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Racking up engine performance

David Tinsley examines the contribution made by advances in turbocharger design

German technicians have secured a further advance in turbocharger technology, giving rise to improved operational, economic and environmental performance of large marine diesel engines.

The latest initiative from MAN Diesel is known as variable turbine area (VTA) technology, and offers entirely new turbocharging possibilities by conferring flexibility as to air and fuel management. Key prospective benefits are improved fuel efficiency and reduced emissions, although broader operational and installation advantages also attend VTA.

VTA is to be rolled out across the range of TCR-series radial and TCA-series axial turbochargers that can be specified with MAN engines, and commercial deliveries are expected to begin before the end of 2008. In the meantime, shop tests have been completed on a six-cylinder S46MC-C two-stroke diesel fitted with a TCA55 turbocharger incorporating the VTA arrangements.

The engine is one of two which will form the propulsion plant in a 65 200dwt newbuild tanker under construction at Croatian shipyard Brodosplit for the Stena group company Concordia Maritime. The heavy fuel oil-burning S46MC-C low-speed design employs mechanically-controlled fuel injection and exhaust valve actuation.

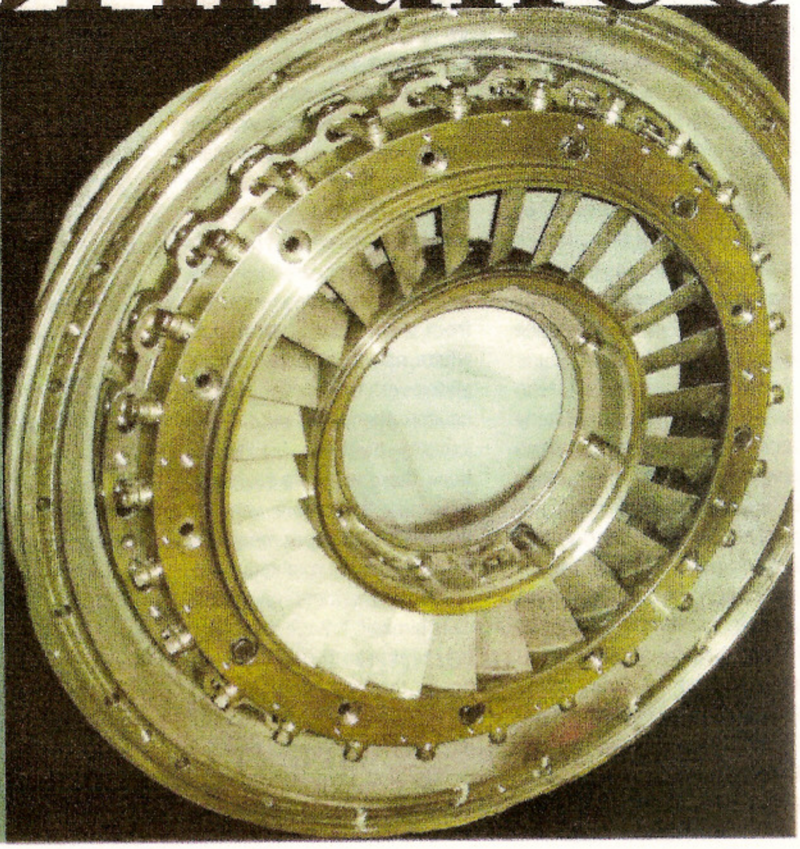
The Concordia application will provide valuable feedback on VTA from the shallow-draught tanker's planned August 2007 sea trials and first trading voyages. Evaluation of the system will be facilitated by the fact that the second of the ship's 6S46MC-C prime movers will have a conventional turbocharger. One element of the programme will be the simulation of emergency running, by operating the VTA-equipped engine at high torque with the second engine shut down.

'Using our VTA system, we can more precisely match the volume of charge air to the quantity of injected fuel at all points on an engine's load profile,' explained Dr Alexander Rippl, Head of Turbocharger Development at MAN. 'The result is reduced specific fuel consumption in combination with reduced hydrocarbon (HC) and carbon monoxide (CO) emissions and improved dynamic behaviour of the engine-turbocharger system,' he added.

Trials with a VTA-embracing TCA turbocharger on the company's 4T50ME-X research engine in Copenhagen had confirmed significant potential for cutting unit fuel oil consumption at part-load, together with improved engine response under load changes. VTA's strong points mean that it is viewed as a tool for meeting both emissions legislation of the future and the rising expectations of customers in terms of overall engine performance and fuel consumption.

Compressor output

Rather than the fixed-vane nozzle rings fitted in standard TCA turbochargers, the VTA system consists of a nozzle ring equipped with adjustable vanes. By adjusting the vanes' pitch, the pressure of the exhaust gases can be regulated and the compressor output optimised at all points on the engine's performance map. Each vane has a lever, directly connected to a control ring, which is actuated by an electric



■ VTA turbochargers feature a nozzle ring with adjustable vanes. Seen here is the axial variant for the TCA axial turbocharger. The system is modular and occupies the same position as a fixed nozzle ring. It can be retrofitted to turbochargers already in the field positional motor with integral reduction gear.

Control of vane position is fully electronic, and a range of control signals can be used, including charge air pressure after the compressor and exhaust gas temperature before and after the turbocharger. In this way, control packages can be tailored to a specific application, including both mechanically-controlled engines and those with electronic management.

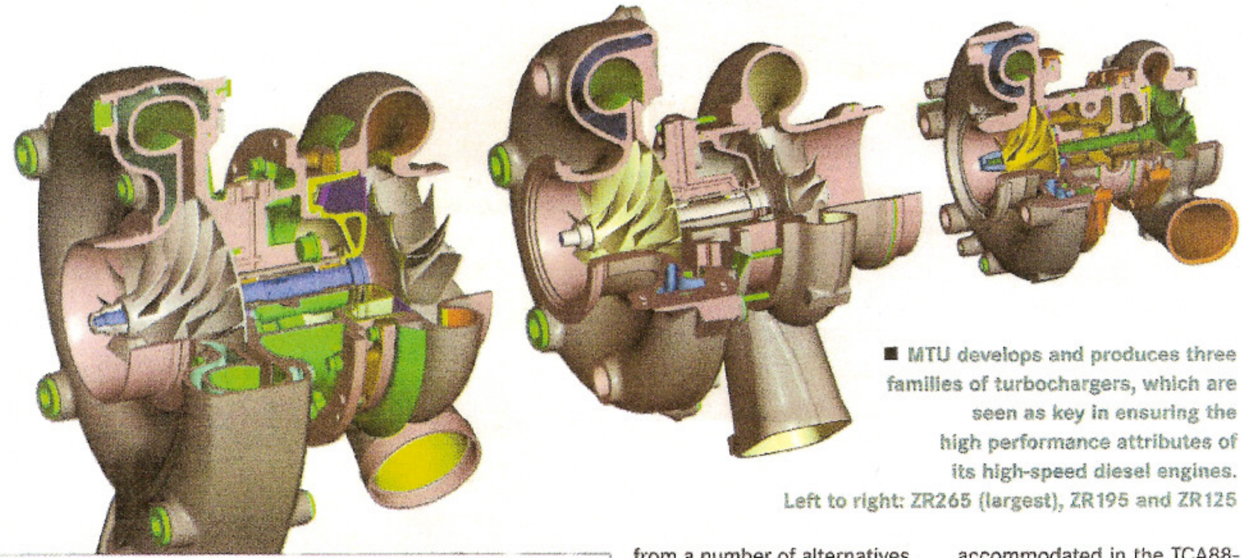
VTA lends itself to retrofit as well as newbuild applications, and the possible adaptation of turbochargers already in the field with complete packages, including the VTA nozzle ring, actuator and associated control system, promises a swifter, wider uptake of the technology.

By giving a new dimension to mechanically-controlled engines, VTA's effects are said to be comparable to the use of variable valve timing and electronic control.

Besides the positive implications for engine performance, emissions and fuel consumption, the new turbocharger technology makes the process of matching the turbo to the engine much simpler. 'In contrast to fixed-geometry turbochargers, where a suitable nozzle ring with fixed vanes is chosen from a number of alternatives, there is only one VTA module per turbocharger size covering all matching possibilities,' observed MAN Application Engineer, Andre Voges.

While the TCR range of radial-flow turbochargers for medium-speed and high-speed diesels and gas engines has been progressively widened, MAN has augmented its offering of TCA axial-flow turbochargers through last summer's launch of the TCA88-25. As an uprated version of the TCA88-20 model, the 25-type extends the latter's application range by 16% through a new compressor design and wheel geometry. The volume flow in the TCA88-25 is 58.6m³/s compared with 50.4m³/s in the TCA88-20, hoisting the maximum supercharged engine output to 27 300kW from 23 400kW.

As a consequence, it is now possible to supercharge larger engines with fewer turbochargers. For example, only three TCA88-25 units are now required to supercharge the 12K98ME-C two-stroke propulsion engine, the most powerful MAN design delivered to date. Despite the increase in power density, the dimensional envelope and weight of the TCA88-25 remain very close to that of the 20 model, since the revised rotor geometry of the new model can be readily accommodated in the TCA88-20 casing.



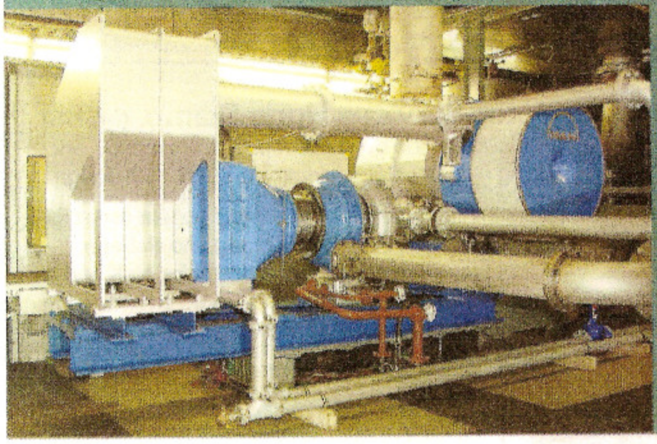
■ MTU develops and produces three families of turbochargers, which are seen as key in ensuring the high performance attributes of its high-speed diesel engines. Left to right: ZR265 (largest), ZR195 and ZR125

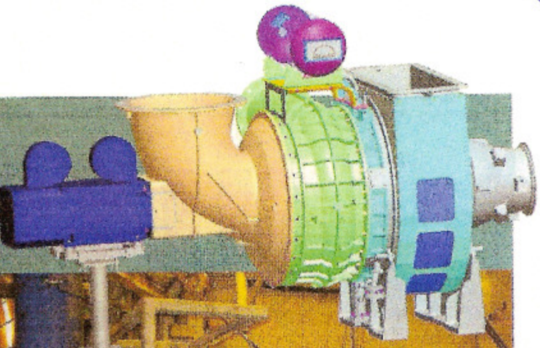
Next generation

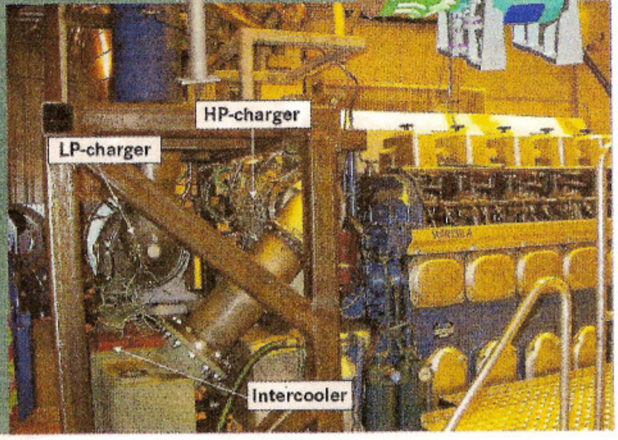
Swiss-based specialist ABB Turbo Systems delivered more than 8000 turbochargers from its factory in 2006, 28% more than the year before. Following on from earlier expansion of production capacity in anticipation of strong demand, additional investments and increased efforts in manufacturing and assembly were made to meet extra pressure on capacity and delivery schedules. The Chinese joint venture ABB Jiangjin Turbo Systems has given added dimension to production resources and product availability.

Although third-party business did not increase as hoped, in-house projects ensured continuity of activities at the company's Thermal Machinery Laboratory. The facility will be pivotal to devel-

■ Progress reports at the most recent Hercules integrated project Forum included (right) PTI configuration for 2-stroke engines (MAN Diesel); (below) two-stage turbocharger on test rig (MAN Diesel); (below right) two-stage turbocharger on engine (Wärtsilä)







opment tests for ABB's next-generation turbochargers. During 2006, a concept was devised for testing new technologies, and the 'road map' for making the requisite modifications to the test rigs was defined.

ABB has expanded its offering with the TPL..-C series for medium-speed, four-stroke diesels and gas engines in the 3MW-20MW power range, and 2006 saw the delivery to an engine builder of the first prototypes of the TPL79-C type.

The company reports that work is progressing on the next generation of turbochargers, for which concepts have been developed. Component tests were carried out last year, evidently demonstrating that the ambitious goals set for the type are attainable, and it is anticipated that the first frame size will be released during 2007. Furthermore, the current year should also see the market launch of a TPS..-F series turbocharger, targeted at the smaller end of the market.

'An important driver of innovation is international and national legislation aimed at reducing engine emissions,' reported ABB Turbo. 'To comply with both current and future environmental regulations, technological progress must encompass the turbocharging system as a whole. We are working closely with our customers among the engine builders to find suitable solutions.'

Investment in research and development over 2006 rose by 7% to SwF42.7M, corresponding to 8.5% of total revenues, and underscoring the company's conviction that a sustained commitment to R&D is vital to safeguarding a strong market standing.

A new service concept introduced for ABB's TPL..-B turbochargers allows ship operators to extend bearing exchange intervals from 18 000 running hours to 36 000h. The move reflects the outstanding field performance of the bearings in the design series, which made its debut in 1999 in application to low-speed, two-stroke diesels.

While a short stay in port for a fast, intermediate inspection is recommended at 18 000 running hours, disassembly of the complete cartridge is no longer required at this interval. The implementation of field-proven 36 000h bearing exchange intervals for the TPL..-B allows the two-stroke turbochargers to be run with the same bearings from one scheduled drydocking to the next. The standard 36 000h overhaul remains the same, with no extra work being necessary.

Single-stage

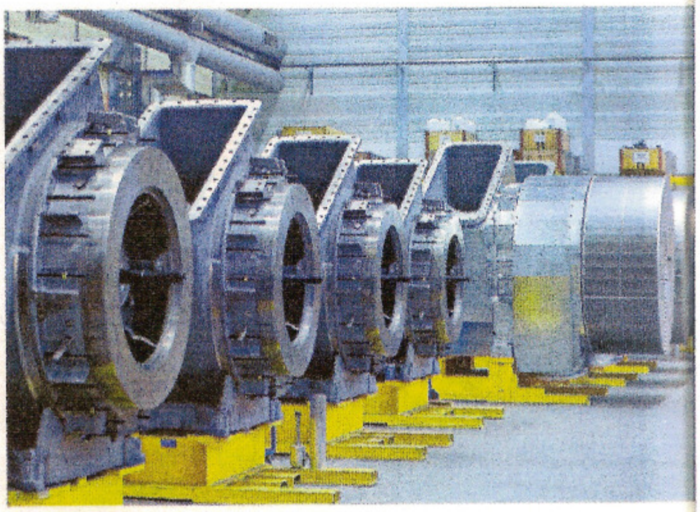
The fact that compact pressure-charging systems are designed and manufactured in-house is regarded by the Tognum Group as one of the instrumental influences on the high performance attributes of its MTU high-speed diesel range, with regard to output, consumption and emissions.

R&D allocations year-on-year confirm its view of supercharging as one of the group's core technologies, and as a field to be considered as an integral part of the company's engine development process, to ensure optimised design and performance. It thereby eschews reliance on outside specialists for the supply of turbochargers.

Systems on MTU diesels operate at up to 96 000rev/min, and reach temperatures as high as 800°C, compressing the intake air to pressures of up to 5bar, while conveying up to 12m^3/s of air into the combustion chambers. Turbochargers are accordingly viewed as key components, subject to enormous thermal and mechanical loads. It is due in no small measure to the powerful pressure charging that MTU is so closely identified with high performance, compact diesel engines.

The turbines harness the heat energy in the engine

■ Assembly of large two-stroke ABB TPL..-B turbochargers



exhaust stream, acting akin to small power plants. When an MTU 20V8000 engine is running at its full power of 9000kW, the four turbochargers are operating at 2700kW, and deliver about 12m^3 of air every second. To provide the same volume of intake air at the required pressure of 4bar in another way would require a compressor station with a power rating of 2700kW.

The largest design in the company's three families of turbochargers is the ZR265, which incorporates a 270mm diameter impeller and runs at a maximum 40 000rev/min, supplying 3.6m^3/s of air. The ZR195 has a 205mm impeller, and operates at up to 54 000rev/min, for a maximum pressure of 4.7bar and 2.2m^3/s air delivery rate. The ZR125 in its largest form embodies a 135mm impeller, working at up to 80 000rev/min to deliver air at 0.9m^3/s and at a pressure of 4.5bar.

A fundamental contributory element to the increase in power achieved with the latest generation of MTU high-speed diesels, such as the Series 2000CR marine engine, is the use of single-stage, high performance turbocharging. ZR125 systems are employed on 2000CR engines, using either two or three turbochargers, depending on the number of cylinders.

Integrated research

Building on the far-reaching research work being carried out by 42 participating organisations and institutes under the Hercules integrated project, MAN and Wärtsilä are advocating a major follow-on programme with ambitious goals as to engine efficiency improvement and emissions reduction.

The first priority of MAN and Wärtsilä is to formalise the Hercules 'B' initiative and apply for partial funding for the tentative project under the European Union's Seventh Framework Programme. As with the current endeavour, the two companies would form the core group within Hercules-B, although the intention would be to have a very large research consortium.

It is likely that the structure and work areas would be generally the same as in the existing project, but with revised emphasis based on results from Hercules-A, which is approaching its scheduled completion.

Recorded achievements thus far with the three-year Hercules-A study have related to an 'extreme value engine' (EVE) for research purposes, an ultra-large spray combustion chamber design, the development of a piston ring friction tester, a cylinder liner for a 'hot'-operating engine, and exhaust gas bypass arrangements for large two-stroke diesels.

At a partners' forum in the latter part of last year, the various progress reports included the work relating to turbocharging technology. Under task 3.1, whereby ABB, Helsinki University of Technology, the National Technical University of Athens, and Wärtsilä are addressing variable turbocharging, it was recorded that prototype designs for two- and four-stroke engines had been completed, and that prototype tests were under way.

■ Assembly of ABB TPS turbochargers

Key objectives of the sub-group are new high-pressure turbocharging concepts for both two- and four-stroke diesels, variable geometry turbocharger components for two-stroke engines, and investigations into electrically-assisted turbos (using PTI/PTO arrangements) for two-strokes.

Task 3.2 relates to intelligent turbocharging, and calls on the know-how and resources of MAN, Kegeul and PBS Turbo. Progress highlighted included the completion of fully automatic variable flow area componentry for two-stroke engines, the construction of a PTI/PTO test unit and commissioning of a two-stage turbocharging system on a burner test rig. A conceptual study of variable compressor area components was underway.

Hercules-B is seen as a four-year, collaborative undertaking. The remit would be to raise the efficiency of marine diesel propulsion systems to above the 60% mark, with resulting improvements in unit fuel consumption and carbon dioxide and other emissions. The highest thermal efficiency rating for modern marine diesels to date is about 50%. To demonstrate the environmental implications, it is estimated that an improvement of just 1% in thermal efficiency across the industry would reduce annual emissions of carbon dioxide from ships by some 5Mt/yr. □