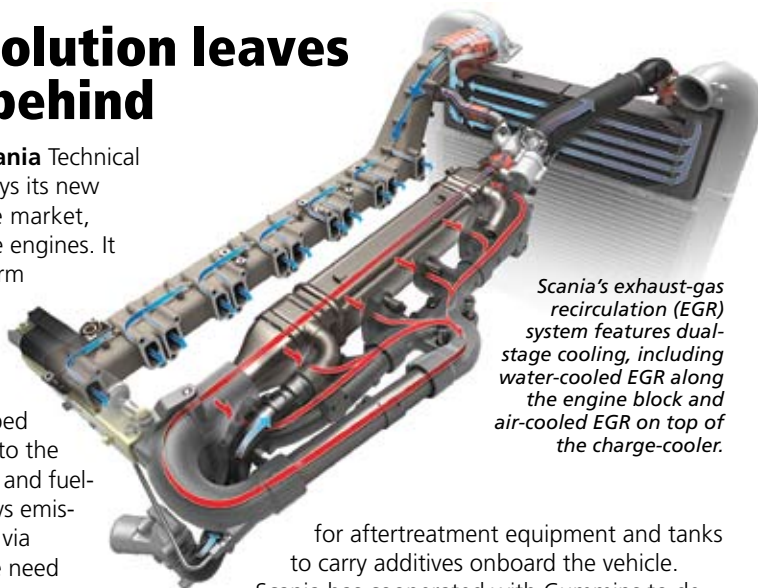


Scania's Euro V solution leaves aftertreatment behind

After five years' development at the Scania Technical Centre in Södertälje, Sweden, Scania says its new Euro V engine platform is ready for the market, starting with five- and six-cylinder inline engines. It will gradually replace the current platform over the next few years. Euro V becomes mandatory within the European Union in October 2009.

Exhaust gas recirculation (EGR) via the Scania XPI injection system, developed jointly with Cummins, was designed into the system to meet performance, emissions, and fuel-economy targets. The EGR system allows emissions to be lowered during combustion via high injection pressures, eliminating the need



Scania's exhaust-gas recirculation (EGR) system features dual-stage cooling, including water-cooled EGR along the engine block and air-cooled EGR on top of the charge-cooler.

for aftertreatment equipment and tanks to carry additives onboard the vehicle.

Scania has cooperated with Cummins to develop injection and combustion technology since the early 1990s. Scania HPI, launched in 2001, was the first result of the alliance.

Two EEV-certified engines that offer 230- and 280-hp (170- and 210-kW) are fitted with a maintenance-free part-flow particulate filter. The other engines manage Euro V without aftertreatment, which includes a 270-hp (200-kW) ethanol version.

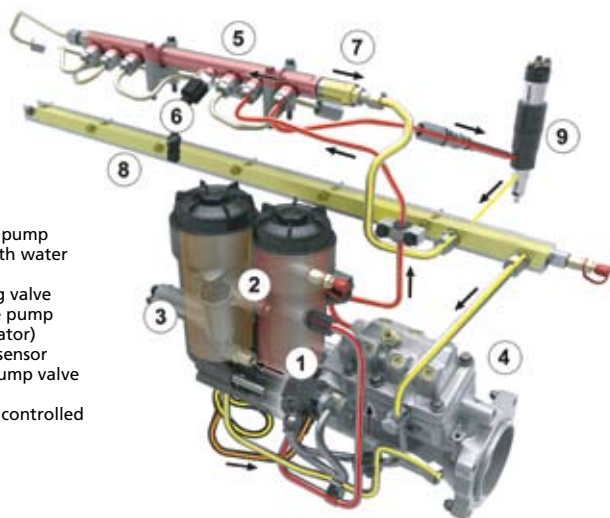
In terms of fuel economy, the new engine range has been developed to fully match Scania's range of Euro III and Euro IV engines. The high torque delivery at low speeds allows additional fuel to be saved by specifying a faster rear axle ratio. Engine oil-change intervals are now up to 120,000 km (75,000 mi) at 36-t (40-ton) gross mass and up to 90,000 km (56,000 mi) at 45-t (50-ton) gross mass.

Like previous Scania engines, the new engine platform is modularized with shared components and systems between the different series, facilitating servicing, staff training, and parts supply. The engine also retains traditional Scania traits such as separate cylinder heads, camshaft located high in the block, rear-mounted timing gears, and a cyclone oil filter.

Oil level indication in the instrument cluster permits checking of the oil level from the driver's seat. The level cannot be checked with the engine running. After stopping, an estimated time is displayed indicating when the level can be measured again after the oil has run back into the sump.

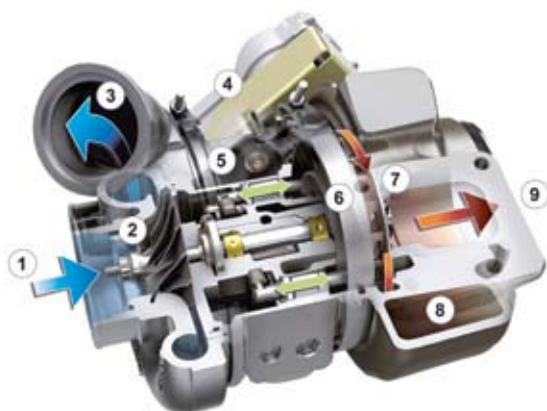
Adaptive battery charging adjusts the charge voltage from the alternator according to the battery temperature. The voltage increases at low temperature and decreases at high temperature, resulting in faster charging of cold batteries and more gentle charging of warm batteries. A more powerful 100 A alternator is standard, with a 150 A heavy-duty option.

Scania has developed a new-generation engine-management system to control functions such as fuel



1. Low-pressure pump
2. Fuel filters with water separator
3. Inlet metering valve
4. High-pressure pump
5. Rail (accumulator)
6. Rail pressure sensor
7. Mechanical dump valve
8. Return rail
9. Electronically controlled fuel injector

Schematic of the XPI common-rail injection system developed jointly by Scania and Cummins and used on Scania's Euro 5 five- and six-cylinder engines.



1. Air intake
2. Compressor wheel
3. Charge air outlet
4. Speed sensor
5. Actuator
6. Sliding nozzle-ring
7. Turbine wheel
8. Exhaust gas inlet
9. Exhaust gas outlet

Scania uses a variable geometry turbocharger on the new engine family, improving engine response and low-speed torque over the previous generation.

AUTOMATICALLY-GENERATED CODE FLYING AT MACH 9.8.

THAT'S MODEL-BASED DESIGN.

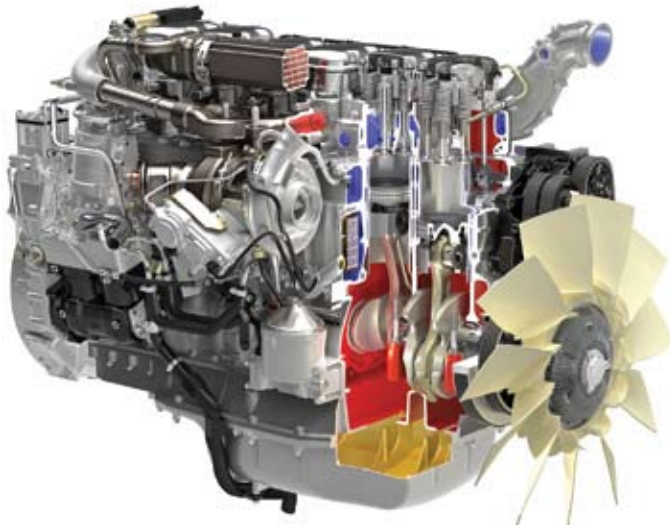
When NASA made history by launching the X-43A, automatically-generated flight code was at the controls for the vehicle's propulsion and stability systems. Engineers developed the autopilot within a radically reduced timeframe using Model-Based Design and Simulink. To learn more, go to mathworks.com/mbd

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A ladder frame is incorporated in the sump of the six-cylinder engines to counteract noise and vibration.

injection, dual-stage EGR, charge-air, cooling fan and engine operating temperature, variable-geometry turbocharger (VGT), exhaust braking, NOx control, exhaust aftertreatment, and engine oil level. The control unit is mounted on the cool side of the engine. On six-cylinder engines, the unit is cooled by the flow of fuel from the tank to the low-pressure pump; five-cylinder engines do not require more cooling than that provided by the airflow when driving.

The engine-management system also provides onboard diagnostics that will be further developed over time and allows detailed logging of operational data for subsequent analysis. Together with the new Scania Communicator, logging can be done remotely via the Scania Fleet Management portal. Analyses can be performed on driver as well as vehicle data.

The cylinder block and other structural components have been redesigned for additional strength without the need for special grades of steel. A ladder frame is incorporated in the sump of six-cylinder engines to counteract noise and vibration, which is achieved by twin balance shafts on five-cylinder 9-L engines.

Development of the common-rail fuel injection system, Scania XPI (extra high-pressure injection), allows a high degree of freedom in terms of injection timing and pressure. With common-rail, injection timing and duration are independent of the camshaft. High injection pressures are available at any time, irrespective of engine speed. It also opens the possibility to use several injection pulses.

Control of the fuel-injection system is all-electronic, meaning that there are no lobes on the camshaft to actuate the fuel injectors, nor are there any tappets, pushrods, or rocker arms for that purpose.

Fuel under high pressure is constantly available in the rail, giving the possibility of injecting fuel at any time, independent of camshaft position. In the XPI, fuel is sucked from the tank by the low-pressure pump via a pre-filter with a water separator via the cooling circuit for the engine-management system to the main fuel filters. Water in the fuel is automatically drained back to the tank via a venture device. The low-pressure pump then supplies fuel via the inlet metering valve to the high-pressure fuel pump. The pumps, which are integrated into one unit together with the fuel metering valve, are driven by the timing gears of the engine. The high-pressure pump supplies fuel un-

Scania Euro 5 Inline Engines

Power, hp (kW)	230 (170)	270 (200)	280 (210)	320 (240)	360 (270)	400 (300)	440 (330)	480 (360)
Torque, N-m (lb-ft)	1050 (775)	1200 (885)	1400 (1030)	1600 (1180)	1900 (1400)	2100 (1550)	2300 (1700)	2500 (1845)
Swept volume, L	9.3	8.9	9.3	9.3	12.7	12.7	12.7	12.7
Bore, mm (in)	130 (5.1)	127 (5)	130 (5.1)	130 (5.1)	130 (5.1)	130 (5.1)	130 (5.1)	130 (5.1)
Stroke, mm (in)	140 (5.5)	140 (5.5)	140 (5.5)	140 (5.5)	160 (6.3)	160 (6.3)	160 (6.3)	160 (6.3)

der operating pressure to the rail, or the accumulator that runs the length of the engine on the cool side.

The operating pressure is regulated by the amount of fuel admitted by the inlet metering valve, ranging from an idling pressure of about 500 bar (7250 psi) to a peak pressure of 2400 bar (34,800 psi). The average working pressure is around 1800 bar (26,100 psi).

An inlet metering valve is controlled electronically by the engine management system via a closed loop from a pressure sensor in the rail. A mechanical dump valve on the rail prevents excess pressure build-up by sending fuel back to the tank via the return rail.

Each cylinder features a fuel injector that is constantly fed with high-pressure fuel from the rail. Injection pulses are controlled electronically via a servo valve in the injector. The injector remains open as long as current is supplied from the ECU.

The amount of fuel injected depends on the opening time and the pressure in the rail. The starting time of the pulse determines the start of injection.

Multiple injections are possible with this electronically controlled injection system. A small amount of fuel (pilot injection) can be injected slightly before the main injection to reduce noise and prepare the combustion chamber for lower emissions. A small post-injection shortly after the main injection reduces soot and NOx. It can also be used to control exhaust temperature for the addition of a future aftertreatment system.

A high-capacity water-cooled EGR system is mounted on the engine. Recirculated exhaust gases are supplied from the exhaust manifold, cooled, and passed on either to the intake side or to a second cooling stage. The amount of EGR admitted to the intake is regulated electronically via an EGR valve and by varying the geometry of the turbocharger, thus varying the exhaust backpressure.

On high-output engines, two-stage EGR-cooling is employed to secure the flow and temperature according to the needs of the engine. The second stage consists of an air-cooled radiator mounted on top of the charge-cooler. A by-pass valve regulates the flow through the second EGR cooler.

The geometry and gas flow in the variable-geometry turbocharger is regulated by the sliding nozzle-ring, which is controlled by an electric actuator and allows control of both charge-air to the engine and the flow of EGR.

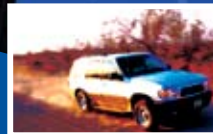
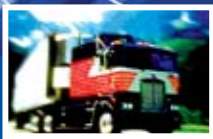
The flow of intake air can be optimized throughout the working speed range of the engine so that the VGT can be used to improve engine response and low-speed torque. It is also used to speed up gear changes with Scania Opticruise by maintaining the turbine speed during gear changes.

Jean L. Broge

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Connaught develops "bolt-on" hybrid system

Small-scale UK auto manufacturer **Connaught** has developed an auxiliary mild hybrid system, named Hybrid+, that is designed to be retrofitted to autos and light commercial vehicles. The first customer for the system is the home delivery division of UK-based supermarket **Tesco**. Seven **Ford** Transit refrigerated delivery vehicles will initially be equipped with the Hybrid+ system.

Connaught Chief Designer Geoff Matthews said that the system could be fitted to "any vehicle where there is sufficient space." He explained that the system uses a secondary, brushed, 48-V motor/alternator driven off the lower pulley drive on the front of the engine. "The unique bit is the con-

stantly variable transmission [CVT] drive between the engine and motor/alternator. Even if the diesel engine is turning at 800 rpm, the CVT drive will ensure that the motor/alternator is spinning at its optimum 3000 rpm," he said. The motor/alternator is sourced in the UK, while the CVT system is supplied from the U.S.

The vehicles are not equipped with an automatic engine stop/start system as with many hybrids because the engine must operate the refrigeration unit. The charge produced by the motor/alternator is stored in a **Maxwell** supercapacitor module about the same size as a heavy-duty 12-V battery. According to Matthews, the complete system, with supercapacitors, has a mass of about 50 kg (110 lb). He believes that this represents a considerable weight savings compared with a system using batteries. For the Tesco Ford Transits, the supercapacitor module is fitted beneath the load floor.

Matthews acknowledges that the vehicle's standard alternator could be removed when the Hybrid+ system is fitted, but Connaught has chosen to leave it in place for this application, "If the belt drive for the system were to fail, it would never disable the vehicle," he said.

The motor/alternator can provide an additional 15 hp (11 kW) of power when the vehicle is accelerating. The supercapacitors feed the stored energy back to the motor/alternator, which then adds a degree of assistance to the engine via the belt drive. In the Tesco vehicles, the diesel engine retains the same power output as before, enabling them to call on the additional 15 hp (11 kW) when needed. As Matthews points out, it would also be possible to reduce the power output of the diesel engine by 15 hp (11 kW) to reduce fuel consumption and emissions further.

On an urban delivery route, Matthews would expect a reduction in fuel consumption and carbon dioxide emissions of between 15 and 20%, depending on the cycle. He believes greater reductions might be possible, again depending on the cycle, traffic conditions, and driver. Connaught has claimed possible reductions of up to 25%. Servicing of the Hybrid+ system is required every 30,000 mi (48,000 km), and the servicing is centered on the motor/alternator, which uses brushes that need to be inspected.

The cost of the Hybrid+ system would be around £2500, but would depend on the number of vehicles involved. "The system was designed and developed for high-volume vehicles," said Matthews. "And this takes six months of design and development to tailor the system to a specific application."

The Connaught name was revived in 2002 by the current company. The original Connaught Engineering Company was a successful producer of Grand Prix and sports cars in the 1950s and early 1960s. The company's Type D hybrid sports coupe is scheduled to reach production later in 2007.

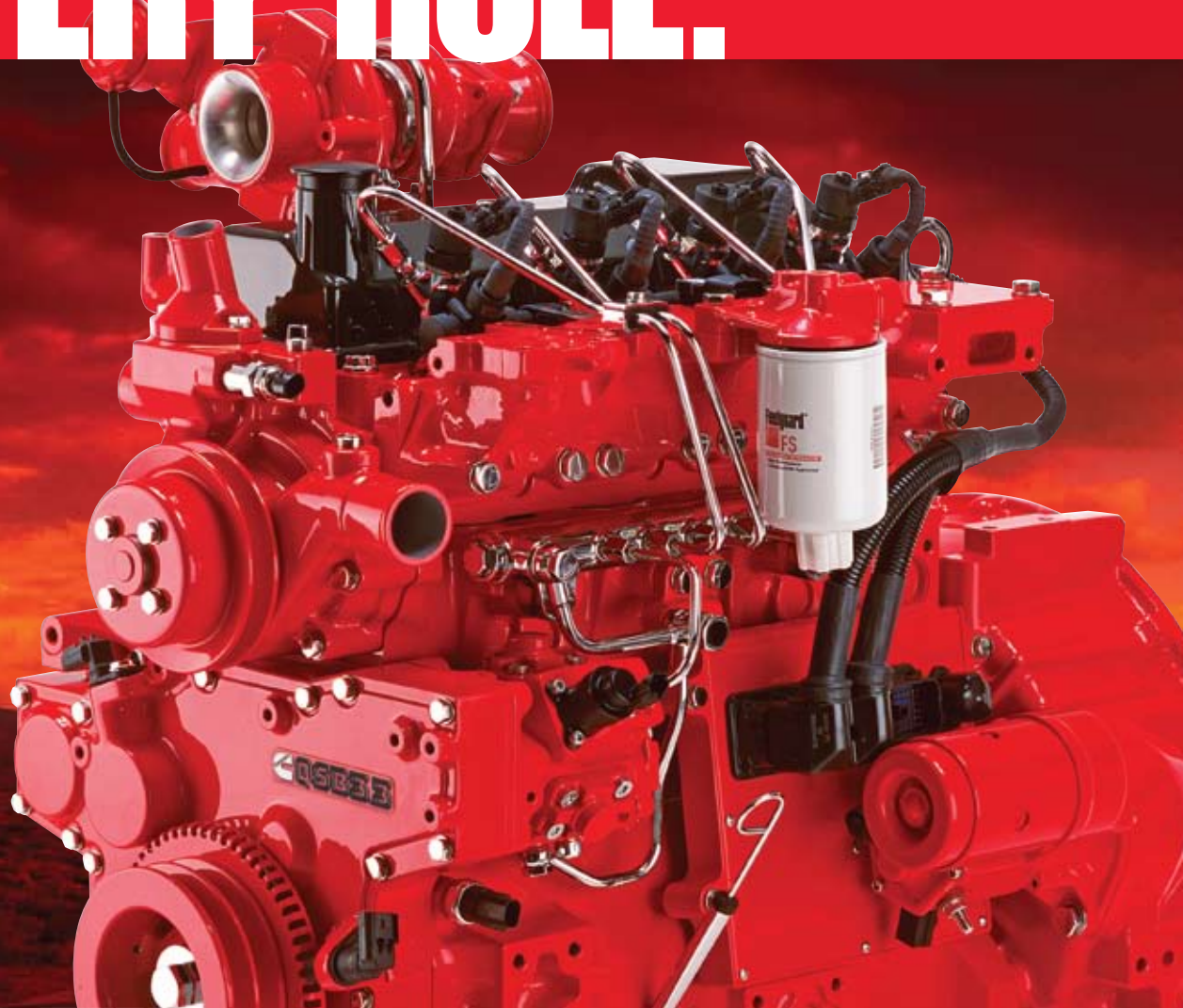
John Kendall



Connaught's "bolt-on" Hybrid+ system, the first application of which is in Tesco Ford Transit cargo vans, takes drive from the lower front pulley of the vehicle's engine.



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Emissions requirements drive shift to thermoset truck parts

For components facing a long, hard existence in the engine compartments of heavy trucks, the material choice has often been some type of metal. But metal components can add a lot of weight to truck designs, which is a major concern at a time of rapidly rising fuel costs. What's more, metal components have a greater impact now that the U.S. **EPA** has introduced new restrictions on diesel-engine emissions.

Many designers of under-the-hood truck components are switching from metals to thermoset composite materials. Thermosets meet all the requirements of under-the-hood applications but are much lighter than metal alternatives, making it easier for designers to comply with the new emissions standards without adding weight. Thermosets can also handle the higher engine-compartment temperatures that result from compliance with the standards. And, as an added bonus, the materials provide excellent corrosion-resistance properties and slash the time and costs involved in manufacturing under-the-hood components.



In the heavy-truck industry, SMC provides strength and durability for under-the-hood components such as oil drain pans, heat and noise shields, and valve and timing chain covers.

Composite materials consist of glass-fiber reinforcement in a polymer resin. Two common thermosets are bulk molding compound (BMC) and sheet molding compound (SMC). SMC includes more reinforcement and longer glass fibers than BMC, so it provides higher mechanical strength than its thermoset counterpart. Suitable for the demanding service conditions in heavy trucks, SMC provides at least as much impact resistance as steel and up to four times as much as BMC.

In the heavy-truck industry, SMC provides strength and durability for under-the-hood components such as oil drain pans, heat and noise shields, and valve and timing chain covers. And it maintains excellent strength during prolonged exposure to high temperatures. This has become more important with the advent of more-stringent EPA diesel-engine emissions requirements, which make heavy-truck engines run at higher temperatures.

Truck designers also prefer SMC because it offers a higher strength-to-weight ratio than steel and most other metals. As

a result, SMC components are typically 25-35% lighter than steel parts of equal strength. Because SMC is lighter than metal alternatives, it offsets some of the additional engine weight introduced by the EPA emissions requirements, and therefore reduces the fuel consumption of heavy trucks. Class 8 trucks must now carry an additional 300-500 lb (136-227 kg) of emissions-reducing equipment to comply with new EPA standards.

Besides adding to vehicle weight, the new emissions equipment adds \$5000-7000 to the cost of a heavy truck. With designers looking to offset these higher costs, SMC is even more attractive when compared to metals, which have become much more expensive in recent years.

SMC lowers costs in other ways as well. In metal manufacturing, complex designs may require components consisting of multiple parts that are made separately and then assembled to create the final product. But by using SMC, manufacturers can mold many features into a component in a single step. This consolidation of multiple parts into one can significantly reduce manufacturing costs, as well as shorten design and production time.

Manufacturing expenses are also lowered by the switch to composite tooling, which costs less than half as much as steel stamping tooling. Less-expensive tooling has a particularly significant impact on the overall cost of products made in low-volume processes, such as those typically used to manufacture under-the-hood truck components.

Parts have to meet a formidable list of requirements to assure their survival and success under the hoods of heavy trucks. Besides handling a combination of mechanical stresses, under-the-hood components must withstand exposure to harsh environments for projected truck lifetimes measured in decades rather than years.

Unlike metals, which are notoriously susceptible to corrosion, SMC will not rust or corrode when used in harsh environments. Without a protective coating of paint, thermoset material provides superior resistance to gasoline, motor oil, coolants, lubricants, automatic transmission fluid, cleaning agents, and water with a wide range of pH values. SMC also maintains its chemical resistance for the entire life span of the truck.

Another advantage of SMC is its ability to reduce engine noise. Tests show that the internal damping of the thermoset is 10 times that of steel and aluminum. Superior damping means that under-the-hood component designers who switch to SMC can expect 10-15% reductions in engine noise levels.

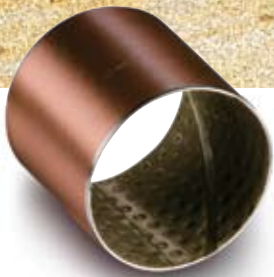
SMC is also dimensionally stable, which minimizes warping and thereby helps parts maintain flat mounting surfaces. This allows SMC components to provide better oil sealing, which helps allay warranty-related concerns of truck makers.

Featuring light weight and long-term resistance to high temperatures, SMC helps heavy-truck designers meet stringent new emissions requirements. SMC also provides superior physical properties and reduces manufacturing complexity and costs. Thus, SMC is an increasingly popular alternative to metals among those seeking to improve the design, manufacture, and performance of under-the-hood truck components.

Gary Littell, Applications Development Engineer at IDI Composites International, wrote this article for *SOHE*.



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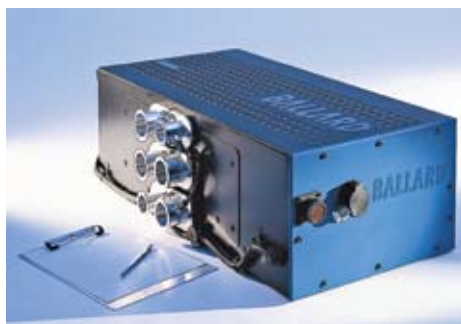
Flow simulation improves robustness of fuel-cell design

Because of their potential to eliminate dependence on fossil-fuel sources and carbon emissions, fuel cells represent one of the most important mobility design opportunities of the 21st century. Yet fuel cells provide enormous design challenges, primarily increasing their power and robustness while reducing their cost to levels that will make them competitive with internal-combustion engines. Flow simulation is playing a major role in this process by enabling engineers to understand and visualize the complex flow within

the fuel cell, which plays a critical role in its performance.

DaimlerChrysler and **Ford** have built more than 100 vehicles powered by proton-exchange-membrane fuel cells (PEMFCs) from **Ballard Power Systems**, and these vehicles have been driven more than 1.2 million km (620,000 mi).

Ballard's Mark 902 fuel cell represents the company's fourth generation of a transportation fuel-cell platform, and the technology is currently powering light- and heavy-duty fuel-cell vehicles worldwide.



Ballard's PEMFCs use a complex design with a stack consisting of multiple cell rows, each cell row having multiple cell plates, and each cell plate having many channels. The extreme variation in scale, which is a key factor in the power density of the device, creates major design challenges. In typical configurations, the oxidant and fuel are fed into a stack through manifolds and then enter each unit cell through a secondary inlet port. After flowing through the unit cells, the spent gases as well as possible liquid water then enter the outlet header to leave the stack. One of the key design goals is to provide a uniform flow distribution in the approximately 20 km (12.4 mi) of total flow circuits in a stack because the stack performance is often limited by the unit cell with the worst performance.

Ballard uses CFD-ACE+ software including its PEMFC module to perform comprehensive 3-D simulations of fuel cells. The CFD-ACE+ PEMFC module includes Butler-Volmer equations for electrochemical reactions, the Springer model for water transport through the membrane, a model for transport of liquid water saturation through porous media, and the liquid-saturation model for two-phase flow in the channels. The full-stack model is too large to run as one job, so Ballard has created several different models that the company uses to optimize fuel-cell performance at different scales.

One key task is to design the manifold to balance mass flow between all cell rows and optimize pressure drops. This required a large-scale model that did not need to account for the details of the flow in the individual cells. First, manifold segments were optimized for pressure drop through CFD simulation. After optimizing the bends, CFD was used to analyze the complete manifold and ensure that mass flow between all cell rows was equally distributed.

The next step in the flow path is the headers that distribute gases to the individual cells. Optimizing the headers required a model that simplified each cell flow field to an equivalent flow



Ballard Power Systems' development and manufacturing facility in Burnaby, British Columbia.

resistance to represent pressure drop in active cells. The CFD-ACE+ model of the header showed that flow exiting the cells hit the outside wall of the header and formed two vortices. Flow separated towards the dead end of the inlet header, leading to poor flow distribution for the last cells. Based on these insights, the header geometry in the model was changed several times and then the model was rerun until the flow field in the header was substantially improved.

The fuel cell must be modeled at even a smaller scale to optimize the cell-plate geometry. Each cell plate can have hundreds of channels for air, fuel, and coolant. Modeling each of these channels would require enormous computational resources, so a model-simplification strategy was needed. One of the strategies used at Ballard is to model one channel each for fuel, oxidant, and coolant.

A structured grid block with about 150,000 cells was created by extruding a 2-D face mesh consisting of 700 quad cells along the length of a 200-node channel. Gas-dispersion layers, catalyst layers, and the membrane were resolved typically with five nodes through their thickness. Computation time for the full electrochemical model on one CPU is on the order of 70 h. By using 5 CPUs in parallel, results can be obtained in about 15 h.

The model was verified by comparing simulation predictions with experimental results for key metrics including cell voltage vs. current density, plate current distribution, MEA water content, coolant temperature rise, and sensitivity to operating conditions and material properties. The simulations closely matched the experiments.

After verifying the model, Ballard analysts varied geometric parameters that affect transport, including channel cross-section area, channel hydraulic diameter, channel length, and ratio of channel width to land area. They gained many insights, such as that predicted cell performance increases with increasing gas channel width and channel pitch, which indicates that coupled transport in the gas-diffusion layer is dictated by electrical conduction. This finding is indirectly supported by a numerical experiment in which predicted cell performance increases with increasing land-width/channel-width ratio. CFD-ACE+ was used to optimize the channel performance by varying the full range of channel parameters.

Sanjiv Kumar, Senior Engineer, Ballard Power Systems, and **Sekhar Radhakrishnan**, Senior Applications Engineer, ESI Group, wrote this article for *SOHE*.

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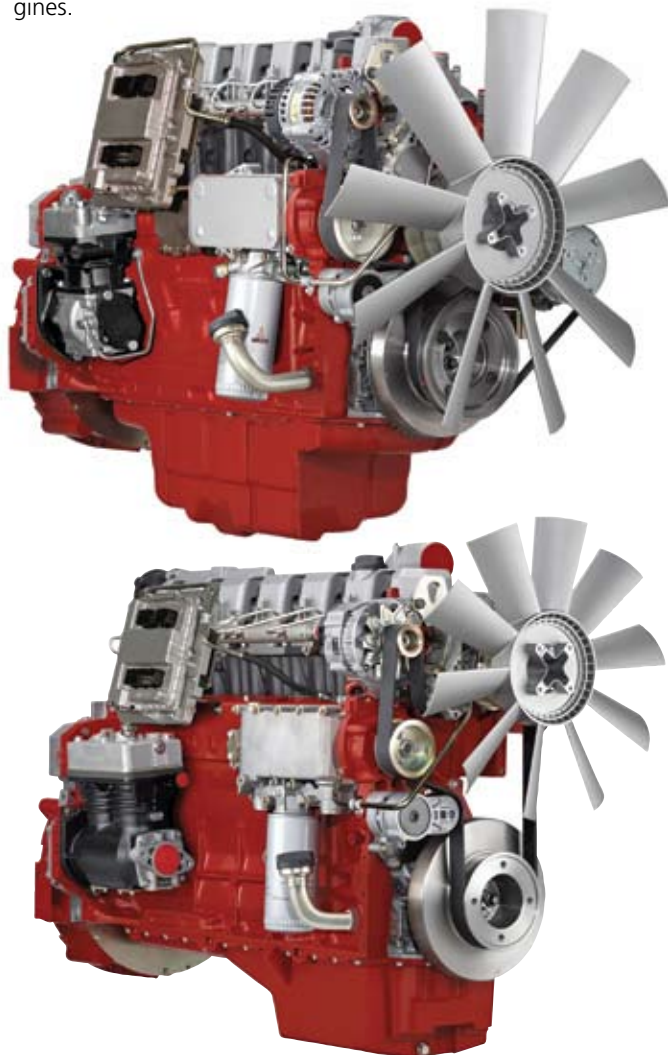
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Deutz gets pumped with biodiesel

Deutz has successfully tested operation of its six-cylinder engines in the TCD 2012 4V series with rapeseed methyl ester (RME), enabling the company to "recommend without restriction" the use of biodiesel in Tier 3 TCD 2012 and 2013 engines.



After completing a series of intense endurance tests, Deutz announced that it has approved the use of biodiesel in its TCD 2012 (top) and 2013 (bottom) engines.

For the final approval of biodiesel suitability for the 101 x 126 mm (4 x 5 in) bore x stroke engines equipped with Deutz common rail (DCR) technology and cooled exhaust gas recirculation, test bench runs and field tests were carried out. The essential step for the biodiesel release of the Tier 3 engines was the successful 500-h run on the test stand. Because **Bosch** generally refuses to approve the use of biodiesel in its injection components, Deutz took over the full risk for all components of the engines.

For the 500-h endurance test, a water-cooled turbocharged six-cylinder engine with a 6-L displacement and four-valve technology was chosen. The rated power of the engine was 177 kW (237 hp) at 2100 rpm, when operated with diesel fuel according to DIN EN 590. The maximum torque of was 1068 N·m (788 lb·ft) at 1450 rpm. The specific fuel consumption at rated output was 216 g/kW·h (0.355 lb/hp·h).

Running the legal mandatory emissions test for tractors the following changes were ascertained when comparing RME with standard diesel fuel operation:

- Power output at rated speed: -8.5%
- Gravimetric fuel consumption: +11.1%
- Volumetric fuel consumption: +5.4%
- Carbon monoxide emissions: -25%
- Hydrocarbon emissions: -50%
- Nitrogen oxide emissions: +2%
- Particulate emissions: -54%
- Soot emissions: -69%

Whereas power output and fuel consumption turns negative because of the lower calorific value of RME compared to diesel fuel, Deutz points out that the emissions show clear advantages.

To judge the fatigue limits, the engine was examined during the endurance test with RME and dismantled after. All important components, such as injection valves, rail, pistons, piston rings, and bearings were measured again and did not show any problem, according to the company.

Beyond the 500-h test, two tractors equipped with common rail engines were put in service with RME. The tractor with a 113-kW (151-hp) engine completed 1419 hours, the other with a 138-kW (185-hp) engine 1755 hours. No problems occurred during operation with RME. The check of the injection systems at the end of the field tests showed a positive result as well, says Deutz.

Jean L. Broge

Desktop dreaming at Bosch Rexroth

Bosch Rexroth's new desktop factory technology now in operation at the Robert **Bosch** facility in Waiblingen, Germany, is a development project built around small, standardized process components that have been engineered to fit within a "desktop-sized" space of 220, 330, or 440 mm (8.7, 13.0, or 17.3 in) wide. The modular and freely combinable units incorporate Bosch Rexroth-equipped hydraulic, pneumatic, and electric drive components into optimized and highly accurate linear-motion systems that can be configured to execute myriad complex production tasks—from pick-and-place and surface preparation to assembly, welding, and component testing.

Like many of the technologies that have been developed

between Bosch Rexroth and the Bosch Group, the desktop factory concept has evolved as the companies worked together to solve a customer need. In this case, that need was Bosch's own quest to upgrade its implementation of lean technologies. In the past, such customer-driven requests have resulted in the development of a number of hallmark Bosch Rexroth technologies. Examples include clean-room initiatives that resulted in special aluminum framing lines and early lean-manufacturing efforts that resulted in full-blown automated conveyor systems and (later) simple roller conveyors to move products through U- or L-shaped lean cells.

Focus on customer needs is also a key component of the

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The desktop factory development project is built around small, standardized process components that have been engineered to fit within a desktop-sized space with a width of 220, 330, or 440 mm (8.7, 13.0, or 17.3 in).



tomers' product. In a modularized production environment, takt time can also help work-cell designers define ideal work spaces in which all tasks are balanced and efficient.

To understand the concept of a balanced workflow, it is helpful to consider the seven categories of waste that were defined by **Toyota's** Taiichi Ohno. Desktop factory addresses transport waste, for example, by designing work cells that fit into the smallest possible work space. In the same manner, potential over-processing wastes are addressed by precisely defining each process step, then matching it to the best possible equipment for each task.

lean methodology, in which customer needs help to define the rate and process by which their product is produced. Lean manufacturing aims to minimize waste by pacing production to match the rate of customer demand based on takt time, a term that comes from the German word for rhythm, or beat. Calculated by dividing net available production hours per day by the customer's demand quantity per day, takt time defines the pace at which the factory should work to produce that cus-

lean technologies, Bosch examined its processes and determined that it needed to develop a much smaller work envelope for automated systems. There was also an interest in having the flexibility to combine automated tasks with some manual assembly tasks, and in finding ways to cut costs on some of the automated tasks. As the groups worked together to address what eventually emerged as the desktop factory concept, a natural synergy emerged between Bosch's manufacturing

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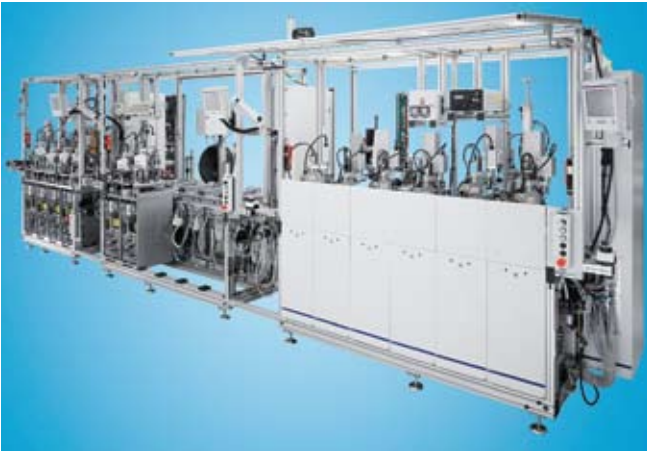
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The modular and freely combinable units incorporate Bosch Rexroth-equipped hydraulic, pneumatic, and electric drive components into optimized and highly accurate linear-motion systems that can be configured to execute myriad complex production tasks.

applications and facilities, and Bosch Rexroth's many automation and control products, which are typically applied in-house, further developed, and prepared for marketing to other manufacturers.

Desktop factory design begins with Bosch Rexroth's bolt-together aluminum profile system, which provides the structural backdrop upon which the desktop factory is constructed. The modular units at the heart of the desktop factory concept

Techniques to Minimize the Classic Forms of Waste

Transport	Minimize movement by moving process steps into close proximity
Inventory	Aim for just-in-time to minimize overstocking
Wasted motion	Remove unnecessary process motion; improve ergonomics
Waiting	Aim for smooth workflow between process steps
Over-production	Aim to make exactly what the customer orders
Over-processing	Use machines of appropriate capacity and quality standards
Defects	Aim for zero defects

are all on wheels and can incorporate any combination of Bosch Rexroth's vast range of products. One of the newest to be implemented at the Waiblingen facility is camoLINE, a Cartesian-based robotic system that allows multiple drive technologies to be configured within one compact, precise application. Named in tribute to a predecessor technology—Bosch Rexroth's Cartesian Motion System—camoLINE is designed for automated multi-axis processes such as pick-and-place or spot welding. The technology is the result of a continuing evolution of connection technologies for putting together individual linear modules into robotic axis systems.

Another technology that is key to Bosch Rexroth's desktop factory concept is the MPS product line, a system design that can be used to set up manual production systems (MPS). MPS incorporates a whole-factory approach, addressing such tasks as the water spider inventory re-supply system. The water spider supplies materials to the work cell through the flow rack—a rack of inventory bins that are loaded from behind then rolled forward to provide inventory to the worker at the correct ergonomic height. Bosch Rexroth's unique design twist is to use colored rollers, with each color representing a specific level of inventory. Green bins are closest to the worker, yellow bins are the intermediate supply, and red bins mean the work team is getting close to running out. Based on roller color, the water spider can see very quickly when a particular cell needs to be re-supplied.

Early results of the Waiblingen desktop factory pilot are promising. According to Bernd Feirabend, Bosch Director of Gasoline Systems, desktop factory has resulted in 10-20% overall savings in investment cost over the product life cycle. The company also reports space savings of up to 75% and energy cost reductions as high as 20%.

Another key benefit is process flexibility: the standardized desktop factory modules can be quickly and easily adapted to production quantity, product, schedule, or sequence changes. In one case, said Feirabend, reusability of the individual desktop modules allowed the plant to develop a completely new platform in just three months, including alteration of assembly sequences, development of new processes, and preparation for assembly application.

The desktop factory modules, which will in time be put to use at sister Bosch facilities worldwide, also hold the promise of increased product uniformity, higher manufacturing reliabilities, and lower engineering and development costs.

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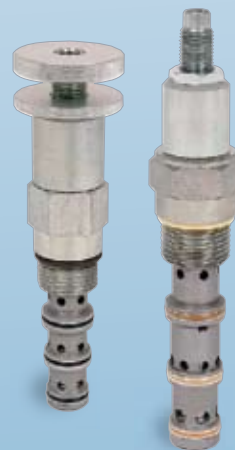
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