

Wärtsilä Low-Speed Engines – Continuing Progress

The Wärtsilä low-speed engine business is continuing its dynamic progress. Not only do we have new engines such as the recently announced, four-member 820 mm-bore family and the Wärtsilä RT-flex50 of which the first two are in vessels that will be handed over in December, but we recently entered into a strategic alliance with Mitsubishi Heavy Industries Ltd (MHI) in the field of low-speed diesel engines to explore how we shall improve our business.

In parallel, we are investing in further technological developments. The RT-flex common-rail technology, which is the result of a programme begun more than 20 years ago, is proving its great value in service and is attracting considerable interest from shipowners and shipbuilders. Some 227 RT-flex engines, totalling more than 9.0 million kW, have been ordered. Of these, 27 are already in service with the first having accumulated more than 23,000 running hours.

RT-flex engines are now available in eight cylinder sizes with powers from 5800 kW to 80,080 kW, which are ideally suited to all types of ships (Fig. 1). The largest of these is the 14-cylinder RT-flex96C which at 80,080 kW will be the most powerful engine ever built. A number of 14RT-flex96C engines have already been ordered and will be installed in four 8600 TEU container ships for Hyundai Merchant Marine Co Ltd (HMM). The first RT-flex96C has been in service since November 2004 with some 6000 running hours. However, the next RT-flex engine types to be tested are the RT-flex84T-D and RT-flex68-B engines due for testing in the first quarter 2006.

Other technological developments are giving

improvements in engine reliability and durability, such as for example the recent developments in piston-running technology that will result in three years' running between overhauls and reduced cylinder oil consumption.

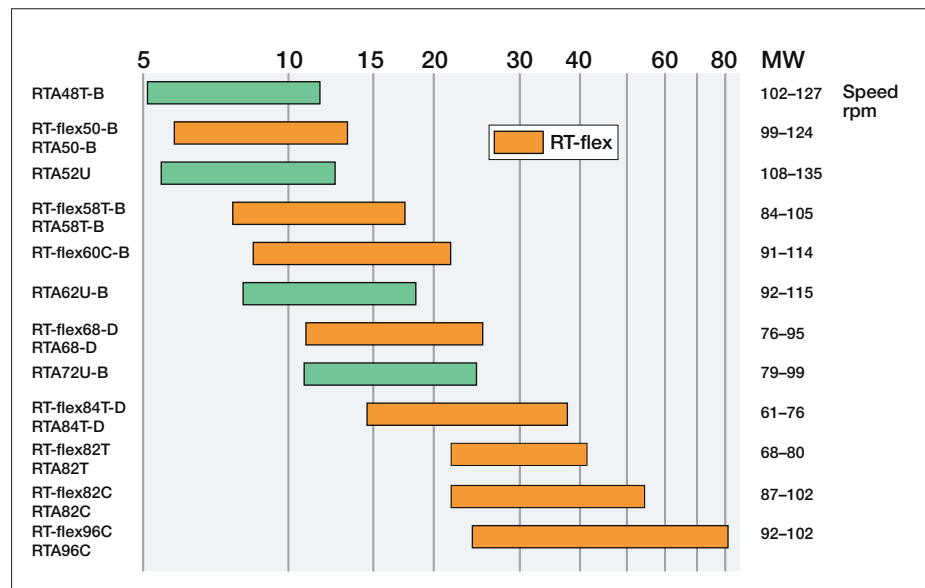
For many years now, we have had an ongoing research programme for reducing and controlling air pollution from exhaust emissions. Although technologies such as direct water injection and exhaust gas recirculation can result in a 70 per cent reduction in NO_x emissions below the current IMO limit, there is always the inevitable trade off giving an increase in fuel consumption. On the other hand, waste heat recovery (WHR) is the only commercially available technology that achieves reductions both in all exhaust emissions and in fuel consumption.

A new WHR system has been developed by Wärtsilä whereby engines adapted to ambient air intake can increase the energy recovery to 12 per cent of the engine shaft power. The lead installation entered service in summer 2005 in the 7000 TEU container ship *Gudrun Mærsk* and is giving excellent results.

Strategic alliance with Mitsubishi

Our relationship with Mitsubishi goes back many years to before 1925 when Mitsubishi signed a licence agreement to build Sulzer diesel engines. Since then, Mitsubishi has not only been a major builder of Sulzer low-speed engines but has also notably been extensively involved in the building and testing of the first examples of newly-designed Sulzer two-stroke engines. More recently, our two companies entered into a joint development agreement in November 2002 to design and develop a

Fig. 1: The Wärtsilä low-speed engine programme now includes eight RT-flex types with fully-electronically-controlled common-rail fuel injection and valve actuation. [05#233]



new low-speed marine diesel engine. The result was the RTA50 with traditional camshaft system from which Wärtsilä developed the RT-flex50 common-rail engine.

Based on the good relations built up during that successful joint development project, our two companies took a step further in September 2005 by forming a strategic alliance in the field of two-stroke diesel engines. The intention is that the two companies will share their resources and experience, and thereby gain synergies for improved business with two-stroke diesel engines. The strategic alliance is led by a Steering Committee with Clas-Eirik Strand of Wärtsilä Switzerland Ltd as its chairman and Mr Hiroo Uchimura of Mitsubishi as the vice chairman.

Various possibilities are being explored by the two companies for pooling their resources and experience. For example, there is potential to co-ordinate marketing and sales efforts to increase the combined market share. The alliance will also look for synergies in the co-ordination of research and development, and for new areas of R&D co-operation to extend further the technological expertise of the two companies in the field of two-stroke engines.

There are also possibilities for rationalising product ranges as Mitsubishi offers engines down to 330 mm bore with a minimum power of 1230 kW while the Wärtsilä range extends up to the 14RT-flex96C of 80,080 kW. The two companies will certainly exchange operating experience from the companies' respective engine ranges, and opportunities will be sought to undertake joint design and development of new engines and joint product care of existing engines.

Attention to the joint product range will, in turn, lead to efficiencies in manufacturing and distribution. Opportunities will also be sought in joint investments into manufacturing in China to participate in the continuing expansion of the Chinese shipbuilding industry.

The Wärtsilä RT-flex50

The Wärtsilä RT-flex50 engine is gaining in popularity with orders having been received for 39 engines for newbuildings contracted with shipyards in China, South Korea, Germany, Japan, Croatia and India for a variety of owners in China, Greece, Scandinavia, Germany, India and the Netherlands. These newbuildings include general cargo ships and bulk carriers in the range of 20,000 to 53,800 tdw, product and shuttle tankers of 37,000 to 52,500 tdw, car carriers and 17,000 m³ LPG carriers.

Owners are proving to be very interested in the special benefits of electronically-controlled common-rail systems for fuel injection and valve actuation in engines of this size, especially the great flexibility in engine setting, bringing benefits in lower fuel consumption, lower minimum running speeds, smokeless operation at all running speeds, and better control of other exhaust emissions.

With powers between 5800 and 13,280 kW, the RT-flex50 is proving to be ideally suited to the propulsion of various sizes of bulk carriers, product tankers and feeder container vessels. A key feature of the RT-flex50 for such ship types is that it allows a compact engine room, with a six-cylinder engine of 9960 kW having an overall length



Fig. 2: The first six-cylinder Wärtsilä 6RT-flex50 marine diesel engine. It has a maximum continuous power of 9960 kW at 124 rpm, and measures about 9.4 m in overall height, and 7.1 m in overall length. [05#186]

of 7093 mm.

The first two engines completed their official shop tests in July and August 2005 (Fig. 2). Their tests included the comprehensive programmes of testing which are usual for a new engine design, together with the type approval tests for RT-flex50 engines and for the WECS-9520 electronic control system which is now incorporated in RT-flex engines.

The 820 mm-bore family

Last month, we announced two further low-speed marine diesel engines each of which will be available in two versions, namely the Wärtsilä RT-flex82C, RTA82C, RT-flex82T and RTA82T.

These are designed for two quite different markets. The Wärtsilä RT-flex82C and RTA82C are intended to be ideal prime movers for the propulsion of Panamax containerships with capacities up to 4500 TEU at a typical service speed of about 24 knots. With cylinder dimensions of 820 mm bore and 2646 mm stroke, the engines will be available with six to twelve cylinders covering a power range of 21,720 kW to 54,240 kW at 87 to 102 rpm.

The Wärtsilä RT-flex82T and RTA82T are designed to provide the right powers and shaft speeds for the propulsion of large tankers, VLCCs and ULCCs of 200,000 tdw to more than 350,000 tdw. With cylinder dimensions of 820 mm bore and 3375 mm stroke, they will be built with six to nine cylinders to cover a power range of 21,720 kW to 40,680 kW at 68 to 80 rpm.

The first engines of the new types are expected to be completed towards the end of 2007, in cooperation with Hyundai Heavy Industries Co Ltd which will provide support in engine production design and testing.

The separate 'C' and 'T' versions are designed in parallel using the platform concept. Their parameters are standardised as far as possible, except principally the piston stroke, so that many components can be same for both versions. This will allow the benefits of rationalisation in the design and manufacturing, lowering manufacturing costs, and rationalising also of spare parts stocks.

The layout fields of these engines, as defined by the power/speed ratings R1, R2, R3 and R4, are extended towards higher speeds at the ratings R1+ and R2+ at the same powers as R1 and R2 respectively (Fig. 3). The extended fields offer widened flexibility to select the most efficient propeller speed for lowest daily fuel consumption, and the most economic propulsion equipment, namely the propeller, shafting, etc.

The Wärtsilä RT-flex82C and RT-flex82T engines incorporate the latest common-rail technology with full electronic control of fuel injection and exhaust valve operation. The RTA82C and RTA82T have traditional mechanically-driven camshafts with fuel injection pumps, exhaust valve actuator pumps, etc. Otherwise the RT-flex and RTA versions have the same principal characteristics and design features.

The engines will meet the market needs for outstanding reliability, high efficiency, compactness, optimised

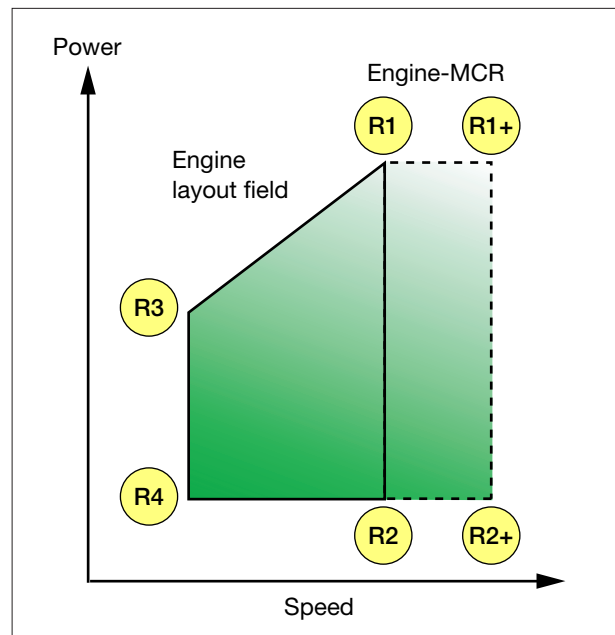


Fig. 3: Rating field for RTA and RT-flex engines with extension to R1+ and R2+ for the RTA82C, RT-flex82C, RTA82T and RT-flex82T engines. [05#239]

industrialisation, and environmental requirements. As with all new marine engines nowadays, they will be fully compliant with the NO_x emission regulation of Annex VI of the MARPOL 1973/78 convention.

The RT-flex versions have the added benefit of no smoke emissions at all operating speeds, together with lower running speeds. The mechanical RTA versions will be available for those shipowners preferring the traditional concept.

Waste heat recovery

Excellent results this year have been gained this year with the lead installation of a new form of waste heat recovery (WHR) plant which successfully confirmed its benefits as an environmentally-clean solution to reducing ships' fuel consumption (Fig. 4).

The plant is installed in the 7000 TEU containership *Gudrun Mærsk* which entered service in June 2005 powered by a 68,640 kW Wärtsilä 12RT-flex96C engine. During sea trials and in operation, the performance of the plant has exceeded expectations.

For example, the calculated output of the turbo-generator set was based upon ISO standard reference conditions which include an ambient temperature of 25°C. During the sea trials, this performance was exceeded as such output was already achieved at the ambient temperature of 14°C.

The equipment for the WHR plant was supplied by Siemens AG, Peter Brotherhood Ltd and Aalborg Industries Ltd. Exhaust gases pass through an Aalborg dual-pressure exhaust-gas economiser to generate superheated steam which is utilised in a 6 MWe Brotherhood turbogenerator set which incorporates both

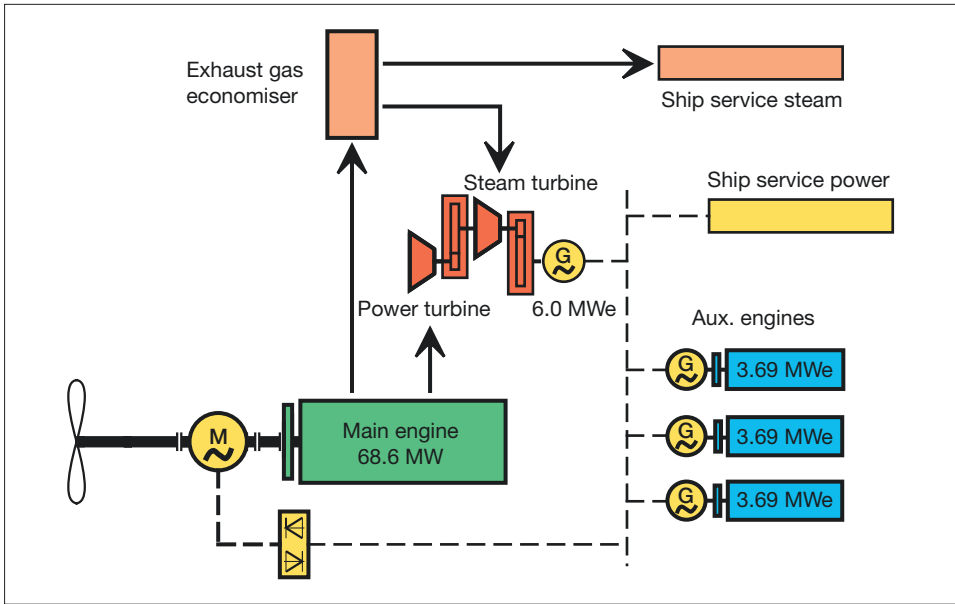


Fig. 4:
Schematic of a typical waste heat recovery plant for containerships in the 7000–9000 TEU range. [04#040]

a multi-stage dual-pressure steam turbine and an exhaust-gas power turbine. The generated electricity is supplied to the ship's main switchboard and employed both in a Siemens shaft motor/generator to assist in ship propulsion, and in shipboard services. A portion of the steam from the exhaust economiser is utilised in shipboard heating services.

The vessel is also equipped with three eight-cylinder Wärtsilä 32 generating sets with a combined electrical output of some 11 MWe. The WHR plant allows the installation of one or two fewer auxiliary generating sets than would normally be installed in this size of ship, taking into account the ship's capacity for reefer containers.

The new WHR concept follows the well-established principle of passing the exhaust gases of the ship's main engine through an exhaust-gas economiser to generate steam for a turbine-driven generator. However, the quantity of energy that can be recovered from the exhaust gases is maximised by adapting the engine to the lower air intake temperatures that are available by drawing intake air from outside the ship (ambient air) instead of from the ship's engine room. The engine turbochargers are matched for the lower air intake temperatures thereby increasing the exhaust energy.

At the same time, today's high-efficiency turbochargers have surplus capacity at the engine's upper load range when matched for ambient air intake. Thus about 10 per

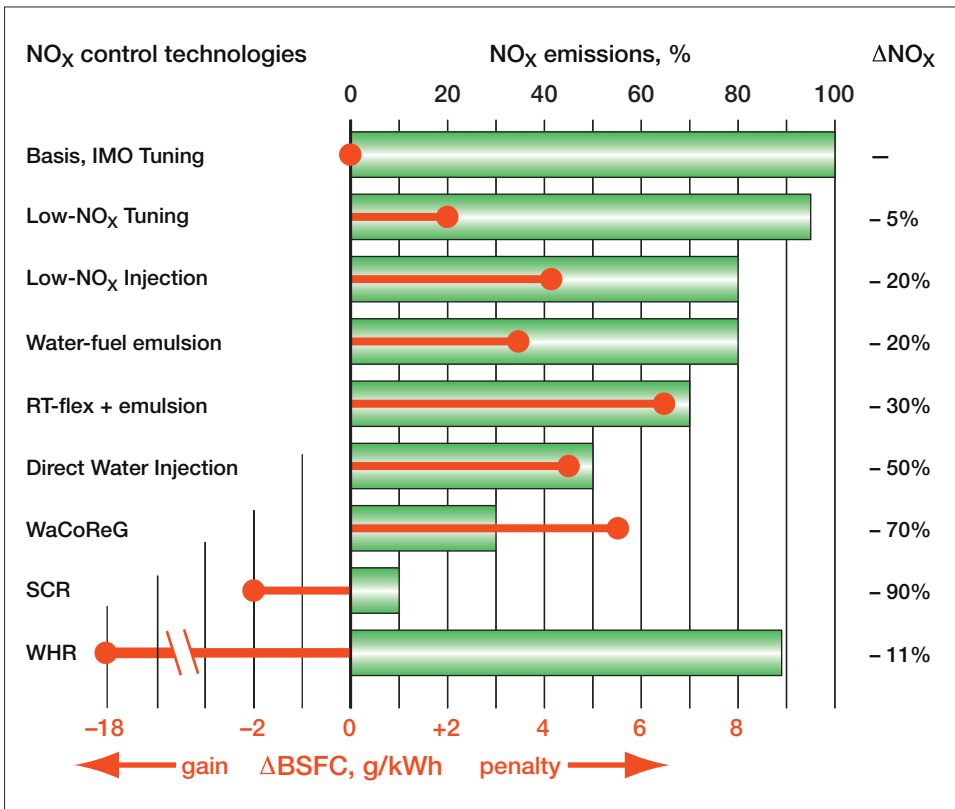


Fig. 5:
Summary of the changes in NO_x emissions and specific fuel consumption (BSFC) for various emissions control technologies. [05#025]

cent of the engine's exhaust gas flow can be branched off to drive a power turbine which is incorporated in the turbogenerator package.

The overall result of the new concept is that the quantity of energy recoverable in the exhaust-gas economiser and in the power turbine is increased without affecting the air flow through the engine. There is thus no increase in the thermal loading of the engine and there is no adverse effect on engine reliability.

Heat is also recovered from the engine's scavenge air and jacket cooling water for feedwater heating. The scavenge air coolers are designed in such a way that the boiler feed water can be heated close to the evaporation temperature.

This type of WHR plant can provide electrical outputs up to about 12 per cent of the engine power. It can thus contribute significant savings in both fuel costs and overall exhaust-gas emissions, such as CO₂, NO_x, SO_x, etc. It is the only technology commercially available today that reduces both fuel consumption and exhaust emissions at the same time (Fig. 5).

The payback time would depend upon the installation design and bunker fuel prices, but should in general be less than five years. The increasing fuel prices make the plant more attractive.

Technology developments

In parallel with designing and introducing new engine types, we also have a continuing R&D programme for developing technological improvements to upgrade the performance, reliability and durability of our existing engine types.

For example, one critically important subject for engine reliability and long times between overhauls (TBO) is piston-running behaviour. The package of design measures introduced by Wärtsilä in 1999 under the TriboPack name has achieved consistently good results in all engine types, except only the largest bore engines the RTA96C and RT-flex96C.

The design package includes multi-level cylinder lubrication, liner of the appropriate material, careful turning of the liner running surface, deep honing of the liner over the full length of the running surface, mid-stroke liner insulation to achieve optimum liner wall temperatures, pre-profiled piston rings in all piston grooves, chromium-ceramic (CrCer) coating on top piston ring, RC (running-in coating) piston rings in all lower piston grooves, Anti-Polishing Ring (APR) at the top of the cylinder liner, and increased thickness of chromium layer in the piston-ring grooves.

These design measures have resulted in cylinder liner wear rates of generally less than 0.05 mm/1000 hours while using cylinder lubricating oil feed rates of 1.0 to 1.4 g/kWh. At the same time, the wear rates of both the top and other piston rings are satisfactory for three years' between overhauls.

The lower wear rates have allowed the guide rates for cylinder lubricating oil to be reduced from less than 1.4 g/kWh to 1.1 g/kWh for all sizes of RTA and RT-flex



*Fig. 6: Piston of an RTA96C engine after testing at 110 per cent load. This piston is according to the latest design standard with chromium-ceramic rings in all grooves and with two bronze rubbing bands in the short skirt.
[05#240]*

engines built to the TriboPack standard.

Although the results of the TriboPack design measures have been excellent in all other Wärtsilä low-speed engine types, there have still been unsatisfactory numbers of liner and piston ring failures in RTA96C and RT-flex96C engines through sudden severe wear.

Further research and development has since led to a number of design measures which have already demonstrated in shipboard trials that the piston-running behaviour can be improved also in these large-bore engines.

One measure has been to introduce an underslung scavenge air receiver design as standard in the RTA96C and RT-flex96C engines. With its high-efficiency separator and more efficient drain system, it considerably improves the efficiency of condensate water removal from the scavenge air flow between the air cooler and the engine cylinders. This receiver design has proved highly successful, with virtually no water being carried over to the engine cylinders, even under high humidity, tropical conditions.

In the underslung air receiver, the scavenge air coolers are arranged horizontally beneath the turbochargers. The scavenge air is then swung round 180 degrees in its flow to the engine cylinders, in the process passing through the vertically arranged water separators in the underslung trunks from the air coolers to the scavenge air receiver. There are ample drainage provisions to remove completely

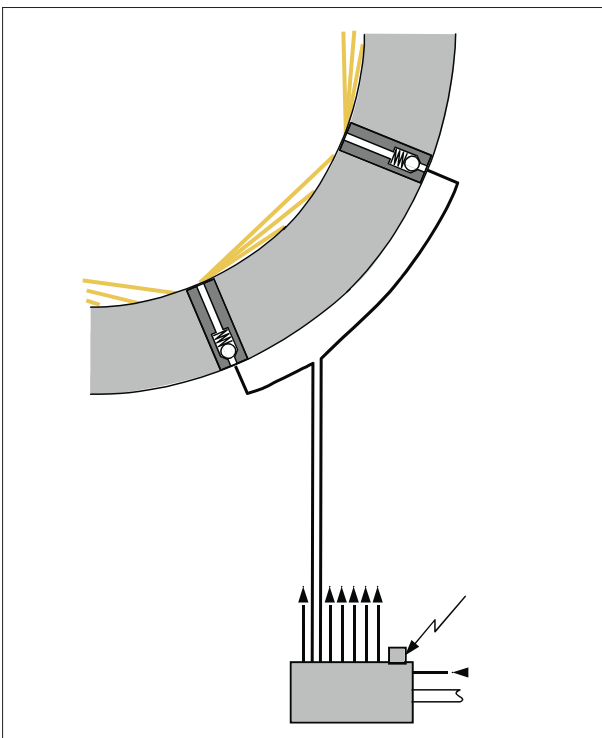


Fig. 7:
The Anti-Polishing Ring (APR) for RTA96C and RT-flex96C engines has a revised geometry with two edges to clean the piston top land during both the up and down strokes of the piston.
[05#241]

the condensed water collected at the bottom of the separator.

In the cylinder itself, the new design measures for the RTA96C and RT-flex96C include lower liner wall temperatures, chromium-ceramic pre-profiled rings in all piston grooves, plateau honing of the cylinder liner, omission of oil distribution grooves on the liner surface, bronze rubbing bands on a shorter piston skirt (Fig. 6), and improved geometry of Anti-Polishing Ring (Fig.

Fig. 8: Schematic of the Pulse Jet Lubricating System with the pump delivering cylinder lubricating oil to multiple oil jets around the cylinder liner.
[05#243]



7). There are still features such as multi-level cylinder lubrication, and chromium plating of piston ring grooves.

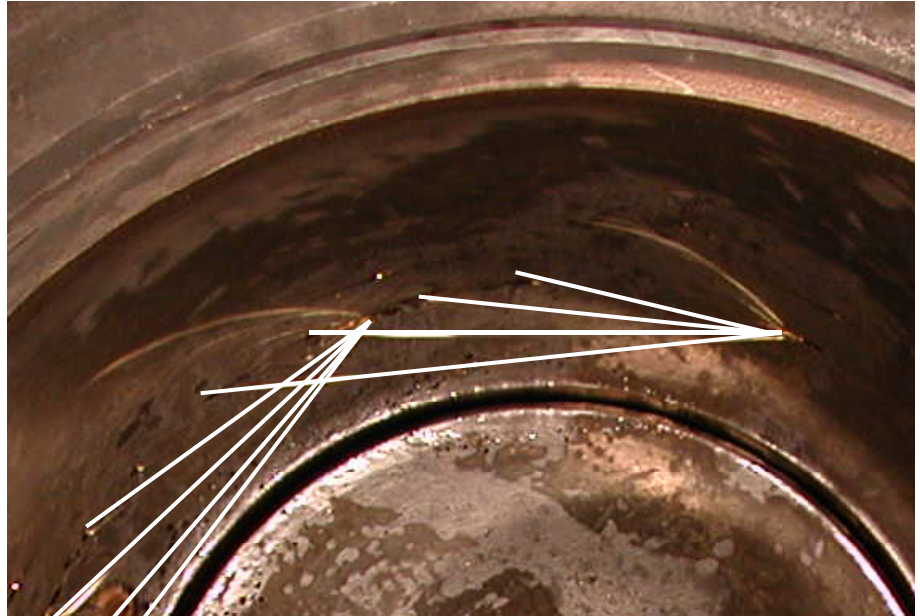
Attention is thus being given to the stability of the lubricating oil film on the liner running surface. Oil distribution grooves are now omitted because it has been found that they disturb the oil film more that it benefits from the oil distribution.

It has become clear that polishing of the liner surface by deposits on the top land of the piston crown must not occur if liner scuffing is to be avoided. Thus an improved APR geometry has already been introduced as standard with a smaller clearance between the Anti-Polishing Ring and the piston crown, and two edges to clean the piston top land during both the up and down strokes of the piston.

Another source of disturbance for the oil film is rubbing of the piston skirt on the cylinder liner running surface. A new, shortened piston skirt has therefore been introduced. Its surface is ground and it is equipped as standard with two bronze rubbing bands. These features contribute to reduced friction and thereby reduce the risk of oil film disturbance.

A reduced liner wall temperature is possible with chromium-ceramic piston rings and it has been found to have a positive effect on the oil film stability in RTA96C and RT-flex96C engines. Shipboard tests have been carried out over one year with cylinder liners having lower wall temperatures. The perfect wear results, with liner wear less than 0.05mm/1000 hours, confirm that liner wear is not increased with the above-mentioned ring pack at the lower liner wall temperatures.

The next step with respect to piston running is to introduce for 2006 a new cylinder lubrication system, the Pulse Jet Lubricating System, that will ensure improved oil distribution of cylinder lubricating oil on the running surface of the cylinder liner, with precise feed timing and dosage of lubricating oil (Fig. 8). It will thus make significant contributions to both the operating economy



*Fig. 9:
Sketch showing the arrangement
of the multiple lubricating oil jets
in the cylinder with the Pulse Jet
Lubricating System.
[05#244]*

and reduced particulate emissions of Wärtsilä low-speed engines.

The Pulse Jet Lubricating System involves the spraying of cylinder lubricating oil on to the liner surface from a single row of quills arranged around the liner, each quill having a number of nozzle holes. For RTA96C and RT-flex96C engines, there are eight quills with each quill having five oil jets giving a total of 40 lubricating points on the liner surface.

The oil jets are individually directed to separate points on the liner surface (Fig. 9). There is no atomisation and no loss of lubricating oil to the scavenge air. The quills are reliable, simple non-return valves.

Cylinder lubricating oil is delivered to the quills by a newly-developed lubricator pump which is powered by the engine's pressurised system oil. The feed rate and timing are electronically controlled through a solenoid valve at the lubricator pump. There is full flexibility in the setting

of the lubricator timing point, and volumetric metering ensures constant spray patterns across the engine's load range. The dosage is precisely regulated even for low feed rates.

Trials with the new Pulse Jet Lubricating System have proven very successful with excellent liner and piston ring conditions and low wear rates. The first shipboard installation has been running very satisfactorily with feed rates down to 0.6 g/kWh (0.44 g/bhph). The total running hours with that installation were about 8000 hours at the end of November 2005.

Conclusion

This review has demonstrated how the Wärtsilä low-speed engine business is continuing its dynamic progress. The engine programme is being adapted to the changed needs of the market, while new technology is being introduced

*Fig. 10: The 2550 TEU container ship P&O Nedlloyd Adriana, built in 2003 with a Wärtsilä 7RTA72U-B engine, is covered by the Global Service Agreement between Wärtsilä and Reederei Blue Star.
[05#245]*



to bring clear benefits to the engine users.

The RT-flex common-rail technology with fully-integrated electronic control has brought a radical advance. Its freedom in engine setting already gives proven benefits in lower fuel consumption, lower steady minimum running speeds, smokeless operation at all running speeds, and better control of other exhaust emissions. The flexibility in engine setting is also opening further avenues of development.

In addition, the engine programme is supported by a comprehensive after-sales service through the Wärtsilä world-wide network. This service goes beyond the expected parts service and technical support. For example, in May this year Wärtsilä signed its first Global Customer

Agreement with Reederei Blue Star GmbH in Hamburg, Germany, covering a substantial part of the maintenance and operation support of a number of ships in its fleet (Fig. 10).

Under this agreement Wärtsilä provides at predetermined costs the regular inspections, all maintenance planning and work, all spare parts, along with operation support and regular reporting for the main engines, generating sets and all relevant ancillary systems in the ships' engine rooms. Wärtsilä is also responsible for contract management and global coordination of these activities, and applies modern remote monitoring technologies and condition-based maintenance principles to secure reliability and achieve long-term savings.

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