsilä have proposed a follow-up to HERCULES in a new large-scale collaborative research project – HERCULES-B, which was announced in October 2006. A proposal was submitted to the European Commission within the "FP7 Cooperation Work Programme: Theme 7-Transport" in June 2007 and it is expected to be evaluated by the end of September 2007.

The principal aim of the proposed HERCULES-B based on the developed know-how and results of HERCULES, is to considerably improve the efficiency of marine diesel propulsion systems and achieve substantial reductions in fuel consumption and emissions. HERCULES-B is planned to reach beyond today's limits set by the IMO, radically improving the environmental effect of waterborne transport.

More information about HERCULES at: **www.ip-hercules.com**

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Notes to the editor:
About Wärtsilä Corporation

Wärtsilä enhances the business of its customers by providing them with complete lifecycle power solutions. When creating better and environmentally compatible technologies, Wärtsilä focuses on the marine and energy markets with products and solutions as well as services. Through innovative products and services, Wärtsilä sets out to be the most valued business partner of all its customers. This is achieved by the dedication of more than 15,000 professionals manning 130 Wärtsilä locations in close to 70 countries around the world.
www.wartsila.com

About MAN Diesel

MAN Diesel is the World's leading provider of large-bore diesel engines. The company designs two-stroke and four-stroke diesel engines, generating sets, turbochargers and CP propellers, for manufacture by MAN Diesel and its licensees. The engines have outputs ranging from 450 to 97,300 kW. MAN Diesel has approximately 6,400 employees, located in Germany, Denmark, the UK, France, the Czech Republic and China. The company's worldwide service organisation, MAN Diesel PrimeServ, consists of a network of own service centres, supported by authorised partners. MAN Diesel is a subsidiary of the German industrial group MAN AG, which is listed on the DAX stock index comprising the 30 largest companies in Germany.
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