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32/44CR

MAN Diesel Presents first All-Electronic Four-Stroke

MAN Diesel recently received its first order for the new 32/44CR diesel, the first medium-speed, large four-stroke engine to feature common rail fuel injection as standard equipment. Moreover, since electronic engine control is very much the enabling technology of common rail fuel injection, the 32/44CR engine is also MAN Diesel's first all-electronic four-stroke.

Significantly, this new development from the company's four-stroke business unit based in Augsburg, Germany, will not be offered with any other form of fuel injection. "This situation reflects both our absolute confidence in our common rail system and the market's confidence in MAN Diesel's electronic controls, based on several years of commercial operation," notes Prof. Dr. Wolfram Lausch, Senior Vice President, Large Propulsion Business at MAN Diesel. "In fact, the 32/44CR engine is creating immense customer interest and above all, this strong anticipation is based on the new engine's ability to meet future emissions limits for oxides of nitrogen (NO_x)."

The 32/44CR diesel offers a high cylinder output of 560 kW and is derived from the established 32/40 heavy fuel engine, which was the first MAN Diesel engine to be fitted with common rail fuel injection and has been undergoing successful field tests for a considerable time. In this way, the company has been able to verify

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the performance of important components like the common rail system itself and the engine control system.

One of the major product objectives with the 32/44CR was to fully exploit the benefits of common rail in both engine performance and engine construction. “A fuel system which allows high injection pressures to be created independent of engine speed allows much closer adaptation of engine performance to a specific application than ever before, and also allows improvements in aspects of engine design,” notes Dr. Ralf Marquard, Senior Vice President R&D Engineering at the MAN Diesel four-stroke business unit. “Thus, with the adoption of common rail technology on the 32/44CR we were able not only to achieve high specific power output but also market-leading fuel efficiency and extremely low exhaust emissions, including invisible exhaust gases over the entire load range.”

In addition to these aspects, the product objectives of the 32/44CR also emphasised high reliability and long maintenance intervals; ease of operation and maintenance; low lube oil consumption; improved engine design including new pipework and wiring concepts; and, naturally, unrestricted heavy fuel oil capability.

As the MAN Diesel system of engine designations reveals, the basic difference between the 32/44CR engine and its 32/40 progenitor is a 10% increase in stroke. “To achieve high specific output, low fuel consumption and low noxious emissions, the stroke dimension has been increased from 400 mm in the 32/40 engine to 440 mm in the 32/44CR, and the

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engine equipped with flexible and intelligent common rail fuel injection and a considerably more efficient turbocharger," notes project leader Stephan Haas. "In combination with optimised valve timing and the stated flexibility of our common rail system, an increased compression ratio has made it possible to gain strong benefits in the NO_x - particulates - fuel consumption trade-off."

The higher power density of the 32/44CR engine vis-à-vis the 32/40 naturally led to several modifications in componentry. "In particular, the cylinder head and the valves have been modified to cope with the increased cylinder pressure. For example, the valve guides have been extended and the valve seats modified," Haas continues. "Likewise, the 32/40 standard engine's crank drive has been completely revised and optimised using the latest computer design techniques."

The piston of the 32/44CR is an all-steel design with two compression rings. Due to the 32/44CR's high output its piston features an enlarged oil cooling gallery and enlarged piston pin diameter. "Further revisions include an enhanced three ring package designed with the help of ring dynamics calculations," Haas reports. "Finally, we have reduced the length of the 32/44CR piston so that, in spite of the above measures, its weight has not increased compared to the piston of the 32/40 engine.

The diameter of the cross section of the connecting rod shaft was increased and the number of bolts at the big end bearing increased from two to four. Using four bolts instead of two has allowed more even distribution of the stresses at the joint line and we were able to

make the connecting rod bearing slimmer compared to a two-bolt design."

Turning to valve and injection pump actuation, the new engine employs two camshafts. A standard, full-length camshaft is used for actuation of the gas exchange valves and a shortened camshaft for the high-pressure injection pumps. "This shortening of the injection camshaft not only reduces its friction characteristics but also engine manufacturing costs," Haas confirms. "It is an example of how the adoption of common rail fuel injection can improve not only engine performance data but also its design and manufacturing."

Common rail injection system

First announced in 2004 on the 32/40 heavy fuel engine, the MAN Diesel common rail fuel injection system has now proven its performance in over 20,000 operating hours. "Our common rail system has verified its compatibility with HFO of viscosities up to 700 cSt (at 50°C) and demonstrated its ability to withstand typical HFO operating conditions like high temperatures and high fuel viscosity," reports Ludwig Maier, head of the MAN Diesel fuel injection department. "Likewise, components and their special coatings have proven well able to withstand wear due to abrasive particles and the aggressive contents in HFO."

The MAN Diesel common rail injection system is modular in design, with pressure accumulators subdivided into a series of segments, each serving one or two injectors. "The use of multiple accumulators reduces pressure fluctuations in the system and makes

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rational use of space available on the engine," notes Maier.

As well as unrestricted HFO fuel oil compatibility and reliability, great attention was also paid to safety aspects in designing the MAN Diesel common rail system. "Pressure control of fuel injector opening makes the system inherently safe, Maier notes. "It means that the injection nozzle is normally closed and hence a leaking control or injection valve cannot result in uncontrolled, 360° injection."

Given the 32/44CR engine's 100% reliance on common rail fuel injection and electronic control, MAN Diesel has built a considerable degree of redundancy into both systems. "The use of at least three high pressure pumps on every engine ensures that emergency operation is possible in the event of the failure of one pump, Maier states. "A further redundancy measure is the use of two rail pressure sensors and two engine speed/positioning sensors to allow continued unrestricted operation in the event of a sensor failure."

Further safety features include a volume limiter valve on each cylinder to prevent uncontrolled injection, while a non-return valve on each cylinder ensures that fuel back-flow from the low-pressure system into the cylinder is impossible. A safety valve with additional pressure control function also ensures that emergency operation is possible in the event of complete failure of pressure regulation.

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Turbocharging

The newly developed radial flow TCR turbochargers used on the 32/44CR engine feature an increase in pressure ratio and flow rate while compressor efficiency has been significantly improved via CFD-aided optimisation. Innovations include integral internal re-circulation (IRC) which increases the stable operating range of the compressor. A new silencer design ensures low-pressure losses and significant damping of intake noise. An option on the TCR radial turbocharger for engine applications with severe load imposition requirements is “Jet Assist”, in which compressed air is injected into the compressor during acceleration.

Controls

The 32/44CR’s engine control and monitoring system is based on MAN Diesel’s “SaCoS” (Safety and Control System), already in use on several hundred engines. In the common rail version of the system, the solenoid injection valves and fuel pressure are controlled according to engine performance maps. “Although only main injection is used at present, to assist compliance with tightening emissions limits both pre- and post-injection are also possible,” notes Alfred Marzinek, head of the software and electronics department.

Returning to the theme of operational safety, a variant of the SaCoS system offering complete redundancy is well suited to single engine propulsion plants. “This redundancy is an important feature of the safety concept of the MAN Diesel common rail system per se,” Marzinek notes. “Two electronic control units (ECU’s) each control and regulate one half of the

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engine and synchronise themselves with each other. Thus, if one ECU fails, that engine half will fail but only for a few ignition cycles and then the second ECU automatically takes over."

Further redundancy is featured in the safety and alarm aspects of SaCoS, where analogue to digital signal conversion takes place in intelligent terminals on the engine. The data is then passed separately via redundant bus systems to the SaCoS safety and alarm units, giving both added security and a significant saving on cabling to the remote switchgear cabinet.

Testing

Since the start of testing in August 2005, the 32/44CR diesel has logged well over 900 operating hours, of which 250 were on HFO. "Results in the prototype tests demonstrate that targets set regarding fuel consumption, NO_x and soot emissions have all been achieved, " Haas reports. "In addition, we are working on further optimisation of operating costs on the 32/44CR engine by fine-tuning the performance of the electronic fuel injection system to specific applications. For example, as an auxiliary engine on large container ships the 32/44CR engine is operated predominantly in a load range between 30% and 70%. If injection pressure and timing are specially adjusted to achieve optimised fuel consumption in this load range, operating costs can be further reduced," Haas observes. "Naturally, this application specific fine-tuning can be achieved while at the same time complying with international exhaust emissions regulations (IMO, MARPOL 73/78 Annexe VI) and

while guaranteeing invisible exhaust emissions over the entire engine load profile.

In addition to numerous examinations and measurements centring on component safety, an extreme condition test was recently performed in which the engine was operated non-stop in overload under severe marginal conditions for at least 100 hours. “In the near future the type approval test for marine engines will also take place, and March 2007 will mark the start of field testing,” Haas concludes. “During field testing on a ferry we can experience real-life engine operation and log a high number of operating hours in a short time. In this way we can obtain valuable findings on the long term behaviour and reliability of individual components.”

Captions:

1. The new 32/44CR four-stroke engine on MAN Diesel’s Augsburg test stand. It is equipped exclusively with common rail fuel injection and offers a cylinder output of 560 kW.

2. Cutaway of the MAN Diesel 32/44CR engine with common rail fuel injection.

3. Cross section of the 32/44CR in-line engine. The new engine is based on the proven type 32/40. Piston stroke was increased from 400 mm on the 32/40 to 440 mm on the 32/44CR.

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4. The MAN Diesel common rail injection system is pressure-controlled and has full heavy fuel capability. Instead of equipping the thermally and mechanically highly stressed injectors with solenoid valves, standard injectors are used and the solenoid valves integrated into the pressure accumulators (common rails).

5. The newly developed MAN Diesel TCR radial turbocharger used on the 32/44CR engines is characterised by its high efficiency.

6. Overview of the typical applications of a medium-speed, heavy fuel engine including the corresponding load ranges in which the engines are predominantly operated.

7. Main engine data of the MAN Diesel 32/44CR heavy fuel engine.

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 and turbochargers, 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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