A turn for the better

New-generation A100 turbochargers for lower engine emissions

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Although fuel prices have fallen in response to the worldwide economic downturn, this trend is likely to be transitory and will no doubt rise again as the world economy recovers. Of course such a reduction in demand has a positive effect on prolonging the supply of fossil fuels and reducing emissions; however, the broader picture is one of ever increasing fuel consumption and higher emissions.

ABB's new A100 series of turbochargers has been designed to meet future demands for higher compressor pressure ratios and lower engine emissions. This new family of turbochargers provides greater engine power and fuel economy, helping to reduce emissions.

Competition for scarce energy resources, unpredictable fuel costs and stricter emissions legislation are having an important influence on diesel and gas engine development Factbox 1. The impact of these factors, together with continued trends toward higher engine power densities (power per unit volume) and higher power output also influence turbocharger technology Factbox 2.

A turbocharger is a gas compressor driven by the exhaust gases of the engine. It is designed to force air into the air intake manifold, enriching the air content of the air/fuel mix so that fuel burns more efficiently and generates more power.

Stricter emissions legislation and unpredictable fuel costs influence the development of diesel and gas engines.

High compressor pressure ratios[1] are required today not only to increase the power output, historically the main aim of the turbocharger, but also to significantly reduce emissions. They are required to increase the efficiency of, for example, the Miller/Atkinson process[2], which forms the basis of almost all modern diesel and gas engines. In diesel engines the turbocharger helps to reduce NO_x emissions, while in gas engines it is used to shift the point at which knocking begins[3]. Increased pressure ratios, generated by the turbocharger, are also required for engines operating at high altitudes. These compensate for the drop in air pressure at altitude and generally maintain an air intake pressure equal to that experienced at sea-level.

Energy-efficient engines need highly efficient turbocharging systems.

Demand for higher engine power means that increases in effective pressures (ie, the ability of the engine to do work), requires higher turbocharger pressure ratios. However, increasing the turbocharger pressure ratio must be done in tandem with combustion technology optimization. New internal-engine measurements and exhaust after-treatment systems must be considered when developing modern turbocharging systems. In short, if an engine is to be energy-efficient, its turbocharging system also must be highly efficient.

Performance – a crucial factor

During the past decade engine-builders have managed a significant increase in mean engine power output. In the high-speed engine segment, for example, this rise has been about 50 percent, while specific fuel consumption has been cut by approximately 10 percent and engine emissions have been reduced by up to 80 percent 1. Over the same period, taking the compressor power at the engine design stage for the given compressor pressure ratios and flow capacity as a reference, the technical demands made on the thermodynamic and mechanical performance of turbochargers have more than doubled. There is in general an upward trend towards increased mean effective pressures and higher compressor pressure ratios for high-speed diesel and gas engines 2. Furthermore, gas engines typically require higher pressure ratios than diesel engines due to their higher control-related system losses and different fuel management. Full-load pressure ratios of up to 5.8 during continuous operation using aluminum compressor wheels, and high efficiencies, set new benchmarks for power density in turbocharger construction, taking the known limits of single-stage turbocharging a significant step further.

From TPS to A100-M/H turbochargers

Ten years after ABB introduced the TPS series turbochargers, more than 25,000 are operating successfully on small medium-speed diesel engines and large high-speed diesel and gas engines rated from 500 kW to 3,300 kW. While these turbochargers continue to be the preferred choice for engines rated at today's power levels, market demand for engines with ever-higher power levels and

Factbox 1 Environmental impact of engine exhausts

New international regulations, for example in the marine industry and powergen sector, set strict limits for the nitrogen oxides (NO_x) and sulfur oxides (SO_x) emitted by diesel and gas engines and aim to further reduce CO_2 and soot (particulate matter) emissions. Solutions include higher boost pressures, higher efficiency, optimized air-fuel ratios and improved cylinder filling at low loads. All these criteria are supported by the newest ABB turbocharger generations.

Factbox 2 A100-L – the new benchmark for single-stage, 2-stroke turbocharging

To meet the growing performance and emissions requirements of a more environmentally oriented maritime sector, ABB is introducing to this market the biggest and most powerful member of the A100 turbocharger family, the A175-L. The A175-L is the first of the next-generation A100 turbochargers under specific development for low-speed, 2-stroke diesel engines designed for compressor pressure ratios of up to 4.7 at the highest turbocharger efficiencies.

The A100-L program caters especially for advanced two-stroke engine generations planned or under development. ABB currently supplies the 2-stroke engine market with its TPL..-B family of turbochargers, which are used on over 2,600 engines with a total output of more than 60 million kW. ABB remains fully committed to supplying the TPL..-B for present, as well as future 2-stroke engines-requiring compressor pressure ratios of up to 4.2.

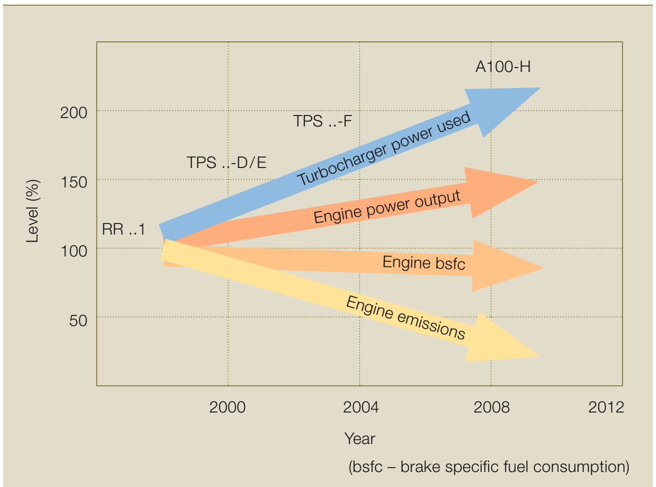
Footnotes

1) Compressor pressure ratio is the difference between the air pressure in and the air pressure out, and is always greater than 1.0. If the compressor entrance is pt2 and the compressor exit is pt3, then pt3 / pt2 = compressor pressure ratio.

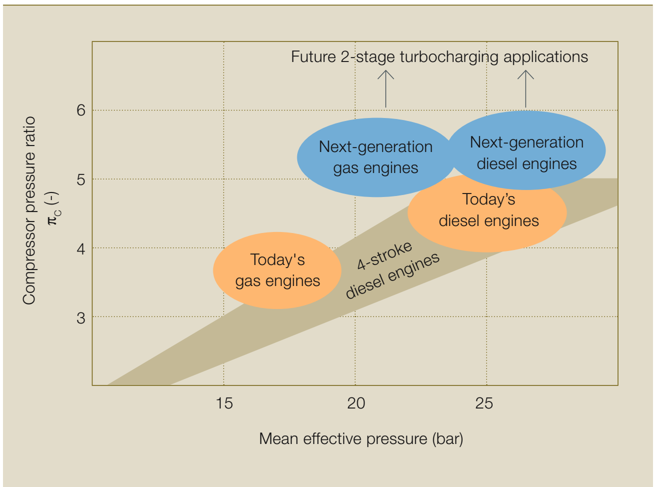
2) Combustion process innovations to the four-stroke internal combustion engine.

3) Knocking (also known as pinking or pinging) occurs when combustion of the air/fuel mixture in the cylinder starts off correctly in response to ignition by the spark plug, but one or more pockets of air/fuel mixture explode outside the normal combustion period. The disruption in the precise ignition timing creates a shock wave with a characteristic metallic "pinging" sound.

1 Increasing demands made on turbocharger performance



2 Trends in the turbocharging of modern high-speed engines



efficiencies, together with lower emissions, requires new concepts in engine design and a new generation of turbochargers. It is for these advanced engines that ABB has developed the high-pressure A100-M/H series – the A100-H series for high-speed engines and the A100-M radial turbocharger series for small medium-speed engines 3.

The frame sizes of the A100-M/H series have the same outer dimensions as the field-proven TPS turbochargers. Their oil inlet and outlet ducts are integrated in the foot to match TPS series turbochargers. This ensures that in the case of further development of current TPS-turbocharged engine platforms, these engines can be fitted with A100 radial turbochargers without having to make major changes to the turbocharger mounting. Development of a smaller and a larger A100-H frame size will depend on future market demand.

Design concept

A100 radial turbochargers are of modular construction with a minimized number of component parts designed to match the special requirements of each diesel and gas engine application. Different casing materials are available for different turbine inlet temperatures.

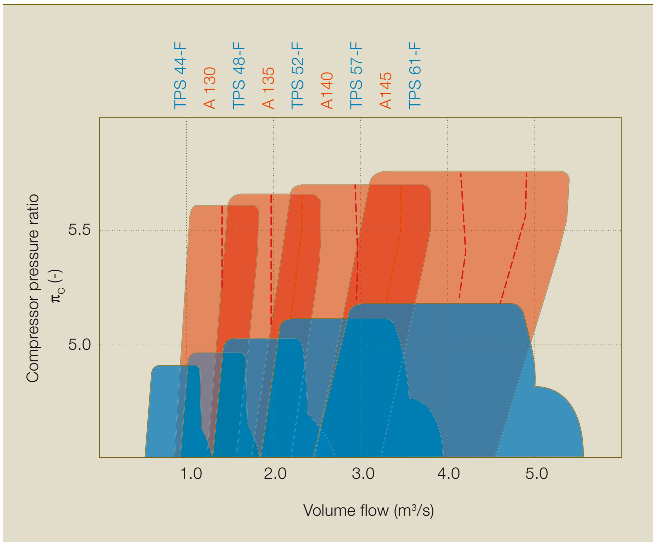
A range of specific design and configuration features enables the A100-M radial turbochargers, for small medium-speed engines, to also be used with heavy fuel oil or with pulse turbocharging systems[4]. Since the exhaust-gas temperatures of these engines are usually lower than those of the high-speed engines, the bearing casings of A100-M turbochargers can be supplied with or without water-cooling.

Aluminum compressor wheels

For the A100 radial turbocharger, ABB developed a cooling technology that allows the continued use of aluminum compressor wheels despite the very high pressure ratios under which they must now operate. This means that cost-intensive titanium components can be avoided, while maintaining the high operational reliability and long

3 New-generation A140 turbocharger

4 Pressure ratio vs volume flow range for A100 turbochargers at full load (for certain specifications even higher values can be achieved)



component exchange intervals users have come to expect from ABB turbochargers.

Cooling with compressor air was shown, by an extensive test program, to be the most efficient and least costly solution for engine builders to implement. The concept is already proven in the field, having been offered for several years as an optional feature for the larger ABB TPL..-C turbochargers.

Turbocharger containment test
The construction of the casing that surrounds the A100 series turbochargers takes full account of the much higher mechanical demands made upon them. During their design, ABB worked closely with engine-builders to ensure optimal mounting of the turbocharger on the engine console and to maintain the compact dimensions of the earlier TPS series. The safety specifications for the turbocharger housing, a vital consideration in view of the significantly increased power density, have been verified both numerically and experimentally using turbocharger containment tests.

In addition to higher casing specifications a stronger shaft to cope with greater power transmission was required. Such a change to the shaft specification meant that a stronger bearing assembly, which was based on the earlier TPS bearing technology, was needed. Furthermore, to retain and ensure safe and efficient turbocharger operation, the A100 series turbines feature a device used successfully in ABB's TPS..-F turbochargers, which maintains turbine centering within the casing.

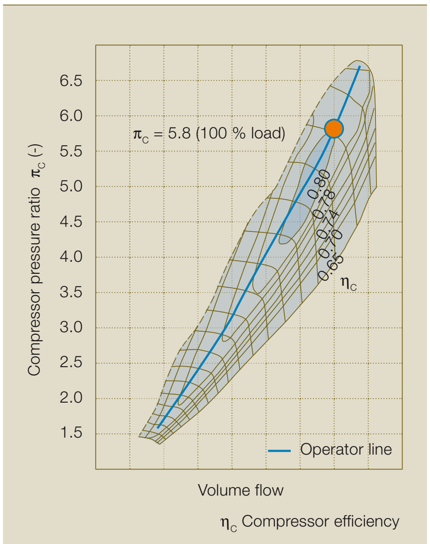
Cooling technology for the A100 radial turbocharger allows the continued use of aluminum compressor wheels, avoiding the use of costly titanium components.

Thermodynamic performance
For the new A100-M/H turbochargers ABB has developed three entirely new compressor stages, each with different compressor wheel blading. These provide significantly higher pressure ratios, while maintaining the compressor volume flow range offered by today's TPS..-F turbochargers 4.

The A100 turbocharger features a single-piece aluminum compressor wheel. New high-pressure diffusers[5] and compressor blades were developed in addition to innovative wheel cooling to ensure that the full-load pressure ratios of about 5.8 could be achieved with aluminum wheels. A range of compressor stages is available for every turbocharger frame size, allowing optimal matching to every application. The compressor map in 5, which is based on measurements taken on the recently released A140 turbocharger, shows the high efficiencies, excellent map widths and more than adequate over-speed margins achieved. 80 percent compressor efficiency is achieved on a typical operation line for a full-load pressure ratio of 5.8.

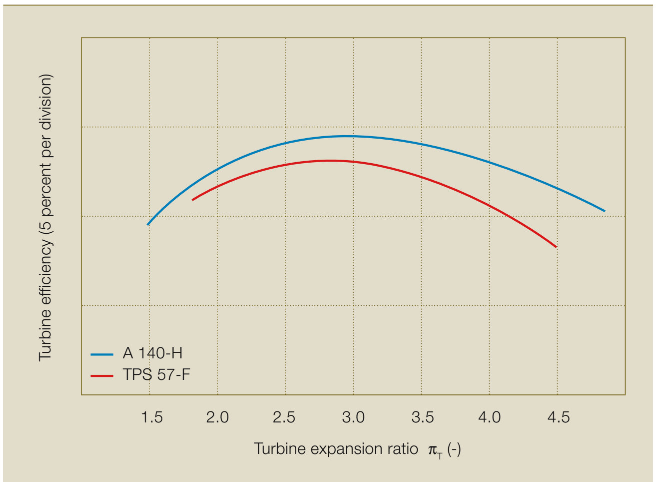
New turbine stages
In addition to the existing TPS mixed-flow turbine stage, a new generation of mixed-flow turbines have been developed for use with the A100 turbochargers.

5 Compressor map (A140-H)

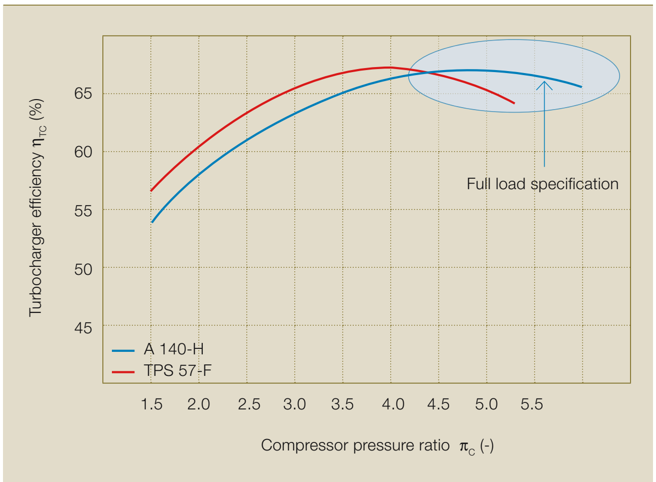


Footnotes
[4] In pulse turbocharging, the turbo's turbine inlet is coupled via narrow pipes to certain engine cylinders such that the turbine is subjected to a pulsating flow field synchronized with the opening and closing of the engine valves.
[5] The diffuser, located behind the compressor wheel, converts the kinetic energy into static pressure.

6 Turbine efficiencies compared, A140-H and TPS57-F



7 Turbocharger efficiency of A140-H with full-load-optimized specification



A characteristic of this new turbine family is a larger operating range. This allows the high pressure ratio potential of the new compressor stage to be exploited over an even wider range of application. The turbine's design has been optimized for each specific volume flow range, resulting in higher turbine operating efficiencies than the current TPS turbine stages. Flexible seals have been introduced to further reduce flow losses. This has allowed a substantial improvement in turbo charging performance at higher boost pressures 6.

The new-generation A100-series turbochargers represent a quantum leap in turbocharger development for single-stage turbocharging of modern medium- and high-speed engines.

A quantum leap in development

A wide range of available compressor and turbine specifications makes ABB's A100 series of turbochargers ideally suitable for marine, industrial and power generation as well as traction sectors. A comparison between the A100 and TPS family of turbochargers shows the outstanding thermodynamic potential of the new generation turbocharger, in the case of a full-load-optimized turbocharger specification 7. This comparison with TPS turbocharger efficiency illustrates well the performance gained using A100 turbochargers at precisely the range of compressor pressure ratio new engine designs demand. The new generation A100 series turbochargers represent a quantum leap in turbocharger development for single-stage turbocharging of modern medium- and high-speed engines.

Qualification program

The ABB A100 family of turbochargers, like all newly developed turbochargers, was subjected to a mandatory qualification program using combustor test rigs to ensure their reliable operation in future engine applications. The comprehensive series of tests ranged from thermodynamic checks made on new compressor and turbine stages to the mechanical qualification of all newly designed component parts.

The new A100 turbochargers are designed to be operated in high-pressure, continuous-duty applications, at higher speeds than the TPS turbochargers. Extensive shaft motion measurements were performed on the A100 radial bearing assembly at speeds of up to 120 percent overspeed to ensure the rotor dynamics of the new components perform optimally at speeds beyond the current TPS speed range. The combination of the new radial bearing assembly with the new compressor and turbine stages displayed excellent stability characteristics at the required high operating speeds.

Maintenance and service

The maintenance intervals for the A100 turbochargers are similar to those of the TPS family of turbochargers. Although the demands made on thermodynamic and mechanical performance are higher, the new A100 generation of turbochargers will satisfy the requirement for high reliability and low-maintenance operation. A network of 100 ABB service stations around the world provides the necessary service know-how and logistical support to satisfy the needs of customers. Customers using advanced diesel and gas engines fitted with A100 series turbochargers can rely on ABB's customary delivery of high standards in performance and maintenance of this new generation of turbochargers.

Introduction program and early results

In mid-2007 the first A140 prototypes were successfully commissioned on ABB test rigs. The rigorous examination program was successfully completed for this first frame size of the new turbocharger series and has been released for series production Factbox 3. ABB is currently introducing further sizes of the A100-M/H turbocharger to the marketplace.

In the run-up to the introduction of the A100 series, engine test rig trials were carried out to verify the thermodynamic performance. The high pressure ratios and efficiencies that can be achieved with the A100 series clearly demonstrate that these turbochargers can accommodate the high power densities expected for future engine requirements. Hundreds of hours of continuous operation on the test rig have also confirmed the high performance level of the A100 series. These new generation turbochargers are currently under trial at selected field installations. Successful engine trials of further frame sizes are already under way.

Factbox 3 The A140-H turbocharger

At Luttelgeest in the Netherlands, power generators, in a combined heat and power plant used to heat large greenhouses, have been fitted with A140-H turbochargers. Here the CO_2 produced by the generators is used to increase plant growth.

A140-H turbochargers run on power generators in large greenhouses at Luttelgeest in the Netherlands.

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