

Edited by **David Alexander**

Boosting a range of engines

BorgWarner Turbo Systems has been developing its turbocharger technology to bring performance and efficiency gains to a variety of engine sizes and types. The company worked closely with **Audi** to develop the world's first gasoline engine to use both direct injection and a turbocharger—the Audi 2.0-L Turbo FSI.

The engine combines the advantages of the fuel stratification ignition (FSI) combustion process with the benefits of exhaust gas turbochargers. The result is a unit that offers high power and torque with moderate fuel consumption—all while meeting EU4 and ULEV2 exhaust

emissions regulations as well as the future onboard diagnostic provisions. The engine was recently introduced in the Audi A3 Sportback, and is now available on the Audi A4, the **VW** Golf GTI, and the VW Passat. The collaboration resulted in an integrated module that represents the further development of BorgWarner's K03 turbocharger.

And BorgWarner Turbo Systems is continuing to expand its business in Asia. In March 2005, series production was started for **Hyundai** in Korea. The first product is the BV43 turbocharger, manufactured at the joint venture company **SeohanWarner Turbo Systems** that BorgWarner Turbo Systems founded together with automotive supplier **Korea Flange Company** in February 2004. The company chose the BorgWarner Engine Group factory in Pyongtaek as the production site, which is where **BorgWarner MorseTec** is already producing systems for Hyundai.

The turbocharger with variable turbine geometry (VTG) is installed in the diesel engine for the new **Kia** Sorento 2.5-L CRDI VGT, which initially will be available only in the Korean market. The BV43 turbocharged direct-injection diesel engine delivers about 25% more power than its predecessor with a wastegate. The development of the engine was also focused on obtaining higher torque and smoother running while achieving better fuel economy and lower emissions.

With its new BV technology, BorgWarner Turbo Systems is presenting the third generation of turbochargers with VTG. Compared to the predecessor models, the latest BV technology offers improved thermodynamics and optimized control behavior while at the same time ensuring greater reliability.

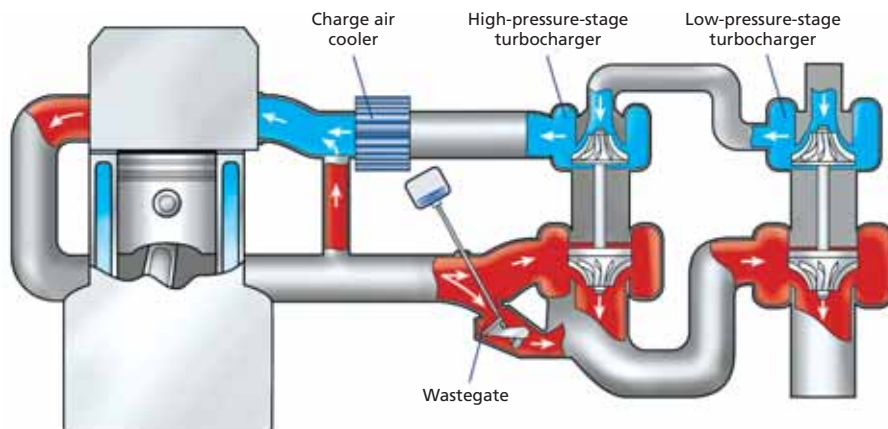
Turbocharging is also important in the heavy-duty market. Commercial vehicle engines need to develop high torque to allow the vehicle to pull away on a hill, while at the same time provide sufficient power at low engine speeds to maximize fuel economy when driving on highways. Power output, fuel consumption, and



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A turbocharger with variable turbine geometry from BorgWarner Turbo Systems is installed in the diesel engine for the new Kia Sorento, which initially will be available only on the Korean market.



With its R2S, BorgWarner Turbo Systems has developed a regulated two-stage turbocharger system in which two turbochargers of different size are arranged in series.

emissions control in particular will make extreme demands on future turbocharger technology as the stricter Euro 4 emissions standards come into force.

Now that the exhaust turbocharger with VTG has become the state of the art in diesel engines for passenger cars, and to some extent for commercial vehicle applications, the limits of single-stage turbocharging have almost been reached. A further increase in the rated power usually leads to reduced starting torque.

So while achieving a further rise in the rated power of an engine would require the use of a larger turbocharger, to ensure that a high boost pressure is generated at low engine speeds the turbine and compressor would have to be made much smaller. The ideal solution would therefore be a combination of both.

With its R2S, BorgWarner Turbo Systems has developed a regulated two-stage turbocharging system that provides a solution. This technology, first seen on

the **BMW 535d**, can now be adapted to the commercial vehicle market. It allows an infinitely variable adaptation of the turbine and compressor side to any engine operating point.

In regulated two-stage turbocharging, two turbochargers of different size (a large low-pressure turbocharger and a small high-pressure turbocharger) are arranged in series. Unlike the system used in passenger-car applications, regulated two-stage turbocharging for commercial vehicles has only one bypass valve as an actuator on the high-pressure turbocharger. In this arrangement, the turbochargers are tuned so that both of them are active at all engine operating points. The boost pressure is controlled by the external bypass, allowing continuous control without any drop in pressure.

"Regulated two-stage turbocharging can now provide commercial vehicles with a technology that meets the highest power requirements and complies with future emissions standards," said Hans-Peter Schmalzl, Vice President, Technology, BorgWarner Turbo Systems.

David Alexander

Bosch keeps the pressure up



Bosch manufactures piezo-inline injectors for the third generation of its common-rail injection system. Compared to the previous system, this injection technology is capable of lowering diesel engine fuel consumption by approximately 3% and cutting emissions by up to 20%.

High injection pressure equates to lower particulate emissions for diesel engines, which is a primary reason researchers are pursuing higher and higher pressures in the search for clean diesel technology.

"We have different scenarios which we are following. For one scenario where we need high-pressure injection, we have the HADI (Hydraulically Amplified Diesel Injector) available. But we also have other strategies," said Stefan Kampmann, Senior Vice President of Engineering for Diesel Systems at Robert **Bosch** in Stuttgart, Germany.

Since 2003, Bosch has spotlighted common-rail injectors using piezo-inline technology. Piezo-inline technology increases from 1600 to 1800 bar (23.2 to 26.1 ksi) this year, but a 2000 bar pressure (29 ksi)—with a 45% engine-out reduction in NOx and particulate matter—will be available in 2007. To handle 2000 bar (29 ksi), the injector and other associated components must be able to withstand the mechanical forces generated by such high-pressure.

"We have to make sure that we get advanced-high-strength steel in the appropriate tolerances. Each injector has to have this advanced-high-strength steel, otherwise we would have a break or a crack in one of the injectors," said Kampmann, adding that a quality manufacturing process for high-volume production is an equally important necessity.

Since emissions regulations are a moving target, Bosch engineers are working on various pollution-reduction technologies. HADI—a technology that could see up to 2500-bar (36.3-ksi) pressure with five injections per cycle—is one example of a solution that is under development.

"The basic requirements of what we see today would mean one pre-injection to keep the noise under control, a second pre-injection to keep the emissions of the first pre-injection under control, a main injection to make the energy for the powertrain, and post-injections—the first closed post-injection to reduce soot emissions and another post-injection for the regeneration of the after-treatment

devices, like diesel particulate filter or NOx catalyst," said Kampmann.

If chosen as a production solution, HADI could be ready as early as 2010. "The biggest challenge with HADI is basically the dynamics of the injection system—meaning the generating of small pre-injections—as well as having the needed processes to assure the quality of the system in high production numbers," Kampmann said.

The HADI is being investigated on a 2.0-L engine. "In our advanced development department, we're doing HADI on a four-cylinder to test the HADI's performance in a real engine," Kampmann said.

Bosch engineers also are evaluating the use of split-injection for use with Piezo-inline technology. "The basic combustion process is a homogeneous combustion process, but chopped-injection—even for the main injection—would be split into

three or four portions and would mean up to 10 injections per cycle," said Kampmann, adding, "This approach could be a totally different combustion strategy, which would require another kind of injector system." Although a further developed piezo-injection system could pan out as the most promising application for split-injection concepts, the HADI is another split-injection application possibility.

Kami Buchholz

Big expectations for dual clutch

Getrag expects its dual-clutch transmission (DCT) to hit production overdrive in the next decade as more vehicles are fitted with the gearbox.

Based on market study analysis, talks with OEMs, and other inputs, Getrag officials expect that the technology will reach a 29% market share by 2015 in Europe. In the Asia-Pacific region—minus Japan—the growth of dual-clutch transmissions is expected to reach 13% in 2015. That's a big shift from 2005, when the technology had a 1% market penetration in Europe and basically was non-existent in Asia-Pacific other than in Japan.

Getrag brings its dual-clutch transmission to the marketplace with the start of production in 2007. "A DCT uses manual gearbox technology as two transmissions in one, which means that one clutch operates odd-numbered gears and the other clutch operates even-numbered gears," said Stephan Rinderknecht, Getrag's Vice President of Research and Development.

Getrag will release five versions of the DCT based on four different architectures. The MPS6 and the SPS6 models are front transverse layout designs with six speeds. "They share the same hydraulics, electronics, and the same clutch," said Rinderknecht. The other versions are the DCT 477, a seven-speed transaxle longitudinal design that can handle 700 N·m (516 lb·ft); the DCT 436, a seven-speed inline design that handles up to 600 N·m (443 lb·ft); and the DCT 250, a six-speed front transverse layout using dry clutches that can deal with 250 N·m (184 lb·ft).

The DCT—depending on the design—uses wet or dry clutches, employs hydraulic or electromechanical actuation, adjusts



Getrag's Stephan Rinderknecht stands next to the company's DCT 477, a seven-speed dual-clutch transmission.

launch behavior via software, and provides high-speed capability (9000 rpm or beyond). "It's a much more flexible transmission than a traditional automatic transmission," said Rinderknecht, adding, "There are a large variety of possibilities of how a dual-clutch transmission can be built."

Getrag is investing €340 million to build a new facility in Slovakia for the production of transverse/transaxle DCTs for front-wheel-drive vehicles. Production of DCTs for inline and longitudinal transaxle applications will occur at Getrag's

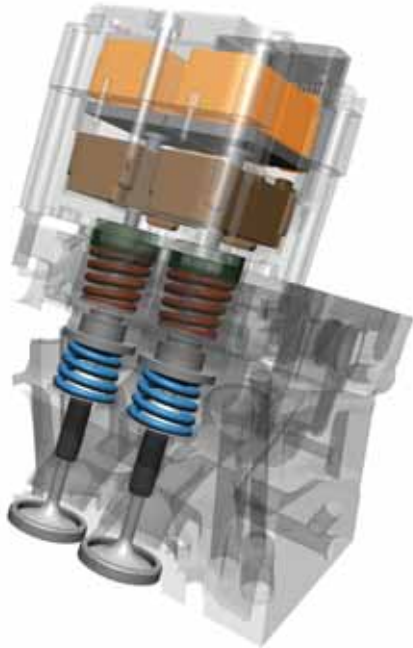
plant in Neuenstein, Germany, which currently is producing a variety of transmissions. DCTs will be mated to gasoline as well as diesel engines in the four- to ten-cylinder range.

A next-generation DCT is likely to reach the marketplace sometime after 2011. "We already have a lot of ideas to improve the DCT technology, especially in terms of fuel economy and the integration of all-wheel-drive functions," said Rinderknecht.

Kami Buchholz

Valeo pushes engine valves

Valeo is actively developing technology for reducing fuel consumption and emissions with an engine cylinder-head design



Valeo calculates that its Smart Valve Actuation technology will be able to reduce fuel consumption and pollutant emissions by 20% while increasing low-speed torque.

that uses its Smart Valve Actuation (SVA) in place of the conventional mechanical operation of engine valves by the cam belt, camshaft, and hydraulic cam followers. SVA is the first of many innovations that Valeo intends to actively develop and market to meet increasing demand for better fuel economy and reduced pollution following its recent acquisition of **Johnson Controls'** Engine Electronics Division, according to Chairman and CEO Thierry Morin.

In a camless engine, each engine valve is operated individually by an actuator that is placed on the upper surface of the cylinder head, directly above the valve guides. Each actuator is linked to an engine-mounted valve control unit (VCU) that ensures the optimal positioning of all valves and performs the power drive function. The actuator includes an upper and lower electromagnet for each valve, with an armature vane between the two that is connected to the valve stem.

When the upper electromagnet is activated, the vane is pulled upward, and the valve is moved to its closed position.

When the upper electromagnet releases, the vane is pulled down by springs, and

the lower electromagnet energizes to maintain the valve in the open position. Each valve operates independently from the others, and from the piston position.

Two different systems are currently being developed at Valeo, each one including: actuators, VCU, wiring rail, and the electronic control unit, with specific strategies dedicated to these new concepts. The first one is called "full camless" as it manages the valves on both the intake and exhaust side of the engine. The second one is called "half camless" as it manages the inlet valves only.

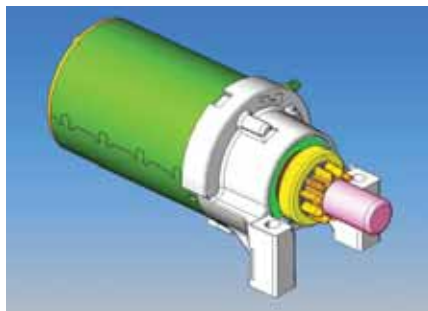
By controlling residual gases, minimizing pumping losses, and deactivating cylinders and valves, this technology can reduce fuel consumption and pollutant emissions by 20%, according to Valeo. Consumers will also benefit from enhanced performance and driving comfort, due to an increase in low-end engine torque. The SVA development program is currently being undertaken with support from several leading car manufacturers and is scheduled for volume production in 2009.

David Alexander

Top-mounted solenoid makes space

Starter motors for gasoline engines were originally designed to allow the pinion mounted on the starter motor shaft to be driven along a helix by the inertial forces created as the starter motor armature accelerates. The pinion moves forward along the shaft helix until it engages the ring gear attached to the engine crankshaft. The motor torque then rotates the engine until it spins fast enough for the ignition system to operate. Once the engine runs under its own power, the electric power to the starter motor is turned off and the pinion is released from the ring gear.

A recurring problem, though, is that the pinion can accidentally become disengaged if the engine misfires, which necessitates a restart of the starter motor. Occasionally, the pinion can suffer a 'bounce-out' or 'pump-out' that results in the pinion oscillating along the starter motor shaft, causing rapid wear of the pinion and alarming noises. This problem



Engineers at Johnson Electric have developed a top-mounted solenoid to save space in the engine compartment.

was solved by adding a magnetic solenoid to the side of the starter motor to secure the starter motor pinion while engaged with the ring gear on the engine until the starting of the engine was certain.

However, engine compartments have become increasingly crowded as more devices are added to engines to increase efficiency and reduce emissions. Starter mo-

tors with side-mounted solenoids take up more valuable space than necessary, and the side mounting also results in the solenoid experiencing considerable vibration.

Engineers at **Johnson Electric** studied the problems and developed a solution called the 'Top-Mounted Starter Motor Solenoid,' changing the shape of the starter motor to economize on space and reduce the degree of vibration to which the solenoid was subjected.

Johnson Electric engineers decided to mount the solenoid between one end cap of the motor and the extended shaft along which the pinion travels. With this design there are no circumferential extensions and it is easier for engine compartment designers to find space for the starter motor. It also provides greater flexibility for routing other components such as intake and exhaust manifolds. Engines can be horizontally or vertically mounted without requiring any modification of the solenoid location.

The new starter motor has the solenoid located between the end of the motor and the extended shaft that carries the engagement pinion. The action of the solenoid helps push the pinion to its engagement position, holding it securely in place until the engine has started, and then retracting to its rest position.

In an un-energized system the return spring holds the pinion close to the solenoid coil. The coil is energized as current

passes into the starter motor. The magnetic field generated by the coil causes the pinion to move to the end of the shaft and compress the return spring. The electromagnetic force ensures that the pinion remains engaged with the ring gear until the engine has properly started.

When the engine has fired and the energy to both the starter motor and the solenoid has been switched off, the return spring forces the pinion and solenoid

armature back to the original position.

Johnson Electric engineers have retained the advantages of a positive-engagement starter without positioning the solenoid on the side of the starter motor, thereby creating a more space-efficient design that also subjects the solenoid to less vibration.

This article was written for *AEI* by **Darin Bremmer** of Johnson Electric.

South Korean automakers go for VGT

South Korea's fourth-largest automaker, **Ssangyong Motor**, has launched its entry-level, five-seat Actyon small SUV with a four-cylinder 2.0-L diesel XDi200 XVT engine that delivers 145 hp (108 kW). The new engine is boosted by a third-generation turbocharger system and is the improved version of the XDi270 installed in the company's Kyron and new Rexton models. Power and torque are increased at both low and high speeds through precise electronic controls.

Compared with existing small SUVs in South Korea armed with second-generation variable-geometry turbochargers (VGTs), the Actyon engine claims higher fuel efficiency. The automaker also said its XDi engine is controlled by a pilot injection system, which has a 1600-bar (23.2-ksi) high-pressure injection system and high-speed 32-bit engine control unit. The Actyon is based on the platform of Ssangyong's larger SUV, the Kyron.

According to Ssangyong, the Actyon's diesel engine could satisfy EURO 3 and 4 emissions standards. Europe is the automaker's largest overseas market, accounting for nearly 50% of its

total annual exports. Ssangyong Motor is currently selling the Rexton, Rodius, and Kyron in its main European markets of Spain and Italy.

"We plan to sell the Actyon in Europe in the second half of next year," said Soh Jin-Kwan, President of Ssangyong Motor. "After that, we will be selling the Actyon in the fast-growing Chinese market in addition to the new Rexton, new Chairman sedan, and Rodius that are currently sold in the country, although the market is currently gasoline-oriented."

Figuring that the Chinese market could shift to diesel in the future, Soh said Ssangyong Motor hopes to build a lead in the potential diesel market by adding the four-cylinder Actyon to its lineup in China.



Ssangyong has launched the Actyon in South Korea with a four-cylinder diesel engine to compete with the Hyundai Tucson and the Kia Sportage.



The XDi 200 XVT diesel engine featured in Ssangyong Motor's Actyon small SUV delivers 145hp (108 kW).



The 1.5 VGT engine is used in Hyundai's new Avante model.

Ssangyong Motor targets 36,000 sales of Actyon in the next 12 months in the Korean market against segment leaders Sportage from **Kia** and **Hyundai's** Tucson.

Regarding the ongoing discussions with **Shanghai Automotive Industry Corporation** (SAIC) to build a Ssangyong Motor plant in China, Soh said Actyon is expected to be built in the Chinese market in the future.

"Although the discussions are being processed step by step, we haven't reached a final agreement yet on when and where we will build the plant, but we

will be producing the two products—Kyron and Actyon—in the potential Chinese plant," Soh said.

Earlier this year, Ssangyong Motor launched the crossover Kyron SUV, the first product since SAIC, the joint venture partner in China of both **General Motors** and **Volkswagen**, took over the Korean automaker in late October last year.

South Korea's top automaker, Hyundai, meanwhile, launched the new Avante XD compact with a 1.5-L VGT engine, which enhances fuel efficiency more than 30% over the previous version and delivers more enjoyable driving.

Compared with the current gasoline engine, the 1.5 VGT enhances low-end torque more than 60%, providing significantly better acceleration. Engine noise is greatly reduced through the pilot fuel-injection system, while a new transmission enhances stability and endurance, the automaker claims.

Kia's all-new 1.5 CRDi diesel engine features common-rail technology and a VGT. This new engine produces 109 hp (81 kW), has a CO₂ rating of 116 g/km, and meets Euro 4 emissions criteria.

Peter Chang

Increased cooling performance from Denso

Denso has developed a double-pipe internal heat exchanger for automobile air-conditioning (A/C) systems that increases cooling performance by up to 12%. Denso claims to be the first to develop

such technology that can be installed in a limited space. The new A/C system was introduced recently in the Middle East on the **Toyota** Prado and in North America on the **Lexus** GX 470.

The double-pipe internal heat exchanger integrates two pipes, which are

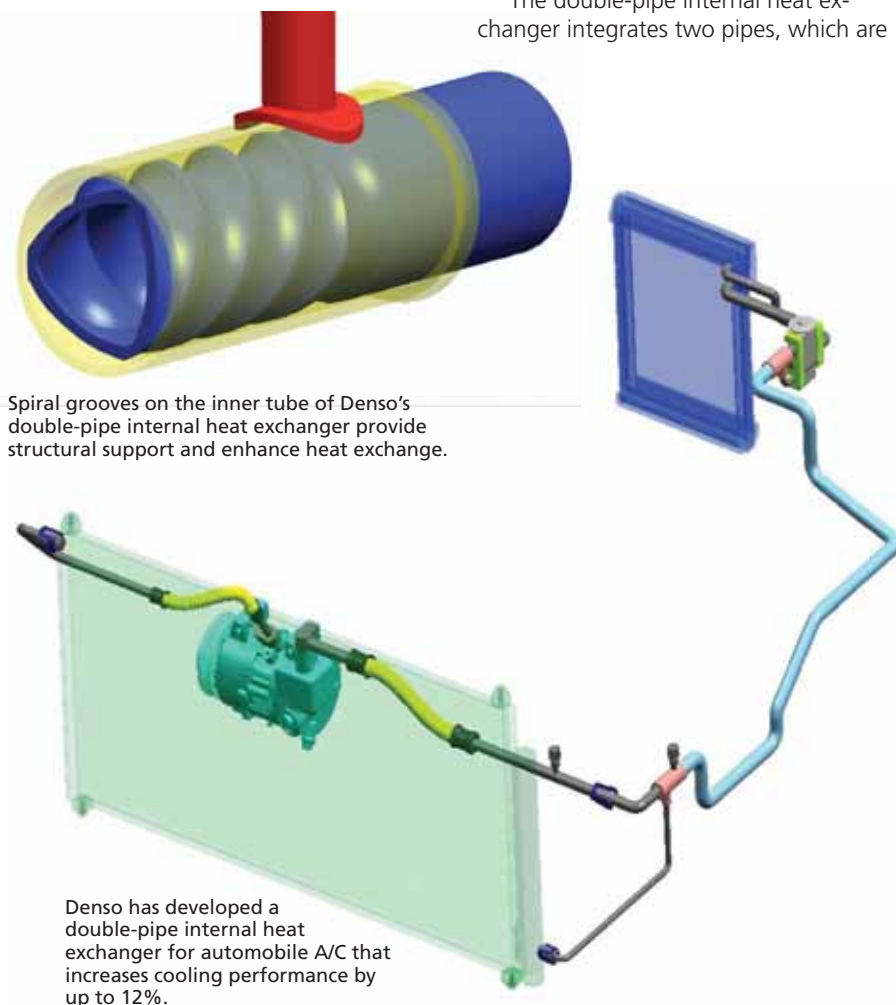
separated in a conventional refrigeration cycle, into a single pipe with inner and outer tubes. In the refrigeration cycle, the low-temperature gaseous refrigerant flows in the inner tube and exchanges heat with the high-temperature liquid refrigerant flowing in the gap between the inner and outer tubes.

In Denso's double-pipe internal heat exchanger, the inner tube wall has spiral grooves that face the outer tube, enhancing heat exchange. This design allows the internal heat exchanger to achieve high cooling performance over a short pipe length. With this unique structure, Denso's double-pipe internal heat exchanger can increase cooling performance by 5 to 12% at the same power level as a conventional system, with a length of only about 400 mm (16 in).

When an A/C system is installed in an engine compartment, the pipes need to be flexible so they can be bent to fit with and around other systems and components. However, with a double-pipe internal heat exchanger, the gap between the inner and outer tubes could be crushed during the bending process, making it unable to function as a refrigerant path.

Denso's solution to this problem was to make the spiral grooves on the inner tube wall structural. As a result, the tubes are not crushed when bent, and A/C systems using Denso's double-pipe internal heat exchanger can be installed in the same space as a conventional front A/C system. Manufacturing is a simple process of inserting the inner tube into the outer tube and fixing the tubes at both ends.

David Alexander



Spiral grooves on the inner tube of Denso's double-pipe internal heat exchanger provide structural support and enhance heat exchange.

Denso has developed a double-pipe internal heat exchanger for automobile A/C that increases cooling performance by up to 12%.