Green ships on the high seas

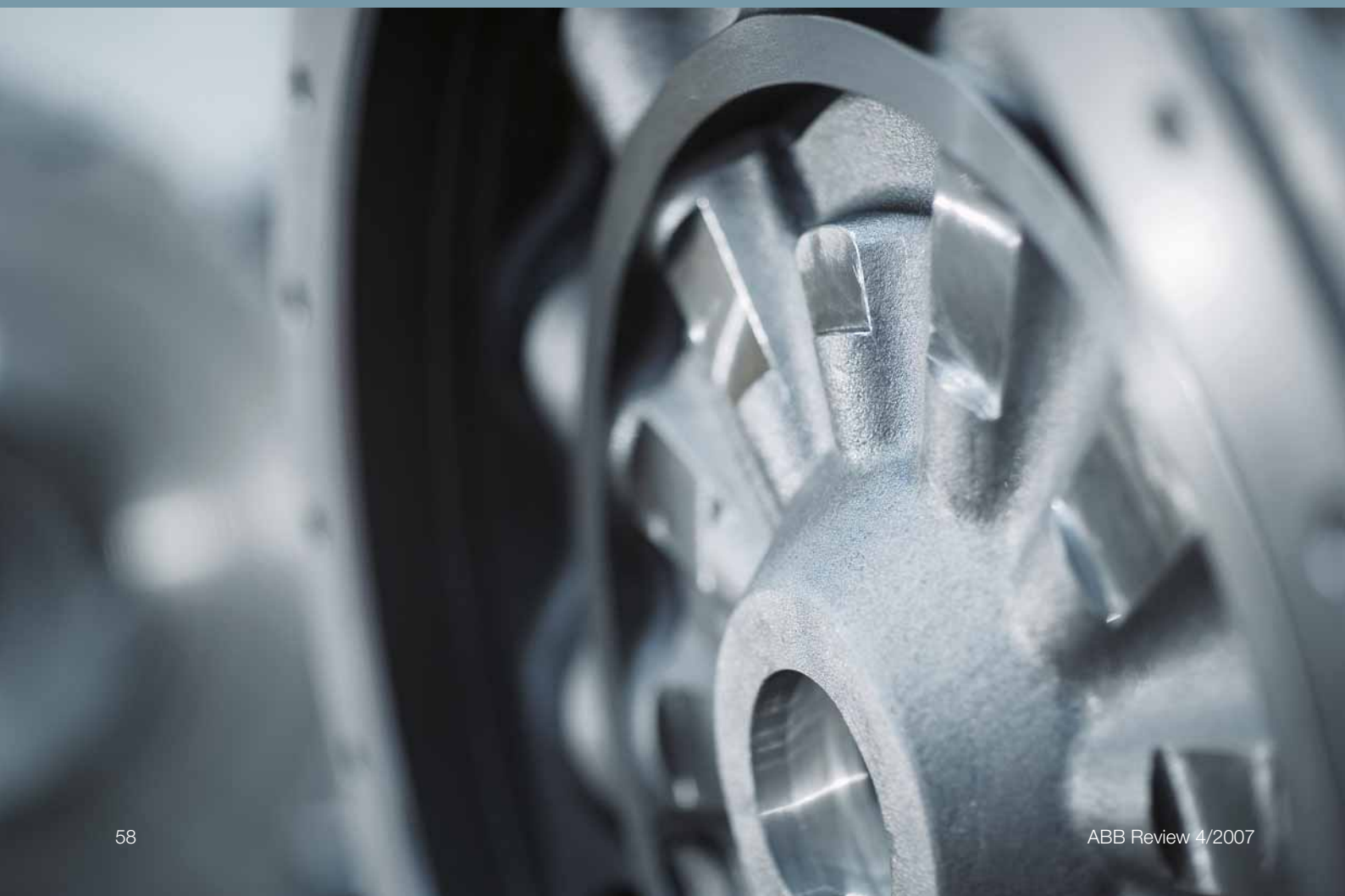
ABB power turbines boost marine fuel economy and emissions compliance

Markus Rupp

Powerful turbocharged diesel engines are the prime movers of container-ships and other large sea-going vessels. The use of turbochargers significantly increases the fuel efficiency of these big ships, and the fleet of ABB turbochargers has been helping shipowners to improve their economy for many decades.

The exhaust gas of the ships' large engines is used in waste heat recovery systems to "squeeze out" more energy from fuel. In addition, there is potential for further savings when the heat recovery is tailored to specific ships.

ABB's new generation of power turbines provides innovative ways for further increasing the efficiency of large marine engines, helping to clean up air pollution and reduce shipowners' operating costs at the same time.



A large proportion – about 25 percent – of fuel energy is lost through exhaust gas dissipation. High-efficiency turbochargers for two-stroke marine engines allow some of the exhaust gas from the engines to be used for other work. One obvious use is to divert the "surplus" gas to a power turbine (connected to a generator), which converts it into useful electrical energy. This additional onboard energy translates into fuel savings and, as a result, lower operating costs.

Shipowners have, of course, long recognized the cost and efficiency benefits of this approach, and numerous waste heat recovery (WHR) systems have been installed on large vessels in the past. Between 1985 and 1994, ABB Turbo Systems delivered more than 130 power turbines with electrical power of up to 1200 kW. Many of these early systems are still successfully operating on various types of ships and continue to save money and provide ABB with an important experience base.

The shipping industry's interest in fuel-savings, however, waned in the 1990s. Increased demand for higher diesel engine output for the ever-bigger ships required engine builders to focus their development efforts primarily on larger, more powerful units. Oil prices, which had stabilized at a relatively low level, contributed to the declining interest in fuel economy.

Energy efficiency is back on stage

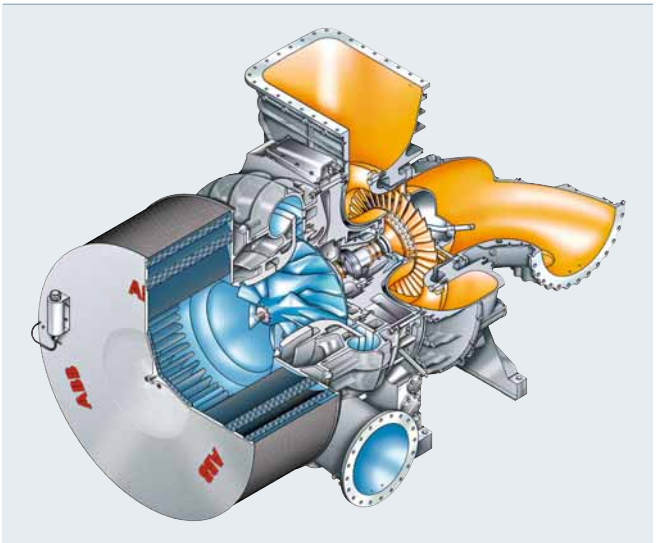
Rising oil prices and a stronger demand for environmental sustainability led to a renewed interest in energy-efficient systems in the shipping industry. In line with this clear trend, ABB began to take a fresh look at the untapped potential of WHR systems in 2001. An internal study examined the whole range of two-stroke diesel engines, with special reference to ABB's high-efficiency TPL..-B turbochargers 1 introduced in 1999.

The TPL series was greatly appreciated by the market – by the end of 2006, more than 3500 units had been delivered or specified for over 2100 two-stroke diesel engines with a total engine output in excess of 67 million bhp[1].

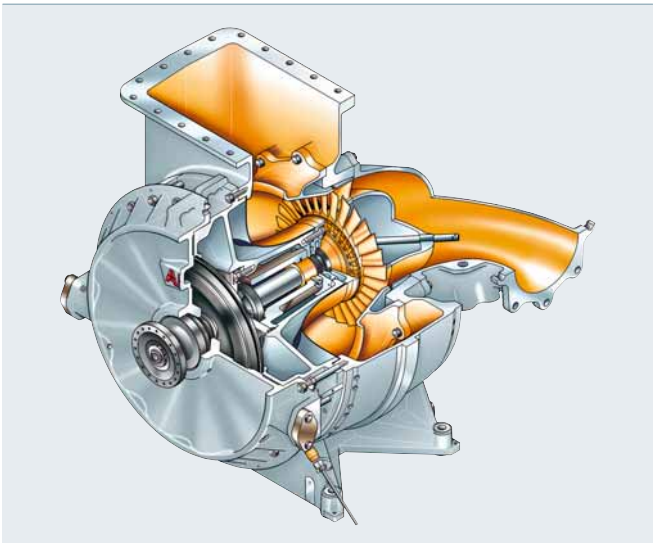
Increasing the fuel efficiency was, however, only half the battle. Environmental issues related to exhaust gas emissions from marine engines had begun to take precedence. As a result, ships will have to further reduce their exhaust emissions to comply with even more stringent legislation in the future, on top of their compliance with already strict IMO[2] regulations.

3 PTL power turbines are built in ABB's modern factory in Switzerland

1 ABB's TPL..-B turbocharger for two-stroke engines



2 PTL power turbine



Footnotes

[1] Bhp, or brake horsepower, is the power delivered directly to the crankshaft of an engine.

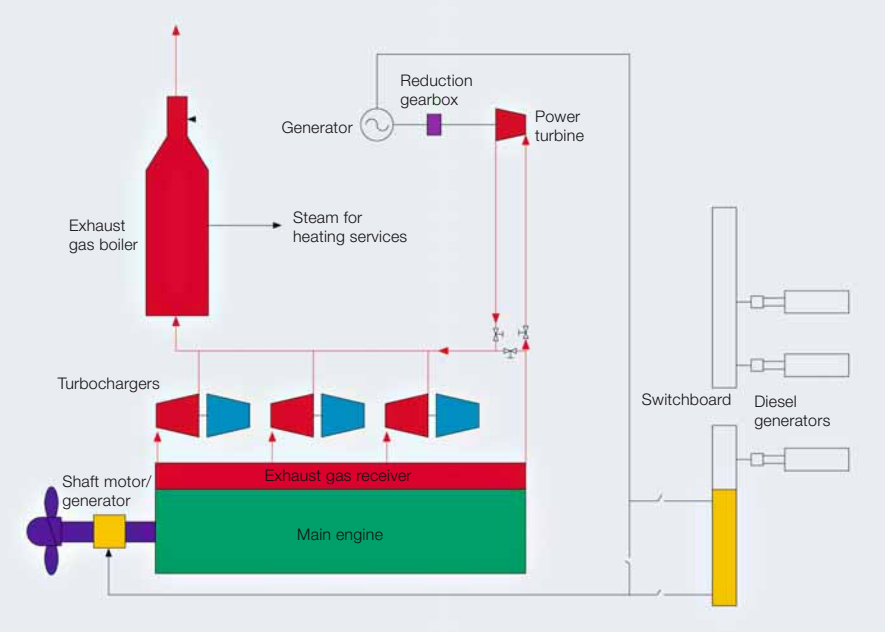
[2] IMO, or International Maritime Organization, is the United Nations agency concerned with the safety of shipping and cleaner oceans.

The market success of the TPL..-B turbochargers, and the end-users' growing interest in vessels being "green" as well as cost-effective, provided the rationale for developing a new power turbine incorporating state-of-the-art turbocharger technology. The result was the market launch in 2005 of ABB's new-generation PTL3200 power turbines, designed for an electrical output range of 1500 to 3200 kW 2 3.

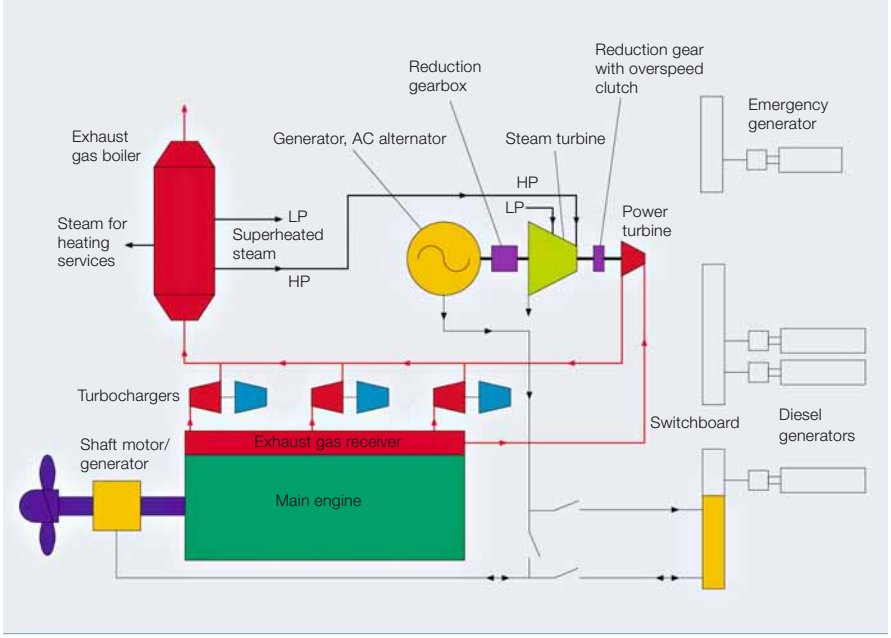
Tailor-made solutions for WHR systems

There are two types of WHR systems with power turbines for improving the fuel efficiency of a ship's main engine. The power turbine can be used in a stand-alone configuration, with its rotational energy directly used to produce electricity via a reduction gearbox and generator. The power turbine also can be integrated into a steam cycle. Waste heat recovery units with ABB power turbines are packaged by the U.K. engineering company Peter Brotherhood in close cooperation with ABB Turbo Systems.

4 Waste heat recovery (WHR) with ABB's stand-alone power turbine



5 Waste heat recovery (WHR) with ABB's power turbine and steam turbine



WHR with stand-alone power turbine

The layout of a WHR system with a stand-alone power turbine is shown in 4. The power turbine and generator unit operate in a fully automated way, feeding electrical power directly to the grid or to an optional shaft motor. Besides ensuring a supply of additional electrical energy on the ship, this configuration allows an up-to-four-percent savings in fuel consumption and exhaust gas emissions.

WHR with power and steam turbines

The saving in fuel and emissions can be increased to over ten percent with the WHR system shown in 5. In this arrangement, which makes full use of the waste heat's energy potential, superheated steam is produced in the exhaust gas boiler after leaving the turbochargers and is fed to a steam turbine, which drives the generator.

ABB's PTL power turbines address two of the most pressing issues in shipping today – fuel economy and environmental compliance.

The first WHR system combining ABB's PTL3200 power turbine with a steam turbine was installed on the recently launched M/S EMMA MÆRSK from MÆRSK LINE 6. With an official capacity of 11,000 TEU[3)], she and her seven sister vessels are the largest container vessels in the world. The giant vessel's Doosan-Wärtsilä 14RTFlex96C engine, which is fitted with four ABB TPL85-B turbochargers, develops 80,000 kW and sets new standards for environmentally friendly sea transportation. The installed WHR system delivers an additional maximum output of 8500 kW, which translates to a more-than-ten-percent reduction in fuel consumption and engine emissions at maximum continuous rating (MCR).

Finding the optimum design

While the operating cost reduction and environmental benefits of installing a WHR system are undisputed, shipbuilders must consider how de-

sign, operating and other parameters will affect profitability and payback for each individual ship. The preferred design depends on the type of vessel and its main operating conditions.

The required turbocharger efficiency for the specific ship also affects the WHR layout. The setup is greatly influenced by a) whether a turbocharger provides only the minimum efficiency a two-stroke engine requires for acceptable thermal loading of the engine components and for proper scavenging[4], or b) whether higher efficiencies are targeted.

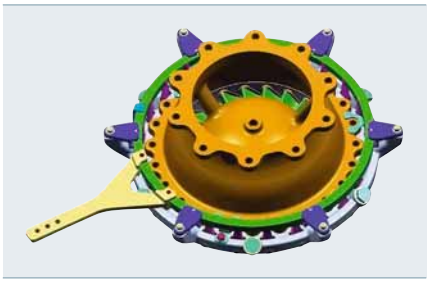
Finally, there are economic considerations – the cost of the fuel, the investment cost and the size of the vessel's power plant with its indirect influence on the electrical energy generated by the WHR system. The payback time for WHR installations is shorter when it is used in combination with large diesel engines.

Matching of the main engine and the power turbine can be further optimized by replacing the standard fixed nozzle ring with variable turbine geometry (VTG). VTG allows the performance of the main engine to be improved; eg, by reducing the nozzle area for use in hot tropical areas 7. Alternatively the turbine area can be increased at low ambient temperatures or at reduced vessel speed to maximize the power turbine's output.

The economic way to reduce emissions

ABB's calculations show that a significant reduction in CO_2 emissions is achieved with the stand-alone power turbine configuration. These reductions can even be doubled when a WHR system with a power and steam turbine is used.

7 Variable turbine geometry (VTG) allows optimal matching of the main engine and power turbine



6 In April 2007 M/S EMMA MÆRSK was awarded "Ship of the Year" by Lloyd's List as one of the most environmentally friendly container vessels ever built

The additional electrical energy for a large container vessel with a typical load profile would allow more than 2300 tons of fuel oil to be saved annually with the stand-alone arrangement and almost 5000 tons annually with the WHR system with steam cycle. In each case, the assumption is made that the additional electrical power is used to replace the power normally produced by the auxiliary diesel engines.

There are two types of WHR systems with power turbines for improving the fuel efficiency of a ship's main engine.

"Green ships" point the way forward

ABB's PTL power turbines address two of the most pressing issues in shipping today – fuel economy and environmental compliance.

While the direct economic benefits of fuel savings mainly depend on the development of fuel oil prices, the tightening of regulations for reduced emissions of vessels remains a major driving force for energy efficiency investments. The combined benefit of cost reduction and environmental compliance will pay off for shipowners. As in other industries with increased environmental focus, the value of "green shipping" should not be underestimated.

Another strong inducement to invest in waste heat recovery could be economic instruments such as differentiated port dues and tonnage taxes, already in place in several ports around the world.

In the highly competitive environment in which shipowners operate, the combination of fuel-savings and emissions reduction make heat recovery systems with power turbines an attractive business proposition.

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Footnotes

[3] TEU, or twenty-foot-equivalent-unit, is a unit that indicates the transport and storage capacity of ships and harbors, with one unit equivalent to approximately 38.5 m^3.

[4] Scavenging is the expulsion of exhaust gases from the cylinder of an internal-combustion engine.

Further reading

Summers, M. ABB turbochargers – history and milestones. *ABB Review 2/2007*, 85–90.
Turbocharging in Switzerland (2005). Turbo Magazine, 2, 1–36.